

Alaska Habitat Management Guide

Life Histories and Habitat Requirements of Fish and Wildlife

Produced by
State of Alaska Department of Fish and Game
Division of Habitat



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ALASKA DEPARTMENT OF FISH AND GAME

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The process of developing the initial plan and procedures for this project involved a number of individuals who are not otherwise listed as authors and contributors. These include many staff within the Division of Habitat, as well as planners and research and management coordinators of other divisions. This group also includes all project team members and all ADF&G regional supervisors. Special mention should be made of the support from

Alvin Ott, Lance Trasky, and Carl Yanagawa, Regional Supervisors of the Division of Habitat for the Arctic and Interior, Southwest and Western, and Southcentral regions, respectively, and of the contributions of Rai Behnert, who was the original coordinator of this project. We would also like to acknowledge the many contributions of John A. Clark, who was Director of the Division of Habitat until his death in 1985.

Introduction

Overview of Habitat Management Guides Project

Background

Alaska is an immense and bountiful frontier, and until just recently it was all but inconceivable that we would ever need to worry about its capacity to sustain the wealth of fish and wildlife resources for which it is renowned. But the impetus of development has not abated, and the pressure to develop our lands and waters intensifies daily. Every year more lands in Alaska are being proposed for uses other than as wildlife habitat, especially around cities, towns, and villages. These proposed uses include logging, mining, hydroelectric projects, agriculture, settlement, geothermal development, and oil and gas leases, among others. As the number of proposals and plans for development continues to increase, so does the need to carefully and efficiently evaluate their possible effects upon species and habitats and to recommend viable managerial options to guarantee that our valuable fish and wildlife resources and habitats are adequately protected and maintained. By using appropriate planning and managerial techniques most of the potential for damage and loss of access for human use can be avoided.

One of the responsibilities of the Alaska Department of Fish and Game (ADF&G) is to assist land managers by recommending to them the best ways and means, based upon the best available data, for protecting local fish, wildlife, and habitats against adverse effects and impacts. Because many proposals and plans for development and land uses require a rapid response from the department, there may not be enough time for staff to actually study the specific area in which the proposed development is to occur. However, the department still needs to accumulate and assess a wide variety of information in order to prepare recommendations for managing habitat. Therefore, the department initiated the Alaska Habitat Management Guides (AHMG) project to prepare reports of the kinds of information upon which its recommendations must be founded in order to responsibly and rapidly address land and water use proposals made by land managers. These guides are a major undertaking and will be of inestimable value to the state in its efforts to avoid or mitigate adverse impacts to Alaska's great wealth of fish and wildlife.

Purpose

The Alaska Habitat Management Guides present the best available information on selected fish and wildlife species: mapping and discussing their geographical distribution; assessing their relative abundance; describing their life functions and habitat requirements; identifying the human uses made of them, including harvest patterns of rural communities; and describing their role in the state's economy. This last kind of

information, because of the variety of values humans place upon fish and wildlife, is not easily derived. There are, however, several methods to estimate some of the economic values associated with these resources, and such estimates have become particularly important in land use planning because many potentially conflicting uses must be evaluated in economic terms.

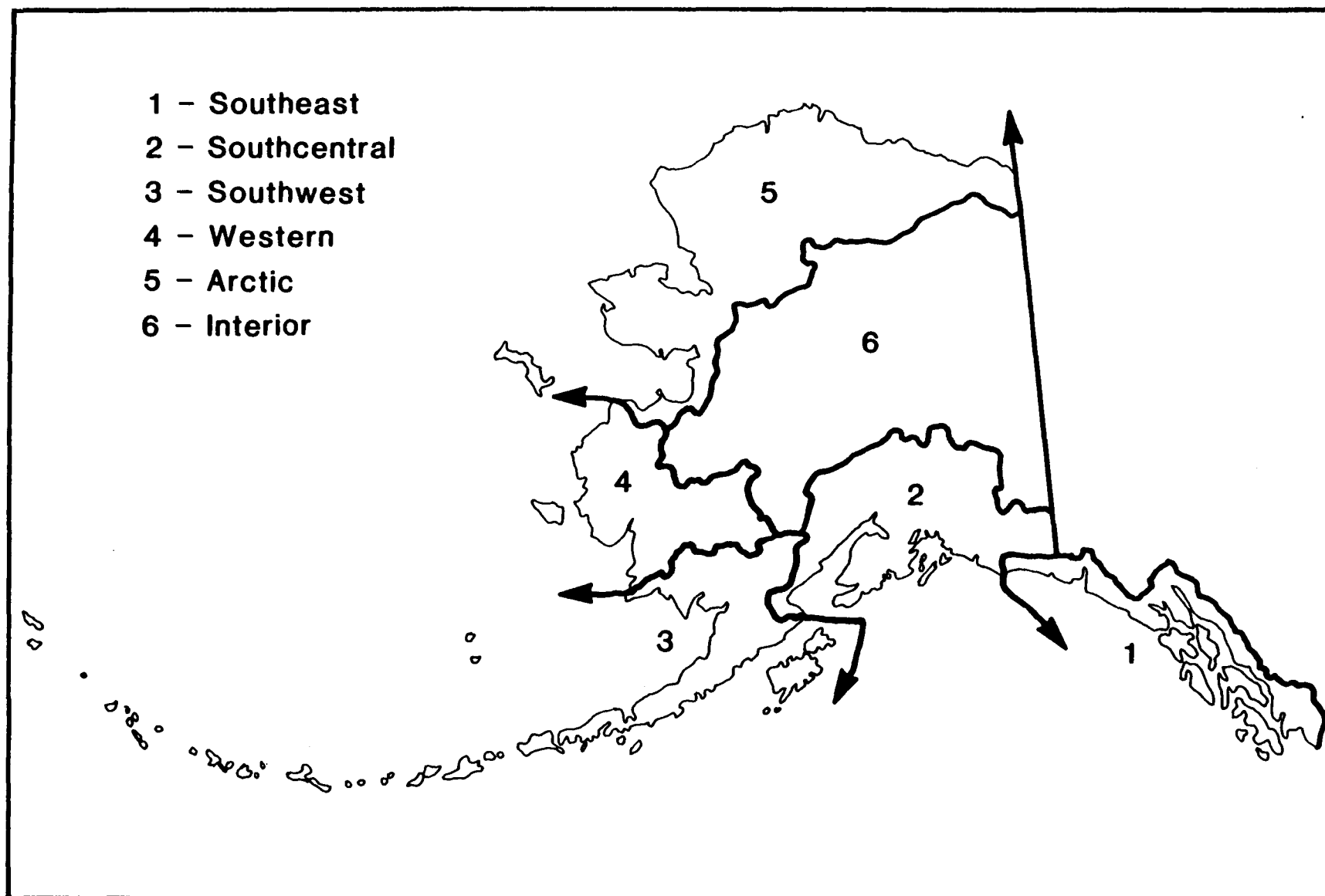
Essential to assessing what might happen to fish and wildlife if their habitats are altered is information about what effects or impacts are typically associated with particular kinds of developmental activities. The habitat management guides therefore also provide summaries of these known effects. This information, in conjunction with compiled life history information, will allow those concerned to estimate how sensitive a given species might be to a specific proposed activity - whether or not, and to what degree, the fish and wildlife are liable to be impacted. The guidance offered (a compilation of existing options for habitat management) is not site-specific. Rather, it is general information available to those who seek to avoid adverse impacts without placing undue restraints upon other land and water uses.

The completed guides coverage of fish and wildlife resources encompasses the Fish and Game Resource Management Regions established by the Joint Board of Fisheries and Game (map 1). These regions provide the most inclusive and consistent format for presenting information about fish and wildlife resources and relating it to management activities and data collection efforts within the department.

Applications

The choice of the term "guides" rather than "plans" for the reports is consistent with the largely advisory role of the department with respect to land management issues. The guides will provide the department as well as other state, federal, and private land managers with information necessary for the development of land and water use plans. Thus, the guides themselves are not land management plans and do not provide for the allocation or enhancement of fish and wildlife. Information included in a guide will be used by the department's staff in their involvement in the land use planning endeavors of various land managers. For specific land use planning efforts, the department joins with other agencies to recommend particular uses of Alaska's lands and waters, as for example in plans by the Department of Natural Resources (e.g., Susitna Area Plan, Tanana Basin Area Plan, Southeast Tidelands Area Plan). The public, by means of the public review that is an integral part of land management agencies' planning processes, then has an opportunity to evaluate any recommendations made by the ADF&G that are incorporated by the land-managing agency.

The guides have been designed to provide users with interrelated subject areas that can be applied to specific questions regarding habitat management. Each type of data will be presented in a separate volume, as



Map 1. The six regions of the Alaska Habitat Management Guides.

indicated in figure 1. Material from the project's database can be used, for example, to correlate information on species' seasonal and geographic habitat use with the written and mapped information on known distribution and abundance. The narratives and maps regarding human uses of fish and wildlife can be compared with abundance and distribution information to obtain an indication of the overall regional patterns of distribution, abundance, and human use for the species of interest. The specific information on habitat requirements also will relate directly to the information on impacts associated with land and water use. This in turn will form the basis for the development of habitat management guidance.

An additional purpose of this project is to identify gaps in the information available on species, human uses, and associated impacts. A particular species, for example, may be known to use certain habitats during certain seasons; yet information on the timing of these use patterns may be inadequate. In general, there is little documentation of impacts from land and water uses on species' habitats and on the human use of those species or on the economic values associated with the use of fish and wildlife resources.

To maintain their usefulness these habitat management guides are designed to be periodically updated as new research and habitat management options are reported to fill data gaps. Users of these guides are advised to consult with the appropriate species experts and area biologists, however, to check on the availability of more recent information.

Statewide Volumes

Besides this statewide volume detailing the life histories and habitat requirements of selected species of fish and wildlife, three other reports have been developed as statewide volumes, in which information is presented for statewide as well as for specific regional concerns. 1) The statewide volumes on impacts summarizes the effects of major types of developmental activities and land and water uses on fish and wildlife, their habitats, and their use by people. The activities discussed are those actually occurring in the state or expected to occur in the future. This survey of impacts is founded upon the most recent pertinent literature. 2) The statewide habitat management guidance volume is a synthesis of information regarding habitat management based upon the impacts literature. The following uses of land and water resources and types of development occur or are likely to occur in Alaska, and they are, therefore, addressed in the statewide impacts and/or guidance volumes:

- ° Oil and gas development
- ° Harbors and shoreline structures

ALASKA HABITAT MANAGEMENT GUIDES PROJECT

Regional Information

Life Histories and
Habitat Requirements of
Fish and Wildlife

Distribution, Abundance,
and Human Use of
Fish and Wildlife

Reference Maps of the
Distribution and Use of
Fish and Wildlife

Index Maps of the
Distribution and Use of
Fish and Wildlife

Statewide Information

Economic Overview of
Fish and Wildlife

Impacts of Land and
Water Use on Fish,
Wildlife, Habitat, and
Human Use

Guidelines for the
Protection of Fish and
Wildlife Species, Their
Habitats, and
Human Use

Figure 1. Types of narratives and maps produced by the Alaska Habitat Management Guides Project.

- Water development
- Placer mining
- Strip and open pit mining
- Underground mining
- Seafood processing
- Silviculture and timber processing
- Transportation - road, rail, air
- Transmission corridors
- Grain and hay farming
- Pipelines
- Geothermal energy development
- Red meat and dairy farming
- Settlement
- Fire management
- Offshore prospecting and mining
- Commercial fishing

Finally, 3) a statewide economic volume provides an overview of the role of fish and wildlife resource use in the regional and state economies. Fish and wildlife are renewable resources whose uses have historically formed the basis for human economies throughout the state. Although fish and wildlife use still plays a critical role in economies throughout the state, the growing complexity of the Alaska economy makes the valuation of these uses increasingly difficult. The recent growth in the Alaska economy has resulted in an increasing divergence between market and nonmarket use of the state's natural resources. This is further compounded by growing urbanization, which is often centered around a large-scale project in contrast to more dispersed rural resource utilization.

As the plans for development continue to increase, the need to evaluate the tradeoffs involved with sometimes competing land uses is necessary. Because of the wide variety of values (some of which are infinite) people place upon fish and wildlife, the task of translating the "infinite value" of wild resources into the more restrictive terms of economic assessment is difficult at best. Its inherent difficulty is compounded by the

circumstance that the data necessary for such an assessment are, with few exceptions, incomplete or unavailable at the present time. The economic data on commercial fisheries, for example, are relatively complete; and in those regions with significant commercial fisheries the dollar value of the fish resource can be fairly accurately estimated. For other regions and other resources, however, economic analysis must remain partial or tentative until a sound database exists. Continuing effort is being made by the department and by other agencies to compile such a comprehensive database in order to more accurately describe the great economic value of fish and wildlife to the people both within and outside the State of Alaska.

Regional Volumes

Narratives. Regional information on the distribution, abundance, and human uses of selected fish and wildlife species is available for each region of the state. The narrative volumes for the Southwest, Southcentral, Arctic, and Western and Interior regions provide the most current estimates of species' distribution and relative abundance and delineate the regional and subregional patterns, locations, and types of human uses of fish and wildlife resources. The narrative information for Southeast Alaska is organized somewhat differently: a brief summary of the distribution and abundance of selected species is presented within the Alaska Habitat Management Guide Reference Maps for the Southeast Region, and more detailed information on the human use of fish and wildlife is available in a Division of Habitat technical report entitled Human Use and Economic Overview of Selected Fish and Wildlife in Southeast Alaska.

Regional versions of this final Life History and Habitat Requirements of Fish and Wildlife volume were released with the publication of each regional database. Although these volumes contain much of the same information found in this final report, this compiled volume supercedes each of the earlier regional volumes.

Maps. A major portion of the guides project was committed to the production of updated fish and wildlife maps at two scales of resolution. The distribution and human uses of selected fish and wildlife species were mapped at a reference scale of 1:250,000 and then were mapped at the index scale of 1:1,000,000 for most subjects. Some reference maps for marine species were actually prepared at the 1:1,000,000-scale because that is the most appropriate scale to portray the level of detail of data on those species distributions. Reference maps are being reproduced as blue-line copies compiled in catalogs that are available at ADF&G offices of the region. Additional copies will be available for other users, at cost of reproduction, from our contract vendor. These maps can quite easily be updated. The index maps are being printed in color and will be included in atlases for all regions except Southeast. Habitat management concerns in Southeast Alaska do not require this resolution of information.

Organization and Use of this Volume

Background

Documented information regarding the life history and habitat requirements of selected fish and wildlife species of Alaska is one foundation upon which habitat management decisions are made. Understanding the types of land and water characteristics associated with viable populations of fish and wildlife allows the land manager to better maintain those aspects of the environment upon which the species depend.

This final volume of compiled information on the life history and habitat requirements of 50 individual species and 5 species groups began as a set of regional species narratives.

As the AHMG project team prepared a regional database on fish and wildlife for each of the Southwest, Southcentral, Arctic, and Western and Interior regions, regional-specific information on species' life histories and habitat requirements was added to the general narratives, which were then released. A similar effort was made to document the habitat requirements of Sitka black-tailed deer, king and Dungeness crabs, Pacific herring, and yelloweye rockfish in Southeast Alaska. For the other species, however, the final narratives may contain some information relevant to Southeast Alaska but should not be considered complete compilations for the Southeast Region. The title of each narrative indicates the regions for which the life history and habitat requirements information was gathered and has been technically reviewed and approved.

Organization

The information on life histories and habitat requirements is presented by species and is organized by species groups: marine mammals, terrestrial mammals, birds, freshwater/anadromous fish, marine fish, and shellfish.

For each aspect of the species' life history, Alaskan habitat requirements and life history is first presented, followed by regional-specific information, where known.

Species Selection Criteria

Each species included in this volume was selected because it met the following criteria: 1) its habitat is representative of some portion of the spectrum of the habitats in one or more of the regions; 2) it constitutes an important resource to human users in the region; 3) the species or its habitat is liable to be adversely affected by present or proposed land or

water uses; and 4) adequate information on its life history and habitat requirements, abundance, and distribution was available.

Many species other than those covered in this volume, including but not limited to the following, are also important to consider when making land or water management decisions or plans:

Terrestrial Mammals:

Arctic fox
Black bear
Land otter
Lynx
Marten
Mink
Mountain goat
Muskox
Red fox
Small game species
Wolf
Wolverine

Marine Mammals:

Gray whale
Humpback whale
Bearded seal
Ribbon seal
Spotted seal
Birds:
Golden eagle
Grebes
Gyr Falcon
Loons
Peregrine falcon
Rough-legged hawk
Shorebirds
Snowy owl

Fish:

Alaska blackfish
Arctic cisco
Arctic flounder
Atka mackerel
Bering cisco
Eulachon
Longnose sucker
Round whitefish
Sand lance
Sculpins
Smelts
Shellfish:
Hardshell clams

Regional Overview Summaries

Southwest Region

The Southwest Region (map 1) includes the area of Bristol Bay, the Gulf of Alaska south of Kennedy Entrance, including Kodiak and other islands, the Alaska Peninsula, the Aleutian Islands, the Pribilof Islands, the drainages of the Nushagak River, the Wood River/Tikchik lakes, and the Togiak River of the Bristol Bay area.

In the following sections, the biophysical and human resources of the region are briefly summarized. Readers desiring a more detailed and extensive discussion of these characteristics of the region should consult the Alaska Regional Profiles¹ and the Bristol Bay Area Plan² (BBAP).

1. Arctic Environmental Information and Data Center. N.d. Alaska regional profiles: Southwest Region. Prepared for the Office of the Governor and Joint Federal/State Land Use Planning Commission. 313 pp.

2. Alaska Department of Resources. 1984. Bristol Bay Area Plan. [Juneau.]

Biophysical features. Portions of the Southwest Region are in the maritime, transitional, and continental climatic zones. The weather in the region is the result of the interaction between land topography and major weather systems that move northward across the Gulf of Alaska or eastward across the Bering Sea. Kodiak Island, the south side of the Alaska Peninsula, and the Aleutians Islands are characterized by a fiordlike coastline rising to volcanic mountainous areas up to 9,000 ft in the Aleutians and occasionally to 8,000 ft on the Alaska Peninsula. The north side of the peninsula and the Bristol Bay area are characterized by a relatively regular coastline with numerous sand and gravel beaches and abutting coastal lowlands, often drained by river systems terminating in broad estuarine areas.

Major storm systems move northward off the Gulf of Alaska and into the south coastal highland areas, dropping precipitation usually as rain on the southern side and leaving the leeward (northern) side in somewhat of a rain shadow. The north side of the peninsula and Bristol Bay, however, are subject to eastward-moving storm systems from the Bering Sea; hence these areas are among the stormiest in the state. Headwater areas of the major Bristol Bay-Togiak drainages receive less precipitation than coastal areas and are subject to greater temperature fluctuations due to the influence of the continental zone.

Biota. Vegetation in the region is varied. The coastal spruce forest (mostly Sitka spruce) is restricted to Kodiak and Afognak islands and scattered locations on the south side of the peninsula. Most of the mountains in the region are covered by alpine tundra or barren areas at higher elevations, with a subalpine zone of mixed low and tall shrubs. On Kodiak and Afognak islands, this shrub layer is coastal alder thicket. Grasslands, shrublands, and wetland meadows comprise most of the remainder of the vegetation types on the peninsula and in the Aleutians; however, the broad river valleys interior to the Bristol Bay coast contain large stands of spruce, cottonwood, and birch.

In addition to the rich marine life of the Bering Sea/Bristol Bay and Kodiak/Shelikof area, the lake systems at the heads of the Nushagak, Kvichak, Naknek, Egegik, Ugashik, and Wood rivers provide optimum conditions for the world's foremost nursery of sockeye salmon, upon which much of the area's human population depends. Much of the North Pacific's population of shorebirds and waterfowl use the extensive estuarine systems of the Alaska Peninsula and eastern Bristol Bay as spring and fall feeding and staging areas. Kodiak Island and the Alaska Peninsula host the largest brown bears in the world, and the region as a whole probably contains the greatest abundance of these animals to be found anywhere in the world. The majority of the world's populations of Steller sea lions and northern fur seals breed in the region, and two endangered species of whales, the gray and bowhead, use the Bering Sea extensively for feeding.

Human activities in the region. As one would expect from the concentration of fish and wildlife in the Southwest Region, human activities revolve around the commercial, sport, and subsistence uses of these resources.

Noncommercial harvest, including subsistence, is a major activity in the region especially important in areas with no direct connection to the commercial fishing and processing industry. Bristol Bay is the world's largest sockeye salmon fishery and the state's largest salmon fishery, which is by far the dominant enterprise in the region. Dillingham and Naknek are the major ports, although fishing fleets work out of numerous smaller communities also. Major fish-processing areas include Kodiak, Unalaska/Dutch Harbor, Naknek, and Dillingham. Kodiak hosts the largest fishing fleet in the state.

Additional economic bases are provided by the tourist industry, mostly associated with sportfishing and hunting lodges in the Bristol Bay lakes area, and by government services, including military bases. A commercial timber industry is located on Afognak and Kodiak islands, although it is small compared to that of Southeast Alaska. Because of soils and climate, commercial agriculture is not feasible, although some cattle grazing occurs on Kodiak Island. There is some potential for offshore oil and gas development in the Shelikof Strait, north Aleutian basin, and St. George basin areas and for upland oil and gas development on the Alaska Peninsula. Onshore reserves are not thought to be as promising as the offshore reserves.

Infrastructure development is minimal. Although Kodiak is a trade and services center for that area, it contains only a small network of roads and an improved harbor. Dillingham has the only improved harbor in the Bristol Bay area, and the road network is minor and local. Dutch Harbor has developed as a seafood supply and processing center with some port development and is being used temporarily as an offshore oil/gas staging area for Bering Sea offshore exploration. Most travel within the region is by plane (scheduled and charter) or private boat. There is no connecting road network, and the Alaska Marine Highway system services only Kodiak, King Cove, Sand Point, and Dutch Harbor.

The population centers of the region are thus physically isolated from one another, as is the region as a whole from other regions. This factor has limited the diversification of the local economies, so that they remain closely tied to the regional fish and wildlife resources.

Southcentral Region

The Southcentral Region (map 1) includes the Chugach, Talkeetna, Wrangell, and Kenai mountains and the southern slopes of the Alaska Range. A few of the larger river basins in the region include the drainages of the Susitna, Beluga, Chakachatna, Big, Crescent, Kasilof, Kenai, Matanuska, Copper, and Bering rivers. Marine waters associated with the region are comprised of the northern Gulf of Alaska, Cook Inlet, and Prince William Sound.

In the following sections, the biophysical, biotic, and human resources of the region are briefly summarized. Readers desiring a more detailed and

extensive discussion of these characteristics of the region should consult the Alaska Regional Profiles.

Biophysical features. Portions of the Southcentral Region are in the maritime, transitional, and continental climatic zones. The weather in the region is the result of the interaction between land topography and major weather systems that move northward across the Gulf of Alaska or eastward across the Bering Sea. Prince William Sound, the southern Kenai Peninsula, and the southwest side of lower Cook Inlet are characterized by a fiordlike coastline rising to mountains up to 12,000 ft. The northwest side of the Kenai Peninsula and lower Cook Inlet and all of upper Cook Inlet are characterized by a relatively regular coastline with numerous sand and gravel beaches and abutting coastal lowlands, often drained by river systems terminating in broad estuarine areas. Major storm tracks move northward off the Gulf of Alaska into the southern coastal highland areas, dropping precipitation on the southern side and leaving the leeward (northern) side in somewhat of a rain shadow. Headwater areas of the major drainages are subject to greater temperature fluctuations due to the influence of the continental climatic zone.

Biota. Vegetation in the region is varied. The Sitka spruce-western hemlock forest is restricted to the lower-elevation coastal areas from Prince William Sound to lower Cook Inlet. Various associations of white spruce, black spruce, paper birch, balsam poplar, black cottonwood, and quaking aspen trees are common throughout the forested lowland areas away from the coast. Low and tall shrub communities comprised primarily of willow, alder, and shrub birch are common throughout the subalpine zone and in areas subject to periodic disturbance, such as floodplains and avalanche chutes. Dwarf shrubs and a variety of herbaceous communities are common in alpine areas and lower-elevation wetlands.

In addition to the rich marine life of Prince William Sound, lower Cook Inlet, and the Gulf of Alaska, the Copper, Susitna, Kenai, and Kasilof river systems provide optimum conditions for the rearing of five species of salmon, upon which most of the region's fishermen depend. Much of the North Pacific's population of shorebirds and waterfowl use the Copper and Susitna river deltas, as well as many smaller estuarine areas, for spring and fall feeding and migratory staging areas. The region supports harvestable populations of brown and black bears, moose, sheep, goats, caribou, Sitka black-tailed deer, furbearers, waterfowl, and small game. Marine habitats support healthy populations of sea otter, harbor seal, sea lion, belukha whale, and many other species of whales.

3. Arctic Environmental Information and Data Center. N.d. Alaska regional profiles: Southcentral Region. Prepared for the Office of the Governor and Joint Federal/State Land Use Planning Commission.

Human activities in the region. As one would expect from the abundance of fish and wildlife in the Southcentral Region, many human activities revolve around the commercial, sport, subsistence, and personal uses of these resources. Commercial fishing, seafood processing, and guiding of hunters and fishermen are important segments of the regional economy. Major fishing ports in the region include Cordova, Valdez, Seward, Homer, and Kenai. Noncommercial harvest for recreation and food is an activity of many residents of the region. The rapidly growing tourist industry is often related to the opportunity to fish, hunt, and view fish and wildlife.

Additional economic bases in the region are provided by Anchorage's role as the state's center for banking, oil, gas, and mineral companies, state and federal government agencies, and service-related businesses. Agriculture and cattle grazing are found primarily in the Matanuska-Susitna valley and Kenny Lake area of the Copper River basin. Forestry is limited to small private logging operations. Oil and gas development and production have occurred in Cook Inlet and on the Kenai Peninsula for the last two decades. There may also be potential for oil and gas development in other areas of Southcentral Alaska.

Infrastructure development is minimal by national standards, but the Southcentral Region has the most extensive network of roads, rail lines, and airstrips in the state.

Arctic Region

The Arctic Region (map 1) includes the Davidson, Philip Smith, Endicott, DeLong, Baird, and Bendeleben mountains. A few of the larger river basins in the region include the drainages of the Canning, Sagavanirktok, Colville, Ikpikpuk, Kuk, Utukok, Noatak, and Kobuk rivers. Marine waters associated with the region are comprised of the Norton and Kotzebue sounds and the Bering, Chukchi, and Beaufort seas.

The biophysical, biotic, and human resources of the region are briefly summarized below. Readers desiring a more detailed and extensive discussion of these characteristics of the region should consult the Alaska Regional Profiles.⁴

Biophysical features. Portions of the Arctic Region are in the arctic, transitional, and continental climatic zones. The weather in the region is the result of the interaction between global air movements, land topography, and major weather systems that move north-south and east-west across the Bering Sea.

4. Arctic Environmental Information and Data Center. N.d. Alaska regional profiles: Northwest Region, Arctic Region. Prepared for the Office of the Governor and Joint Federal/State Land Using Planning Commission.

Sea ice formation in the Bering, Chukchi, and Beaufort seas begins in October, and the ice pack persists through late June, although the ice begins to melt and break up in April.

The topography of the region is primarily characterized by lowlands on the arctic coastal plain and along the Noatak, Kobuk, and Selawik rivers, the rolling plateaus and hills of the arctic foothills, and the more rugged Brooks Range and associated mountains. Continuous or discontinuous permafrost underlies the entire region. The entire marine area of the region lies within the continental shelf.

Biota. Wet, moist, and relatively dry alpine tundra is the dominant vegetation of the Arctic Region. These highly variable tundra communities are comprised of herbaceous sedges, grasses, and low-growing forbs, lichen, and dwarf shrubs, with the percentage of shrubs generally increasing as the soil conditions become drier. Low and tall shrub communities comprised primarily of willow, alder, and shrub birch occur primarily along floodplains and fairly well-drained low-elevation foothill slopes. Various associations of white spruce, black spruce, paper birch, quaking aspen, and balsam poplar trees are found on well-drained soils in valley bottoms and on southerly slopes, generally below 1,000 ft.

The variety of habitats in the Arctic Region supports harvestable populations of caribou, moose, brown and polar bears, Dall sheep, furbearers, ducks, geese, small game such as ptarmigan and arctic hares, Pacific walruses, and several species of seals and whales. All five species of salmon, arctic grayling, arctic char/Dolly Varden, lake trout, broad whitefish, least cisco, sheefish, and many other fish species are found in the freshwater habitats. The marine environment produces harvestable populations of arctic cod, capelin, Pacific herring, saffron cod, starry flounder, king crab, and Tanner crab, as well as several other marine species.

Human activities in the region. Many human activities in the Arctic Region revolve around the subsistence, sport, and commercial uses of fish and wildlife. Commercial fishing, trapping, reindeer herding, seafood processing, fur tanning and sewing, and guiding hunters and fishermen are important segments of the local economy.

Oil and gas development and production on the arctic coastal plain has provided the primary source of wage employment and government funds over the last 12 years. The proposed development of the Red Dog zinc deposit may alter the economy of the Kotzebue Sound area in the near future. Mining for gold continues at a relatively low level compared to the mining activity around the turn of the century.

Infrastructure development is minimal by national standards, except within the developed oil fields.

Western and Interior Regions

The Western and Interior regions (map 1) include the Kuskokwim, Kaiyuh, Ray, White, and Crazy mountains and the southern slopes of the Endicott and Philip Smith mountains (eastern Brooks Range). A few of the larger river basins in the regions include the drainages of the Yukon, Andreafsky, Innoko, Koyukuk, Chandalar, Sheenjek, Porcupine, Tanana, Kantishna, Delta, Nabesna, Chisana, Fortymile, Kuskokwim, Kwethluk, Aniak, Holitna, Stony, Big, Kanektok, Arolik, and Goodnews rivers. Marine waters associated with the regions are comprised of the Kuskokwim, Hazen, Hopper, Kokechik, Scammon, and Pastol bays and Baird Inlet, and the Bering Sea to the west of the Yukon-Kuskokwim delta, including Nelson, Nunivak, and St. Matthew islands.

The biophysical, biotic, and human resources of the region are briefly summarized below. Readers desiring a more detailed and extensive discussion of these characteristics of the regions should consult the Alaska Regional Profiles.⁵

Biophysical features. The Yukon-Kuskokwim delta in the Western Region is in the transitional climatic zone, with a relatively narrow range of seasonal and diurnal temperatures as compared to the continental climatic zone of the Interior Region. In the continental climatic zone, temperatures are generally extreme in both summer and winter, and precipitation and wind are normally light. Fog, precipitation, and winds frequently occur along the coast of the Western Region. The weather in the regions is the result of the interaction among global air movements, land topography, and storms that move northeast across the Bering Sea and the North Pacific Ocean.

Sea ice formation in the Bering Sea begins in October. The ice pack persists through May, although the ice begins to melt, break up, and move northward in April.

The topography of the Western Region is dominated by the Yukon and Kuskokwim rivers and the marshy alluvial plain known as the Yukon-Kuskokwim delta. The topography of the Interior Region is also dominated by the Yukon and Kuskokwim rivers, although there are also extensive upland areas in addition to broad alluvial lowlands such as the Yukon and Minto flats. Permafrost is discontinuous throughout the two regions. The entire marine area of the Western Region lies within the continental shelf.

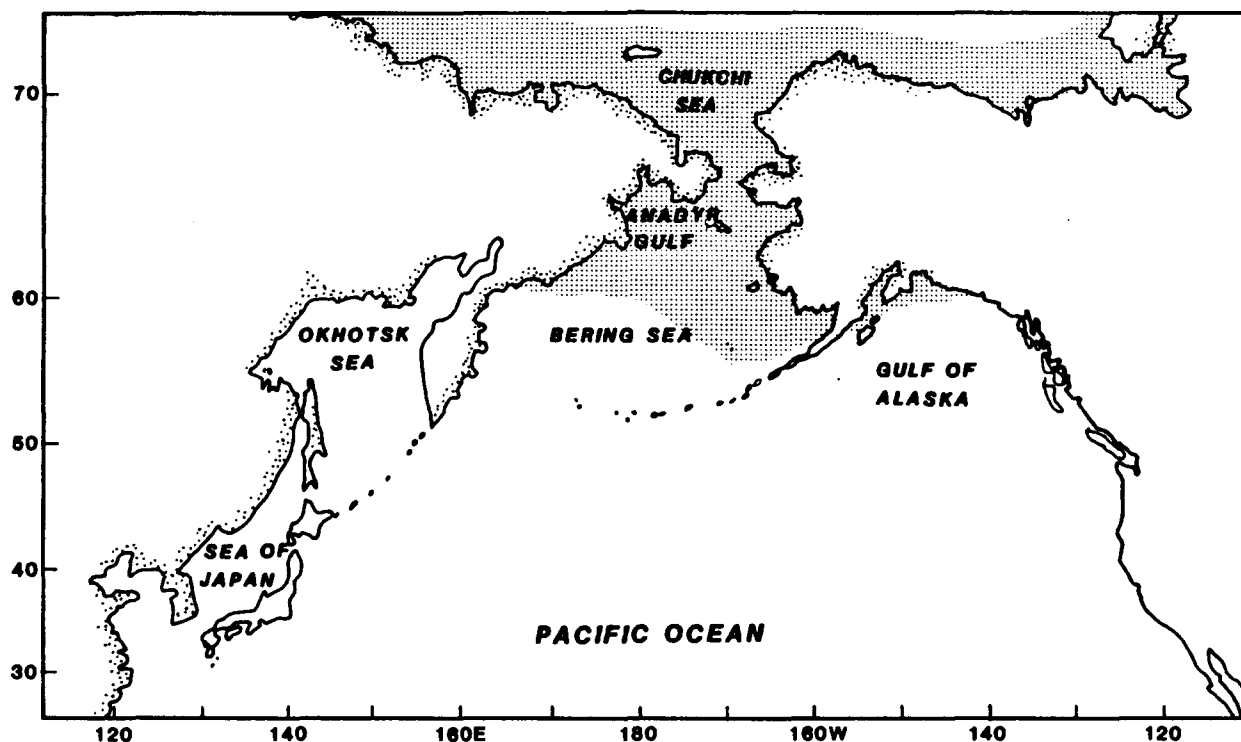
5. Arctic Environmental Information and Data Center. N.d. Alaska regional profiles: Southwest Region, Yukon Region. Prepared for the Office of the Governor and Joint Federal/State Land Use Planning Commission.

Biota. Major vegetation types of the Western Region are dry alpine tundra, wet tundra, and moist tundra. The highly varied tundra plant communities are comprised of herbaceous sedges, grasses, and low-growing forbs, lichens, and dwarf shrubs, with a generally greater percentage of shrubs where soil conditions are drier. In contrast, the vegetation of the Interior Region is characterized by closed- and open-canopied forests comprised of various associations of white spruce, black spruce, quaking aspen, white birch, balsalm poplar, and tamarack trees. The treeline is at approximately 1,000 ft or lower along the lower Yukon, at 2,000 ft on southern slopes of the Brooks Range and northern slopes of the Alaska Range, and at 2,000 to 3,500 ft along the Alaska-Yukon border. Low and tall shrub communities comprised primarily of willow, alder, and shrub birch occur on floodplains, lowland boggy areas, and mountain slopes in both regions. In wet tundra areas characterized by lakes, there are various aquatic herbaceous plant communities.

The variety of habitats in the Western and Interior regions supports harvestable populations of caribou, moose, Dall sheep, brown and black bears, furbearers, waterfowl, small game such as ptarmigan and grouse, Pacific walrus, seals (ringed, spotted, and bearded), belukha whale, and a wide variety of fish, including salmon, whitefish, northern pike, arctic grayling, char, herring, and Pacific halibut, to name a few.

Marine Mammals

Belukha Whale Life History and Habitat Requirements Southwest, Arctic, and Western Regions



Map 1. Range of belukha whale (Seaman and Burns 1981, Lowry et al. 1982)

I. NAME

- A. Common Names: Beluga, belukha
- B. Scientific Name: Delphinapterus leucas (Pallas 1776)
- C. Native Names: See appendix A.

II. RANGE

- A. Worldwide
Belukhas occur off North America, Europe, and Asia in seasonally ice-covered waters of the Arctic Ocean and subarctic seas (Kleinenberg et al. 1964). They have been sighted as far south as Tacoma, Washington (Scheffer and Slipp 1948), the New Jersey coast (Anthony 1928), the Loire River, France, (Fraser 1974), and the Sea of Japan (Gurevich 1980, Seaman and Burns 1981). The several

somewhat discrete stocks of this monotypic species are separated on the basis of adult size, concentration areas, seasonal movement patterns, and physical and geographical barriers; the number of stocks is still being debated (Sergeant and Brodie 1969, Gurevich 1980).

B. Statewide

Belukhas in Alaska are considered to comprise two stocks.

The Gulf of Alaska stock ranges from at least Kodiak Island to Yakutat Bay, with its center of abundance in Cook Inlet (Calkins and Pitcher 1977, Harrison and Hall 1978, Lowry 1984).

The western arctic stock is much larger and winters along the ice edge and ice fringe in the Bering Sea and in regularly occurring polynyas in the northern Bering and Chukchi seas (Kleinenberg et al. 1964, Seaman and Burns 1981). As the sea ice retreats in spring, most of this stock moves northward and coastward to summering areas in the Bering, Chukchi, Beaufort, and East Siberian seas (Klinkhart 1966, Braham and Krogman 1977, Harrison and Hall 1978).

C. Regional Distribution Maps

To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for the Southwest, Western, and Arctic regions at 1:250,000 scale. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of belukha distribution has been prepared and may be found in the Atlas that accompanies the Southwest, Western and Interior, and Arctic regional guides.

D. Regional Distribution Summary

1. Southwest. Belukhas are seasonally abundant in coastal portions of the Southwest Region. In late March, April, and May, belukhas concentrate at the mouth of the Naknek River, feeding on smelt (Osmerus mordax) and moving upriver as breakup progresses (Seaman and Frost 1983). Several weeks later they move to the mouth of the Kvichak River to feed on out-migrating sockeye salmon (Oncorhynchus nerka) smolts (ibid.).

During the calving season (June to August), belukhas are distributed throughout Kvichak and Nushagak bays, and calving and feeding concentrations overlap considerably (ibid.).

Specific areas, such as the mouth of the Snake River and Kvichak Bay, have been identified as calving concentration areas (ADNR/USFWS 1983, maps; Frost, pers. comm.).

Belukhas remain in inner Bristol Bay throughout the summer, exploiting the runs of different fish species present, often ascending the rivers to feed as far upstream as King Salmon on the Naknek River, Portage Creek on the Nushagak River, and Levelock on the Kvichak River (ibid.).

Belukhas become progressively less common in inner Bristol Bay as winter approaches and are presumed to move offshore by October. The extent of belukha use of offshore areas is unknown (Seaman and Frost 1983). They have been reported east of Hagemeister Island in September, and one animal was sighted near the Pribilof Islands in October (ibid.). Increased sightings in offshore areas in autumn corresponds with a sharp decrease in the use of coastal waters by anadromous fish (ibid.).

Winter distribution of the Bering Sea stock is not well known but is probably dependent on ice conditions. In years of heavy ice, they have been observed in western Bristol Bay, near the Naknek River, and near Nunivak and the Pribilof islands (Seaman and Frost 1983; Frost, pers. comm.). (For more detailed narrative information, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)

2. Arctic. During the summer months, belukhas occur primarily in the coastal zone and along the pack ice edge (Kleinenberg et al. 1964, Frost et al. 1982). Major concentrations occur in Norton Sound, Kotzebue Sound, near Kasegaluk Lagoon (central Chukchi Sea coast), and in the MacKenzie River estuary of the Canadian Northwest Territories (Fraker et al. 1978, Seaman and Burns 1981, Frost et al. 1982).

Belukhas gradually move offshore in late summer/autumn and probably winter in the pack ice in the Bering Sea and southern Chukchi seas (Klinkhart 1966, Harrison and Hall 1978, Lowry 1984). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Arctic Region.)

3. Western. Prior to the 1950's there were several concentration areas along the Yukon-Kuskokwim coast that were used from spring through autumn. Sightings in recent years, however, have been irregular and consist of small numbers of animals (Frost et al. 1982). One area in the Western Region where moderately large groups of belukhas still occur is the delta of the Yukon River. These groups appear in May or June and remain through September and October (ibid.). (For more detailed narrative information, see the Alaska Habitat Management Guide for the Western and Interior regions.)

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

Belukhas tolerate waters with a wide range of temperature, salinity, turbidity, and depth characteristics (Lowry 1984).

1. Water quality. Belukhas have been recorded in fresh waters of larger rivers (Kleinenberg et al. 1964), brackish estuarine areas (Fraker et al. 1978), and marine areas (Seaman and Frost 1983, Lowry 1984). Fraker et al. (1979) found that in areas where belukhas concentrated in the

Mackenzie River estuary, salinities ranged from less than 1 ppt to 12 ppt saline, and turbidities ranged from less than 6 to over 150 ppm sediment. He concluded that they appeared neither to avoid nor select areas because of salinity or turbidity. Belukhas leave the Mackenzie River estuary before the salinity, turbidity, and temperature ranges change from summer conditions (ibid.).

2. Water depths. Belukhas have been observed in water depths ranging from shallow coastal waters to deep marine pelagic areas (Fay 1978). During the summer, belukhas frequent the shallow coastal and shelf waters to take advantage of the seasonal food supplies and warm water (Murray 1979, Consiglieri and Braham 1982, Lowry 1984). Fraker et al. (1979) reported belukhas in the Mackenzie River estuary in water depths of less than 2 m.

The western arctic stock overwinters over the continental shelf in the southern Chukchi Sea and the southern and central Bering Sea, feeding on species found at depths from 30 to 365 m (Bakkala et al. 1981). Consiglieri and Braham (1982) conclude that the tidal range of up to 10 m in Cook Inlet may limit distribution; however, similar tidal extremes in other regions of belukha distribution (e.g., Bristol Bay, the northeastern Atlantic coast) do not appear to have a limiting affect (Lowry, pers. comm.).

3. Water temperature. Belukhas are found in a wide range of water temperature, from 0°C in winter (Lowry 1984) to 18°C in summer in estuarine areas of the Mackenzie River delta (Fraker et al. 1979). Fraker et al. (1979) observed that early in the season belukhas in the Mackenzie River estuary concentrated in the warmest water available (10-12°C), and as the water temperature increased, they expanded their range until the 18°C isotherm was reached; few whales occurred in water temperatures above 18°C. Fraker et al. (1979) and Lowry (1984) believe that the observed spring and summer movement to shallow, warmer areas may confer a thermal advantage upon all age classes, especially upon newborn calves without a thick blubber layer. In Bristol Bay, however, this shoreward movement commences in March or April (a few months prior to calving) and is more likely related to increased availability of food (smelt) than to providing a thermal advantage for calves (Lowry and Frost, pers. comm.). Fraker (1977) observed neonates in offshore waters, preceeding arrival at the shallow estuarine concentration areas near the Mackenzie River delta and elsewhere. It is not known how frequently calving occurs outside shallow, warm estuarine areas or whether calves born in colder water suffer higher mortality rates (Fraker et al. 1978).

Blackburn et al. (1983) observed water temperatures of 11-12°C in shallow estuarine areas of western Cook Inlet

during periods when belukhas are known to use those areas (Murray 1979).

4. Acoustic properties. Belukhas possess the finest resolution biosonar described to date for cetaceans (Leatherwood et al. 1982). Commercial whalers called the belukha the "sea canary," because of its range of vocalizations (ibid.). Belukha sounds are varied and complex and are probably used mainly for communication and food location in turbid waters of estuaries and rivers (Fay 1978). Although no unequivocal evidence was found on acoustical habitat requirements, many observations of belukha reactions to various types of noise have been reported; the significance of the observed behavior changes is unclear (see the references in the Impacts of Land and Water Use volume).

B. Ice

1. Effects on movement and distribution. In general, belukhas spend considerable time in ice-covered offshore waters. They are unable to make and maintain breathing holes in ice more than 8 cm thick (Kleinenberg et al. 1964) and so are found in areas where geographic, oceanographic, or meteorologic factors cause ice motion and the formation of open water (Burns et al. 1981). Fraker et al. (1979) reported that belukhas can travel up to 3 mi under the ice without surfacing; however, according to Kleinenberg et al. (1964), 2-3 km is the maximum reported submerged swimming distance. Rapid ice formation in bays or polynyas can block escape routes, trapping belukhas in the ice, where they die if breathing holes are frozen over (Porsild 1918, Kleinenberg et al. 1964, Leatherwood and Reeves 1982). Murray (1979) reported that few belukhas were observed in Cook Inlet in years of extensive ice conditions.
2. Protection from natural elements. Burns et al. (1981) point out that turbulence caused by winter storms in the Bering Sea is depressed by sea ice. The calmer water inside the ice fringe may allow easier feeding in the productive waters of the continental shelf under the ice pack (ibid.).
3. Protection from predators or other disturbances. Although killer whales (Orcinus orca) occur along the southern fringe of the pack ice, the ice offers more protection from killer whales than the open sea (Burns et al. 1981). Polar bears (Ursus maritimus) occasionally kill belukhas; however, they do not range into the unstable ice zone in the Bering Sea where the majority of belukhas winter (ibid.).

IV. NUTRITIONAL REQUIREMENTS

Studies of food habits of belukha whales throughout their range have identified more than 100 different species in the diet (Kleinenberg et al. 1964). In coastal waters of Alaska, belukhas feed on a series of

sequentially abundant and highly available prey, particularly anadromous and coastal spawning fishes. These include primarily salmon (Oncorhynchus spp.), smelt, capelin (Mallotus villosus), eulachon (Thaleichthys pacificus), herring (Clupea harengus), and saffron cod (Eleginus gracilis). Other organisms, such as shrimps (Crangon spp.), octopuses (Octopus sp.), and sculpins (Cottidae), are also commonly eaten. Arctic cod (Boreogadus saida) and pollock (Theragra chalcogramma) may be particularly important foods in offshore waters during winter and spring (Seaman et al. 1982). Kleinenberg et al. (1964) state that belukhas do not feed on deep-water organisms. Young-of-the-year feed exclusively on milk; yearlings supplement the milk with small fish and other prey items (ibid.).

A. Food Species Used

1. Spring and summer foods:

a. Arctic Region:

- 1) Eschscholtz Bay-Kotzebue Sound. Stomach contents were sampled from 90 belukhas harvested in June 1978 and 1980 in Kotzebue Sound (Seaman et al. 1982). Food items were generally similar in both years. Stomach contents included the bones and otoliths of fishes, primarily saffron cod and sculpins, and small amounts of shrimp, isopods, snails, polychaetes, and octopuses. The average size of saffron cod eaten was 12.4 cm, and that of sculpins, 22.5 cm. Table 1 summarizes the food items found.

The belukha stomachs sampled at Eschscholtz Bay in 1978 were examined for age and sex-related differences. Stomach contents were similar for young and old whales, as was the size range of saffron cod eaten, although within that range younger whales ate more small cod (ibid.). Stomach contents were slightly different between male and female belukhas. Shrimp occurred more frequently and in greater proportions in females than in males. The opposite was true for isopods. The most obvious difference between sexes occurred in the consumption of sculpins; 4 of 28 females ate sculpins, whereas 21 of 29 males ate sculpins (ibid.).

- 2) Point Hope. The stomachs of 35 belukhas taken by subsistence hunters at Point Hope in May 1977 and 15 taken in April 1978 were examined by Seaman et al. (1982). In 1977, 30 stomachs were empty, and in 1978 6 stomachs were empty. Stomach contents examined in May 1977 contained almost exclusively octopus beaks, with 625 occurring in one stomach. Contents examined in April 1978 contained mostly crangonid shrimp (see table 2).

Table 1. Stomach Contents of Belukha Whales Collected in Eschscholtz Bay

Prey Item	13-18 June 1978, n=62			16-24 June 1980, n=28		
	Percent Volume	Percent Number	Percent Frequency	Percent Volume	Percent Number	Percent Frequency
Shrimps	4	---	76	3	---	50
Isopod	6	---	34	1	---	14
Octopus	1	---	52	1	---	14
Other invertebrates	1	---	41	1	---	29
Total invertebrates	11	---	90	5	---	82
Rocks and pebbles	1	---	66	1	---	4
Total fishes	87	---	94	95	---	96
Saffron cod	---	88	94	---	90	86
Sculpins	---	11	42	---	2	25
Rainbow smelt	---	1	29	---	7	39
Pacific herring	---	1	3	---	1	7
Eelpout	---	1	2	---	---	---
Mean volume of contents (ml)	47.2			81.1		
Total number identified fishes	4,346			434		

Source: Seaman et al. 1982.

--- means no data were available.

Table 2. Stomach Contents of Belukha Whales Collected at Point Hope

Prey Item	22-27 May 1977, n=5			25-26 April 1978, n=9		
	Percent Volume	Percent Number	Percent Frequency	Percent Volume	Percent Number	Percent Frequency
Shrimps	1	---	20	99	---	67
Squid	0	---	0	1	---	11
Octopus	75	---	100	1	---	78
Other invertebrates	1	---	60	1	---	11
Total invertebrates	75	---	100	100	---	100
Rocks and pebbles	25	---	40	1	---	22
Total fishes	0	---	0	1	---	11
Arctic cod	---	0	0	---	100	11
Mean volume of contents (ml)	53.3			48.4		
Total number identified fishes	0			43		

Source: Seaman et al. 1982.

--- means no data were available.

- b. Southwest Region. Belukhas in Bristol Bay consume a large variety of prey and shift their distribution and feeding habits in relationship to the most available food items (Brooks 1954, Klinkhart 1966). Belukhas are attracted to the mouths of large rivers in early May because of large concentrations of outmigrating smelt. At the end of May, belukhas shift from smelt to out-migrating sockeye salmon fingerlings, which are the predominate prey until mid June. After mid June and through August, adult salmon become the primary prey in Bristol Bay (Brooks 1955). Additional species eaten

include flounder, sole, sculpin, blenny, lamprey, shrimp, and mussels (ibid.).

c. Western Region:

- 1) Yukon-Kuskokwim delta. Nelson (1887) reported that belukhas feed on spawning herring in early June in southern Norton Sound and on saffron cod from mid summer to freeze-up at the mouths of tidal creeks near the Kuskokwim River. Moderately large groups of belukhas appear off the mouths of the Yukon in May and June with the first of the summer salmon runs and remain until late September or October, when salmon runs diminish and saffron cod are more abundant offshore (Frost et al. 1982).
2. Autumn and winter foods. Although no stomach samples are available from belukha whales in Alaska in autumn and winter, their probable foods can be inferred from the distribution and abundance of their potential prey (Seaman et al. 1982). Pollock is the most abundant species of finfish in the vicinity of the ice front (Pereyra et al. 1976) and is probably a major belukha food in this area. Based on the stomach contents of ringed seals (Phoca hispida), arctic and saffron cods are by far the most abundant forage fishes in the northern Bering Sea in autumn and winter (Lowry et al. 1980). Arctic cod is the most important single item in the winter diet of belukhas over much of their range, and thus the winter movements of belukhas are closely tied to the distribution of arctic cod (Lono and Oynes 1961, Kleinenberg et al. 1964, Tarasevich 1974). Saffron cod may also be an important autumn and winter food of belukhas in some portions of the Bering Sea. Nelson (pers. comm.) has observed belukhas feeding on saffron cod in autumn near Cape Nome. Residents of Gambell on St. Lawrence Island note that the presence of belukhas is closely linked with the abundance of saffron cod along the western and southern shores of St. Lawrence Island, where prevailing northeasterly winds keep the coast free of ice throughout most of the winter (Seaman et al. 1982). In addition to pollock, saffron cod, and arctic cod, many other species of demersal, semidemersal, and pelagic fishes occur in the Bering Sea in autumn and winter and are certainly eaten at times by belukhas (ibid.). Spawning smelt are abundant in some coastal areas in autumn; shrimps and octopuses may be eaten in quantities in some areas (ibid.). However, based on observations of belukha foods in other areas and seasons and the winter distribution and abundance of potential prey, the bulk of the belukha autumn and winter diet in the Bering Sea is probably composed of arctic and saffron cods in northern Bering Sea areas and of pollock in southeastern and southcentral Bering Sea regions (ibid.).

B. Types of Feeding Areas Used

1. Spring/summer. In spring and early summer, belukhas move inshore and frequent shallow bays and the mouths of large rivers (Cook Inlet, Bristol Bay, the Yukon-Kuskokwim delta, Norton Sound) to feed on seasonally abundant migrating fishes (Brooks 1955, Klinkhart 1966, Seaman et al. 1982).
2. Summer/fall. Belukhas in Bristol Bay remain and feed in estuarine areas and the mouths and main stems of major rivers, especially of the Kvichak and Nushagak rivers (Lowry et al. 1982); other portions of the western arctic stock summer and feed in the nearshore areas of the northern Bering, Chukchi, and Beaufort seas (Norton Sound, especially in Golovin and Norton bays, the passes and waters adjacent to Kasegaluk Lagoon, and the MacKenzie River estuary) (ibid.).
3. Winter. Winter distribution is determined by the abundance and distribution of potential food species and sea ice (Seaman and Burns 1981, Seaman et al. 1982).
Most feed offshore, near the pack ice edge, or in polynyas in water to 50 fathoms in depth (Braham et al. 1982).

C. Factors Limiting Availability of Food

The prey consumed by belukha whales are also major foods of other species of cetaceans and pinnipeds in the Bering and Chukchi seas (Johnson et al. 1966, Frost and Lowry 1981, Lowry and Frost 1981). Arctic and saffron cods, pollock, herring, capelin, and smelt are of particular importance in the diet of at least six species of pinnipeds and four other species of cetaceans (ibid.). Competition for food may be particularly great between belukhas and spotted seals (*Phoca largha*) because their distributions and food habits overlap broadly throughout much of the year (Lowry and Frost 1981). Saffron cod and sculpins eaten by belukhas are generally larger than those eaten by seals, whereas arctic cod, capelin, smelt, and herring consumed by belukhas and seals are probably of similar size classes (Frost and Lowry 1981). The number of fish-eating pinnipeds in the Bering and Chukchi seas is difficult to estimate but certainly exceeds 2 million (ibid.). Given the broad dietary overlap with pinnipeds and the relatively much smaller population of belukha whales, limitation of the belukha population through competition for food is a possibility (ibid.). If so, the carrying capacity of the Bering-Chukchi system for belukha whales, as expressed by population size and productivity, may be influenced by the foraging activities and population sizes of other species of marine mammals. In addition, commercial fisheries, particularly for herring and salmon in coastal areas of the Bering and Chukchi seas and for groundfish in the southeastern Bering Sea, remove great quantities of marine mammal forage fishes (Pruter 1976; Lowry et al. 1979, 1982). The combined effects of predation and fishing on fish stocks and the possible resultant effects on marine mammal populations remain unclear (Lowry et al. 1982, Seaman et al. 1982).

D. Feeding Behavior

Little information is available on daily feeding patterns, percentage of time spent feeding, or foraging behavior. The maximum diving depth of belukhas is not known, but the duration of feeding dives is generally short, usually three to eight minutes; therefore, belukhas are thought to feed at comparatively shallow depths (Fay 1978, Lowry 1984). Prey are generally swallowed whole (Fay 1971, Fraker 1977); fish 5 to 74 cm in length are found in stomach contents (Lowry and Frost, pers. comm.). Sergeant (1969) reported that belukhas in captivity consumed food equal to 4-7% of their body weight per day; the highest rate was for a calf.

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Beginning in February and lasting through April, belukhas disperse from wintering areas (Seaman and Burns 1981). During the breeding period, some are in coastal waters, some in lead systems, and others are still in the ice (ibid.). Calving generally occurs in or near warm estuarine areas (Sergeant 1973), but some calves are born in colder, deeper water (Fraker et al. 1979).

B. Reproductive Seasonality

In Alaskan waters, most breeding activity takes place from February through April (Seaman and Burns 1981). Most births occur in June and July, although some calves are born from mid May to early September (ibid.).

C. Reproductive Behavior

Reproductive behavior has not been directly observed in belukhas (Murray 1979, Fraker et al. 1978); however, limited data from other toothed whales suggest that males are probably polygynous (Fraker et al. 1978).

D. Age at Sexual Maturity

1. Females. Age at first ovulation for females is four to five years (Brodie 1971, Seaman and Burns 1981), but maximum reproductive performance starts at seven to nine years (Ognetev 1981). Females mature physically at nine to ten years (ibid.).
2. Males. Reproductive activity commences at about 8 years (Brodie 1971, Lowry 1984); they mature physically at 11 to 12 years (Ognetev 1981).

E. Frequency of Breeding

Females normally produce one calf every three years (Brodie 1971, Seaman and Burns 1981). Few females ovulate in the estrous cycle that follows 10 months after calving; most do not become pregnant again until the following year (ibid.). If a group of sexually mature female belukhas were to be examined in early summer, approximately one-third would be about to calve, one-third would be recently pregnant, and one-third would not have bred in the year of collection. Most of these nonbreeders would be accompanied by a nursing year-old calf (ibid.).

- F. Fecundity
Sergeant (1973) computed a production rate of 11-14% for belukhas in Hudson Bay, Canada. Lowry (1984) estimated the gross annual production of belukha calves in Alaska to be 9%, a low rate, compared to marine mammals with annual breeding periods (ibid.).
- G. Gestation Period
Gestation requires 14 to 14.5 months (Brodie 1971, Seaman and Burns 1981).
- H. Lactation Period
Females nurse young for 18 months to two years (ibid.).

VI. FACTORS INFLUENCING POPULATIONS

- A. Natural
 - 1. Mortality. Although no mortality rates for Alaskan belukhas were located, known causes of mortality (other than hunting by humans) are predation by polar bears (Freeman 1973) and killer whales (Sergeant and Brodie 1969) and entrapment in sea ice (Porsild 1918). Lowry et al. (1982) state that "the relatively low rate of production and large proportion of older animals in harvests suggest that natural mortality rates are low."
 - 2. Competition. Interspecific competition for food could affect belukha distribution and/or abundance.
Although belukhas prey on the same fish species as a number of other marine mammals and birds, their feeding habits are most similar to those of spotted seals and harbor porpoises (Phocoena phocoena) (Lowry 1984). By exploiting pack ice habitat, belukhas avoid direct competition with harbor porpoises during winter (Burns et al. 1981; Frost and Lowry, pers. comm.). Both their seasonal range and food habits, however, extensively overlap those of the spotted seal (Lowry 1984).
- B. Human-related
Possible impacts of human-related activities include the following:
 - Barriers to movement, physical and behavioral
 - Chronic debilitation due to ingestion or contact with petroleum or petroleum products
 - Entanglement in fishing nets or marine debris
 - Prey base, alteration of
 - Harassment, passive
 - Harvest, change in level
 - Interference with intraspecies communication
 - Interference with reproductive behavior
 - Interruption of ongoing behavior: alarm, flight
 (See the Impacts of Land and Water Use volume of this series for additional information regarding impacts.)

VII. LEGAL STATUS

A. Federal

Belukhas are protected by the U.S. Marine Mammal Protection Act of 1972 (MMPA, PL 92-522).

B. State

The state of Alaska currently has no responsibility for belukhas but may request return of management of 10 species of marine mammals, including belukhas whales.

C. Population Management History

Data are presented for the entire state rather than by GMU.

1. Summary of harvest. A few belukhas from the Cook Inlet stock are harvested by humans (Lowry 1984). In the 1930's, about 100 whales were netted and processed for meat and oil before the attempted commercial venture was abandoned (ibid.). A few Cook Inlet whales were taken by hunters in the 1960's.

In contrast, the Bering-Chukchi stock of belukhas is an important food resource for the residents of coastal Alaska, Canada, and Siberia. In the late 1950's, Lensink (1961) estimated that the annual harvest was 400-500 whales; however, by the mid 1960's, Seaman and Burns (1981) estimated that the take had declined to 150-300 whales per year, perhaps largely due to the decline in the number of dog teams to be fed. From 1968 through 1973, the Alaskan harvest of whales from the western arctic stock averaged 183 animals annually (ibid.). From 1977 through 1979, more complete records were kept of the belukha harvest. In 1977, a harvest of 247 animals was recorded; 5 were from the Southwest Region, 33 from the Western Region, and 209 from the Arctic Region (ibid.). In 1978, a total Alaskan harvest of 177 was recorded, 2 from Southwest, 18 from Western, and 158 from Arctic. In 1979, a total Alaskan harvest of 138 was recorded, 3 from Southwest, 46 from Western, and 89 from Arctic (ibid.).

Belukhas from the western arctic stock are taken in Soviet waters (an average of 100-200 animals taken per year) (Lowry 1984), as well as in the MacKenzie estuary of Canada (an average of 141 whales were taken annually from 1972 through 1977) (Fraker et al. 1979). The loss rate associated with harvest varies with the area and hunting methods and ranges from 20 to 60% (Seaman and Burns 1981).

Using harvest estimates from Alaskan, Canadian, and Soviet waters and appropriate loss-rate estimates, Lowry (1984) estimated that "total annual removals from the Bering-Chukchi stock in recent years have therefore been about 600-700 animals."

2. Period of state authority. Belukhas were managed by the state of Alaska from statehood in 1959 until passage of the MMPA in 1972. Harvest levels were low and reduced from previous years, so no limit was imposed on the take, although harvests were monitored.

3. Period of federal authority. Passage of the MMPA had little effect on the overall harvest of belukhas because although only Alaskan Natives could harvest belukhas after the MMPA and sale of belukha products to non-Natives was prohibited, most of the take and use had always been by Eskimos (Lowry 1984). No federal program was instituted to gather harvest or biological data; state biologists, however, again monitored harvests from 1977 through 1979 and from 1981 to the present (ibid.).
 4. International agreements. The United States has entered into no international agreements concerning belukhas.
- D. Current Population Management
- The National Marine Fisheries Service (NMFS) of the Department of Commerce has the responsibility for management of belukhas for the federal government.
1. Management objectives. NMFS has no published plan for management of belukha whales (Zimmerman, pers. comm.).
 2. Management considerations. Conflicts with fisheries, especially the Bristol Bay salmon fishery, the unknown effects of development on belukhas, the lack of a federal management plan, and data gaps in the basic biological information for the stock are problems in the management of belukhas in Alaska.

VIII. LIMITATIONS OF INFORMATION

Information is needed on natural mortality rates. The role of diseases and parasites in belukhas is poorly known. The limits of the wintering area suspected to be in the Bering Sea needs to be determined. More information is needed about what portions of the western arctic population migrate north, what portion stays along the southern coastal region, and what degree of intermixing occurs in the Bering Sea wintering area.

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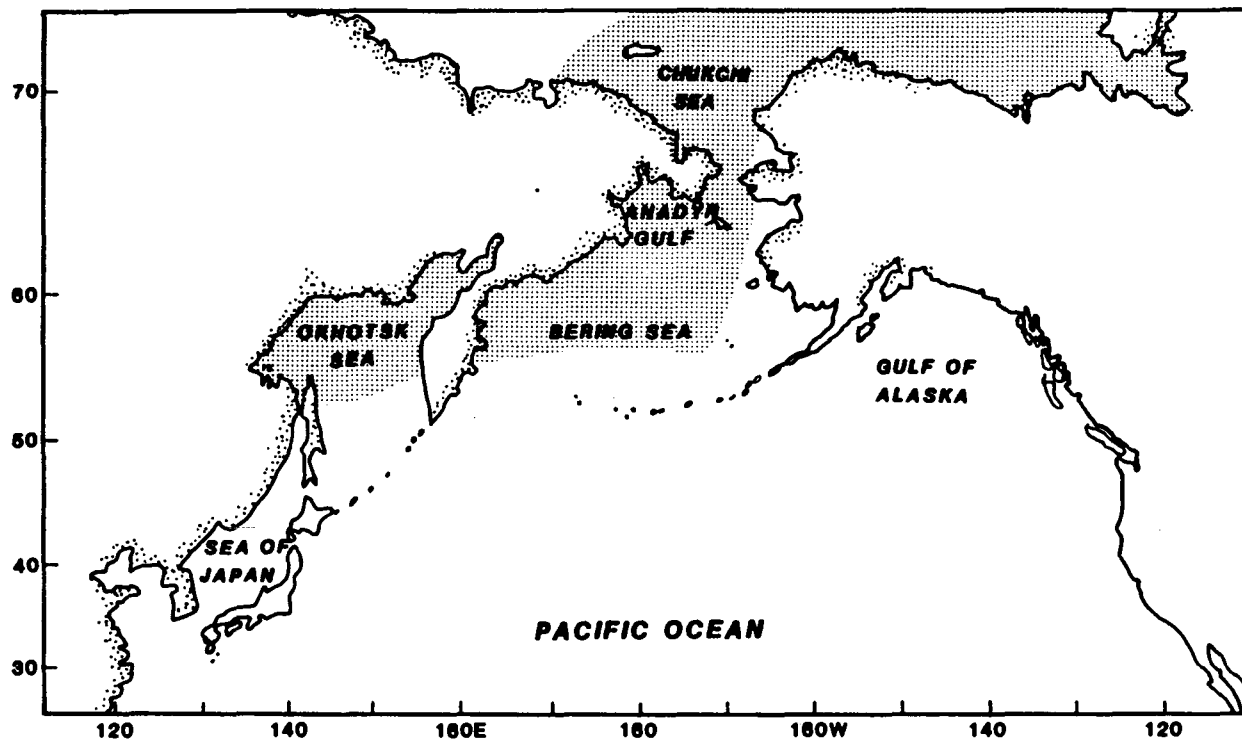
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Bowhead Whale Life History and Habitat Requirements Arctic and Western Regions



Map 1. Range of bowhead whale (Braham 1983)

I. NAME

- A. Common Names: Bowhead whale, Greenland whale, Greenland right whale, arctic right whale, great polar whale
- B. Scientific Name: Balaena mysticetus (Linnaeus 1758)
- C. Native Names: See appendix A.

II. RANGE

- A. Worldwide
Prior to the commercial whaling period (1842-1914), bowhead whales were nearly circumpolar in distribution in arctic and subarctic waters (map 1). Four separate stocks of bowheads occurred in 1) the Sea of Okhotsk; 2) the Bering, Chukchi, and Beaufort seas (western arctic stock); 3) Hudson Bay, Baffin Bay, Davis Strait, and adjacent waters; and 4) the Greenland and Barents seas

(Spitsbergen stock) (Tomilin 1957, Marquette 1977). Commercial whaling severely depleted all of these stocks (Marquette 1977).

B. Statewide

The western arctic bowhead stock ranges from the westcentral Bering Sea north throughout the eastern Chukchi Sea and eastward throughout the Beaufort Sea to Banks Island and Amundsen Gulf, Northwest Territories, Canada (Krogman 1980).

C. Regional Distribution Maps

To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for the Arctic Region at 1:250,000 scale. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of bowhead whale distribution has been prepared and may be found in the Atlas that accompanies the Arctic and Western and Interior regional guides.

D. Regional Distribution Summary

1. Arctic. The summer range for most of this stock is in Amundsen Gulf and the Canadian Beaufort Sea east and north of Herschel Island (Fraker and Bockstoce 1980). Some bowheads may not migrate into Canadian waters and may spend the summer in the northern Chukchi Sea and/or western Beaufort Sea (Braham et al. 1980b, Bogoslovskaya et al. 1982). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Arctic Region.)

2. Western. Old whaling records show that bowheads historically overwintered in the pack ice between St. Lawrence and St. Matthew islands in the Bering Sea, but the specifics of wintering areas are poorly known (Brueggeman 1982). During years of extensive pack ice formation, bowheads may winter as far south as the Pribilof Islands (Braham et al. 1980a). (For more detailed narrative information, see the Alaska Habitat Management Guide for the Western and Interior regions.)

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

1. Water quality. No specific information was found; however, bowheads occur in areas of both clear and turbid water. Oil in the water may foul baleen plates and reduce filtering efficiency (Braithwaite 1980a, b, 1983).

2. Water depth. Bowheads migrate over fairly deep water, but in summer the "20-25 fathom whaling ground" (40-50 m water depth) was considered the most productive (Bodfish 1936). Although whales frequent both deeper and shallower water, many are found in water about 50 m deep off the Tuktoyaktuk Peninsula (N.W.T., Canada) in August and September (Fraker and Bockstoce 1980). Hazard and Cubbage (1982), however, suggest that "the greater proportion of whales seen in shallow water is an artifact of more observation time devoted to shallow water."

3. Water temperature. No information was found on the range of temperatures selected or tolerated by bowhead whales.
 4. Substrate. No information was found, but bowheads feed primarily on pelagic crustaceans (Lowry and Frost 1984), and substrate is unlikely to be of particular importance.
 5. Acoustic properties. Although no unequivocal evidence was found on acoustic habitat requirements, many observations of bowhead reactions to various types of noise have been reported (Carroll and Smithhisler 1980, Reeves et al. 1984, Davis and Richardson 1985). The significance of the observed behavior changes is unclear (ibid.).
- B. Ice
1. Effects on movement and distribution. Bowhead whales apparently migrate in response to changes in ice conditions, moving north as leads open and south before freeze-up (Lowry et al. 1978, Ljungblad et al. 1985). Brueggeman (1982) noted more whales than predicted in areas of 3-4 okta ice in early spring, apparently waiting for leads to open; Braham and Krogman (1977) noted the same situation near Point Barrow. Carroll and Smithhisler (1980) noted that whales seemed to follow one another and surfaced in the same places to breathe as they migrated north. If the ice beyond was closed, the whales dove to search for open water, then returned to mill about and keep the surface of the water from freezing. Although bowheads can break through ice 22 cm thick, they are occasionally trapped in the ice (see references in Carroll and Smithhisler 1980). Hazard and Cabbage (1982) noted more bowheads than predicted near the ice edge on aerial surveys in the eastern Beaufort Sea in summer.
 2. Protection from elements, predators, disturbance. Sea ice dampens waves from storms (Burns et al. 1981) and makes escape from predators easier unless the amount of open water or thin ice is restricted.

IV. NUTRITIONAL REQUIREMENTS

Aspects of the feeding biology of bowheads are poorly known. Few stomach samples have been analyzed, and some reports of prey items were based on indirect or limited data.

Beginning in 1976, stomach content samples were taken from 20 bowhead whales harvested by Eskimo hunters at several locations along the northern and western Alaskan coasts (Lowry and Frost 1984). Samples were taken opportunistically and represent different seasons and locations. Approximately 56 species were found, including 50 species of crustaceans, 3 species of molluscs, and 3 species of fishes. Although most of the prey species (23) were gammarid amphipods, the most frequently encountered species, in order of occurrence, were the euphausiid, Thysanoessa raschii; the copepod, Calanus hyperboreus; and the hyperiid amphipod, Parathemisto libellula. Organisms smaller than about 2.5 mm are not effectively retained by bowhead baleen (ibid.). The largest prey regularly consumed are ± 30 mm and include euphausiids, mysids, and amphipods (ibid.).

A. Food Species Used

1. Spring. Lowry and Frost (1984) found that most prey species in whale stomachs (53/56) were invertebrates, and most of those were primarily benthic organisms (35/53). Benthic organisms made up a small proportion of the overall stomach contents, however, with the exception of five small whales taken in spring in the Bering and Chukchi seas. Lowry and Frost (1984) believe "the incidence of feeding during the northward migration appears to be less in the Chukchi Sea than in the Bering. Feeding whales may be predominantly juveniles, and their prey are mostly benthic invertebrates."
2. Summer. Many bowheads summer in the eastern Beaufort Sea, where they presumably feed extensively (Wursig et al. 1981); no direct information on summer food items is available. Whales probably feed on locally abundant food items, especially pelagic crustaceans, during this period.
3. Autumn. The caloric value of copepods collected in September was 1.5 times that of the same species collected in late July and early August. Therefore, although the autumn feeding time is short, it may be of relatively great importance (Lowry and Frost 1984).
 - a. Barter Island. Samples collected from five whales harvested near Barter Island between 20 September and 11 October 1979 indicate that in this area bowhead whales were feeding primarily on pelagic copepods, euphausiids, and mysids (Lowry and Burns 1980). Table 1 lists the major food items identified from bowhead stomach samples, and table 2 presents the quantitative composition of those samples.
 - b. Barrow. Stomach samples taken from two bowhead whales harvested near Point Barrow in September 1976 were almost entirely (90% of the volume) euphausiids, with some gammarid and hyperiid amphipods (Lowry et al. 1978). The principal euphausiid species, (*Thysanoessa raschii*) was the same found in whales taken at Kaktovik (Lowry and Burns 1980) and is widely distributed in arctic waters, primarily in the nearshore neritic zone (Nemoto 1966).
4. Winter. No data on winter foods are available.

B. Types of Feeding Areas Used

1. Summer. The eastern Beaufort Sea and Amundsen Gulf may be important feeding areas for bowhead whales during early summer (Fraker 1979). Later, from mid July to mid September, they move to the MacKenzie River delta region, usually staying in water 50 m or shallower (Fraker and Bockstoce 1980). Although no stomach samples are available from bowheads in summer, presumed feeding behavior has been observed in these areas (Wursig et al. 1981, Wursig 1985).
2. Autumn. Bowheads feed regularly in at least two main areas in the Alaskan Beaufort Sea in September and October: 1) east of Barter Island to at least the United States-Canada

Table 1. Food Items from Bowhead Whale Stomach Samples Collected at Kaktovik, Barter Island, Alaska, September-October 1979

Copepods:

<u>Calanus finmarchicus</u>	0	0	0	XX	0
<u>Calanus hyperboreus</u>	XXX	XXX	XX	XXX	XX
<u>Chiridius obtusifrons</u>	0	0	0	XX	0
<u>Heterorhabdus</u> sp.	0	XX	0	XX	0
<u>Metridia lucens</u>	0	XX	0	XX	0

Euphausiids:

<u>Thysanoessa raschii</u> ^a	0	XX	XXX	XX	XXX
<u>Thysanoessa inermis</u>	0	0	0	0	X

Mysids:

<u>Mysis litoralis</u>	0	XX	XX	0	XX
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Hyperiid amphipods:

<u>Hyperia medusarumi</u>	0	X	0	0	0
<u>Hyperia</u> sp.	X	0	0	0	0
<u>Parathemisto abyssorum</u> ^a	0	0	XX	0	0
<u>Parathemisto libellula</u> ^a	X	X	X	X	*

Gammarid amphipods:

<u>Acanthostepheia</u>					
<u> behringiensis</u> ^a	0	0	X	0	*
<u>Acanthostepheia</u>					
<u> incarinata</u>	0	X	0	0	0
<u>Apherusa glacialis</u>	0	0	0	X	0
<u>Atylus carinatus</u>	0	0	X	0	X
<u>Gammaracanthus</u>					
<u> Loricatus</u>	0	0	X	0	*
<u>Gammarus</u> sp. ^a	0	X	0	0	0

(continued)

Table 1 (continued).

Food Item	Whale Specimen Number				
	79-KK-1	79-KK-2	79-KK-3	79-KK-4	79-KK-5
Gammarid amphipods:					
<u>Monoculoides c.f. M. schneideri</u>	0	0	X	X	0
<u>Munnopsis c.f. M. typica</u>	0	0	X	0	0
<u>Onisimus glacialis</u>	X	0	0	0	0
<u>Onisimus litoralis</u>	X	0	0	0	0
<u>Rozinante fragilis^a</u>	0	0	0	X	0
<u>Weyprechtia heulgini</u>	0	0	0	X	*
Family Lysianassidae	X	0	0	0	0
Shrimps:					
<u>Eualus gaimardii</u>	0	0	0	X	0
<u>Sabinea septemcarinata</u>	0	0	0	X	0
Family Crangonidae	X	0	0	0	0
Unidentified	0	X	0	0	0
Isopods:					
<u>Saduria entomon</u>	0	0	0	0	X
Cumaceans:					
<u>Diastylis sp.</u>	0	0	0	X	0
Fishes:					
<u>Boreogadus saida</u>	0	X	0	0	*
<u>Myoxocephalus quadricornis</u>	0	0	X	0	*
<u>Pungitius pungitius</u>	0	0	0	0	*
Unidentified	0	0	0	X	0
Pebbles	X	0	0	0	X

Source: Lowry and Burns 1980.

* = present in qualitative sample only.

X = 1-10 individuals in sample.

XX = more than 10 individuals in sample.

XXX = dominant item in sample.

a = previously reported XX food items of bowhead whales from northern Alaska (Lowry et al. 1978, Marquette 1979).

Table 2. Quantitative Composition of Stomach Contents from Bowhead Whales Collected at Kaktovik, Autumn 1979

Prey Type	Whale Specimen Number					Overall Mean Percentage Contents ^b
	79-KK-1 ^a	79-KK-2	79-KK-3	79-KK-4	79-KK-5	
Copepod	99.7	99.0	23.4	88.3	0.1	59.8
Euphausiid	0	0.3	67.8	4.9	97.9	37.2
Mysid	0	0.3	7.0	0	0.8	0.2
Hyperiid						
amphipod	0.1	0.1	0.5	0.4	0	0.1
Gammarid						
amphipod	0.1	0.1	0.3	2.4	0.1	0.4
Other						
invertebrate	0.1	0.1	0	2.3	1.1	0.6
Fish	0.1	0.1	1.0	1.7	0	0.4
Sample volume (ml)	2,406.2	545.2	399.7	131.3	357.9	
Estimate total volume of contents (gallons)	12	5	6	5	10	

Source: Lowry and Burns 1980.

a For each whale, numbers indicate percentage of the sample volume comprised of each prey type.

b The overall mean percentage of contents was calculated based on the volume and percent composition of each sample and the estimated total contents of stomachs from which the samples were taken.

demarcation line (141° W) and 2) east of Barrow to Pitt Point (Lowry and Frost 1984). Feeding behavior has been observed in these areas, and stomachs of whales taken at Barrow and Kaktovik in autumn contain food (ibid.).

C. Factors Limiting Availability of Food

Sea ice limits the availability of food to bowhead whales by blocking light, thus limiting productivity, and by limiting the areas to which the whales have access (Ljungblad et al. 1985). Ringed seals (*Phoca hispida*) and arctic cod (*Boreogadus saida*) are the bowhead's most significant trophic competitors in the Beaufort Sea (Lowry and Burns 1980). Broad dietary overlap is probably

less important to the euryphagus ringed seal, which eats many species of fishes and crustaceans, than to the relatively stenophagus bowhead, which depends more on "swarms of small to medium sized zooplankton" (Lowry et al. 1982).

D. Feeding Behavior

Three major types of feeding behavior occur in bowhead whales: skimming, water column feeding, and bottom feeding (Ljungblad 1981, Wursig et al. 1981, Wursig 1985). Another behavior, bubble-blowing, has been associated with feeding, although its function is uncertain (Wursig et al. 1981). The relative frequency of feeding behavior types changed from year to year; the distribution of prey probably dictates bowhead movements and behaviors in the Beaufort Sea in summer (Wursig 1985).

Skim-feeding whales swim slowly at the surface with the rostrum at or above the water surface and parallel to it and the lower jaw dropped (Wursig et al. 1981).

Whales occasionally skim-feed alone but more commonly are observed in groups of 2 to 10 individuals. In these cases, each group covers an area of about 10 km². The groups are separated from each other by 10-20 km and remain in the same general area while feeding (ibid.). Skim-feeding whales have been observed swimming in echelon formation, staggered to the side and behind the whale at the apex, with each whale separated by 10-50 m (ibid.). At other times, bowheads have been noted swimming abreast and parallel to one another. The largest skim-feeding formation observed contained five individuals (ibid.).

Although bowheads are basically "skimmers," they do forage near the bottom, at least in shallow areas (Ljungblad 1981, Hazard and Lowry 1984). Bottom-feeding whales are widely separated when they surface, usually no closer than 300 m apart (Wursig et al. 1981).

While water-column feeding, bowheads swim slowly at the surface, taking a series of breaths before diving obliquely to the bottom and back to the surface. Water-column feeding whales remain submerged longer and spend somewhat more time at the surface between dives than do whales engaged in other activities (Wursig et al. 1981).

Although no direct observations were found on the percentage of time spent feeding, Lowry and Frost (1984), making a number of assumptions (e.g., average caloric value of prey, swimming speed, filtering efficiency, average whale size), calculated that an average-sized whale would need to feed for 1,744-2,528 of the 3,120 hours available in a typical feeding season.

Assuming a six-month feeding season, Brodie (1980) estimated that an average bowhead would need to consume 1.1-1.3% of its total body weight (TBW) per day. Frost and Lowry (1981) estimated an intake of 3% TBW per day, and Marquette (1978) estimated an intake of 4% TBW per day.

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Mating probably takes place during spring migration (Braham and Krogman 1977, Everitt and Krogman 1979). Imm (1980) believes that mating is the principal bowhead activity prior to ice breakup in the Bering Strait.

Apparent reproductive activity was observed in an open-water lead in the pack ice about 32 km east of Point Barrow (Everitt and Krogman 1979). Pack ice appeared to be solid east of the immediate area, suggesting that migration was delayed.

B. Reproductive Seasonality

The mating season for bowheads is not well known. Marquette (1977) states that breeding occurs during the spring migration and in early summer. Presumed breeding behavior has been observed near Point Barrow (Everitt and Krogman 1979) and Point Hope (Foote 1964) in early May. Nerini et al. (1982) reported that breeding activity has been observed from March through May.

Based on sightings of young of the year, fetal lengths, and harvest of lactating females, Nerini et al. (1982) estimated that calving probably occurs from March to August, with a peak in May.

C. Reproductive Behavior

Reproductive activity has been observed only rarely in bowhead whales because of the difficulty in observing these animals in their natural environment. Everitt and Krogman (1979) observed a pod of six bowheads in a lead in the pack ice east of Point Barrow engaged in what they thought to be reproductive activity: aggregation of several whales, flipper-touching or twisting, one whale clasping another with its flippers, and attempted copulation. Spring ice conditions (i.e., denser pack ice with few open-water leads) may cause the population to be more aggregated than at other times of year, increasing the number of social interactions that eventually lead to mating (Braham and Krogman 1977, Everitt and Krogman 1979, Imm 1980). The rate of social encounters decreases steadily from spring to autumn (Wursig 1985).

D. Age at Sexual Maturity

Most bowhead whales harvested in recent years are immature, making it difficult to obtain data about reproduction and sexual maturity. All data on sexual maturity are given as a function of body length, but there is no adequate method of aging bowheads or of correlating body length and age (Nerini et al. 1982).

1. Females. Nerini et al. (1982) found that all sexually mature females examined were 13-14 m in length. Davis et al. (1983) found that 91% of all females observed to be accompanied by a calf were longer than 13.5 m.

2. Males. Tomilin (1957) stated that bowheads are sexually mature at 14-18 m.

E. Frequency of Breeding

Durham (1972) concluded from indirect evidence that bowheads calve every second year or less often. Marquette (1978) stated that the

calving interval was two to three years, and Nerini et al. (1982) believed it to be three to five years.

F. Fecundity

Female bowheads normally produce only one calf; a female with two calves is rarely observed (Scoresby 1820, Eschricht and Reinhardt 1866). Nerini et al. (1982) reported that 4 of 13 sexually mature females examined were pregnant or recently postpartum and suggested a pregnancy rate of 0.31. Extrapolating these data and making a number of assumptions, they give a gross annual recruitment rate of 2.0-3.5%.

G. Gestation Period

Based on lengths of fetuses, neonates, and calves, as well as assumed calving and mating periods, Nerini et al. (1982) estimated the gestation period to be 13 months. Gestation periods of 9 to 13 months have been suggested for bowheads (see references in Nerini et al. 1982).

H. Lactation Period

The length of the lactation period is not known; however, lactating female bowheads have not been taken in the autumn harvest, indicating that weaning may occur at five to six months of age (ibid.).

VI. FACTORS INFLUENCING POPULATIONS

A. Natural

Bowheads suffer no predation other than hunting by humans and occasional attacks by killer whales (Orcinus orca) and have few parasites or diseases (Gusey 1983). Bowheads may occasionally be caught in ice and die. Mortality rates are not known. (See section IV. C., Factors Limiting Availability of Food, for a discussion of trophic competition.)

B. Human-related

A summary of possible impacts from human-related activities includes the following:

- Barriers to movement, physical and behavioral (e.g., structures)
- Chronic debilitation due to ingestion or contact with petroleum or petroleum products
- Chronic debilitation due to ingestion or contact with chemicals
- Collision with vehicles or structures
- Harassment, passive
- Harvest, change in level
- Interference with intraspecies communication
- Interference with reproductive behavior
- Interruption of ongoing behavior: alarm, flight
- Prey base, alteration of

VII. LEGAL STATUS

A. Federal

Bowhead whales are classified as endangered and are protected under the Endangered Species Conservation Act of 1969 (PL 91-135) and Marine Mammal Protection Act of 1972 (MMPA, PL 92-522). The NMFS (NOAA, U.S. Department of Commerce) oversees bowhead whales for the federal government.

B. State

The State of Alaska has no managerial authority or responsibility for bowhead whales.

C. Population Management History

1. Summary of harvest. During the commercial whaling period (1848-1914), over 18,000 bowheads were killed, and at least 16,000 were taken by Yankee whalers (Bockstoe and Botkin 1980). The western arctic stock was depleted quickly; two-thirds of the total Yankee harvest was taken within the first two decades of whaling (ibid.). By 1914, commercial take of bowheads ended because of the decline of the bowhead population and the collapse of the whalebone and whale-oil markets (ibid.). Between 1910 and 1969, the annual catch dropped sharply; records indicate that 704 bowheads were taken, for an average take of 11.7 whales per year (Marquette and Bockstoe 1980). The harvest then jumped: from 1970 through 1977, a total of 259 whales were landed, with an average of 32.4 per year (ibid.). Beginning in 1978, the annual harvest quota has been set by the International Whaling Commission (IWC) and has ranged from 14 to 18 whales landed (ibid.).

2. Period of state authority. The State of Alaska has never had managerial authority or responsibility for bowhead whales.

3. Period of federal authority and international agreements. Bowhead whales have been completely protected from commercial whaling since 1946 by the International Convention for the Regulation of Whaling, the same act that set up the IWC. In 1969, the Endangered Species Conservation Act (ESA, PL 91-135) placed the bowhead under further protection and ended all nonsubsistence whaling by the United States. The MMPA placed restrictions on the importation of marine mammal products and allowed only Alaskan Natives to take bowhead whales for subsistence and for creating handicraft items and clothing for personal use and sale. The MMPA and ESA allow for regulation of subsistence take if the stock is declared depleted. Rather than go through the lengthy hearing process to set up regulations under those laws, the United States proposed to the IWC a yearly quota system of whales struck and whales landed. The first quotas took effect in 1978; enforcement was through the Whaling Convention Act. At the same time (1978), the Alaska Eskimo Whaling Commission (AEWC) was organized.

D. Current Population Management

In 1981, NMFS entered into a two-year cooperative agreement with the AEWG for cooperative bowhead whale management. An amendment to the cooperative agreement, passed in July 1982, extends the agreement through 1987. The IWC sets overall quotas, usually for a block of several years. NMFS and AEWG then determine, through annual negotiations, the number of whales that may be struck in each year; if they are unable to agree in a particular year, the quota from the previous year applies.

1. Management objectives. The AEWG Management Plan provides for the following:
 - Enforcement powers held by the AEWG
 - Definitions of permissible whaling equipment and methods
 - Registration of each Eskimo whaling captain in Alaska
 - Requirement of reporting all whaling occurrences, strikes, landings, or accidents
 - Establishing the level of harvest in conjunction with NMFS and setting the level of fines for infractions
 - Supporting bowhead and weapons research (AEWG 1985)
2. Management considerations. Research is continuing on more efficient and humane methods of whale harvest and reducing the number of whales struck and lost.

VIII. LIMITATIONS OF INFORMATION

More data are needed on mortality and recruitment rates and other basic vital parameters, the effects of disturbance and development on bowheads, wintering areas and foods, and the effects of competitive trophic interactions. In addition, a better method of estimating population size needs to be developed.

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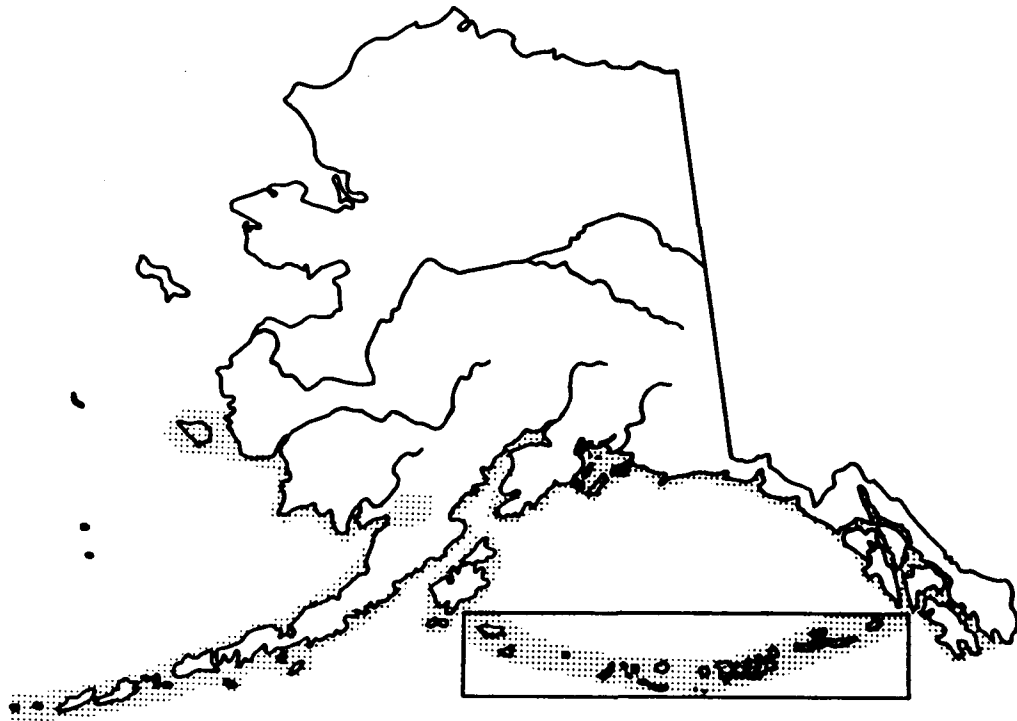
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Harbor Seal Life History and Habitat Requirements
Southwest and Southcentral Regions



Map 1. Range of harbor seal (ADF&G 1973)

I. NAME

- A. Common Name: Harbor seal
- B. Scientific Name: Phoca vitulina richardsi (Shaughnessy and Fay 1977)
- C. Native Names: See appendix A.

II. RANGE

- A. Worldwide
The North Pacific harbor seal is found in coastal waters from northwestern Mexico along the North American coast as far north as the Bering Sea, along the Aleutian Islands chain, in the Pribilof, Commander, and Kuril islands, eastern Kamchatka, the Okhotsk Sea, and northern Japan (Burns and Gol'tsev 1984). Burns and Gol'tsev (1984) could not substantiate the physical characteristics that

separated P. v. Stejnegeri and P. v. richardsi (Shaughessy and Fay 1977) and so rejoined the subspecies as P. v. richardsi.

B. Statewide

Harbor seals inhabit coastal waters from Southeast Alaska to the Kuskokwim Bay-Nunivak Island region of Alaska and westward throughout the Aleutians (ADF&G 1976, Frost et al. 1982). They are also frequently found in major rivers where seasonal concentrations of food species occur.

C. Regional Distribution Maps

To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for the Southwest, Southcentral, and Southeast regions. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of harbor seal distribution has been prepared and may be found in the Atlas that accompanies the Southwest and Southcentral regional guides.

D. Regional Distribution Summary

1. Southwest. Harbor seals occupy virtually all coastal areas in the Southwest Region. Illiamna Lake appears to support a year-round subpopulation (ADF&G 1976). (For more detailed narrative information, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)
2. Southcentral. Harbor seals occupy virtually all coastal areas in the Southcentral Region and seasonally are found in certain rivers and lakes (Pitcher and Calkins 1979). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

Harbor seals are typically found where water depths are less than 30 fathoms (ADF&G 1976). They tolerate a wide range of temperatures and water salinity (Boulva and McLaren 1979). Harbor seals are generally considered a coastal species, but they have been seen up to 100 km offshore (Spalding 1964, Fiscus et al. 1976, Wahl 1977).

B. Terrestrial

1. Haulout areas. Haulouts are used for resting, giving birth, and nursing young. They may be especially important during the molt (Pitcher 1984). In the Gulf of Alaska, commonly used haulout substrates include offshore reefs, rocks and ledges, beaches of isolated islands, mainland or island beaches backed by cliffs, sand and mud bars (often located in estuaries), ice floes calved from tidewater glaciers, and sea ice (Pitcher and Calkins 1979). On the northern coast of the Alaska Peninsula, seals concentrate on shoals and sandbars exposed during low tides, primarily in estuaries (Frost et al. 1982). Ready access to water, isolation from disturbance, protection from wave and wind action, and access

to food sources are characteristics often associated with haulout sites (Pitcher 1981). In the Gulf of Alaska, according to Pitcher and McAllister (1981), although fidelity to a single haulout area was not consistent, there was a strong tendency to use one or, in some instances, two hauling areas repeatedly.

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

In the Gulf of Alaska, Pitcher and Calkins (1979) found that fish, including walleye pollock (Theragra chalcogramma), capelin (Mallotus villosus), herring (Clupea harengus), Pacific cod (Gadus macrocephalus), flatfishes (Pleuronectidae), eulachon (Thaleichthys pacificus), and salmon (Oncorhynchus sp.); cephalopods, including both octopus (Octopus sp.) and squid (Gonatidae); and decapod crustaceans, mainly shrimp, were the primary prey species consumed by harbor seals. In Prince William Sound, the most important food items were pollock, herring, and cephalopods, whereas along the Copper River delta the major prey was eulachon (Pitcher 1977). Stomach samples collected in the Aleutian Islands (Wilke 1957, Kenyon 1965, Lowry et al. 1979) included fishes, octopuses, and crustaceans.

B. Types of Feeding Areas Used

Harbor seals are opportunistic feeders and generally feed in nearshore shallow waters (FAO 1976).

C. Factors Limiting Availability of Food

No pertinent discussion was found in the literature.

D. Feeding Behavior

Harbor seals swallow small fish whole underwater. Larger fish are taken to the surface, where they are eaten in pieces (Ronald et al. 1982).

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

1. Pupping. Pupping appears to take place at nearly all locations where seals haul out (Pitcher and Calkins 1979).
2. Breeding. Actual mating occurs in water. Some aggressive behavior related to breeding occurs at haulouts (Bishop 1967).

B. Reproductive Seasonality

1. Pupping. In Alaska, harbor seals generally give birth between late May and mid July, with most pups born during the first three weeks of June (ADF&G 1973).
2. Breeding. Breeding usually occurs from late June to late July shortly after females have ceased nursing their pups (Pitcher and Calkins 1979).

C. Reproductive Behavior

During the breeding season, males become aggressive toward other males and toward females. Actual breeding and probably most of the aggressive behavior occur in coastal waters (Bishop 1967).

Observation by Pitcher and Calkins (1979) indicated that the first several hours following birth were critical to formation of the mother-pup bond. It appeared that if disturbance separated the mother and pup shortly after birth, before a strong bond was formed, permanent separation often occurred, resulting in the death of the pup.

- D. Age at Sexual Maturity
Both males and females become sexually mature between three and seven years of age (Bigg 1969, Pitcher 1977).
- E. Frequency of Breeding
Breeding takes place annually (Pitcher and Calkins 1979).
- F. Fecundity
Generally one pup is born. Estimates of adult pregnancy rates range from 92 to 100% (Pitcher 1981).
- G. Gestation Period
From the time of breeding to the time of pupping is about 330 days. However, because of a delayed implantation period of about 11 weeks (Pitcher and Calkins 1979), the actual gestation period is about 255 days.
- H. Lactation Period
The reported lactation period ranges from three to six weeks (Bishop 1967, Bigg 1969, Knudtson 1974, Johnson 1976).

VI. FACTORS INFLUENCING POPULATIONS

- A. Natural
Little is known about the effects of food availability, disease, parasitism, and predation on harbor seal populations. However, Steller sea lions, killer whales, and sharks are known to prey on both adult and newborn harbor seals (Calkins and Pitcher 1982, Pitcher 1981). Pitcher and Calkins (1979) found that in the Gulf of Alaska mortality rates for both sexes were high from birth to four years. Estimated mortality for females was 74.2% and for males 79.2%.
- B. Human-related
A summary of possible impacts from human-related activities includes the following:
 - Chronic debilitation due to ingestion or contact with petroleum or petrol products
 - Mortality due to ingestion of petroleum or petrol products
 - Harassment, active and passive
 - Terrain alteration or destruction
 - Entanglement in fishing nets or marine debris(See the Impacts of Land and Water Use volume of this series for additional information regarding impacts.)

VII. LEGAL STATUS

Harbor seals are federally protected under the Marine Mammal Protection Act (MMPA) of 1972. Native Alaskan residents may harvest harbor seals without restriction under this act, providing harvest is not done in a wasteful manner. The State of Alaska is considering petitioning the

federal government for renewed managerial authority over 10 species of marine mammals, including harbor seal.

VIII. SPECIAL CONSIDERATIONS

A. Molting

Observations by Pitcher and Calkins (1979) in the Gulf of Alaska indicated that the molt began about the first of June and extended into early October. The highest proportion of molting animals was found in late July.

During the molt, seals are thinner than at any other time (Pitcher and Calkins 1979). Stress occurs in molting seals (Ronald et al. 1970, Garcia and Smith 1976), and hauling out during the molt may be important to warming the skin (Feltz and Fay 1966). Disturbance during the molt that causes hauled out seals to enter the water could be detrimental to their health (Pitcher and Calkins 1979).

IX. LIMITATIONS OF INFORMATION

As was noted above (VI.A.), little is known about what factors may limit the availability of food for harbor seals nor the effects of predation on populations.

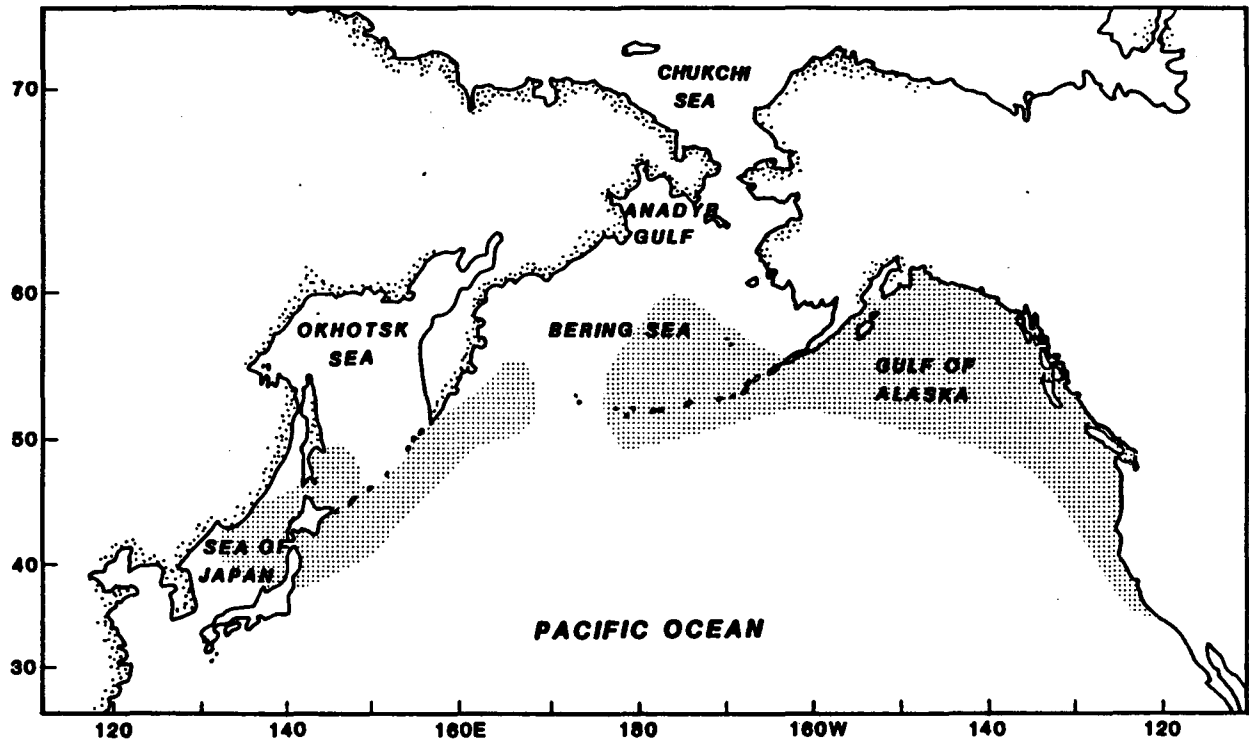
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Northern Fur Seal Life History and Habitat Requirements Southwest Region



Map 1. Range of northern fur seal (Anon. 1980, Ronald et al. 1982, Lowry et al. 1982)

I. NAME

- A. Common Name: Northern fur seal
- B. Scientific Name: Callorhinus ursinus
- C. Native Names: See appendix A.

II. RANGE

- A. Worldwide
Northern fur seals seasonally inhabit a vast area of the North Pacific Ocean and the southern Bering Sea, from north of the Pribilof Islands, south along the eastern side of the Pacific Ocean as far as the California-Mexico border, and along the western side of the Pacific Ocean as far as Honshu, Japan (Anon. 1980).

- B. Statewide
Terrestrial distribution is limited to haulout and breeding rookeries on the Pribilof Islands; pelagic distribution includes most of the southern Bering Sea, the Gulf of Alaska (Ronald et al. 1982), and the eastern continental shelf area of the Pacific Ocean south to the Pacific Northwest (Consigliari and Braham 1982). A large concentration winters in the nearshore area around Baranof Island (ibid.).
- C. Regional Distribution Maps
To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for the Southwest Region at 1:250,000 scale. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of fur seal distribution has been prepared and may be found in the Atlas that accompanies the guide for the Southwest Region.
- D. Regional Distribution Summary
 - 1. Southwest. Northern fur seals are seasonally abundant in a 100-mi-radius area surrounding the Pribilof Islands, in the Bering Sea between the Pribilof Islands and the eastern Aleutian Islands (Lowry et al. 1982), and in Unimak, Akutan, and Umnak passes (Lowry et al. 1983, MMS 1982). (For more detailed narrative information, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)

III. PHYSICAL HABITAT REQUIREMENTS

- A. Aquatic
 - 1. Water quality:
 - a. Temperature. Although found in water from -1 to 15°C, fur seals are most abundant where temperatures range between 8 and 12°C, which may be in response to food availability rather than reflecting a temperature preference (Ronald et al. 1982).
 - b. Depth. No direct information has been found; however, fur seals in the Bering Sea are generally distributed within or at the edge of the continental shelf and slope (Gentry 1981). They may descend to 100 m when feeding, and they have been recorded diving to 190 m (Berg 1977).
- B. Terrestrial
The terrestrial habitat of the northern fur seal is confined to rookeries and haulout areas, mostly on the Pribilof Islands (Anon. 1980).
 - 1. Physical characteristics. Fur seals use rocky outcroppings along shorelines with exposed beach areas (ibid.).
 - 2. Functional use:
 - a. Protection from natural elements. No literature was found indicating that protection from natural elements is an important function of terrestrial haulouts for age classes other than pups; the strongly pelagic nature of

fur seals (Gentry 1981) suggests that protection from the elements may not be important except for newborn pups and injured or sick subadults and adults.

- b. Protection from predators. Major predators are sharks and killer whales (Orcinus orca) (ibid.), which cannot utilize terrestrial habitat, and northern sea lions (Eumetopias jubatus) (ibid.). Frost and Lowry (1981) note that killer whales are not common near the Pribilof Islands despite the concentration of fur seals there.

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

Fur seals feed almost exclusively on fish and squids, the latter being more important in the Bering Sea than in the Gulf of Alaska (Harry and Hartley 1981, Perez and Bigg 1981).

1. Gulf of Alaska. Nearshore (shallower than 200 m), they primarily feed on herring (Clupea harengus) during February/early March; capelin (Mallotus villosus) during March-July; and sand lance (Ammodytes hexapterus) during May-July (Perez and Bigg 1981). Offshore (deeper than 200 m), they primarily feed on rockfish (Scorpaenidae); Salmonidae; and squid (Berryteuthis magister, Gonatopsis borealis, Loligo opalescens) (ibid.). Fur seals also eat walleye pollock, Octopoda (Perez and Bigg 1981), and gadids (Anon. 1980).
2. Bering Sea. The primary food of fur seals are capelin, sand lance, and Atka mackerel (Pleurogrammus monopterygius) in early summer; capelin, Salmonidae, herring, and walleye pollock (Theragra chalcogramma) in mid-to-late summer; squid in deeper water (Berryteuthis) in early summer; and Gonatopsis in mid-to-late summer (Perez and Bigg 1981, Lowry et al. 1982). They also eat sablefish (Anoplopoma fibria), deep sea smelts (Bathylagidae) (Perez and Bigg 1981), sandfish (Trichodon trichodon), and tomcod (Microgadus proximus) (Lowry et al. 1982).

B. Feeding Locations

1. During the breeding season, nursing females feed in a 160 km radius from the Pribilof Islands (Anon. 1980); adult males do not feed while on the rookery (Gentry 1981).
2. During the spring migration, Portlock Banks, Fairweather Ground, and Albatross Banks appear to be important feeding grounds (Anon. 1980).
3. During the fall migration, feeding areas off the eastern Aleutian passes are used heavily (ibid.).

C. Factors Limiting Availability of Food

1. Many prey species move to deeper water during daylight (Anon. 1980, Ronald et al. 1982).

D. Feeding Behavior

1. Prey selection. Fur seals swallow whole fish smaller than 25 cm while underwater (Ronald et al. 1982); this size prey

- constitutes most of their diet (Berg 1977).
2. Diel feeding patterns. Fur seals feed on Mallotus, Clupea, Ammodytes, squid, and Salmonidae primarily at night and dawn. They feed on Theragra primarily during the day and on Pleurogrammus monopterygius during the night or morning. In general, they feed mostly during the night (Perez and Bigg 1981).
 3. Other. Fur seals often make repeated dives of less than five minutes duration to the same depth (Gentry 1981).
- E. Nutritional Requirements
1. In water of 5°C, subadult and adult fur seals require 12 to 13.5% of their body weight/day in fish (Harry and Hartley 1981).
 2. There is an inverse correlation between water temperature and food consumption in the normal range of the Bering Sea/Gulf of Alaska water temperatures (Lowry et al. 1982, Harry and Hartley 1981).

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Breeding takes place on terrestrial rookeries. The rocky beaches on the Pribilof Islands support 75 to 80% of the world's population (Harry and Hartley 1981).

B. Reproductive Seasonality

1. Males. Males are capable of spermatogenesis over the entire summer (mid June to mid August) (Gentry 1981).
2. Females:
 - a. Estrus. Ovulation follows parturition by 6 to 10 days; behavioral estrus begins at the same time and terminates at first copulation or 48 hours after onset. The female will not become behaviorally receptive again that year (ibid.).
 - b. Parturition. Parturition occurs from early June to early August (Anon. 1980).
 - c. Lactation. Lactation continues three to four months following parturition (ibid.).

C. Reproductive Behavior

1. Males. Sexually mature males establish territories upon arrival at the rookery in May in a descending order of age; dominant bulls maintain territories closest to the beach front and exclude other males but do not actively herd or interfere with the females' movements. Males remain full-time on females' territories until August (Gentry 1981).
2. Females:
 - a. Breeding. The receptive female selects a territorial male, and copulation occurs soon thereafter (ibid.).
 - b. Nursing. The female begins feeding excursions seven days postpartum. For the duration of lactation, females alternate several days of feeding at sea (usually within

160 km, Lowry et al. 1982) with two-day suckling visits to her pups on the rookery (Gentry 1981).

D. Age at Sexual Maturity

1. Males. Males become mature at five to six years (Anon. 1980). However, they are not behaviorally mature (i.e., able to maintain territory) until 8 to 12 years (Gentry 1981, Anon. 1980). They become reproductively senescent by age 15 (Gentry 1981), possibly due to the stress associated with maintaining territories (Harry and Hartley 1981).
2. Females. Females are sexually mature at four to seven years (Gentry 1981, Anon. 1980); they are reproductively active until 23 years (Anon. 1980). They are, however, most active between 8 and 16 years (Gentry 1981).

E. Fecundity

Estimates of the pregnancy rate vary from 60% for all females (Ronald et al. 1982) to 93% for ages 7 to 17 (Lowry et al. 1982). Pup survival to the first year is 40 to 50% for males (ibid.). No information is available for female pup mortality. Females have a single pup (Gentry 1981).

F. Frequency of Breeding

Fur seals breed annually (ibid.).

G. Gestation Period

The gestation period is one year. However, there is a four-month delayed implantation (Anon. 1980).

VI. FACTORS INFLUENCING POPULATIONS

A. Natural

1. Pup mortality:

- a. On the rookery. Total pup mortality on the rookery varies from 5 to 20% (Gentry 1981, Anon. 1980). Gentry (1981) reported pup losses on the rookery as follows: emaciation, 34%; disease and parasitism, principally hookworm, Uncinaria, 59%; trauma (e.g., trampling, injury from males), 3%.

- b. At sea. Storms, predation by sea lions (3 to 6% in 1975), sharks, and killer whales are the principal causes of pup mortality. Total pup mortality estimates range from 38 to 72% (Berg 1977, Anon. 1980, Lowry et al. 1982).

2. Adult mortality. The total mortality up to and including age-class three may be up to 85% in some years (Ronald et al. 1982); however, mortality to older age classes is "very low" (Anon. 1980).

3. Competition with other species. Larga seals (Phoca largha) and ribbon seals (Phoca fasciata) feed on many of the same species as fur seals. Larga seals are in the Pribilof area only during winter and early spring, when fur seals are absent (Harry and Hartley 1981), whereas ribbon seals probably overlap northern fur seals in the southern Bering Sea during summer. Marine birds such as kittiwakes (Rissa

spp.), murre (Uria spp.), horned puffin (Fratercula corniculata), and tufted puffin (Lunda cirrhata) eat many of the same prey species as fur seals but mostly small sizes of these species (ibid.).

B. Human-related

A summary of possible impacts from human-related activities includes the following:

- Pollution of water and/or food supply
- Disturbance of rookeries/abandonment of pups
- Reduction of food supply
- Destruction of rookery sites
- Oiling of fur
- Mortality from fishing gear

VII. LEGAL STATUS

Northern fur seals are managed by the United States Department of Commerce, National Oceanic and Atmosphere Administration (NOAA), under conditions of the Marine Mammal Protection Act (1972) and the North Pacific Fur Seal Convention (1957). The National Marine Fisheries Service (NMFS) oversees the commercial harvest on the Pribilof Islands; the pelts are distributed to the signators of the 1957 treaty (Ronald et al. 1982).

VIII. LIMITATIONS OF INFORMATION

A. Location of Male Wintering Concentrations Areas

Large numbers of males are thought to winter in the Bering Sea north of Unimak Pass. There have been no definitive surveys, however, because of poor weather and light conditions.

B. Estimates of Man-Induced Mortality Other Than Harvest

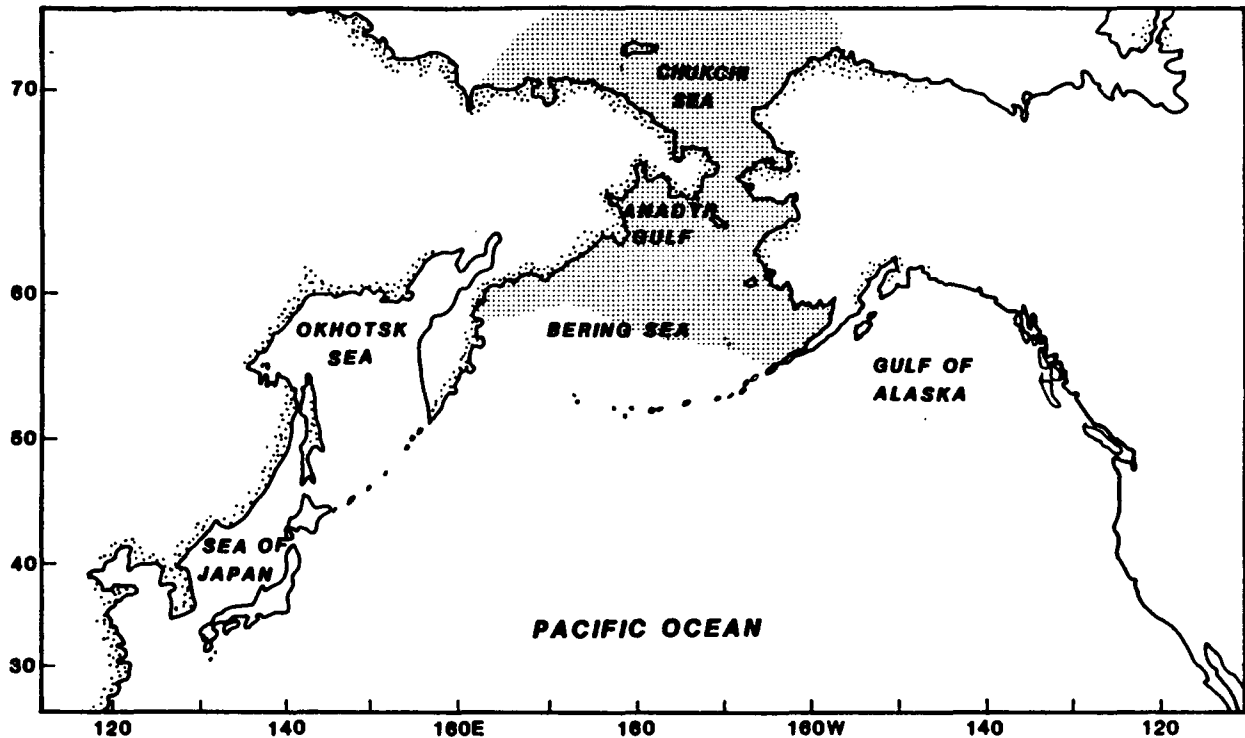
Entanglements in nets and debris may be causing a decline in the population size (Lowry, pers. comm.).

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Pacific Walrus Life History and Habitat Requirements
Southwest, Arctic, and Western Regions



Map 1. Range of Pacific walrus (Fay 1982)

I. NAME

- A. Common Name: Pacific walrus
- B. Scientific Name: Odobenus rosmarus divergens (Illiger 1811)
- C. Native Names: See appendix A.

II. RANGE

- A. Worldwide
The single species of living walrus, Odobenus rosmarus, is holarctic in distribution and comprises six geographically isolated and morphologically different subpopulations centered in 1) the Hudson Bay-Davis Strait region, 2) eastern Greenland, 3) Svalbard and Franz Josef Land, 4) Kara Sea-Novaya Zemlya, 5) Laptev Sea, and 6) Bering and Chukchi seas (Fay 1982). Walruses from the first four areas are considered to be "Atlantic

walrus" (O. r. rosmarus); those from the Bering and Chukchi seas are "Pacific walrus" (O. r. divergens); those from the Laptev Sea have been included in both subspecies by different authors and were put in their own subspecies, O. r. laptevi, by Chapskii (1940).

B. Statewide

Walruses range from the southern edge of the summer pack ice, usually from just east of Barrow to Wrangel Island and, in winter, to the southern edge of the ice, occasionally as far as the eastern Aleutian Islands (Fay 1982, Fay et al. 1984). The distribution of Pacific walruses has been affected in the past by depletion of their numbers by Yankee whalers, American arctic traders, and Soviet sealers from 1868 through the 1950's (Fay et al. 1984). The Pacific walrus population apparently reached its new maximum in the late 1970's and currently inhabits nearly all its pre-nineteenth-century range (ibid.).

C. Regional Distribution Maps

To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for the Southwest, Western, and Arctic regions at 1:250,000 scale. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of walrus distribution has been prepared and may be found in the Atlas that accompanies the Southwest, Western and Interior, and Arctic regional guides.

D. Regional Distribution Summary

1. Southwest. Walruses occur in Bristol Bay, the north side of the Alaska Peninsula, and the Pribilof Islands (Fay 1982). (For more detailed narrative information, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)
2. Arctic. Most walruses in the Arctic Region are found from just east of Point Barrow to Wrangel Island and from the southern edge of the summer pack ice south, except Kotzebue Sound, Norton Bay, and Port Clarence (ibid.). Regularly used terrestrial haulout areas in the region are the Diomedes and Penuk islands and Cape Chibukak on St. Lawrence Island (Fay et al. 1984). Irregularly used haulouts are Egg Island, Besboro Island, Cape Darby, Sledge Island, several places on St. Lawrence Island, King Island, and Cape Lisburne (ibid.). One of the two main breeding groups is found in this region from the St. Lawrence polynya southward (map 2) (ibid.). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Arctic Region.)
3. Western. Much of the Pacific walrus population may pass through the Western Region, depending on the extent of the winter ice. The only major terrestrial haulouts in the region are on St. Matthew and Hall islands. They have again been regularly occupied by many walruses only since autumn 1980 (Frost et al. 1982, Fay 1984). One of the two main

breeding groups usually is found in this region from south of Nunivak Island to Kuskokwim and Bristol bays, depending on the extent of the ice (map 2) (Fay et al. 1984). (For more detailed narrative information, see the Alaska Habitat Management Guide for the Western and Interior regions.)

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

1. Water quality. No published information was found.
2. Water depth. Walruses have been observed to feed in water as deep as 100 m, but feeding generally is restricted to depths of 80 m or less. Whether the observed range is a function of the diving capacity of walruses or the depth distribution of their prey is not known (Fay 1982, Lowry 1984).
3. Water temperature. No data were found on preferred or tolerated water temperatures.
4. Substrate. Benthic invertebrates, upon which walruses feed, require marine sediments up to 30 cm deep (Fay 1982) composed of sand and silt (McDonald et al. 1981). However, walrus stomachs often contain stones and coarse gravel, indicating that they apparently feed in areas with other sediment types (Fay, pers. comm.).
5. Acoustic properties. Walruses in open water when approached by a ship showed little concern "until the ship was about to run over them"; they then dove and swam off to one side (Fay et al. 1984). Walruses often approach to within 20 m of stationary ships, diving under and around them, "apparently more curious than concerned" (ibid.). However, when approached by a ship breaking through ice, walruses often haul out onto the ice. Hauling out onto ice in response to noise or disturbance is common among ice-associated pinnipeds and may have survival value when ice is compacting, breaking, and ridging under pressure (ibid.).

B. Terrestrial

Terrestrial habitat is used only for haulout areas, predominantly by bulls in Bristol Bay and Bering Strait during late spring, summer, and early fall (Frost et al. 1982) and by bulls, cows, calves, and subadults during fall migration in the Chukchi and northern Bering seas (Fay 1982, Taggart and Zabel 1982). Patterns of terrestrial haulout use have changed dramatically during the cycles of population depletion and abundance; nearly all historic terrestrial haulout sites have now been reoccupied (Fay et al. 1984).

1. Physical characteristics. Characteristics common to all haulouts include absence of extensive exposed tidal flats (Fay 1982), proximity to normal distributional and migrational areas (Lowry 1984), and absence of regular and frequent disturbance (Fay et al. 1984, Lowry 1984). Terrestrial haulouts are shoreline areas with one or more of the following physical characteristics:

- Rocky islands with steep cliffs and boulder beaches
 - Low-lying sand and gravel spits extending from islands or the mainland
 - Tundra-covered islands with gently sloping gravel beaches
 - Mainland coast with sand/gravel beaches backed by steep bluffs
2. Influence of weather on haulout use. Walruses abandon terrestrial haulouts during periods of severe storms accompanied by heavy surf (Fay 1982).
 3. Functions of terrestrial haulouts:
 - a. Escape from predators. Terrestrial haulouts provide escape from killer whales (*Orcinus orca*) but not from polar bears (*Ursus maritimus*). Walruses are more likely to be harassed by humans on terrestrial haulouts than when hauled out on ice (ibid.).
 - b. Resting platform. Terrestrial haulouts provide a secure surface out of water for grooming, resting, nursing, and basking (Fay 1981, 1982). In fall, cows and calves migrate southward ahead of advancing pack ice and haul out on land to rest (ibid.).

C. Ice

1. Physical characteristics of ice habitat. Floes of sufficient area and thickness (10 to over 100 m in diameter) are needed to accommodate hauled out groups, which may number hundreds of animals; these are usually thick, pressure-ridged floes. Open water or ice less than 20 cm thick between thicker floes is required to allow walruses to surface for air and to gain access to the water for feeding; no more than 80% of the water surface should be covered by thick ice (ibid.).
2. Seasonal use. Winter ice habitat is heavy ice located north of the ice front and in a loose pack; densely consolidated ice farther north is a barrier to winter walrus distribution (Burns et al. 1977). Summer ice habitat is near the southern edge of the pack ice, generally in the northern Chukchi Sea, and is characterized by multi-year floes and considerable open water (ibid.).
3. Functions of ice haulouts:
 - a. Escape from predators. The shifting nature of ice, as well as its location remote from most human activity, provides better refuge from human disturbance than terrestrial haulout areas (Fay 1982). Polar bears are the most numerous nonhuman predators of walruses in pack ice (ibid.).
 - b. Protection from the elements. Ice ridges provide shelter from wind, and ice cover moderates the severity of ocean waves in the immediate area (Burns 1981).
 - c. Use as a resting platform. Grooming, resting, basking, parturition, nursing, and molting take place on the ice. The pack ice serves as the arena in which courtship

display and breeding activities take place; and moving ice may serve as continuous transport to new feeding grounds (Fay 1982).

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

Walrus feed almost entirely on benthic organisms; over 60 genera representing 10 phyla have been identified from walrus stomachs (ibid.). Bivalve mollusks of the genera Mya, Serripes, Spisula, Hiatella, Clinocardium, and Tellina are the clams most commonly eaten when available; in most seasons and most areas, clams occurred most frequently in the stomach contents, although they did not always make up the greatest proportion by weight (Fay 1982, Fay et al. 1984, Lowry et al. 1982).

Other bivalves of importance are Astarte, Macoma, and Siliqua. Echiurids, Priapulids, Sipunculids, Polychaetes, moon snails (primarily Polinices and Natica spp.), whelks, and anemones are important in some areas at some times. Walrus occasionally eat sand lances (Ammodytes hexapterus) and seals; incidence of observed walrus predation on vertebrates seems to have increased since 1978 (Fay 1982, Fay et al. 1984, Lowry and Fay 1984). In the Bering Strait region in spring prior to the early 1980's, male walrus fed primarily on the largest age classes of the larger bivalve genera Mya and Serripes, and females fed on the smaller genera (Tellina, Astarte, and Hiatella) (Fay and Stoker 1982). In the early 1980's, males were feeding on smaller individuals of Mya and Serripes, and females apparently shifted from the smaller genera to the same species and size classes as the males (ibid.). The average size of nearly all prey types was about 50% smaller in 1980 than in 1975. These changes in food habits were presumed to be the result of a depletion of the older age classes, probably caused by the increase in the number of walrus feeding on them (ibid.).

B. Types of Feeding Areas Used

Most Pacific walrus stay with the floating ice for most of the year and feed primarily on immobile bivalve mollusks, which are widely distributed on the continental shelf of the Bering and Chukchi seas and which are available to the walrus as long as the ice remains over the shelf. Therefore, seasonal differences in feeding locations are due more to abiotic influences (e.g., ocean currents, surface winds) on ice conditions than on active selection of feeding areas by walrus (Fay 1982).

C. Factors Limiting the Availability of Food

During the southward fall migration, ice usually is too thin to be used for support; animals generally swim ahead of the ice, thus decreasing the amount of time they can feed (ibid.).

Sessile bivalve mollusks are susceptible to excessive sedimentation and to pollution (Stoker 1981); activities that cause pollution or that alter sedimentation patterns will adversely affect the biomass of the food supply.

Use of terrestrial haulout areas limits foraging activities to reasonably accessible ranges. Haulout areas presumably are established in the vicinity of appropriate food resources (Lowry, pers. comm.). Because of the 50% decrease in the average size of prey between 1975 and 1980 in the Bering Strait region, at least twice as much effort is now needed to forage for the same amount of food (Fay and Stoker 1982).

Walrus may interact trophically with both gray whales and bearded seals in the Bering and Chukchi seas (Lowry et al. 1980, Lowry and Frost 1981). Walrus and bearded seals may compete for bivalves. Gray whales do not consume large bivalves, but they may have a negative effect on walrus' food resources by reducing recruitment or survival of the walrus' preferred prey (Oliver et al. 1983). Gray whale disturbance of the sea floor while feeding may have a positive effect on several species of amphipod crustaceans, and these crustaceans may decrease the recruitment of young bivalves by predation, trampling, or some less direct interference (ibid.).

As the Pacific walrus population increases, food resources that were formerly partitioned by geographical segregation of the sexes and by seasonal segregation of their feeding schedules are under increasing pressure, and intraspecific competition may become increasingly important (Fay and Stoker 1982). The species primarily eaten by walrus generally require about as many years as walrus to reach maturity and live nearly as long as the walrus (Fay et al. 1984). Fay et al. (1984) believe that the depletion of walrus in the 1930-1950's allowed an increase in prey populations, particularly in the Bering Strait region. The abundant prey fueled a rapid recovery of the walrus population, but changes in stomach contents of spring migrant walrus now indicate a decline in numbers of clams in the region (ibid.).

D. Feeding Behavior

Fay (1982) noted that in spring (March-June) walrus were in the water more often in the morning and evening than at other times and that animals taken at those times were most likely to have food in their stomachs. In February and March 1981, Fay et al. (1984) noted that on the ice south of Nunivak Island and Kuskokwim Bay females and young were synchronous but not circadian in their feeding schedules. They would usually spend 24 to 36 hours in the water feeding, then haul out onto the ice to rest for 36 to 48 hours. They usually fed during the passage of a storm front and rested during the fair weather between storms (ibid.). The duration of feeding dives is a function of the water depth and, presumably, the abundance of food (Fay 1982). Dive times of up to 10 minutes have been reported for walrus feeding in water 70 to 79 m deep (see references cited in Fay 1982). The maximum depth at which walrus feed was reported to be about 80 m (Vibe 1950). Recent data from the central Bering Sea confirm that walrus can feed at greater depths, to at least 113 m (Fay, pers. comm.).

Walrus are highly specialized for feeding on benthic bivalve mollusks (Fay 1982). They generally move snout-first along the bottom, dragging their tusks, and may search for visually conspicuous prey by sight as well as by "rooting" with snout and vibrissae for less obvious prey, not by digging with their tusks (Fay 1982). Instead, walrus may use a pulsing stream of water to excavate prey (Oliver et al. 1983). Hydraulic jetting, rooting, and consumption of prey during feeding bouts appear to leave a distinct record of furrows, pits, and discarded bivalve shells on the sea floor (ibid.). Continuous pit-furrow systems indicate the prey consumed in one dive; in one system, 34 clams had been consumed along more than 60 m of bottom. Dive times for that water depth averaged about five minutes (Fay 1982), suggesting that one walrus ate more than six clams per minute (Oliver et al. 1983). Prey are excavated before consumption; then soft parts of clams are sucked from between the two shells (Oliver et al. 1983, Vibe 1950).

Based on daily food intakes of captive walrus, nutritional requirements by age, sex, and season have been calculated (Fay 1982, Fay et al. 1984, Gehnrich 1984). Walrus in captivity consumed energy at mean annual rates ranging from about 25,120 kcal/day in a 2-year-old female to 70,310 kcal/day in an 18-year-old male (Gehnrich 1984). For both sexes, the annual mean of daily intakes increased with age at about the same rate until about ages 7 or 8, when rates for females leveled off while those for males continued to increase until about ages 15 or 16 (ibid.). Although females consumed more when pregnant or lactating, their annual mean of daily intake still averaged less than that of adult males (ibid.). Adult males ate very little during a three-to-five-month period in winter corresponding to the breeding season for wild walrus; they compensated by increasing their energy intake outside the breeding season (ibid.). For both sexes, maximum food intake during the year was in November-December, corresponding to the time of autumnal migration in wild walrus (Fay et al. 1984).

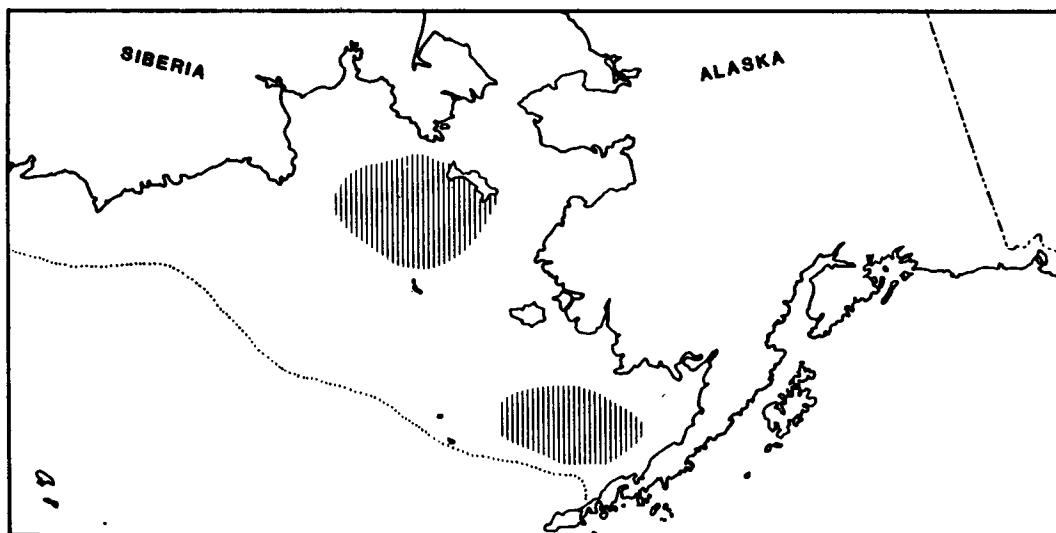
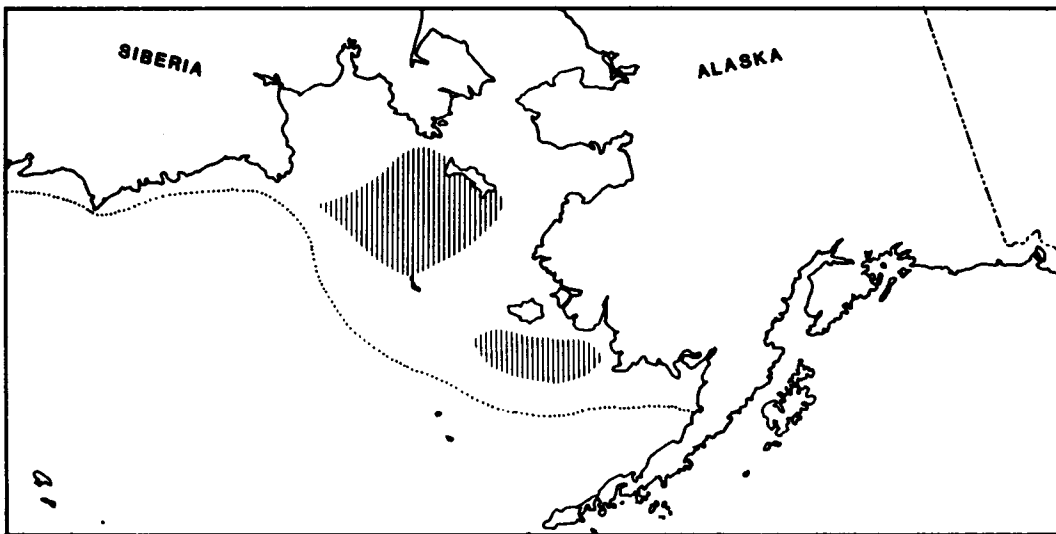
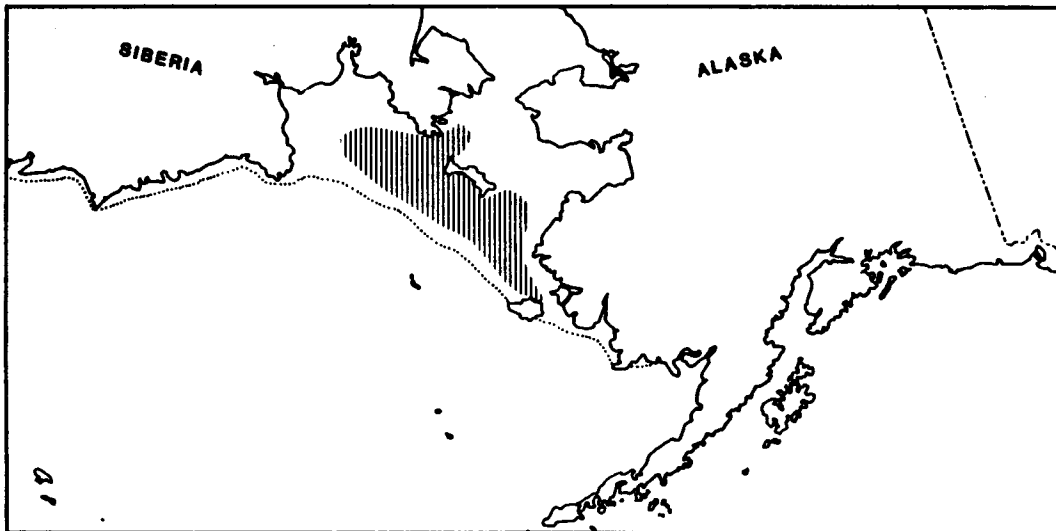
V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Fay et al. (1984) observed that walrus breed in areas that are well within the pack ice edge on the leeward side of ice-forming zones, where divergence of the ice continually permits leads and polynyas to form and the floes are thick enough to be supportive and dry. Breeding herds of walrus appear to be divided into two general areas, one from the St. Lawrence polynya southward and the other south of Nunivak Island and into Kuskokwim and Bristol bays, depending on the extent of the ice (map 2) (ibid.).

B. Reproductive Seasonality

Breeding takes place from December to March. Adult females are fertile from December to March; nonpregnant females are in estrus mainly from January to early March; a postpartum estrus takes



Map 2. Estimated location of Pacific walrus mating herds, January-March, during minimal (top), median (center), and maximal (bottom) extent of the pack ice. Dotted line is approximate location of ice edge (Fay 1984).

place in June to August (Fay 1982). Males that are sexually potent but not yet physically mature reach their peak of testicular development about two months after fully adult males (ibid.). Implantation is delayed three to four months following mating. Calving takes place from mid April to mid June on stable ice in the central Bering and southern Chukchi seas (map 3) (Fay 1982, Fay et al. 1984).

C. Reproductive Behavior

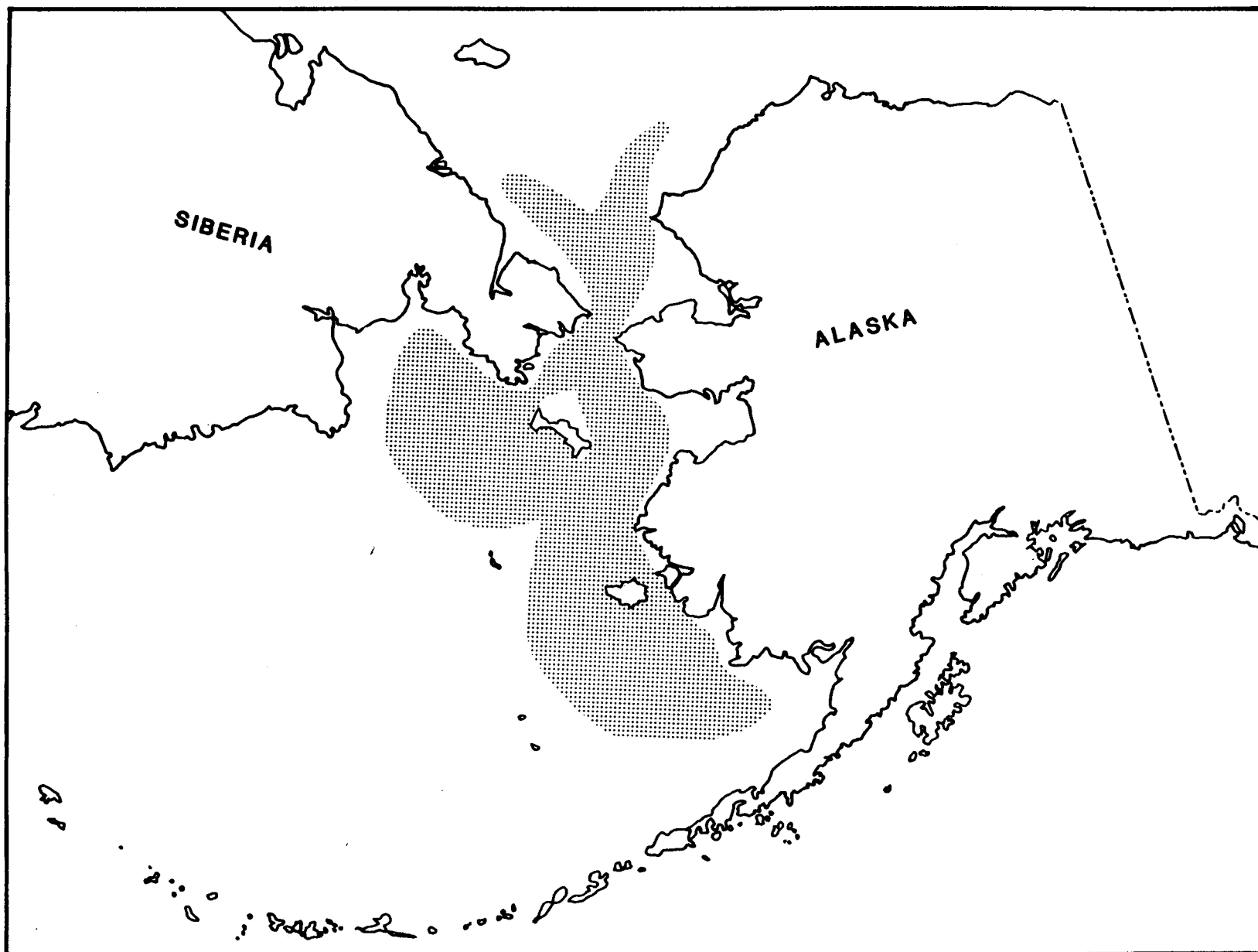
Most of the adult males and females concentrate in two main breeding areas (map 2) during at least January to early March (Fay et al. 1984). The females and young tend to stay together in groups of about 10 to 50 individuals; each group is attended by one or more large mature males. When the group is resting on the ice, the males perform courtship displays in the water alongside the floe. Each such male displays as long as the females are at rest, presumably to display sexual readiness and to keep other males away. Individual females then leave the herd to join a displaying male in the water, diving beneath the surface, where copulation probably takes place. When more than one bull displays to a group of females, they maintain a separation of about 7-10 m from each other. Invasion of a display site results in visual threats and violent fighting. Observed ratios of adult males to potentially available mates have ranged from 1:5 to 1:15 (average, about 1:10) (ibid.).

The prepartum female selects a clean floe, often isolated from the group; parturition occurs on the ice (Fay 1982). After a few days, the female and young rejoin the nursery herd of females and young (ibid.). The female forms a strong social bond with her young, actively defending it and not leaving it even to feed. Orphaned calves are occasionally adopted by other females (ibid.).

D. Age at Sexual Maturity

1. Males. Fay (1982) found that although some male walruses attain sexual potency as early as their seventh winter or spring, most become sexually mature in their eighth or ninth winter. In their eighth to tenth year, growth of secondary sexual characteristics begins (increased size of body, tusks, baculum, and thickening of the skin on neck and shoulders) and is completed by about age 15. They are probably then sufficiently large and powerful to compete successfully with other adult males for mates (ibid.). Captive walruses, which have no competitors, have sired their first calves in their tenth year, but wild walruses, which have many competitors, probably do not compete successfully for mates until they attain physical maturity (ibid.).

2. Females. A few female walruses become pregnant for the first time at age 4; about two-thirds have ovulated at least once by age 6; and virtually all are fertile by age 10 (Fay 1982). Most "attain the peak of their reproductive performance" in their ninth or tenth year (Fay 1982).



Map 3. Estimated maximal extent of calving areas of the Pacific walrus population in mid-April to mid-June (Fay 1984).

E. Frequency of Breeding

Females at the peak of their reproductive performance breed in alternate years; older females breed every third or fourth year for an average interval between births of about 2.3-2.5 years prior to the 1970's (Fay 1982, Lowry et al. 1982). During the late 1970's, abortions and stillbirths were widespread, perhaps because of increased pressure on the food supply and disease (i.e. walrus calicivirus) (Fay et al. 1984). Synchronous breeding and "pulses" of higher calf production every two to three years resulted (ibid.).

F. Fecundity

As the Pacific walrus population has recovered from exploitation and approached what may be the carrying capacity of the environment, fecundity has changed. Fay and Stoker (1982) noted that the conception rate of adult females decreased from about 38% prior to the 1970's to about 30% per year in 1977-1979; the percentage of gestations resulting in normal births declined from about 95% in the 1950's to the early 1970's, to about 73% in 1979-1980, mainly as a result of increased abortion and premature birth.

G. Gestation Period

Including the 3 to 4 months of delayed implantation, the gestation period is 15 to 16 months (Fay 1982).

H. Lactation Period

Fay (1982) reports:

The data available suggest that 1) calves are dependent on milk alone in at least the first five months after birth, 2) some calves may begin to eat invertebrates infrequently by the time they are six months old, 3) a few are proficient at benthic feeding by the end of their first year, but 4) they usually continue to suckle, at least as a dietary supplement, for several months longer, 5) their milk intake probably declines radically toward the end of the second year, 6) they usually are fully weaned at two years of age, but 7) a few may continue to suckle for another year if not supplanted by a younger, more dependent calf.

VI. FACTORS INFLUENCING POPULATIONS

A. Natural

1. Mortality. Morbidity and mortality data through 1979 have been reviewed by Fay (1982), who remarked that "the walrus has the lowest known reproductive rate for a pinniped, is slow to mature, and has a long life-span. For those reasons, its rate of natural mortality probably is very low . . . the killing of walruses by man is a form of predation, and it appears to have been the most important single cause of death over the past 120 years or so." Other known predators of walruses include polar bears, which reportedly take mainly calves, and killer whales, which take animals of all ages. Although many diseases and 16 species of parasites of walruses have been reported, they do not seem to be an

important cause of death or illness (Fay 1982). Some walrus, especially calves, may be crushed or trampled when herds stampede off haulouts on ice or land in response to disturbance caused by humans or polar bears (ibid.). Fay and Kelly (1980) documented mass natural mortality on the Punuk Islands in the autumn of 1978; carcasses examined appeared to have been rolled and trampled.

2. Competition. For information on inter- and intraspecific competition for food, see section IV.C., Factors Limiting Availability of Food. Walrus breed and calve on and near ice rather than on land, so that competition for rookery space probably does not limit breeding, although competition among males for access to females often results in fights and bloody wounds (Fay 1982).

B. Human-related

A summary of possible impacts from human-related activities includes the following:

- Chronic debilitation due to ingestion or contact with petroleum or petroleum products
- Chronic debilitation due to ingestion or contact with chemicals
- Collision with vehicles
- Entanglement in fishing nets or marine debris
- Harassment, active
- Harassment, passive
- Interruption of ongoing behavior
- Mortality due to ingestion of chemicals
- Mortality due to ingestion of petroleum or petroleum products
- Prey base alteration
- Terrain alteration or destruction

(See the Impacts of Land and Water Use volume of this series for additional information regarding impacts.)

VII. LEGAL STATUS

A. Federal

Walrus are administered by the USFWS for the federal government under the Marine Mammal Protection Act (MMPA) of 1972.

B. State

The State of Alaska may request return of managerial authority for 10 species of marine mammals, including walrus.

C. Population Management History

Material is presented for the whole Pacific walrus population rather than by GMU or subpopulation.

1. Summary of harvest. Pacific walrus are harvested by both the United States and the USSR. Coastal residents take about two-thirds of the Soviet harvest; about one-third is taken by a commercial high-seas fishery from large multipurpose vessels. The total Soviet harvest averaged about 5,000 animals per year in the 1940's and 1950's, decreased to about 900 per year from 1965-1971; increased again to 1,200-1,500

annually in the 1970's, and was approximately 4,000 animals in 1982 (Lowry 1984).

From 1958 to 1972 the average harvest was approximately 1,600 animals per year. Passage of the MMPA in 1972 prohibited harvest by non-Natives; from 1973 to 1977, the average annual harvest rose to 2,162. From April 1976 through August 1979, the State of Alaska managed walrus populations under a waiver of the MMPA, which specified a harvest of no more than 3,000 animals per year (ibid.).

Although the number of walruses killed but not retrieved is difficult to estimate, Lowry (1984) stated that the retrieved harvest represents about 60% of the total kill. Including both Soviet and American harvests, the estimated total number of animals killed annually between 1958 and 1977 averaged 5,577 (range 3,078 to 9,230). The population more than doubled in that period, so the kill was clearly below the sustainable yield (ibid.).

2. Period of state authority. From 1959 through 1972, the State of Alaska had managerial authority over Pacific walruses. Before ADF&G regulation, the harvest probably included more females than males (Burns 1965). In 1960, Alaska game regulations allowed residents to take unlimited numbers of male walruses and only seven females or subadults; in 1961 that was changed to five females or subadults. Recreational hunters were limited to one male walrus per year. The new state regulations and the fact that Soviet hunters took only males after the mid 1950's, changed the harvest to about 75% bulls, 20% cows, and 5% immature animals, affecting the composition of the population and enhancing overall productivity (Fay 1982). In 1960, male summer haulout areas in Bristol Bay were protected by the creation of the Walrus Islands State Game Sanctuary. About the same time, the Soviet government stopped hunting on all haulouts in Siberia (Fay et al. 1984). Passage of the MMPA in 1972 returned authority to the USFWS. Under the MMPA, only Native Alaskans are allowed to hunt walruses. No restrictions, other than the mandate that taking not be in a wasteful manner, may be placed on walrus harvest unless the species is declared depleted. Under provisions of the MMPA, the state petitioned the federal government for return of authority over walruses; it was granted in April 1976. The state managed walruses under a waiver of the MMPA, which, by federal decree, limited the total annual take to 3,000 animals. After a U.S. District Court decision in April 1979 that Alaskan Natives could hunt walruses for subsistence in areas closed to hunting by state regulation, the state returned responsibility for walruses to the federal government in August 1979.
3. Period of federal authority. After extreme exploitation of walruses by Yankee whalers in the mid-to-late 1800's and

further depletion by "arctic traders" around the turn of the century, the United States government prohibited commercial taking of walrus in Alaskan territorial waters in 1909 (Madsen and Douglas 1957) and the taking of walrus for ivory alone in 1915 (Chandler 1943). The United States walrus harvest was further curtailed by the Walrus Act of 1941 (Fay 1982). In response to a second major population decline brought about by the increased Soviet harvest, the USSR enacted a decree for "security of the animals of the arctic" in 1956 and phased out the government-operated walrus hunting vessels by 1962 (ibid.). The USFWS now administers walrus for the federal government. (See section D. Current Population Management for more details.)

4. International agreements. Although Pacific walrus occur in both United States and Soviet waters, the two countries have no cooperative agreement for their management (Fay 1982). Research information is exchanged under the Marine Mammal Project (V.6) of the United States-USSR Environmental Protection Agreement of 1972, but walrus are still managed unilaterally (ibid.).

D. Current Population Management

Under the MMPA of 1972 and amendments enacted in 1981, the USFWS is responsible for administering Pacific walrus, but it cannot manage by regulation or protection unless it can demonstrate that the population is depleted. Their overall goal for the walrus is "to conserve the Pacific walrus and its habitat while providing for beneficent human use" (USFWS 1982).

1. Management objectives. The goals of the USFWS with regard to walrus are as follows (ibid.):
 - Maintain the Pacific walrus population within a range of 140,000 to 300,000 animals
 - Monitor the harvest
 - Determine effects of human activities, other than hunting, on walrus populations
 - Minimize illegal take, trade, and use of walrus
 - Identify and protect essential walrus habitat to maintain populations within Optimum Sustainable Populations (OSP)
 - Maintain sufficient natural food supply to maintain OSP
 - Minimize adverse impacts on the walrus population as a result of natural resource development activities
 - Provide for subsistence use as the primary consumptive use of the resource
 - Provide for regulated sport hunting use after subsistence needs are met
 - Provide for other uses
 - Develop effective communications between management agencies and both urban and rural inhabitants to improve mutual understanding of management objectives and regulations

- Promote public involvement and education in programs to conserve the walrus
 - Promote a formal agreement between the United States and the USSR to conserve and manage the walrus and other pinnipeds of the Bering and Chukchi seas
2. Management considerations. Potential management problems identified by the USFWS (1982) include the following:
 The walrus population may have exceeded the carrying capacity of the habitat and probably will decline, perhaps rapidly. Increased human disturbance and harassment may disrupt reproductive behavior.
 Public concern over illegal take, trade, and use is intense (harvest of walruses for ivory only, e.g., and the high percentage of walruses shot but not retrieved).

VIII. LIMITATIONS OF INFORMATION

Scant information exists on habitat relationships during late fall and winter; walruses are probably concentrated in the central Bering Sea area, but short daylight and intense storms preclude observation (Fay 1982).

The long-term effects of the high walrus population on the diversity and abundance of bivalve mollusks are unknown (Fay and Stoker 1982), as are the trophic implications of those effects on gray whales and bearded seals (Oliver et al. 1983).

The effects of industrial activity (especially oil and sea-bottom mining), including harassment (aerial, terrestrial, and marine), pollution, and siltation, are unknown (Ronald et al. 1982).

More data are needed to understand the full range of variability in the location and extent of calving areas in spring (Fay et al. 1984).

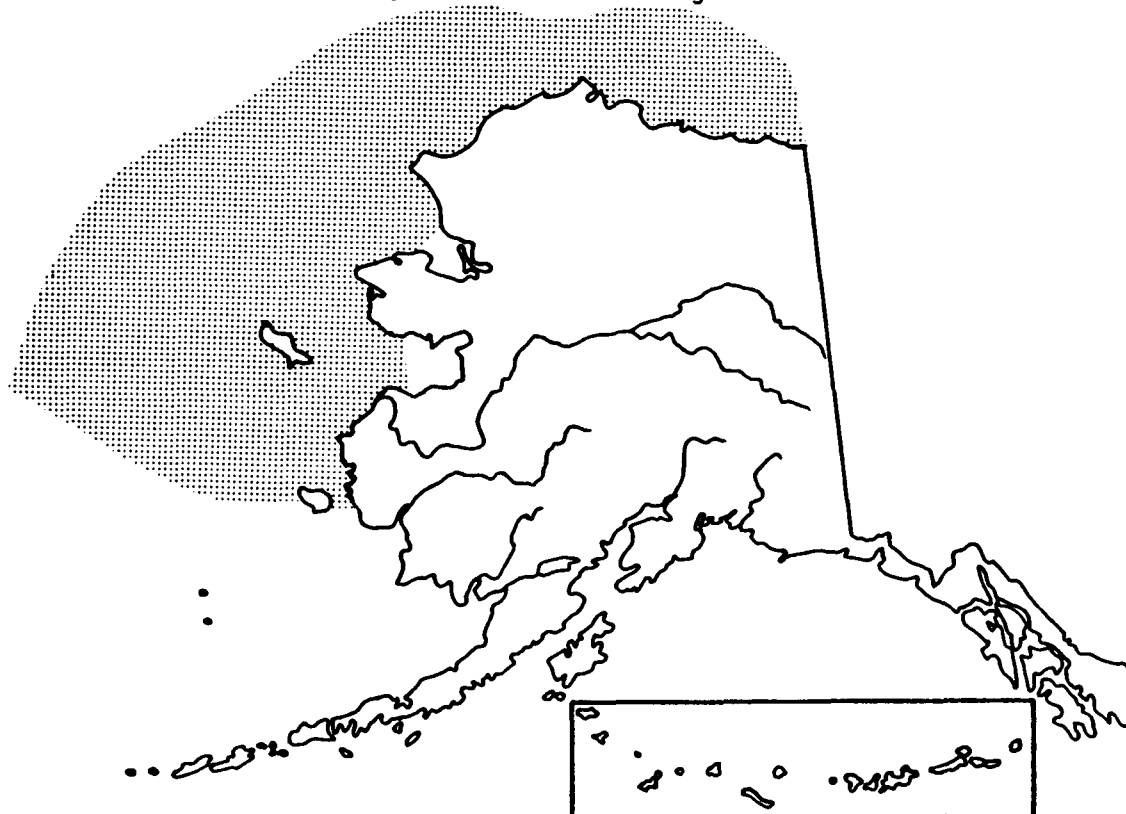
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Polar Bear Life History and Habitat Requirements
Arctic and Western Regions



Map 1. Range of polar bear (Amstrup, pers. comm.)

I. NAME

- A. Common Name: Polar bear
- B. Scientific Name: Ursus maritimus Phipps
- C. Native Names: See appendix A.

II. RANGE

- A. Worldwide
Polar bears are found only in the northern hemisphere and are distributed throughout the north polar basin, particularly in association with shorefast and drifting pack ice (Lentfer 1982). Although most abundant around the perimeter of the polar basin, generally within 200 to 300 km of land, polar bears have been found as far north as 88° north latitude and south to St. Matthew, Nunivak, and the Pribilof islands in the Bering Sea, James Bay and

Newfoundland in Canada, southern Greenland, Iceland, and the Barents and Kara seas (ibid.). Polar bear densities are not uniform but are divided into six somewhat discrete groups centered at 1) Wrangel Island - Western Alaska; 2) Cape Bathurst - northern Alaska; 3) northern Canadian archipelago; 4) Greenland; 5) Spitsbergen-Franz Joseph Land; and 6) central Siberia (ibid.).

B. Statewide

In Alaska, polar bears are associated with shore-fast and drifting pack ice along the Beaufort, Chukchi, and northern Bering Sea coasts. In summer, they concentrate along the southern edge of the drifting pack ice, which may recede up to 200 km north of Point Barrow (Lentfer 1983); they then move south with the ice in autumn. In winter, polar bears are found throughout the drifting pack and shore-fast ice and occasionally on land but are most numerous near the flaw zone (Lentfer 1972, 1982). Based on tagging study results, morphometrics, and tissue contaminant levels, Lentfer (1974) concluded that polar bears in Alaska belong to two at least partially discrete subpopulations, the northern and western Alaskan subpopulations, with the dividing line extending northwest from about Point Lay. Amstrup (pers. comm.), basing his conclusion on several more years of tagging data, agrees that there are two populations but feels the placement of a dividing line is still uncertain.

C. Regional Distribution Maps

To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for the Arctic and Western regions at 1:250,000 scale. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of polar bear distribution has been prepared and may be found in the Atlas that accompanies the Arctic and Western and Interior regional guides.

D. Regional Distribution Summary

1. Arctic. The northern Alaska subpopulation ranges from Cape Bathurst, N.W.T., Canada, to somewhere just west of Barrow and from the drifting pack ice 200 to 300 km north of the coast south up to 50 km inland (Lentfer 1983; Amstrup, pers. comm.). Tagging studies show that exchange of Alaskan bears with Canadian subpopulations is limited to bears caught along the mainland coast; no exchange is reported between the Banks Island (N.W.T.) breeding area and the Alaskan Beaufort Sea area (Stirling et al. 1981, Lentfer 1983). The Western Alaska subpopulation probably ranges from west of Barrow to Wrangel Island, although their distribution and the degree of interchange with bear populations in Soviet waters is not well known (Lentfer 1983, Amstrup 1984). In winter, the Western subpopulation regularly ranges as far south as St. Lawrence Island (Fay 1974). (For more detailed narrative

information, see volume 2 of the Alaska Habitat Management Guide for the Arctic Region.)

2. Western. During heavy ice years, when pack ice moves far south of its average winter extent, polar bears have been seen near Nunivak Island and the Pribilof Islands (Lentfer 1982; Patten, pers. comm.). During the ice-free season, polar bears are extremely rare in the Western Region, although they are occasionally seen in the area between Kotlik and Newtok on the western coast of Alaska, especially after heavy ice winters, late breakup, and/or appearance of pack ice offshore in summer (ibid.). (For more detailed narrative information, see the Alaska Habitat Management Guide for the Western and Interior regions.)

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

Polar bears are associated with sea ice; their aquatic habitat requirements are those that allow the formation of sea ice and abundant and accessible populations of seals, their primary food (Lentfer 1972).

B. Terrestrial

Although in other areas (Hudson Bay, e.g.) polar bears regularly summer on land, Alaskan polar bears spend little time on land except for maternal denning and occasional feeding, especially on beached carrion. During years of heavy ice and late breakup, they may summer on land more by accident than by design (Stirling et al. 1981; Amstrup, pers. comm.).

1. Summer use and dens. During periods in summer when the drifting pack ice is within a few miles of the coast, bears easily swim ashore to scavenge carrion along the shore. They probably do not make the summer dens found in other areas, such as Hudson Bay (Stirling 1974a, 1974b; Amstrup, pers. comm.), although they may make temporary earth or snow shelters for thermoregulation or protection from insects (Lentfer 1982).
2. Winter dens. In Canada, the USSR, Norway, and Greenland, males and females of all ages have been found in winter dens (see references in Lentfer et al. 1980, Kolenosky and Prevett 1983). In the Beaufort Sea, only pregnant females have been found to stay in winter dens (maternity dens) for extended periods, although probably any bear may excavate a temporary shelter during particularly bad storms (Stirling 1974a, Lentfer and Hensel 1980).
3. Maternity dens. In Alaska, maternity dens have been found on the mainland (up to 48 km from the coast), offshore islands, shore-fast ice, and drifting pack ice (Lentfer 1975; Lentfer and Hensel 1980; Amstrup, pers. comm.). Often, dens are on slopes of 20 to 40° (Uspenski 1977) or on coastal bluffs or river banks (Harrington 1968, Lentfer and Hensel 1980). Ice movement and time of freeze-up are affected by weather and

wind patterns and probably determine the distribution of females that come to the coast in search of den sites (Lentfer and Hensel 1980, Amstrup 1984).

The coast of Alaska is not one of the "core," or particularly high-density, denning areas such as Wrangel Island or Svalbard (Lentfer and Hensel 1980). Prior to 1983, despite major search efforts from 1967 through 1976, substantial human activity in potential denning areas in recent years, and an estimate of at least 150 female Alaskan bears that should be denning each year, fewer than 50 dens had ever been reported on land in Alaska (Lentfer and Hensel 1980, Amstrup 1984). Lentfer and Hensel (1980) speculate that "female adult polar bears may show fidelity to parturition sites and therefore try to reach specific denning areas" but present no supporting evidence. Amstrup (pers. comm.), however, has observed one radio-tagged female denning on the coast one year and, in a later year, denning far out on the drifting pack. Conditions leading to maternity denning on pack ice are unknown, but in 1984 12 of 14 dens found by following radio-tagged females were on drifting pack ice. The relative frequency of denning on pack ice and on land is currently being investigated (Amstrup, pers. comm.).

The main habitat requirement for a maternal den site, whether on land or sea ice, is snow deep enough for den excavation and protected enough not to thaw during the denning period (Harrington 1968, Jonkel et al. 1972, Uspenski and Kistchinski 1972, Kolenosky and Prevett 1983, Amstrup 1984). Another factor that may be important, especially in Alaska, is the occurrence of seals nearby and ice conditions that enable bears to catch seals during pre- and postdenning periods (Lentfer and Hensel 1980). On land in Alaska, such denning habitat requirements are met by any area within 30 to 40 mi of the coast with enough relief for snow to drift and stay in sufficient depth for den excavation from October or November until April (Amstrup, pers. comm.). (For more information, see the polar bear Distribution and Abundance narrative in volume 2 of the Alaska Habitat Management Guide for the Arctic Region.)

C. Ice

In general, polar bears spend most of their time on sea ice in which their main food, seals, is both abundant and accessible (Stirling et al. 1975). Depending on the time of year, that may be the flaw zone, the shore-fast ice, or the edge of the summer pack (Stirling et al. 1981). (For more information and definitions of ice-related terms, see section IV. B. below and the Sea Ice narrative in volume 2 of the Alaska Habitat Management Guide for the Arctic Region.)

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

Polar bears in Alaska feed primarily on ringed seals (Phoca hispida) and, to a lesser extent, on bearded seals (Erignathus barbatus) (Eley 1978, Amstrup 1984). Belukha whales (Delphinapterus leucas) and walruses (Odobenus rosmarus) are occasionally taken (Freeman 1973, Eley 1978, Killian and Stirling 1978). Carrion, including whale, seal, and walrus carcasses, is scavenged frequently, especially along the coasts of St. Lawrence Island and the northern Bering Sea (Eley 1978). In other areas, polar bears are known to occasionally eat small mammals, birds, eggs, and vegetation when on land, especially in postdenning and summer periods (Russell 1975, Hansson and Thomassen 1983); however, the small amount of time that Alaskan polar bears spend on land makes these sources of food relatively unimportant (Lentfer, pers. comm.).

B. Types of Feeding Areas Used

Polar bears feed primarily in the flaw zone but also hunt and/or scavenge on the shore-fast ice, on land, on the drifting pack ice, and, occasionally, in open water (Stirling et al. 1975, Stirling and Archibald 1977, Stirling et al. 1981). Stirling (1980) noted that

shore lead polynya systems also appear to support higher densities of seals and polar bears during the winter than do the adjacent fast ice areas. Whenever the leads freeze over, the seals simply maintain breathing holes in the young ice until the lead opens up again (Smith and Stirling 1975). Consequently, it is easier for seals to breathe there while feeding than to maintain their own breathing holes in areas which are continuously frozen, or to compete for access at breathing holes being maintained by other seals. The moving ice appears to be the habitat of bearded seals (Burns 1967) and an area where subadult and possibly non-breeding ringed seals concentrate as well. Polar bears appear to be more abundant in these areas in which the ice continuously opens and re-freezes, partly because the seals are more abundant there and possibly also because the breathing holes are not covered deeply with drifted snow so that the seals are more vulnerable to predation (Stirling et al. 1975).

Stirling et al. (1981) analyzed 627 sightings of polar bears or their tracks in the spring (March-May) of 1970-1979 in the western Canadian Arctic; 82% of all sightings were from floe edges and areas with 88% (7 oktas) or greater coverage of moving ice. Their analyses showed that adult males preferred moving ice; subadult males' preference was less pronounced but still significant; slightly more sightings occurred at floe edges. Adult females with cubs of the year preferred fast ice, as did subadult females, but to a slightly lesser extent. Observations of lone adult

females and females with older cubs showed no significant difference in choice of ice habitat, but females with yearlings were found more often in areas with 88% (7 oktas) or greater coverage of moving ice, and females with two-year-olds were found more often at floe edges (ibid.).

Most bears hunt in the drifting pack ice and the flaw zone rather than on fast ice; however, in order to avoid adult male bears (which occasionally kill cubs) females with very young cubs hunt on fast ice, primarily by opening ringed seal birth lairs (Stirling et al. 1975, Stirling and Archibald 1977). From 1971 through 1973, in the western Canadian arctic, 54.8% of the seals that were found killed by polar bears in fast ice and could be aged were pups (Stirling and Archibald 1977). On shore-fast ice, Martin and Jonkel (1983) found that polar bears hunted and slept almost exclusively in "rough ice" and used flat ice significantly less often than its availability in the area would indicate. Amstrup (pers. comm.) believes that ice of about 20 to 40% deformation is most commonly used for hunting by polar bears. (See the Sea Ice narrative in volume 2 of the Alaska Habitat Management Guide for the Arctic Region for definitions of ice deformation.)

Although polar bears are slower and less agile in open water than are seals, Furnell and Oolooyuk (1980) documented bears catching ringed seals in ice-free water.

Land is a relatively unimportant feeding area for Alaskan bears, except for scavenging carrion (Lentfer 1974).

C. Factors Limiting Availability of Food

The main factors limiting availability of food to polar bears are the distribution of seals and ice conditions favorable to seal hunting (Amstrup, pers. comm.). Intraspecific agonistic interactions over food, especially large adult males chasing off other bears, may also limit the availability of food for some individuals, especially for subadults (ibid.).

In young bears, age (experience) affects hunting success. Stirling and Latour (1978) found that one- and two-year-old bears did not hunt in spring. In summer, the percentage of time spent hunting and the duration of still hunts were equal for both one- and two-year-olds but were shorter than for adult summer hunts. Although total time spent hunting was equal for one- and two-year-olds, two-year-olds spent twice as much of that time still-hunting, and their kill rates approached those of adults (ibid.).

Although polar bears are known to kill walruses, usually only the young are taken; polar bears killed by (presumably large) walruses have been reported (Fay 1982).

D. Feeding Behavior

1. Hunting techniques. Polar bears were observed in the Canadian high arctic during summer 1973 (Stirling 1974b) and during spring and summer 1974-1976 (Stirling and Latour 1978). Hunting behavior fell into two categories,

still-hunting and stalking, with several variations on each. When still-hunting, a bear lies, sits, or stands by a pool or breathing hole waiting for a seal to come to the surface. Stalking hunts of basking seals were made either by creeping up behind irregularities on the ice surface or by slipping into the water and swimming cautiously to the seal. Still-hunts were far more common (23.4% of total minutes of observation in 1973) than were stalking hunts (1.2%) and were far more successful (four of five kills observed in 1973 were from still-hunting).

Winter and spring hunting on the fast ice appears to require a higher level of proficiency than hunting in the summer (ibid.). In fast ice, the subnival birth lairs and breathing holes of seals must be located accurately by smell from a distance, and the arrival of a seal at its hole beneath the snow must be detected. Then, with a rush, the top of the lair must be broken over the breathing hole and the seal caught (ibid.).

Most bears observed by Stirling (1974b) began feeding on the seal immediately after capture, usually eating just the skin and blubber. The remains were scavenged by arctic foxes, other bears, or, occasionally, birds. During and after a feeding period, bears usually washed and licked themselves, spending up to 15 minutes on a final washing (ibid.).

In spring and summer, the maximum numbers of seals are hauled out on the surface of the ice in the afternoon and the minimum in the early morning. Hunting success is far higher for still-hunting at breathing holes than for stalking basking seals, so most bears hunt in the early morning (0100-0800) and sleep in the afternoon (ibid.).

2. Caloric requirements. From tracking and observing marked bears, Eley (1978) estimated that, on the average, each adult bear would need to kill one average-sized ringed seal every 6.5 days. Based on a model using average sizes of ringed seals and polar bears, observed caloric requirements of captive polar bears, and caloric values of whole ringed seals, Best (1977) calculated that a 27.8 kg ringed seal would supply the energy requirements of a 229 kg polar bear for 6.4 days.

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Most mating occurs on the sea ice near open leads, where most bears (except females with cubs of the year) concentrate in spring (Amstrup, pers. comm.). (For maternity denning habitat, see section III.B.3, Maternity Dens.)

B. Reproductive Seasonality

Male Alaskan polar bears show evidence of spermatogenesis from February through April (Lentfer and Miller 1969); pairs of an adult male and a female in estrous have been seen in Alaska

through May (Lentfer et al. 1980) and, in Spitsbergen, Lønø (1970) observed mating or attempted mating through late June.

The earliest and latest dates at which evidence of estrous has been observed in female polar bears in Alaska are 21 March and 15 May (Lentfer et al.; Amstrup, pers. comm.); although estrous may have occurred before or after these dates, opportunities to make observations were limited (Lentfer 1982).

Mating in Alaskan polar bears therefore occurs mostly in March, April, and May. Ovulation is probably induced (Amstrup, pers. comm.), and implantation is delayed until about September (Lønø 1970). In late October or November, pregnant females seek out denning areas on land or on drifting sea ice, depending on ice movements and the speed of the freeze-up (Lentfer and Hensel 1980). Cubs are born in December or January, and the female and cubs break out of the dens in late March or early April (ibid.)

Hansson and Thomassen (1983) studied bear families in Svalbard in the immediate postdenning period and found that the average time spent in the maternity den area after initial breakout was 14 days (range, 5-28 days). The females ate little, the cubs nursed, acclimated to outside temperatures, played, and developed their motor skills before moving out of the den area and onto sea ice (ibid.).

C. Reproductive Behavior

Males locate females in estrous by following their tracks (Lentfer 1982). Males are promiscuous and may fight over females; no territories are maintained (Amstrup, pers. comm.). No information was found on how long pairs remain together.

D. Age at Sexual Maturity

The average age of first successful breeding for female polar bears in the Alaskan Beaufort Sea averages 5.4 years and ranges from 3 to 7 years (Lentfer et al. 1980). Although mature sperm have been found in the reproductive tracts of male bears from 3 to 19 years, ages of males captured with females during the breeding season ranged from 3 to 11 years (Lentfer and Miller 1969, Lentfer et al. 1980). Maximum breeding age has not been determined, but maximum ages of reproductively active males and females observed were 19 and 21 years, respectively (ibid.).

E. Frequency of Breeding

Females usually breed at about the time of separation from young (about 28 months postpartum); therefore, litters are generally produced about every three or four years (Amstrup 1984). Based on eight recaptured females, Lentfer et al. (1980) reported an average time between successive births of 3.6 years in the Alaskan Beaufort Sea.

F. Fecundity

In the Alaskan Beaufort Sea, female polar bears usually give birth to two cubs, less often one, and rarely three (Lentfer et al. 1980). Mean litter sizes of cubs (observed sometime after leaving the den), yearlings, and two-year-olds were 1.58, 1.65, and 1.47, respectively (ibid.). DeMaster and Stirling (1983) feel that the

average number of cubs born per litter is underestimated by these and other figures and developed a model to derive litter size at birth from the observed number of yearlings and two-year-olds per litter and the calculated survival rate of yearlings. When the model was applied to published North American population data, the estimated average number of cubs born per litter was between 1.70 and 1.98.

G. Gestation

In polar bears, implantation is delayed, so the time from conception to parturition is relatively long, 195-265 days (Uspenski 1977).

H. Lactation Period

Polar bear cubs nurse for at least one year and usually 2 to 2-1/2 years (Amstrup, pers. comm.). Stirling et al. (1975) cited two instances of three-year-olds still with an adult female in the Canadian Beaufort Sea, but presence of milk or nursing activity was not noted.

VI. FACTORS INFLUENCING POPULATIONS

A. Natural

Natural mortality factors, diseases, and parasites of polar bears are poorly known (Lentfer 1982). Survival rates of bears in Alaska cannot be accurately calculated from existing data, but the overall composition of the population has been estimated at 32% young (0-2 years old), 43% older females, and 25% older males (Lentfer et al. 1980, Lowry et al. 1982). Amstrup et al. (in press) give age distribution of polar bears live-captured in the Alaska Beaufort Sea from 1967 through 1974 as 33% bears 0-2 years of age, 21% older males, and 46% older females (N=490). From 1975 through 1982, 33% of the bears captured were 0-2 years of age, 31% were older males, and 36% were older females (N=395) (ibid.). Stirling et al. (1976) assumed that the mortality rate of young bears in the western Canadian arctic was equal to the annual mortality rate of 8% of the adult females they depend upon. In Ontario, Kolenosky and Prevett (1983) found the mortality rate of cubs from the time of den abandonment to their first autumn to be 15%; therefore, if adult female mortality is similar to that in the western arctic, the total first-year mortality rate would exceed 20% (ibid.).

Changes in the abundance of seals may affect the distribution of polar bears as well as their reproductive and cub survival rates (Stirling et al. 1975, 1976, 1977; Lentfer 1983). In the Canadian Beaufort Sea during the winters of 1973-1974 and 1974-1975, numbers of ringed and bearded seals dropped by about 50% and their productivity by 90%. Numbers of adult polar bears declined markedly in the area, and the large reduction of yearlings observed in 1974 and 1975 indicated a high level of cub mortality prior to one year of age (ibid.). Both adult males and adult females have been observed eating cubs, but this is not common and is unlikely to be a major source of mortality (Uspenski and

Kistchinski 1972, Belikov and Kuprijanov 1977, Lentfer 1982, Hansson and Thomassen 1983).

Adult males fight, especially during the breeding season, as evidenced by tracks, wounds, and scars. Adult females may also be scarred, but this is found less often. Stirling (1974b) noted that an adult male and a female with a 2.5 year old cub fought and wounded each other over a seal the female had killed. After several charges and some fighting, all three bears fed on the carcass at once. Intraspecific aggression is not likely to be a significant mortality factor in itself, although it may keep some animals, particularly subadults, out of prime feeding areas.

The parasite most commonly found in Alaskan polar bears is Trichinella spiralis; 64% of 292 Alaskan bears examined had Trichinella larvae, probably from ingestion of infected seals, walruses, or other bears (Lentfer 1976).

B. Human-related

A summary of possible impacts from human-related activities includes the following:

- Attraction to artificial food source
- Harassment, active
- Harassment, passive
- Interference with reproductive behavior (disturbance of denning bears)
- Mortality due to ingestion of chemicals
- Mortality due to ingestion of petroleum or petroleum products
- Reduction of food supply

(See the Impacts of Land and Water Use volume of this series for additional information regarding impacts.)

VII. LEGAL STATUS

A. Federal

Polar bears are federally protected under the Marine Mammal Protection Act of 1972 (MMPA PL 92-522). The USFWS administers polar bears for the federal government.

B. State

The State of Alaska may petition the federal government for renewed managerial authority over 10 species of marine mammals, including polar bear.

C. Population Management History

1. Summary of harvest. Within the Arctic and Western regions, the harvest of polar bears has ranged from 29 bears reported taken in 1979 to 405 bears reported taken in 1966 (Amstrup et al. in prep.). These figures are minimum estimates of harvest, especially after 1973, when implementation of the MMPA made reporting harvest voluntary (ibid.).

Prior to the late 1940's, most polar bear hunting in Alaska was by Eskimos for food and hides for sale (Lentfer 1982). Based on fur export records for 1925-1953, estimated annual harvest averaged 117 bears (Lentfer 1982). Trophy hunting with the aid of aircraft began in the late 1940's, and the

annual harvest increased to a high of 405 in 1966 (Lentfer 1982, Amstrup et al. in prep.). State regulations became more and more restrictive as the efficiency of guides and the number of hunters increased; between 1960 and 1972, an average of 260 polar bears was taken annually (ibid.). Alaska banned polar bear hunting with aircraft in 1972. Proposed regulations for hunting from the ground were never implemented because the MMPA was passed (ibid.).

2. Period of state authority. During the period of state management of polar bears, 1960 through 1972, no accurate estimates of population size, rates of reproduction, or natural mortality yet existed (ibid.). Management was based on harvests at what were judged to be moderate levels, protection of females with young, collection of specimens and other data from hunters, who were required to present hides and skulls to ADF&G representatives for sealing, sightings from trophy-hunter guides, and data from mark-and-recapture projects and other research carried out by the ADF&G beginning in 1966 (ibid.). Shortly after passage of the MMPA, the state requested return of managerial authority for certain species, including polar bears, as provided for in the act. After a review period of six years, Alaska's request for return of management was approved but with stipulations that were unacceptable to the state (ibid.).
3. Period of federal authority. The federal government had managerial authority of polar bears prior to 1960 and from 1972 to the present. The MMPA effected a moratorium on the taking of marine mammals by anyone other than Alaskan Natives, who can take them for subsistence without restriction, provided waste does not occur (Lentfer 1982). The act does not protect females with young (ibid.). Polar bears are currently administered by the USFWS for the federal government, with no restrictions on take.
4. International agreements:
 - a. 1973 International Agreement on Conservation of Polar Bears. All nations with polar bears under their jurisdiction (Canada, Greenland, Norway, the United States, and the USSR) provided for international management of polar bears in the 1973 International Agreement (Lentfer 1982). It creates a de facto "high seas" sanctuary for bears by not allowing them to be taken by aircraft, large motorized boats, or in areas where they have not been taken by traditional means in the past. It states that nations shall protect the ecosystems of which polar bears are a part and that nations shall conduct national research and exchange research results and harvest data. Annexes to the agreement request an international hide-marking scheme to control illegal traffic in hides, the protection of cubs and females with cubs, and the prohibition of

hunting in denning areas when bears are moving into the areas or are in dens (ibid.). The United States, by allowing Native Alaskans to take females with young, is not in full compliance with the agreement.

- b. Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). More than 50 countries have signed CITES, which took effect in July 1975. In each member nation, a permit is required to export certain animals or parts thereof, including polar bears (ibid.). Polar bears are listed in Appendix II (potentially threatened with extinction) of CITES.

D. Current Population Management

1. Management objectives. One general goal of the MMPA is to maintain the stocks of marine mammals at optimum sustainable population (OSP) levels. Under existing regulations, OSP is defined as ". . . any population level smaller than or equal to the largest average supportable level within the ecosystem (carrying capacity) and larger than or equal to the population level for a given species or stock that results in maximum net productivity" (USFWS 1982). A second general goal of the MMPA, as amended in 1981, is to provide for continued subsistence use.

USFWS policies with respect to polar bears are as follows:

- Recognition of polar bears as a renewable resource of considerable historic and current value to humans
- Maintenance of an optimum sustainable polar bear population and the health and stability of the marine ecosystem of which they are a part
- Management of polar bears based on sound, objective biological data
- Encouragement of cooperative management and survey and research programs at local, state, national, and international levels
- Public participation in planning
- Subsistence use as the priority consumptive use of polar bears
- Recognition of the rights and interests of citizens to use and enjoy the resource
- Support return of management authority of polar bears to the State of Alaska (USFWS 1982)

Specific goals of the USFWS to implement the above policies are as follows:

- Maintain the Alaskan polar bear population within the OSP range and at a minimum of 5,700 animals
- Monitor the population health and status
- Regulate and monitor the harvest
- Determine seasonal and annual distribution and movement patterns

- Monitor coastal and offshore energy and mineral development that may affect polar bears and provide recommendations to minimize impacts
 - Delineate and protect essential habitats such as significant denning and other concentration areas
 - Minimize impacts of oil pollution on polar bears and their habitat
 - Provide for regulated subsistence use of polar bears as the first priority
 - Provide for regulated incidental take
 - Provide for taking of polar bears for scientific and public display purposes
 - Provide for a regulated sports hunt if MMPA is changed
 - Provide for nonconsumptive uses where feasible
 - Fully implement the International Agreement on the Conservation of Polar Bears
 - Facilitate the return of marine mammal managerial authority to the State of Alaska (ibid.)
2. Management considerations. The MMPA was ammended in 1981 to provide for continued subsistence use. As defined in the amendment, subsistence use is "the customary and traditional use by rural Alaska residents of marine mammals for direct personal or family consumption of food, shelter, fuel, clothing, tools or transportation and for making and selling of handicraft articles from non-edible by-products of marine mammals taken for personal or family consumption" (USFWS 1982). Although the harvest must be accomplished in a nonwasteful manner, no restrictions are placed on the age or sex of animals that may be taken (ibid.); percentages of females and animals of "unknown" sex in total harvest numbers have increased since implementation of the MMPA in 1973 (Amstrup et al. in prep.). The federal government cannot regulate subsistence take under the MMPA unless a species is declared depleted; the state, however, if managerial authority is transferred, may be able to regulate the harvest for subsistence as well as for other purposes if the subsistence harvest is considered a threat to the population (USFWS 1982). Amstrup et al. (in prep.) state:

Levels of human activities, particularly aircraft, vessel, and motor vehicle operation, in Alaska's arctic are increasing. The mean size of annual polar bear harvests has dropped since aerial trophy hunting ceased, but many females continue to be killed. The Beaufort Sea population can sustain little if any increase in the present mortality rate of females. The absence of regulatory controls over the harvest and impending changes in the arctic habitats mandate concern for the future welfare of Alaska's polar bears. Available evidence suggests a properly regulated harvest could

assure the security of the critical female portion of the population.

VIII. LIMITATIONS OF INFORMATION

In his 1984 review of polar bear research in Alaska, Amstrup identified the following objectives as most important for continued and future research:

- ° To determine the size and trends of polar bear populations in Alaska, including mortality, natality, and recruitment rates, sex and age composition, and the effects of human activities on bears
- ° To determine movement and distribution patterns, including seasonal ranges and distributions, seasonal and annual site fidelity, and interchange with other populations
- ° To determine the timing, distribution, and importance of maternity denning in Alaska, including location, site fidelity, the effects of human activity, and the importance of sea ice as a maternity denning habitat.

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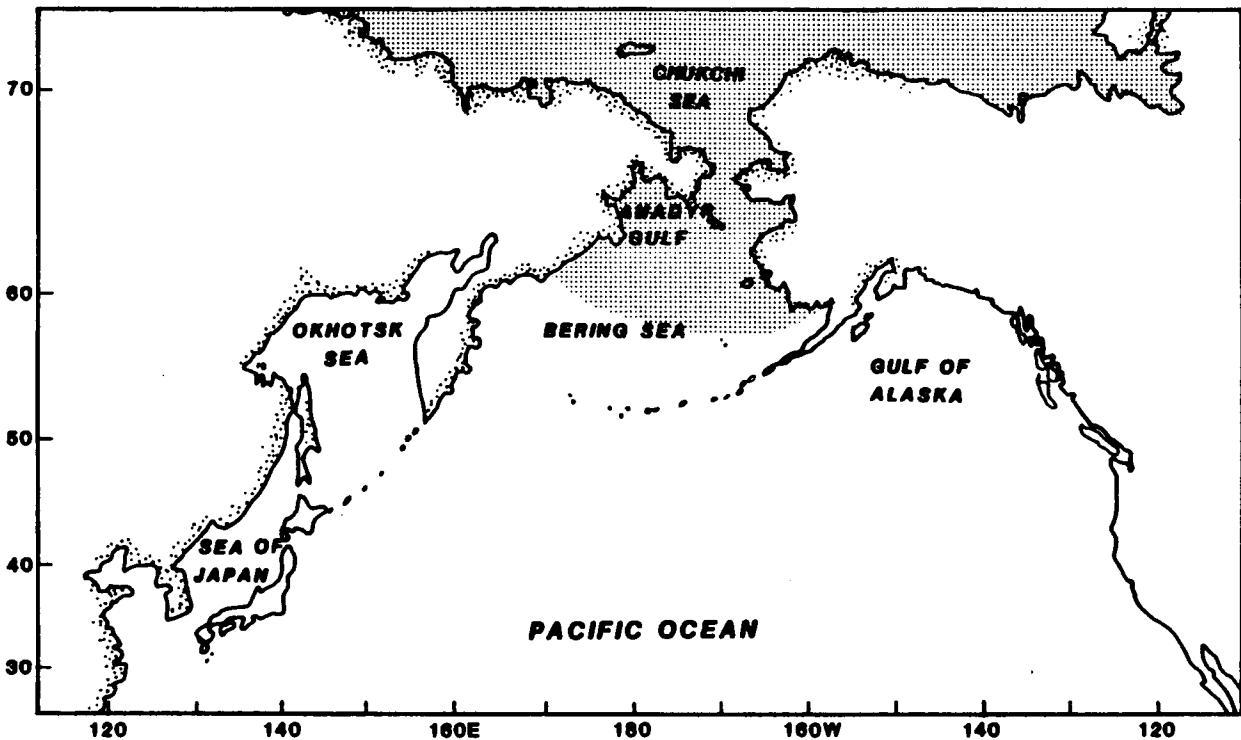
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Ringed Seal Life History and Habitat Requirements
Arctic Region



Map 1. Range of ringed seal (Frost 1984)

I. NAME

- A. Common Name: Ringed seal
- B. Scientific Name: Phoca hispida hispida (King 1964)
- C. Native Names: See appendix A.

II. RANGE

- A. Worldwide
The ringed seal is found throughout the arctic basin, along the arctic coasts of North America and Eurasia, including Greenland, Baffin Island, Novaya Zemlya, Spitsbergen, and Labrador. They also range seasonally into the North Atlantic, Hudson and James bays, and the Bering Sea (Frost and Lowry 1981).

- B. Statewide
Seasonally, ringed seals range as far south as Nunivak Island and Bristol Bay and are abundant in the northern Bering Sea, Norton and Kotzebue sounds, and throughout the Chukchi and Beaufort seas (Frost 1984).
- C. Regional Distribution Maps
To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for the Arctic Region. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of ringed seal distribution has been prepared and may be found in the Atlas that accompanies the guide for the Arctic Region.
- D. Regional Distribution Summary
The ringed seal is a species primarily associated with ice. Although they can and do occur in all types of sea ice, the seasonal cycle of sea ice has a great effect on their distribution and regional abundance (Burns 1970, Frost 1984). During the summer, ringed seals range freely, most spending the summer season in the pack ice of the northern Chukchi and Beaufort seas, as well as in nearshore ice remnants in the Beaufort Sea. With the onset of winter freeze-up, their movements become increasingly restricted. Many seals that have summered in the Beaufort Sea move west and south with the advancing ice pack and disperse throughout the Bering and Chukchi seas. Some seals remain in the Beaufort, probably concentrating in areas of abundant prey (Lowry et al. 1980).
The distribution of ringed seals during the open-water period is poorly understood because they spend virtually all of their time in the water feeding (Frost and Lowry 1984).
(For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Western and Interior regions.)

III. PHYSICAL HABITAT REQUIREMENTS

As stated by Frost (1984), "suitable ringed seal habitat must include an adequate food supply, freedom from excessive predation, and physical conditions appropriate for the completion of major life history events such as reproduction and molting. Requirements are not static but change seasonally and with age and physiological condition of the seals."

- A. Aquatic
Because ringed seals prey mostly on pelagic organisms, their distribution does not appear to be limited by water depth, and substrate does not appear to play a major role. They are found over the abyssal depths of the high arctic as well as in shallow waters of the continental shelf (Burns 1978).
Water temperature does not appear to affect distribution, other than as it relates to ice formation.

B. Terrestrial Cover Requirements

In Alaskan waters, ringed seals do not normally haul out on land. Those seals found on beaches are usually debilitated; most are starving pups that come ashore in early summer (ibid.).

C. Ice

Ringed seals are the most ice-adapted of all northern pinnipeds and are the only seals in the Northern Hemisphere that regularly inhabit the fast ice (Burns 1970). Sea ice provides a stable platform on which to bear and nurse young and for hauling out to complete the annual molt cycle. The ice also provides some protection from predators and from exposure to severe weather conditions. Ringed seals require regular access through the ice to air and water. Because they maintain breathing holes by frequent use and abrasion of the ice by the claws of their front flippers, they are able to occupy areas of heavy unbroken ice unsuitable for other northern pinnipeds (Burns 1978, Frost 1984). Holes have been measured in ice over 2 m thick (Smith and Stirling 1975, Smith and Hammill 1981).

1. Winter and spring (November-June). During winter and spring, the highest densities of breeding adult seals occur on stable land-fast ice. During spring, subadults may be excluded from fast ice (see Sea Ice appendix, volume 2, Alaska Habitat Management Guide for the Arctic Region) where adults, which may be territorial, are numerous during the pupping and breeding season. Subadults are the most numerous age group in the adjacent flaw zone (McLaren 1958, Burns 1970, Smith 1973). Throughout the pack ice, seals of all ages are found at low densities (Frost 1984).

a. Lairs. Ringed seals use open leads and cracks in the ice to surface and breath during freeze-up. Wind, ice movement, and freezing create pressure ridges and ice hummocks in some areas. As the ice mass solidifies, the seals begin to actively keep breathing holes open. Snow drifts around pressure ridges and hummocks, covering the breathing holes, and it is in these areas that breathing holes are enlarged so that seals can haul out and excavate lairs (Smith and Stirling 1975). Lairs are used by males and females of all ages for resting and by adult females for pupping (Burns 1978).

Lairs are found in a minimum snow depth of 20 cm. Sufficient snow for lair construction is usually found to the lee side of ice hummocks or along pressure ridges. Flat areas with little or no snow accumulation contain breathing holes but few lairs of any type (Smith and Stirling 1975).

Smith and Stirling (1975) found two distinct types of lairs in the Admudsen Gulf and Prince Albert Sound areas. The most common type in both offshore and inshore areas were what they referred to as "haulout lairs," which are used for resting and consist of a

single round or oval chamber. The second distinct type was termed the "birth lair," where pups are born and weaned, and consists of a network of tunnels made by the pup. Two major lair types were found in the Chukchi and Beaufort seas of Alaska (Frost, pers. comm.). These were single-chambered haulout lairs and multichambered "complex" lairs. Some complex lairs consisted of only two chambers and contained no evidence of a pup. Others consisted of 2 to as many as 10 chambers, with many small pup tunnels and pup chambers as well as other evidence of pups, such as claw marks, white pup hair, birth blood, or placenta.

Lairs afford protection from predators and the cold. Newborn pups accumulate blubber slowly and depend on the lair for thermal protection. Because of the small volume of the lair under the insulating snow layer and because the lair is connected to the ocean by the breathing hole, the temperature likely remains near 0°C. The additional heat generated by the seal when it hauls out in the lair could result in a temperature difference between the inside and outside as great as 30 to 40°C (Smith and Stirling 1975).

2. Late spring and early summer (May-July). During the late spring and early summer, ringed seals haul out on ice to complete their annual molt. They use the fast ice as well as relatively large flat floes in the pack ice and are usually seen near cracks, leads, or holes where they have rapid access to water. Feeding is greatly reduced at this time (Frost and Lowry 1981).
3. Summer and early fall (July-September). Ringed seals spend most of the summer and early fall in the water feeding intensively. Very few seals haul out at this time (Frost, pers. comm.).
4. Fall (October-November). With the onset of freeze-up in fall many ringed seals migrate southward and are abundant in grease and slush ice in areas south of the advancing pack (Frost 1984).

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

Ringed seals exhibit seasonal, geographical, and age-related differences in feeding, consuming a variety of organisms. Fishes of the cod family, particularly arctic and saffron cods (*Boreogadus saida* and *Eleginus gracilis*), pelagic amphipods, euphausiids, shrimps, and other small crustaceans such as mysids and amphipods make up the bulk of the diet (Lowry et al. 1980). Pup and subadult ringed seals eat proportionately more crustaceans and fewer fish than do adults. Crustaceans make up a progressively smaller proportion of the diet as age increases from zero to five years, while the proportion of fish increases. In the

Beaufort Sea, however, pups as well as adults eat large quantities of arctic cod (Lowry et al. 1980).

1. Winter (November through March). During winter, arctic cod compose 83-98% of the diet in most areas where samples have been collected (Lowry et al. 1980, Frost and Lowry 1981). Arctic cod concentrate to spawn from November through March (Andriyashev 1954). In the vicinity of Nome, however, from November through December saffron cod composed 56% of the diet, compared with 28% arctic cod. Arctic cod composed 97% of the diet during the January-through-February period near Nome (Lowry et al. 1980).
2. Spring and early summer (April through July). The volume of arctic cod eaten begins to decrease in late spring. During this period, saffron cod was the most important food item in the nearshore zone of the northeastern Bering and southeastern Chukchi seas. Shrimps (Pandalus spp., Eualus spp., Lebbeus polaris, and Crangon septemspinosa) were the major food in the northcentral Bering Sea, hyperiid amphipods (Parathemisto libellula) in the central Beaufort Sea, and euphausiids (Thysanoessa spp.) in the Barrow area, where the Chukchi and Beaufort seas meet. During this period, the volume of prey consumed is quite small (Lowry et al. 1980, Frost and Lowry 1984).
3. Summer and early fall (August and September). Feeding begins to intensify during this period. Hyperiid amphipods were important foods in both the Alaskan Beaufort and southeastern Chukchi seas (Lowry et al. 1980, Frost and Lowry 1984). Samples prior to 1980 in the Alaskan Beaufort Sea suggested that euphausiids and hyperiid amphipods were the major foods of ringed seals in August and September (Lowry et al. 1979, 1980). Collections made in 1980, however, indicated that in some circumstances arctic cod are the major prey, possibly at times or in locations where euphausiids or hyperiids are not adequately abundant (Frost and Lowry 1984).

B. Types of Feeding Areas Used

The distribution of seals and their prey is patchy. The distribution of seals is probably determined, at least in part, by the availability of prey. Preference for fast ice may partly be due to the stable platform it provides and partly to the availability of food (Lowry et al. 1980; Frost, pers. comm.). Because ringed seals often prey on pelagic organisms, their distribution does not appear to be limited by water depth (Burns 1978). (See III., above.)

C. Feeding Behavior

During the molt in late spring and early summer, ringed seals feed little. This period of reduced feeding occurs when available prey appear to be difficult to obtain in large quantities (Lowry et al. 1980).

The ringed seal is probably not a deep diver; a depth of 600 ft is probably the limit for this species. In very deep water, seals

feed on organisms in the upper part of the water column (Burns 1978). Fedoseev (1965) suggests that the cusps of the postcanine teeth are functional in filtering small organisms such as euphausiids from bites of water.

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Relatively stable ice with snow cover adequate for the excavation of lairs is necessary for the survival of pups to the age of independence, at four to six weeks of age. Land-fast ice supports the highest densities of breeding or pupping female adults, although some pups are born on the stable pack ice (Frost and Lowry 1981). Geographical differences in the size attained by adults may be attributable to varying ice conditions (Mansfield 1967, Pastukhov 1969). In Alaska, pups born on stable shore-fast ice tend to be larger than pups born in the moving pack ice (Burns, unpubl. data, from Frost, pers. comm.) because the shore-fast ice allows a longer nursing period (Frost and Lowry 1981). (See III. C., above).

B. Reproductive Seasonality

Most pups are born during March and early April. Most breeding occurs in late April and early May within one month after parturition (Burns 1978).

C. Reproductive Behavior

The ringed seal may be territorial. The focal point of the territory of a female with pup is probably the birth lair. Newborn pups probably remain in or near the birth lair until they are weaned. Females abandon their pups at or around ice breakup (Frost and Lowry 1981). If an early breakup occurs, destroying the lair, the pups may be abandoned and, depending on their age, may starve (Burns 1978). Although there has been no direct observation of ringed seal breeding behavior, it has been suggested that males are monogamous and that breeding occurs in the water (Frost and Lowry 1981).

D. Age at Sexual Maturity

Sexual maturity occurs at about the same age in both males and females, between four and seven years of age. Female ringed seals may ovulate for the first time at three years of age, but successful pregnancy does not occur until the fourth to seventh year of life (ibid.).

E. Frequency of Breeding

Most ringed seals breed annually. For various reasons, such as intrauterine mortality, some females do not produce a pup each year (Frost 1984).

F. Fecundity

A single pup is by far the most common, although twinning has been reported (Frost and Lowry 1981). The average for adult female ringed seals is one pup/1.2-1.4 years (Lowry et al. 1982). The observed pregnancy rates for seals in Alaska from 1975 through 1977 was 72% for females 7 years or older and 84% for those 10

years or older. The minimum estimated gross productivity is 16 to 18% (Frost 1984).

G. Gestation Period

Including delayed implantation of about 3.5 months, gestation lasts 10.5 months (Frost and Lowry 1981).

H. Lactation Period

Lactation lasts for four to six weeks, depending on the stability of the ice where the birth lair is built (Burns 1978).

VI. FACTORS INFLUENCING POPULATIONS

A. Natural

Polar bears (Ursus maritimus) and arctic foxes (Alopex lagopus) are the most significant natural predators of ringed seals. Polar bears prey extensively on ringed seals throughout the year. Although the impact of this predation is unknown, it is certainly significant (ibid.).

Ringed seal pup mortality appears to be about 30%, which is lower than that for young of other northern pinnipeds, which may exceed 50%. Causes of pup mortality include exposure to extreme weather conditions prior to the accumulation of sufficient blubber layers, crushing by ice, starving of the pup while it is first learning to feed, and predation (Frost 1984).

Smith (1976) reported heavy fox predation upon pups in birth lairs in Prince Albert Sound, Canada. Over a three-year period, annual predation by foxes on pups born in nearshore ice averaged an estimated 26%, with a high of nearly 40%. Smith concluded that the most important cause of natural mortality of ringed seals in nearshore ice during the first year of life was probably foxes. This mortality is known to vary greatly in relation to the cyclic abundance of arctic foxes. The extent of this predation in Alaska is unknown (Frost 1984). Preliminary studies in 1983 and 1984 suggest considerable regional variation in fox predation rates, ranging from almost zero in Kotzebue Sound to perhaps 20 to 30% along parts of the Chukchi Sea coast (Frost, pers. comm.).

Lowry and Fay (1984) found evidence that seal-eating by walruses was 10 to 100 times more common during the 1970's and early 1980's than it had been during the previous three decades. They attributed the increased predation of walruses on seals to a larger walrus population and, especially in 1979, to unusually restrictive spring ice conditions, which caused greater than usual overlap of their distributions.

B. Human-related

A summary of possible impacts from human-related activities includes the following:

- Chronic debilitation due to ingestion or contact with petroleum or petroleum products
- Mortality due to ingestion of petroleum products
- Displacement from preferred habitats due to disturbance
- Entanglement in fishing nets or marine debris
- Human harvest

- ° Interference with intraspecific communication
(See the Impacts of Land and Water Use volume of this series for additional information regarding impacts.)

VII. LEGAL STATUS

- A. Federal
Ringed seals are protected under the U.S. Marine Mammal Protection Act of 1972 (MMPA, PL 92-522).
- B. State
The State of Alaska currently has no responsibility for ringed seals but may request return of management of 10 species of marine mammals, including ringed seals.
- C. Population Management History
Data are presented for the entire state rather than by game management unit.
 1. Summary of harvest. Ringed seals are a dependable source of food and material for Alaskan coastal residents from Kuskokwim Bay to Demarcation Point (Frost 1984). From 1962 through 1972, the Alaskan harvest ranged from an estimated 7,000 to 15,000 seals annually, and the combined Soviet and American harvest was 9,000 to 16,000 annually (ibid.). Due to changes in lifestyle (e.g., replacement of dog teams with snowmachines for most travel) and the restrictions of the MMPA (e.g., seal skins not made into handicraft items can no longer be sold to non-Natives), harvest of ringed seals declined markedly after 1972 (ibid.). In 1973-1977, Alaskan residents took 3,000 to 6,000 seals per year, and by 1979 the harvest was further reduced to 2,000 to 3,000 (ibid.).
 2. Period of state authority. Ringed seals were managed by the State of Alaska from statehood in 1959 until passage of the MMPA in 1972. Harvest levels were low relative to estimated total population, and no limit was imposed on the take, although harvests were monitored (ibid.). A long-standing general bounty on "hair seals" was stopped in 1967 (ADF&G 1977).
 3. Period of federal authority. The federal government has never imposed any restrictions on the take of ringed seals. In 1927, a bounty was placed on "hair seals," including ringed seals (ibid.). Management responsibility reverted to the federal government after passage of the MMPA in 1972; no additional management regulations were enacted. Passage of the MMPA lowered the overall harvest of ringed seals in Alaska because seal skins could no longer be sold to non-Natives. See C.1. above.
 4. International agreements. The United States has entered into no international agreements concerning ringed seals.
- D. Current Population Management
The NMFS of the U.S. Department of Commerce was given the responsibility for management of ringed seals for the federal government after passage of the MMPA in 1972.

1. Management objectives. The NMFS has no published plan for management of ringed seals (Zimmerman, pers. comm.).
2. Management considerations. Because ringed seals occur in areas of shore-fast ice, they are more likely than other seal species to be affected by the noise and disturbance associated with oil and gas development and seismic exploration (Frost 1984). Expansion of commercial fishery operations would probably have little effect on ringed seals because their major prey are not, or not likely to become, commercially important (ibid.). NMFS has no management plans, research or harvest monitoring programs, so there are no reliable current harvest and population estimates. Frost (1984) summarized: "Management concerns such as the impacts of coastal development, seismic exploration, and interspecies competition are being addressed by the state under funding from a variety of sources, as available. Thus, programs are of relatively short duration and directed at specific, localized problems rather than at important, overall information needs."

VIII. SPECIAL CONSIDERATIONS

- A. Molting occurs from late March until July, with the peak in June. During this period, seals haul out on the fast ice as well as on relatively large flat floes in the pack, and feeding intensity is greatly reduced (Frost and Lowry 1981). Reproductively immature animals molt earlier than do breeding adults. Vibe (1950) found that older animals began to haul out about 10 days later than did young animals. He also found that early in the molt the maximum number of seals hauled out on ice occurred between 10:00 A.M. and 3:00 P.M. The amount of time spent on the ice increases as the molt season progresses because daylight and temperatures increase, and basking in the sun raises skin temperature for faster hair growth. Animals lose weight and may be physiologically stressed during the molt and therefore more susceptible to additional exogenous stress (Frost, pers. comm.).
- B. Vocalization
Four types of vocalization made by ringed seals were classified by Stirling (1973). Frost and Lowry (1981) suggested that because all four types were heard at all times of the year, it appears unlikely that any have a specific relationship to reproductive behavior. Stirling (1983), however, suggests that vocalizing probably serves an important role in the reproductive behavior of this species and that calls may be used for social organization and determining access to breathing holes.

IX. LIMITATIONS OF INFORMATION

Mortality rates are difficult to estimate, although most causes of mortality are known (Frost 1984).

It is unknown whether ringed seals use the same wintering and summering areas every year. Because of this gap in knowledge, the identity and

degree of interchange between populations is unknown (Frost and Lowry 1981).

It is not known whether or not ringed seals are food-limited (Lowry et al. 1980).

The effects of human activity on ringed seals and their food species are inadequately known (Frost 1984).

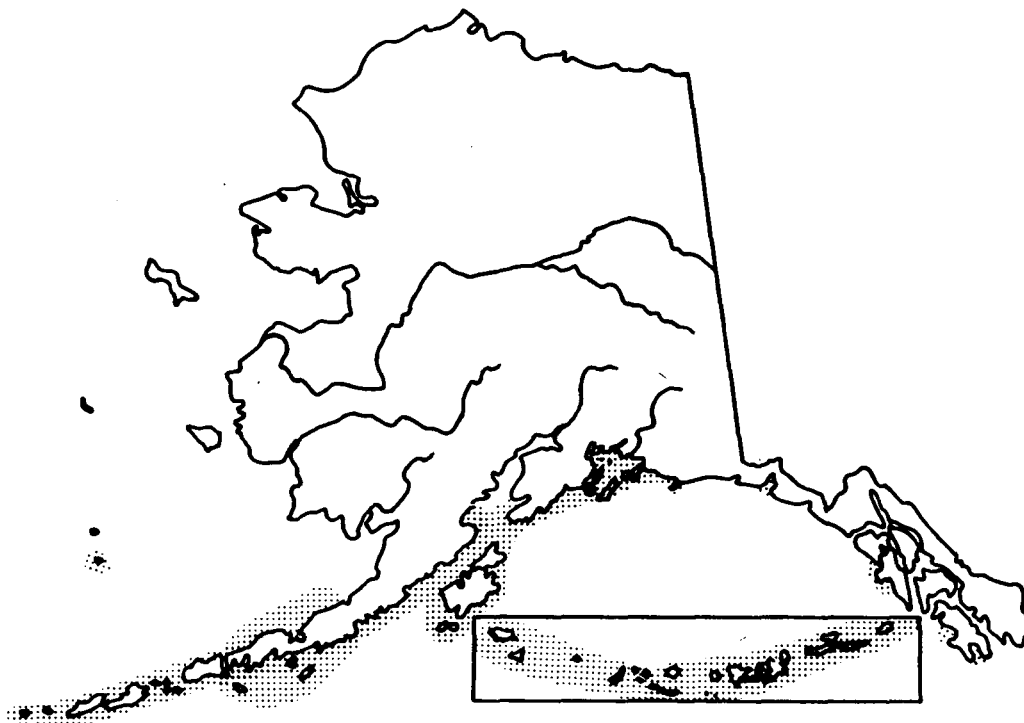
It has yet to be investigated how ringed seals locate food in the total darkness of the arctic winter (Frost and Lowry 1981).

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Sea Otter Life History and Habitat Requirements
Southwest and Southcentral Regions



Map 1. Range of sea otter (Kenyon 1969, Lensink 1962)

I. NAME

- A. Common Name: Sea otter
- B. Scientific Name: Enhydra lutris
- C. Native Names: See appendix A.

II. RANGE

- A. Worldwide
Sea otters historically inhabited the coastal areas of the North Pacific Ocean and the Bering Sea from the Kamchatka Peninsula south to the Kurile Islands and Hokkaido Island (Japan), eastward through the Commander, Pribilof, and Aleutian islands, and along the North American coast from the Alaska Peninsula, Kodiak Island, and Prince William Sound (PWS) to southern California (Kenyon 1969, Lensink 1962).

Commercial harvesting eliminated sea otters from most of this range. In 1911, commercial harvesting of sea otters was curtailed, leaving only remnant populations present in widely scattered areas of the sea otters' former range (Lensink 1960). Sea otters have now repopulated most of their former ranges. These populations have resulted from range expansion (Schneider, pers. comm.) or transplants taken from high density areas (Burris and McKnight 1973).

B. Statewide

Sea otters occur in nearshore Alaskan waters from Southeast Alaska (with small populations near Chichagof, Yakobi, Maurelle, Barrier, and Coronation islands resulting from transplants in the 1960's) to Yakutat (where small groups have become established), through PWS, the Kenai Peninsula extending into Kachemak Bay, the Kodiak archipelago, along the south side of the Alaska Peninsula, throughout the Aleutian Islands, and along the north side of the Alaska Peninsula as far as Port Heiden (Kenyon 1969, Burris and McKnight 1973). Sea otters have occasionally been reported from the Pribilof Islands and northward; however, permanent populations are not likely to occur in areas of winter sea ice (Kenyon 1969, Schneider and Faro 1975).

C. Regional Distribution Maps

To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for the Southwest, Southcentral and Southeast regions at 1:250,000 scale. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of sea otter distribution has been prepared and may be found in the Atlas that accompanies the Southwest and Southcentral regional guides.

D. Regional Distribution Summary

1. Southwest. Sea otters are present in substantial numbers all along the Aleutian Islands where favorable habitat is found. Important concentration areas include the Rat and Delarof islands, Andreanof Islands, and the area north of Unimak Island. (For more detailed narrative information, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)
2. Southcentral. Sea otters are locally abundant throughout PWS, where there is sufficient suitable habitat to support them. Small groups and single individuals are common, and larger established groups are found in many areas of the sound. Sea otter populations are expanding in PWS, and adjacent historic areas with suitable habitat will be settled by exploring members from this core population. Densities of 15 to 30 otters per square mile of habitat, 10 fathoms or less, can be expected (Johnson, pers. comm.). Some areas where sea otters are abundant in PWS include College and Harriman fiords, Hinchinbrook Island, Montague

Island, Sheep Bay, Orca Inlet, Green Island, Port Fidalgo, and Port Gravina (Pitcher 1975; Johnson, pers. comm.). On the Kenai Peninsula, sea otters are present and abundant almost everywhere along the southern coast, including Elizabeth Island, Perl Island, Nuka Bay, Chugach Bay, and Harris Bay. (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)

III. PHYSICAL HABITAT REQUIREMENTS

The two most important sea otter habitat requirements are an abundant, high quality food supply, and clean, uncontaminated water. These habitat requirements are the same throughout the year.

A. Aquatic

1. Water quality. Clean, uncontaminated water is essential for sea otter survival. Sea otters rely on a dense coat of fur to trap a layer of air and prevent water from penetrating to the skin. Contamination of the fur will interfere with this insulating air layer, greatly increasing thermal conductivity, and the animal will quickly die of hypothermia (Schneider 1976, Kooyman et al. 1976). To prevent fur contamination, a considerable proportion of the sea otter's daily activity pattern (up to 60% during some time periods) is spent grooming their fur (Siniff et al. 1982). Sea otters subjected to contamination of 130-260 cm² (less than 10%) of their pelage by only 25cc of Prudhoe Bay crude oil showed significant changes in both level of activity and activity pattern (ibid.). These changes were manifested mainly in increased grooming activity. Metabolic rate increases up to 40% above average have been observed for sea otters with 20% of their pelage contaminated (Costa and Kooyman 1979). An otter that was completely contaminated by oil died less than 24 hours after soilage. Results from an autopsy suggested hypothermia as the cause of death, although toxicity from oil ingestion was also possible (Siniff et al. 1982).
2. Sea ice. Sea otters appear to be limited in their northward expansion by permanent sea ice conditions (Kenyon 1969). Temperatures that allow the rapid formation and advancement of sea ice are detrimental to otter populations. Schneider and Faro (1975) observed ice-related mortality near Port Moller during the below normal winters of 1971 and 1972 (average 5.6-10.3°C below normal temperature). Ice-related mortality of sea otters was also observed in this area in 1974 and 1982 (Frost et al. 1982).
3. Water depth. Sea otters inhabit a wide range of water depths. Accessible habitat is considered to be anywhere within the 75-m depth curve (Calkins and Schneider 1984). There are observations of sea otters diving to depths of 90 m, and adults are often seen feeding in depths up to 80 m;

however, all known self-sustaining populations have access to, and heavily use, waters less than 40 m deep (ibid.).

4. Substrate. Sea otters favor shallow water areas with a variety of bottom substrates, ranging from rocks and underwater reefs to soft sediment bottoms and sandy beaches (Schneider, pers. comm.). Coastlines adjacent to extensive areas of shallow underwater reefs are particularly attractive (Kenyon 1969). The sea otter's association with kelp beds has been assumed to be a necessary habitat requirement. However, large permanent otter populations occur in areas where no kelp beds exist (e.g., southeast Bristol Bay) (Calkins and Schneider 1984).

B. Terrestrial Cover Requirements

Severe winter storms, with associated rough-water conditions, can prevent otters from foraging efficiently, resulting in serious food-related stress (Kenyon 1969). Lee shorelines of prominent points or capes and offshore islets can provide protected areas (Lensink 1962). Haulout areas, consisting of intertidal rocks or areas above the storm-tide line, are used by some otter populations but are not considered essential (Schneider 1978).

1. Southwest Region. Kenyon (1969) reported that otters regularly haul out in the Aleutian and Shumagin islands. In those areas, they favor rocky points but also utilize sand beaches.
2. Southcentral Region. Sea otters in PWS have been observed hauled out on ice floes, intertidal rocks, and on shore above the high-tide line during winter. Sea otters also regularly haul out on sand bars exposed by low tide in areas such as Orca Inlet (Johnson, pers. comm.).

IV. NUTRITIONAL REQUIREMENTS

Abundant food at accessible depths is clearly the most important habitat requirement (Calkins and Schneider 1984). If this food source is not available, otter densities will remain low or populations will disperse.

Sea otters require large quantities of food, about 20 to 25% of their body weight per day (average 5 kg), to support their high metabolic rate (Kenyon 1969). This requirement makes it necessary that an abundance of high quality food be available to the otter population at all seasons of the year (ibid.). In areas where sea otter populations are at or near maximum density, further population growth appears to be limited by the availability of high-quality food items (Schneider, pers. comm.).

A. Food Species Used

Sea otters are opportunistic feeders, and their diet depends largely on what is available (ibid.). They generally feed on a wide variety of benthic invertebrates (Calkins and Schneider 1984); however, when these organisms are scarce, otters are known to prey on other species (e.g., slow-moving fishes) (Kenyon 1969).

1. Southwest Region:

a. Aleutian Islands. In the Aleutian Islands, otters are known to eat many species of invertebrates and mollusks and some species of fishes (ibid.). The following are some of the species eaten by sea otters: green sea urchin (Strongylocentrotus drobachiensis), mussel (Musculus vernicosa, VolSELLA volessa), sea stars (Leptasterias spp., Henricia spp.), Tanner crab (Chionoecetes bairdi), king crab (Paralithodes platypus), octopus (Octopus spp.), chitons (Cryptochiton stelleri), limpets (Acmaea spp.), snails (Buccinum spp.), sea cucumbers (Cucumaria spp.), pearly monia (Pododesmus macroschisma), globefish (Cyclopterichthys glaber), red Irish lord (Hemilepidotus hemilepidotus), and rock greenling (Hexagrammos superciliosus).

b. Northern side of Alaska Peninsula. No specific sea otter food studies are available from the north side of the Alaska Peninsula (Schneider, pers. comm.). It is believed, however, that otters in that area feed heavily on clams, crabs, and other invertebrates (Calkins and Schneider 1983).

Large populations of bivalve mollusks, including surf clams (Spisula polynyma), Alaskan tellin (Tellina lutea), and cockles (Serripes groenlandicus, S. lapereusii), and marine snails (Neptunea spp.) have been discovered in portions of Bristol Bay (Hughes et al. 1977, MacIntosh and Somerton 1981). Distribution of the clam species was greatest between 10 and 22 fathoms (Hughes et al. 1977), well within the sea otter diving range. Snail distribution was more widespread but still accessible to sea otters. These species represent good food sources for sea otters (Schneider, pers. comm.).

2. Southcentral Region. In the Montague Straits area of PWS, Calkins (1972, 1978) found that sea otters fed primarily on benthic invertebrates, including clams, crabs, octopuses, sea stars, mussels, and sea cucumbers. No fish species were observed to be consumed.

Major prey species are similar throughout PWS, with primary importance placed on the prey item most available. Fish have been observed to be taken as prey but only rarely (Johnson, pers. comm.).

Calkins (1972, 1978) determined that five species of clams were the most often consumed prey item in his study area in PWS. The most commonly consumed species was Saxidomas gigantea; however, the species taken depends upon what is locally abundant. Other clam species included Protothaca staminea, Mya truncata, Macoma inquinata, and M. incongrua. Additional favored food species included crabs (Telemessus cheiragonus Cancer spp.), octopuses (Octopus sp.); and mussels (Mytilus edulis) (Calkins 1972, 1978). Other prey

species consumed, but not preferred, included sea stars (Evasterias troschelii) and sea cucumbers (Cucumaria sp.) (ibid.).

B. Types of Feeding Areas Used

Sea otters prefer to feed in shallow water, usually less than 55 m. The maximum depth of food dives may be up to 90 m (Kenyon 1969). Subadult females and females with pups usually occur in areas of higher prey density and in shallower, more protected waters than do males (Schneider 1981).

Sea otters forage from the intertidal zone to generally within 3 to 10 mi of shore, apparently following shallow-water areas to forage. The farthest offshore observations range from 17 mi (Kenyon 1969) to over 30 mi (Schneider, pers. comm.). Offshore foraging movements appear to be associated with weather conditions. After severe storms, otter concentrations tend to be nearshore, whereas after a calm period animals are distributed farther offshore (Schneider 1981).

C. Factors Limiting Availability of Food

Normal foraging activity in a high-density otter population can deplete the food supply, thus affecting the otter population. Sea otters will exploit a favored prey species, utilizing it until the availability or size is greatly reduced. This concentration on a single food species appears to have happened with sea urchins at Amchitka Island (Lensink 1962, Kenyon 1969, Estes and Palmisano 1974), clams in PWS (Calkins and Schneider 1983), and red abalone (Haliotis spp.) in California (Lowry and Pearse 1973).

Sea otters exert a significant influence on marine nearshore communities and have been described as a keystone species (Estes and Palmisano 1974).

Winds of 20 to 30 knots and accompanying rough seas force most sea otters to find protection in sheltered areas or near shore. Long periods of rough sea conditions can prevent otters from foraging in some areas (Lensink 1962).

D. Feeding Behavior

Sea otter feeding behavior is directly associated with the high energy requirements of the species and the availability of high-quality food items. The level of feeding activity needed to meet those requirements varies with the quality and quantity of prey items. If high-quality food items are present in sufficient quantity, otters need to spend only a small amount of time foraging. With a poorer food source, a proportionately larger amount of foraging time is necessary (Schneider, pers. comm.).

In general, feeding behavior accords with the following pattern: Soon after daylight, otters move from resting areas to adjacent feeding areas (usually less than 100 yd) and forage until approximately 1000 hr. Grooming and resting occur throughout the day, with a peak near 1200 hr. Foraging continues during the day, with movement from foraging areas occurring by sundown and activity usually ceasing by dark (Lensink 1962). However, patterns of activity are variable, and night feeding is not

uncommon in areas of poorer quality food sources (Johnson, pers. comm.).

At Amchitka Island, an area of low prey availability, about 51-55% of the daylight hours are spent foraging (Estes 1974, Kenyon 1969).

In contrast, otters had to spend only 17% of the daylight hours foraging in an area of high prey availability (Estes et al. 1982). The difference in foraging activity is related to prey availability and quality (ibid.).

Sea otters use a rock or shell held on their chest to break open some food items (Kenyon 1969, Wild and Ames 1974, Estes 1974).

No apparent differences in feeding, resting, or grooming behavior occur between summer and winter (Estes 1974).

V. REPRODUCTIVE CHARACTERISTICS

The sea otter reproductive strategy is characterized by a low natality rate and a relatively long rearing period by the female, which results in a high rate of survival for the young (Schneider, pers. comm.). This strategy, however, does not allow for a rapid increase in population size.

Lensink (1962) described discrete male and female areas around Amchitka Island (Southwest Region). He speculated that females used areas of more favorable habitat, and that scattered territorial males excluded younger males from these female areas. Younger or nonterritorial males remain in peripheral male areas (Lensink 1962). Other authors (Kenyon 1969, Schneider 1978) have found this segregation to occur in other Aleutian Islands populations.

Calkins (1972) did not observe discrete sexual segregation in PWS; however, breeding territoriality was observed between two males. Garshelis (1983) and Johnson (pers. comm.) observed male and female areas in an expanding population in PWS. Because of the transitional nature of an expanding population, these areas do not exhibit the classical sexual segregation observed in the Aleutians (Schneider, pers. comm.).

A. Reproductive Habitat

Calm waters within female areas near feeding and resting areas are used for breeding (Kenyon 1969).

B. Reproductive Seasonality

Breeding behavior has been observed in all seasons, with a peak occurring in September-October (Kenyon 1969, Lensink 1962, Schneider 1978).

C. Reproductive Behavior

Males maintain exclusive areas of space (territories) within female areas during the breeding peak (Kenyon 1969). Surplus males wait on the periphery of female areas for estrus females to approach (Schneider, pers. comm.).

Pairs remain together for three or more days (Kenyon 1969).

D. Age at Sexual Maturity

Males reach sexual maturity at about five to six years (Schneider 1978). Females are sexually mature at about three to four years

- (Schneider 1978, Kenyon 1969).
- E. Frequency of Breeding
The breeding interval is approximately two years (Schneider 1972, Kenyon 1969, Calkins 1972). However, females are physiologically capable of annual breeding. Annual breeding appears to be related to the food supply (Calkins and Schneider 1984). In areas of abundant food supplies, young animals are capable of providing for themselves at an earlier age, eliminating the need for the adult female to supply food and releasing her back into the breeding portion of the population (Schneider, pers. comm).
- F. Fecundity
Single births are usual; however, twinning does occur in about 2% of all pregnancies examined (Calkins and Schneider 1984). Survival of more than one pup has never been observed. The female is unable to provide sufficient food and care for more than one pup (Schneider 1978, Lensink 1962, Kenyon 1969). The gestation period averages 7.5 months, according to Schneider (1972), and 8 to 9 months according to Kenyon (1969). The fetus is implanted about one-half of this time (Schneider, pers. comm.). Pupping occurs throughout the year, peaking in April, May, and early June (Schneider 1981, Kenyon 1969).

VI. FACTORS INFLUENCING POPULATIONS

- A. Natural
High-density otter populations close to carrying capacity may experience competition for food, with a resulting higher mortality rate for juvenile and older animals (Kenyon 1969, Lensink 1962). Survival of pups is usually excellent until weaning, but mortality of recently weaned otters can be high in areas of limited food availability. This juvenile mortality appears to be a major population-regulating mechanism in populations at or near carrying capacity (Calkins and Schneider 1984). Severe weather conditions with high winds and rough seas can prevent otters from obtaining adequate food supplies. Mortality among otters can be very high, primarily from injuries in rough seas, disease, and starvation leading to enteritis (Kenyon 1969). Bald Eagles at Amchitka Island have been observed preying on young otters and may be a significant cause of mortality when pups are small (Sherrod et al. 1975, Kenyon 1969). Predation by white sharks occurs in California and may be a significant mortality factor but has not been documented in Alaska (Kenyon 1969). Predation by killer whales is possible; however, it has not been documented in Alaska and is not considered significant (ibid.). The periodic formation of heavy sea ice appears to be the limiting factor in the northeastern range expansion of sea otters in Bristol Bay (Schneider and Faro 1975).
- B. Human-related
- Entanglement in fishing nets or marine debris
 - Passive harrassment (tour boats, increased pleasure boating)

- Mortality due to contact with or ingestion of petroleum or petroleum products
 - Decrease in prey base due to oil/chemical pollution
 - Illegal shooting
- (See the Impacts of Land and Water Use volume of this series for additional information regarding impacts.)

VII. LEGAL STATUS

Sea otters are federally protected under the Marine Mammal Protection Act (MMPA) of 1972, (PL 92-522). The legal harvest of sea otters by Native residents is provided for by this act. The State of Alaska may petition the federal government for renewed managerial authority over 10 marine mammals, including the sea otter.

VIII. SPECIAL CONSIDERATIONS

Current and proposed petroleum developments and related activity in PWS will inevitably result in the contamination of the marine ecosystem. The sea otter is a highly visible and dynamic part of that ecosystem. The otter and its prey would be directly affected by contaminated waters resulting from petroleum pollution.

IX. LIMITATIONS OF INFORMATION

Because of the dynamic status of sea otter populations in Southcentral Alaska, distribution and abundance surveys need to be conducted for the east side of the Kenai Peninsula, eastern PWS near Cordova, and continued in other areas of PWS.

Evidence indicates that classical male areas, as found in the Aleutian Islands, do not presently exist in PWS. Further studies are needed to determine at what level expanding sea otter populations become sexually segregated into permanent areas.

Studies are needed to determine the effect of sea otter foraging on commercially important crab stocks. The breeding interval (i.e., annual or biennial) and potential rate of increase for expanding populations in PWS needs to be determined.

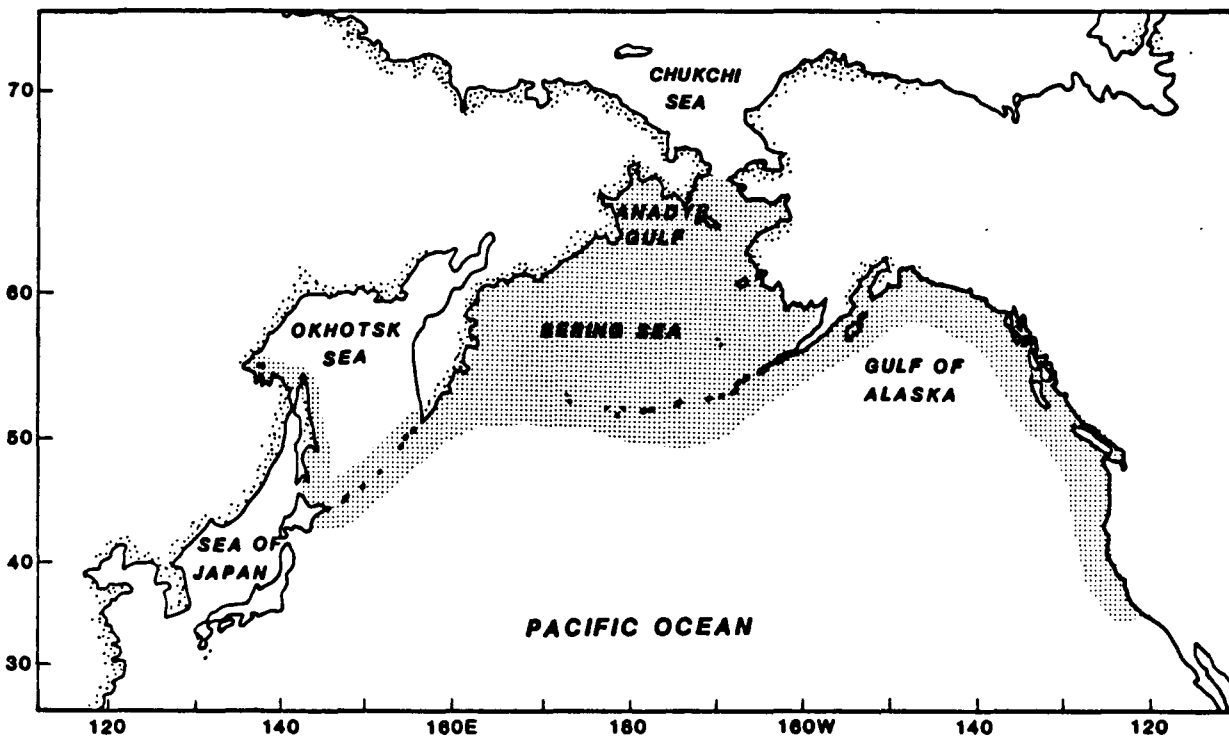
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Steller Sea Lion Life History and Habitat Requirements
Southwest and Southcentral Regions



Map 1. Range of sea lion (Gusey 1978; Kenyon and Rice 1961; Calkins, pers. comm.)

I. NAME

- A. Common Name: Sea lion, Steller sea lion, northern sea lion
- B. Scientific Name: Eumetopias jubatus
- C. Native Names: See appendix A.

II. RANGE

- A. Worldwide
The range of Steller sea lions extends from the southern California Channel Islands northward along the eastern North Pacific to Prince William Sound (PWS), the Alaska Peninsula, the Aleutian Islands, and the Bering Sea to the Bering Strait (Kenyon and Rice 1961); westward through the Kurile Islands, the Commander Islands, and Okhotsk Sea of the Soviet Union; and south in the

western North Pacific to Hokkaido and northern Honshu in Japan (Calkins and Pitcher 1982).

B. Statewide

In Alaska, sea lions range in nearshore waters and seaward to the continental shelf break from southeast Alaska north throughout the Gulf of Alaska and west through the Aleutian Islands and Bering Sea (Kenyon and Rice 1961).

C. Regional Distribution Maps

To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for the Southwest, Southcentral, and Southeast regions at 1:250,000 scale. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of sea lion distribution has been prepared and may be found in the Atlas that accompanies the Southwest and Southcentral regional guides.

D. Regional Distribution Summary

1. Southwest. Sea lion distribution is determined by the location of haulouts and rookeries and by the movements of prey species. Sea lions are abundant in the western Gulf of Alaska from the Barren Islands to the Aleutian Islands (Calkins and Pitcher 1982) and in the Bering Sea from the Aleutian Islands to Cape Seniavin on the Alaska Peninsula north to Walrus Island and Cape Newenham (Frost et al. 1982). (For more detailed narrative information, see volume 1 of the Alaska habitat Management Guide for the Southwest Region.)
2. Southcentral. Sea lions are distributed along the entire outer coast of Southcentral Alaska to the edge of the continental shelf. Sea lion distribution is associated with specific land areas (rookeries, haulouts, and stopover areas), where they concentrate in conspicuous numbers for breeding, pupping, and resting (Calkins and Pitcher 1982). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

1. Water depth. Fiscus and Baines (1966) found that sea lions forage in relatively shallow water (less than 100 fathoms) nearshore, although Kenyon and Rice (1961) have observed them 85 nautical miles offshore. These movements may be related to shallow water depths found offshore.

B. Terrestrial

Terrestrial habitat requirements for sea lions revolve around rookeries, haulouts, and stopover areas (Calkins and Pitcher 1982). Sea lions are rarely seen hauled out more than 200 m away from water (Calkins, pers. comm.).

A variety of areas are used seasonally as hauling out areas, but all types provide areas free of water at lower tidal stages.

These areas include large rocks awash at high tide (Harbor Pt.), rocky beaches flanked by sand beaches (Sitkagi Bluff), beaches with large boulders (Cape St. Elias), and, rarely, sand bars exposed to storms and high tides (Middleton Island) (ibid.). During stormy weather and/or high-sea conditions, the majority of sea lions remain in the water rather than on haulouts (Kenyon and Rice 1961).

1. Rookeries. Rookeries are terrestrial sites where adult males actively defend territories and where the majority of breeding and pupping activities take place (Calkins and Pitcher 1982). A rookery may be used as a haulout during nonbreeding periods of the year.
2. Haulouts. Haulouts are any areas where sea lions haul out on a regular basis but where few or no pups are born (ibid.). Sandegren (1970) described the haulout area on Lewis Island, PWS, as being exposed to the sea, with a very irregular rock substrate ranging from loose, round rocks a few decimeters in diameter to bedrock. Cracks, overhanging ledges, and caves are abundant.
3. Stopover areas. Stopover areas are locations where sea lions have been sighted on land but only on an irregular basis in low numbers (ibid.). No specific descriptions of stopover areas were found; however, habitat requirements are similar to other areas used by sea lions (Calkins, pers. comm.).

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

Major prey items of sea lions are off-bottom schooling species (i.e., walleye pollock, herring, cod, etc.), and it appears that sea lions feed where these species are abundant (Calkins and Pitcher 1982).

Pitcher (1981) found that preferred food species of sea lions in the Gulf of Alaska were walleye pollock (Theragra chalcogramma), squids (Gonatidae), Pacific herring (Clupea harengus pallasii), capelin (Mallotus villosus), Pacific cod (Gadus macrocephalus), salmon (Oncorhynchus spp.), octopus (Octopus spp.), sculpins (Cottidae), flatfishes (Pleuronectidae), and rockfishes (Scorpaenidae). Walleye pollock was the predominant prey, composing 58% of the total stomach volume and occurring in 67% of stomachs with food (Pitcher 1981, Calkins and Pitcher 1982).

1. Southwest Region. The principal prey of sea lions along the Alaska Peninsula were walleye pollock and salmon (Calkins and Pitcher 1982).

The principal prey of sea lions from the Kodiak area were capelin, walleye pollock, salmon, Pacific cod, octopus, skates (Raja spp.), and flatfishes (ibid.).

Examination of seasonal use of prey in the Kodiak area indicated that predation on salmon and capelin was largely limited to spring and summer. This likely reflected

seasonal, nearshore distribution associated with spawning by these species (Hart 1973, Jangaard 1974).

2. Southcentral Region. In PWS, the principal prey of sea lions were walleye pollock, herring, squids, sculpins, and rockfishes (Calkins and Pitcher 1982).

Pacific herring and squids were used extensively by sea lions in PWS but were less important elsewhere in the Gulf of Alaska (Pitcher 1981, Calkins and Pitcher 1982).

Along the Kenai Peninsula coastline of the Gulf of Alaska, the principal prey of sea lions were walleye pollock, Pacific tomcod, Pacific sandfish (Trichodon tridodon), octopus, saffron cod (Eleginus gracilus), and Pacific cod (*ibid.*).

Pitcher (1981) described additional food sources from the Gulf of Alaska as including shrimps (Decapoda), Tanner crab (Chionocoetes spp.), spider crab (Hyas sp.), skate, Pacific sandfish, and harbor seal (Phoca vitulina).

Stones up to 12 cm in diameter were found in 16 of 34 stomachs from sea lions sampled in Alaska and California (Fiscus and Baines 1966). Their purpose is not known.

B. Types of Feeding Areas Used

Sea lions typically feed nearshore or in relatively shallow water (less than 100 fathoms) on the continental shelf. They may travel considerable distances from haulout areas to feed (*ibid.*); however, large groups (100 or more) are seldom found more than 10 to 15 mi from a hauling ground or rookery (during breeding season) (*ibid.*). Small groups (2-12) and individuals occur farther from land (*ibid.*).

C. Factors Limiting Availability of Food

Some food species are present nearshore only during certain periods of the year (*ibid.*). Salmon and capelin, for example, are abundant near shore during spring and summer, and capelin are abundant near Unimak Pass during summer (Fiscus and Baines 1966). Sea lions appear to feed on most abundant prey species in the area (Calkins and Pitcher 1982). The apparent recent increase of pollock in the sea lion diet is concurrent with the increase in pollock stocks in the Gulf of Alaska (Calkins and Pitcher 1982, Pereyra and Ronholt 1976).

D. Feeding Behavior

1. Daily cycle. From May through October near Unimak Pass, sea lions left their hauling grounds in early morning in large compact groups, swam 5 to 15 mi to feeding areas, and dispersed into groups of less than 50 animals of mixed sexes and ages. In late afternoon, they reformed into larger groups and returned to haulout areas (Fiscus and Baines 1966).

2. Food size. The estimated mean fork length of walleye pollock eaten by sea lions in the Gulf of Alaska is 29.8 cm (Calkins and Pitcher 1982).

3. Prey selection. Most of the important prey species of sea lions in Alaska are off-bottom schooling species (*ibid.*). Use

of this prey type may be important in minimizing foraging effort and conserving energy (Smith and Gaskin 1974, Pitcher 1981).

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Breeding takes place on land on the rookeries (Sandegren 1970).

B. Reproductive Seasonality

1. Southwest Region. Pitcher and Calkins (1981) observed that in the Gulf of Alaska births occurred between mid May and mid July, with a peak between 5 and 26 June (Sugarloaf and Marmot islands).

Breeding on Sugarloaf and Marmot islands (Gulf of Alaska) occurs shortly after parturition, usually between late May and mid July, with a peak between 7 June and 4 July (Pitcher and Calkins 1981).

2. Southcentral Region. Sandegren (1970), observing a small breeding population on a haulout in PWS, found that most pups were born from 29 May through 1 July, with a peak from 10 to 12 June.

Breeding in PWS occurs from 10 to 14 days after females give birth (Sandegren 1970).

C. Reproductive Behavior

Sea lions are polygynous, and most breeding is done by bulls that defend territories against other bulls (ibid.). Males with semi-aquatic territories (partially above and below the high-tide line) were most involved in breeding activity. Some bulls maintain territories for over 60 days (ibid.). Cows initiate breeding with distinct behavior directed towards territorial bulls (ibid.).

Females leave their young for the first time 5 to 12 days after birth. Males do not attend or protect pups. Female departures after the initial one are regular, with periods on land ranging from 9 to 42 hours and periods at sea ranging from 9 to 40 hours (ibid.).

The mother-offspring bond is usually one year, but adult females have been observed nursing both a pup and a subadult (Calkins and Pitcher 1982, Sandegren 1970).

D. Age at Sexual Maturity

Females mature between three and eight years; the average age at first ovulation is 4.6 ± 0.8 years, and at first pregnancy 4.9 ± 1.2 years (Pitcher and Calkins 1981). One observation of a female breeding at two years of age was reported. Males mature between 3 and 8 years, although the ages of most males (88%) defending territories were between 9 and 13 years. It appears males become sexually mature before they are able to defend territories (Calkins and Pitcher 1982).

E. Frequency of Breeding

Mature females breed annually (Pitcher and Calkins 1981).

F. Fecundity

Females have a single pup (ibid.).

The pregnancy rate for females 8 to 20 years old in the Gulf of Alaska was 87%. The projected annual birth rate (after prenatal mortality) for mature females in the Gulf of Alaska was 63% (ibid.) and 68% in California (Gentry 1970).

Sea lions delay blastocyst implantation until late September and October (Calkins and Pitcher 1982).

VI. FACTORS INFLUENCING POPULATIONS

A. Natural

Rice (1968) concluded that in offshore coastal waters of the eastern northern Pacific, killer whales feed primarily on marine mammals, including Steller sea lions. Killer whales are frequently seen in the Aleutian Islands near large Steller sea lion rookeries (ibid.), and predation likely occurs.

Pup mortality of 12.5 to 14% was observed by Sandegren (1970) in PWS. Injuries sustained from crushing and/or fighting adults were main causes of death.

For female sea lions in the Gulf of Alaska, combined mortality from birth to three years is estimated to be 53%; and for age classes 3 through 11, the average annual mortality is 11%. Approximately 30% of the females born survive to reproductive maturity. In males, mortality from birth to three years is 73%, and the average annual mortality for ages three through five years was 13%. Data are not available for accurately estimating mortality in males beyond age five. However, based mainly on the age distribution of harem bulls, the mortality rate apparently increases substantially after age eight. By age 10, it is probably about 25% and by age 14 about 50% (Calkins 1984).

In the Gulf of Alaska, aborted fetuses are an important source of prenatal mortality (Calkins and Pitcher 1982). Based on declining pregnancy rates, a monthly prenatal mortality rate of 4.7% was determined for sea lions in the Gulf of Alaska (Pitcher and Calkins 1981).

San Miguel Sea Lion Virus (SMSV) and leptospirosis are diseases associated with abortions in related pinniped species (Smith et al. 1973, Smith et al. 1974, Smith et al. 1977). Seriological evidence of both leptospirosis and SMSV has been detected in the Gulf of Alaska sea lion population (Fay, pers. comm.). Further studies need to be conducted to determine the extent of these diseases and their effect on the sea lion population.

B. Human-related

A summary of possible impacts from human-related activities includes the following:

- Mortality due to contact or ingestion of petroleum or petroleum products
- Passive and/or active harrassment
- Decrease in prey base due to oil/chemical pollution or competition with humans

- Destruction of haulout and rookery sites
- Entanglement in fishing gear or marine debris
- Harvest, change in level (legal subsistence harvest, plus an increase in illegal harvest associated with increased development activities)

(See the Impacts of Land and Water Use volume of this series for additional information regarding impacts.)

VII. LEGAL STATUS

- A. Sea lions are federally protected under the Marine Mammal Protection Act (MMPA) of 1972 (P.L.92-522). The legal subsistence harvest of sea lions by Native Alaskan residents is provided for by this act. The State of Alaska may petition the federal government for renewed managerial authority over 10 marine mammals in the state, including sea lions.

VIII. LIMITATIONS OF INFORMATION

Specific movement and migration information is needed for Steller sea lion populations in the Gulf of Alaska.

Information on sea lion population dynamics is needed. Information on factors limiting sea lion populations in the Gulf of Alaska is needed. Such information includes data on predation and disease.

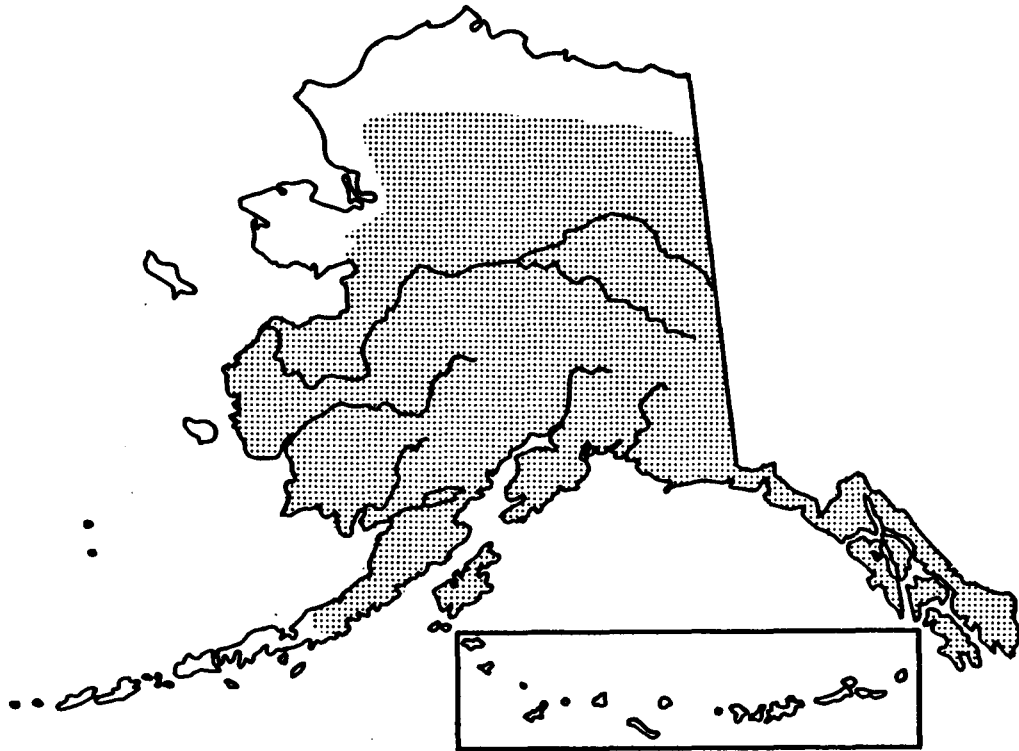
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Terrestrial Mammals

Beaver Life History and Habitat Requirements
Southwest Region



Map 1. Range of beaver (ADF&G 1978)

I. NAME

- A. Common Name: Beaver
- B. Scientific Name: Castor canadensis
- C. Native Names: See appendix A.

II. RANGE

- A. Statewide
Beavers are distributed throughout mainland Alaska from the Brooks Range south to Port Moller on the Alaska Peninsula and into Southeast Alaska, from sea level to elevations of 4,000 ft. Beaver transplants have produced well-established populations on Kodiak, Raspberry, and Afognak islands, as well as on some of the other smaller islands of the Kodiak archipelago and the Yukon-Kuskokwim delta.

B. Regional Distribution Maps

To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for the Southwest Region at 1:250,000 scale. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of selected fish and wildlife species has been prepared and may be found in the Atlas that accompanies each regional guide.

C. Regional Distribution Summary

1. Southwest Region. Beavers are distributed throughout Bristol Bay (ADNR/USFWS 1983) and the Alaska Peninsula south to Port Moller (ADF&G 1976a). Beaver transplants to Kodiak Island in 1925 and to Raspberry Island in 1929 have resulted in well-established populations on these islands as well as on Afognak, Shuyak, Long, Spruce, Whale, and Woody islands (ADF&G 1976a, 1976b).

III. SELECTION CRITERIA FOR FURBEARER GROUP REPRESENTATIVE

The following criteria qualify beavers as representative of the fur-bearer group: they are closely associated with aquatic and riparian habitats, which are often subject to development, and thus they are valuable indicators of aquatic habitat quality; they have economic value; and current levels of scientific interest in them are high.

IV. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

1. Annual:

- a. Water levels. Beavers require seasonably stable water levels (Slough and Sadleir 1977). Gipson (1983) believes that a 3 ft or greater rise in seasonal water levels is detrimental to beaver habitat, whereas Murray (1961) suggested 2 ft or greater. Extreme seasonal fluctuations in water levels can wash away dams and displace lodges or flood them out.
- b. Stream sinuosity. A high degree of sinuosity (streambed distance/straight line distance) is preferred because it increases the availability of food within short distances from the water. Sinuosity values greater than 2 are acceptable, but 3 or greater is optimum (Boyce 1974).
- c. Stream gradient. Less than 6% is optimal but 6 to 12% is acceptable (Retzer et al. 1956).
- d. Flow rates. Flow rates less than 4 mph are preferred; 4 to 7 mph is limiting; and 7 mph or greater is unsuitable for beavers (Gipson 1983).
- e. The width factor. Narrow streams and/or lakes with dammable outlets are preferred but not absolutely necessary (Slough and Sadleir 1977).

- f. Substrate of stream channel and lake. Beavers prefer a channel bed lined with rocks, gravel, and some large boulders, dikes, or moraines to prevent rapid down-cutting of the stream. Lake beds of rock and kettle lakes are preferable (Retzer et al. 1956).
 - g. Remoteness. Beavers prefer a degree of remoteness from human activities (Slough and Sadleir 1977). However, they will occupy suitable aquatic sites in residential areas of Alaska and can be found adjacent to major roads with high traffic levels.
 - h. Width of valley. Beavers need a valley width greater than the stream channel width, preferably 150 ft or more (Allen 1982, Yeager and Rutherford 1957). Dams constructed across relatively wider valleys can better withstand heavy flood conditions than those in V-shaped valleys, and they are less subject to erosion and soil movement during high-water periods.
- 2. Summer:
 - a. Water levels. The minimum depth needed at lodge entrances is 3 ft, to provide protection from predators (ibid.).
 - b. Food supply. The presence and availability of aquatic vegetation is necessary to beavers for food (Slough and Sadleir 1977).
- 3. Winter:
 - a. Water levels. Generally speaking, there must be a minimum depth below the ice of approximately 20-30 inches, to avoid freezeout (Hakala 1952).
- B. Terrestrial
 - 1. Spring, summer, fall:
 - a. Distances to forage. Vegetated land up to 30 m from the water's edge with a supply of food and building materials is preferred (Hall 1960, Jenkins 1980), with areas up to 200 m from water acceptable (Bradt 1938); limited use is made of areas farther than 200 m but less than 0.8 km from water (Murray 1961).
 - b. Shoreline preference. Shorelines with low banks are most suitable for lodge construction and serve to increase the structure's durability (Slough and Sadleir 1977, Murray 1961).
 - c. Canopy closure. Forty to sixty percent tree and/or shrub canopy closure is considered optimum (Allen 1982). Extremely dense stands inhibit beavers' mobility and increase the likelihood of their cut trees hanging up in adjacent trees. In areas of the Southwest Region where trees are not prevalent, such as around tundra ponds or streams or above timberline, canopy closure is not an important consideration.

- d. Bank suitability. Stable banks along river channels or lakes are necessary for construction of bank burrows (Murray 1961).
- e. Shoreline convolution. Heavily convoluted shorelines provide protection from wind, waves, and ice-scouring, increase the amount of food available, reduce the risk of predation, and lessen the amount of energy expended in gathering food (Boyce 1974).
2. Winter. No pertinent published information on winter terrestrial habitat requirements has been found.

V. NUTRITIONAL REQUIREMENTS

A. Preferred Foods

1. Summer forage includes a) leaves and growing tips of willow (Salix spp.), poplar (Populus balsamifera), alder (Alnus spp.), cottonwood (Populus spp.), and birch (Betula spp.); and b) aquatic and moist soil plants (Hakala 1952) such as water lily (Nupha variegatum) (Aleksiuk 1970), pondweed (Potamogeton spp.) (Hakala 1952), duckweed (Lemna spp.) (Allen 1982, Banfield 1974), and herbaceous vegetation (Banfield 1974).
2. Winter food includes a) the bark of willow, poplar, and alder (Aleksiuk 1970, Boyce 1974), b) spruce (Picea spp.) needles (Hakala 1952), and c) water lilies (Taylor, pers. comm.).

B. Feeding Locations

1. During fall, spring, and summer, beavers feed in shallow water (ibid.).
2. Although beavers may eat inside their lodges in winter, they must travel to their food caches outside their lodges to get their food (Hakala 1952, Banfield 1974).

C. Factors Limiting Availability of Food

Any or all of the following factors can limit the availability of food for beavers:

- The extent of the total biomass of plant types preferred for their winter's food cache (Boyce 1974)
- Steep topography preventing development of a food transport system on land (Williams 1965, Slough and Sadleir 1977)
- Competition for preferred plants by moose, hares, and porcupine (Boyce 1974)
- Absence of fires, which maintain high-quality early seral stage vegetation (Viereck 1973)

VI. REPRODUCTIVE BIOLOGY

A. Reproductive Habitat

Beavers breed in the water (Kowalski 1976, Rue 1964) and under the ice or in bank dens or lodges (Wilsson 1971).

B. Reproductive Seasonality

In Interior Alaska, beavers breed in February (Hakala 1952), with parturition occurring in early June.

- C. Reproductive Behavior
Beavers are monogamous (Boyce 1974).
- D. Age at Sexual Maturity
In exploited populations, beavers reach sexual maturity at three years and in unexploited populations at four years (ibid.).
- E. Pregnancy Rate/Litter Size
Females have one litter per year, averaging 2.8 to 3.1 kits in Interior Alaska (Boyce 1974, Hakala 1952). The litter size varies according to the female's age (Gunson 1970), nutritional plane (Pearson 1960), human disturbance (Leege and Williams 1967), and trapper harvest (Boyce 1974). In Boyce's study (1974) in Interior Alaska, approximately 50% of the breeding females were pregnant or had given birth.
- F. Gestation Period
Gestation is from 95 to 105 days (Banfield 1974, Hakala 1952).

VII. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

- A. Home Range
Beavers range within an 0.8-km radius of their lodges in the Northwest Territories (Aleksiuk 1968). The mean distance between colonies in Interior Alaska was 1.5 km (Boyce 1974).
- B. Feeding Range
The average feeding range size in Pennsylvania, excluding water, was 0.56 ha (Brenner 1962); the maximum foraging distance in Alaska was 800 m on upstream forages and 300 m on downstream (Boyce 1974); 90% of food cutting was done within 30 m of the water (Hall 1960), with distances up to .5 mi reported (Murray 1961).
- C. Dispersal
The young leave the parent colonies at one to three years of age (Boyce 1974). Subadult emigration distances have been reported from 8 to 16 stream km (Slough and Sadleir 1977). Hibbard (1958) estimated up to 238 stream km for transplanted beaver populations. Emigration distances depend upon local beaver densities and the availability of suitable habitat, and are generally less than 20 km.

VIII. FACTORS INFLUENCING POPULATIONS

- A. Natural
Any or all of the following factors can influence beaver population levels:
 - Hydrologic conditions: stream gradient, depth, shape (see Physical Habitat Requirements, this report)
 - Availability of vegetation: food sources, construction materials (Boyce 1974)
 - Climatic conditions: temperature, snow cover, wind (ibid.)
 - Predation: wolf, lynx, brown bear, wolverine (Hakala 1952, Boyce 1974)
 - Dispersal of young (Gunson 1970, Boyce 1974)
 - Disease: tularemia (Stenlund 1953), endemic hemorrhagic disease (ADF&G 1980)

B. Human-related

A summary of possible impacts from human-related activities includes the following:

- Pollution of water and/or food
- Reduction in food supply
- Alteration of aquatic habitat (including substrate)
- Overharvest
- Oiling of fur

IX. SPECIAL CONSIDERATIONS

A. Primeness

The time of beaver fur primeness is from January to April, with March the month of optimum primeness (Stains 1979).

B. Overtrapping

Because beavers can be easily overtrapped, concentrated trapping effort near settlements and along road systems can result in depletion of local populations. In Southwest Alaska, beavers are five times more abundant in remote areas than in areas near villages (ADF&G 1980).

C. Nonconsumptive Use

Beavers are one of the few furbearer species providing nonconsumptive uses. Much viewing and photography occur around larger settlements and in bush areas as well (ibid.).

D. Conflicts

Water impoundments due to beaver dams can block roads. Beaver dams may also block the passage of spawning anadromous fish and plug up road culverts (Sellers, pers. comm.; Smith, pers. comm.). More important than blocking the passage of spawning salmon, they change stream flow characteristics, causing increased siltation of salmon spawning beds and raised water temperatures.

X. LEGAL STATUS

The managerial authority over beavers is the Alaska Department of Fish and Game.

XI. LIMITATIONS OF INFORMATION

Compared with other parts of North America, there has been very little research work on this species in Alaska. Only four beaver studies have been completed since 1952, and these focused only on Interior Alaska.

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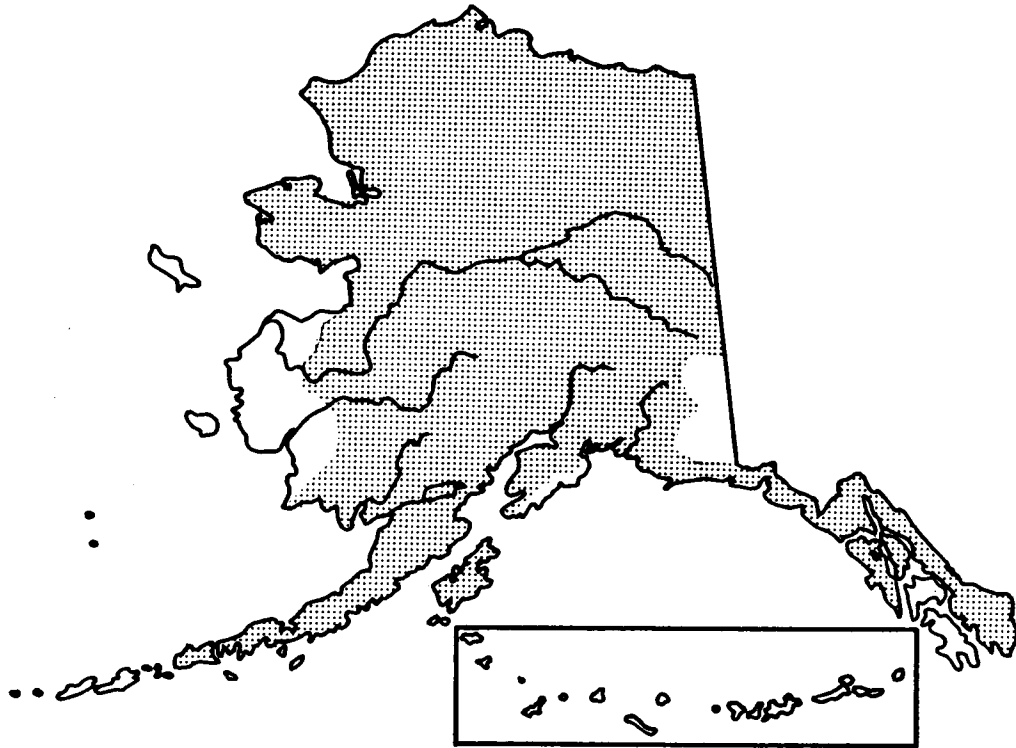
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Brown Bear Life History and Habitat Requirements
Southwest, Southcentral, and Arctic Regions



Map 1. Range of brown bear (ADF&G 1973)

I. NAME

- A. Common Names: Brown bear, Kodiak bear, grizzly bear
- B. Scientific Name: Ursus arctos
 - 1. Ursus a. horribilis and U. a. middendorffi are subspecies of Ursus arctos; the latter subspecies occurs only on the Alaska islands of Kodiak, Afognak, and Shuyak (Rausch 1963). All other brown/grizzly bears in North America belong to the first subspecies. In this report, all bears of the species Ursus arctos will be referred to as brown bears.
- C. Native Names: See appendix A.

II. RANGE

A. Statewide

Brown bears are distributed throughout Alaska, except on the islands south of Frederick Sound in Southeast Alaska, the islands west of Unimak along the Aleutian chain, the islands of the Bering Sea, and several island groups south of the Alaska Peninsula and the Yukon-Kuskokwim delta (Eide 1978).

B. Regional Distribution Maps

To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for the Southwest, Arctic, Western, Interior, and Southeast regions at 1:250,000 scale. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of brown bear distribution has been prepared and may be found in the Atlas that accompanies each regional guide.

D. Regional Distribution Summary

1. Southwest. Brown bears are distributed throughout the Southwest Region, except on the islands west of Unimak along the Aleutian chain, the islands of the Bering Sea, and several island groups south of the Alaska Peninsula, such as the Semidis, Shumagins, and Sanaks (ADF&G 1976a). (For more detailed narrative information, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)
2. Southcentral. Brown bears are distributed throughout the Southcentral Region, including Montague, Hitchinbrook, and Hawkins islands in Prince William Sound (ADF&G 1976b). Major ice fields, such as occur on the south side of the Kenai Peninsula and the Wrangell Mountains, are not considered brown bear habitat.
3. Arctic. Brown bears are found throughout the Arctic Region, with the exception of St. Lawrence and Diomed islands (ADF&G 1976c, 1976d). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Arctic Region.)
4. Western and Interior. Brown bears are found throughout the Western and Interior regions, with the exception of the Yukon-Kuskokwim delta (ADF&G 1977). (For more detailed narrative information, see the Alaska Habitat Management Guide for the Western and Interior regions.)

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

Water is believed to be a necessary factor in brown bear habitat (USDA Forest Service 1975), but in Alaska water is not considered a limiting factor.

B. Terrestrial Cover Requirements

1. Denning requirements. Most dens are excavated, although natural cavities are used to some extent when available

(Reynolds et al. 1976, Craighead and Mitchell 1982). Den entrances are bare or may be enclosed by brush. Tunnels and chambers are commonly dug under the root systems of trees or shrubs or located beneath boulders or rock strata that provide roof support. Although den reuse may occasionally occur, most bears construct new dens each fall because most excavated dens collapse after the spring thaw (Reynolds 1980, Craighead and Mitchell 1982).

Terrain slope where denning has been observed ranges between 0° and 75° , but a majority of dens have been reported from slopes of 30° to 45° (Craighead and Mitchell 1982). The orientation of den openings varies within populations and from one population to another and even from year to year (Reynolds 1980, Craighead and Mitchell 1982). Seasonal wind directions commonly play a role in den site selection. The slopes most favored are leeward of prevailing winter winds in a particular area. Dens not situated to the apparent leeward of prevailing winds are often found oriented to local topography so that wind eddy provides heavy snow deposition (Reynolds 1980, Craighead and Mitchell 1982) so that the entrance is sealed.

- a. Southwest Region. Lentfer et al. (1972) reported that elevations for 80 brown bear dens on Kodiak Island ranged from 30 to 1,006 m above sea level, with the greatest proportion at about 550 m. Smith and Van Daele (1982) reported the mean elevation for 34 dens in their Terror Lake study area on Kodiak Island to be 620 m (range: 152-1,006 m), with the greatest proportion (53%) at or above 610 m. Most of the observations of Lentfer et al. (1972) were from the southwestern part of the island, which is less precipitous and where most peaks are at lower elevations than in the Terror Lake study area. Spencer and Hensel (1980) reported that brown bears den at intermediate and upper elevations (240 to 750 m) in the Terror Lake study area and that alpine areas above 635 m provide marginal denning habitat. Smith and Van Daele (1982), however, found that alpine habitats were preferred for denning. Some dens they observed were, however, located in lower-elevation habitat similar to that described by both Lentfer et al. (1972) and Spencer and Hensel (1980). The apparent discrepancy between Smith and Van Daele's study and previous denning studies may be the result of the techniques used to determine denning characteristics. Smith and Van Daele located dens by radio-tracking, a more precise technique than aerial reconnaissance surveys used by Lentfer et al. (1972) and Spencer and Hensel (1980). The radio-tracking study showed that alpine areas were used more than previously thought on Kodiak.

Lentfer et al. (1972) reported that the greatest proportion of observed bear dens on the Alaska Peninsula was at about 396 m above sea level. They found that areas where dens commonly occurred were characterized by alder-willow thickets and, in winter, deep snow cover. The alder and willow provide concealment and, in some cases, bedding material.

On Kodiak Island, north-facing slopes were most often chosen for denning, and on the Alaska Peninsula, east-facing slopes. Slopes used for denning ranged from 0 to over 60°, with a majority of observed dens on slopes of 30 to 45° (ibid.).

Dens observed by Lentfer et al. (1972) had been excavated, although these authors stated that denning in natural rock caves had been reported on Kodiak Island and the Alaska Peninsula. Preliminary indications from only two years of observations in the Terror Lake study show that some bears return to the same general location to den (Smith, pers. comm.).

- b. Southcentral Region. Reported den locations of radio-collared bears in studies conducted along the Susitna River ranged in elevation from 635 m to 1,570 m and averaged 1,255 m. Typically, dens were dug in gravelly soil on moderately sloping (average 32°) southerly exposures. None of the radio-collared bears in these studies reused the same den; however, many of these bears tended to den in the same general area in successive years (Miller and McAllister 1982, Miller 1983).

- c. Arctic Region. Studies conducted along the North Slope of the Brooks Range (Reynolds 1980) found radio-collared bears denning in a variety of terrain, ranging from creek banks at low (270 m) elevations to mountain slopes near the crest of the Brooks Range (1,280 m). Of 45 newly excavated dens located, most were found within the individual bear's home range; however, in 1978 four radio-collared bears denned from 16.1 km to 43.8 km from their spring, summer, and fall ranges. Additionally, three bears were not located and had presumably moved from their previously identified home ranges.

Den site elevations in the western Brooks Range ranged from 270 to 1,280 m and averaged 661 m (Reynolds 1980), compared with a mean elevation of 975 m for dens found in the eastern Brooks Range (Reynolds et al. 1976). This difference probably reflects the fact that the eastern Brooks Range study area was located in higher, more mountainous terrain.

Den sites were located on all exposures. There were differences between 1977, when 72% of the dens (13 of 18) had a generally southern exposure, and 1978, when

only 38% faced generally south. Wind direction and snow deposition were probably important factors in den site selection. All of the observed den sites were located in areas of snowdrift deposition. The depth of permafrost, which influenced the exposures selected by bears in the eastern Brooks Range (Reynolds et al. 1976), was not important in the North Slope study area, possibly because of the difference in soil types. Another factor that may be responsible for north- or south-facing den exposures is that the topographic character of the foothill area is dominated by a series of east-west-running ridges that have northern and southern exposures, making the occurrence of these exposures highest (Reynolds 1980). There does not appear to be a pattern of selection of similar types of terrain, exposure, or elevation by individuals from year to year (ibid.).

IV. NUTRITIONAL REQUIREMENTS

Brown bears are omnivorous but depend heavily on plant foods. They are opportunistic feeders and will eat the flesh of fish, wildlife, or domestic animals when available. Carrion is readily eaten when found (Eide 1978).

A. Food Species Used

There have not been sufficient food habit studies conducted in Alaska to provide a definitive regional breakdown of brown bear food habits. There are no doubt local and regional differences and similarities in food species used, depending upon their availability and quality. Seasonal differences do occur and are broken down as such; however, there may be considerable overlap from one season to the next.

1. Spring (mid April to early July). On Kodiak Island, the ADF&G (1976e) reported that brown bears "feed primarily on newly emerged plant species such as cow parsnip and red poque, sedges, horsetails, lupine, false hellebore, and grasses; they will also scavenge carrion from winter kills of elk, deer and marine mammals" Moose and/or caribou calves are important food species for bears on the Alaska Peninsula (Glenn 1975), in the Nelchina basin (Ballard et al. 1980, 1981; Spraker et al. 1981), and on the North Slope (Reynolds 1980). In some areas, such as in the Nelchina basin, brown bears are, or are suspected to be, the most important ungulate mortality factor (Spraker et al. 1981; Ballard et al. 1980, 1981). Brown bears are known to prey upon adult moose and caribou (Spraker et al. 1981, Ballard et al. 1981).

On the North Slope, Hechtel (1979) found the roots of viscid oxytropes (Oxytropis borealis), American hedysarum (Hedysarum alpinum), and the overwintered berries of alpine bearberry (Arctostaphylos rubra) to be the most important foods used.

2. Summer (early July to mid August). On Kodiak Island, Atwell et al. (1980) observed bears in alpine habitat eating angelica (Angelica lucida), Alaska long-awned sedge (Carex macrochaeta) and other sedges (Carex spp.), common horsetail (Equisetum arvense), cow parsnip (Heracleum lanatum), nootka lupine (Lupinus nootkatensis), and willow (Salix spp.). Alaska long-awned sedge was used predominantly. Red elderberry (Sambucus racemosa) and salmonberry (Rubus spectabilis) are heavily used on Kodiak. Bears feed heavily on red elderberries well before they ripen. On Afognak Island, bears feed upon huckleberry (Vaccinium ovalifolium) (Smith, pers. comm.). Sellers (pers. comm.) indicated that Carex lyngbyaei is an important food source in estuarine areas on the Alaska Peninsula and that bears use the berries of devil's club (Oplopanax horridum) and the seeds of cow parsnip.
- On the North Slope, Hechtel (1979) found that during the growing season brown bears seemed to concentrate on grasses and sedges, the leaves, stems, and flowers of boykinia (Boykinia richardsonii), and the fruiting and vegetative stems of common horsetails.
- Salmon (Oncorhynchus spp.) are used extensively when and where they are available (Glenn 1975, Berns et al. 1980). Brown bears are known to prey upon adult moose and caribou (Spraker et al. 1981, Ballard et al. 1981).

3. Fall (mid August to mid December). Crowberries (Empetrum nigrum), blueberries (Vaccinium uliginosum), soapberries (Shepherdia canadensis), and lowbush cranberries (Vaccinium vitis-idaea) are readily eaten when available (Murie 1944, Erickson 1965, Somerville 1965, Crook 1971, Pearson 1975, Reynolds 1976). Bears will shift back to hedysarum roots if berries are not abundant (Murie 1944, Dean 1957, Crook 1971, Valkenburg 1976, Reynolds 1976). Lupine roots and broomrape (Boschniakia rossica) roots are also preferred as foods by Kodiak bears. Also, gut piles of deer (Odocoileus hemionus sitkensis) and elk (Cervus elaphus roosevelti) are becoming increasingly important fall foods on both Kodiak and Afognak islands as harvest of these animals increases (Smith, pers. comm.). Salmon remain important along coastal areas (Somerville 1965, Erickson 1965, Berns and Hensel 1972). Bears have been observed salmon fishing during December on the Alaska Peninsula (Glenn 1975). Brown bears are known to prey upon adult moose and caribou (Spraker et al. 1981, Ballard et al. 1981). Hechtel (1979) found that hedysarum roots, alpine bearberry, and ground squirrels (Spermophilus parryii) were important foods for bears in the North Slope.

B. Types of Feeding Areas Used

1. Spring. On the Alaska Peninsula, there was high use of the coastal plain along the beaches, where bears searched for dead marine mammals. Grassland areas, especially grass

flats, sedge meadows, and saltwater wetlands are also used extensively by foraging bears (Glenn and Miller 1980). In the Nelchina basin, Miller and McAllister (1982) found that spruce forests and shrublands were used most during the spring.

On the North Slope, bears were observed foraging along river courses and snow-free ridges and mountain slopes during early spring. During late spring, bears foraged along small creeks and moist drainages. In addition, during the breeding season (late May through mid July), bears were observed in all types of terrain, from tussock tundra to talus slopes (Reynolds 1980, Hechtel 1979).

2. Summer. Anadromous fish streams in coastal areas (Somerville 1965, Erickson 1965, Berns and Hensel 1972, Glenn 1975, Glenn and Miller 1980, Smith and Van Daele 1982) and lowland areas (Berns et al. 1980) are frequently used by bears. Atwell et al. (1980) reported that bears in the Kodiak NWR made extensive use of alpine habitat during summer. Sedge-forb meadows are used extensively on the Kodiak NWR (Atwell et al. 1980).

In the Nelchina basin, brown bears tended to move to shrublands at higher elevations (Miller and McAllister 1982). On the North Slope, Hechtel found wet sedge meadows, late snowbank communities, and tussock tundra used most frequently.

3. Fall. On the Alaska Peninsula and Kodiak Island, salmon feeding areas continued to be used extensively. Use of foothills increased by early October. By mid October, the coastal plain is increasingly used, although less than during spring (Berns and Hensel 1972, Glenn 1975, Glenn and Miller 1980).

In the Nelchina basin, Miller and McAllister (1982) found that brown bears move to shrublands at higher elevations in late summer and early fall.

On the North Slope, bears tended to use the floodplains of large creeks and rivers as well as dry ridge areas or mountain slopes with ground squirrel populations (Reynolds 1980, Hechtel 1979).

C. Factors Limiting Availability of Food

During spring, snow cover and depth can limit food availability.

The size of the salmon escapement can be influenced by both natural factors and human management.

Weather conditions that cause poor berry production can reduce the availability of this important food source during late summer and fall.

Human disturbance in areas where food sources are concentrated can limit food availability.

D. Activity Patterns

At McNeil River falls, Egbert and Stokes (1976) observed brown bears fishing and found the level of activity lowest during early

and mid morning hours and peaking by mid afternoon. Activity dropped sharply by late evening and remained low until mid morning. During their evaluation of brown bear aerial survey results in the Chignik-Black lakes drainages, Erickson and Siniff (1963) found that peak activity on salmon streams occurred in the early morning and evening.

Twenty-four-hour observations of a brown bear in the Canning River drainage indicate that feeding and resting take place throughout the day but that rest occurred more during the morning (Linderman 1974).

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Breeding does not appear to be habitat-specific. Den characteristics are described in section III.B.1., above.

B. Reproductive Seasonality

Breeding takes place from May to early July, with the peak of activity in early June (Eide 1978).

C. Reproductive Behavior

Brown bears are polygamous. Pairing normally occurs only for a short time and is dependent on a male's ability to defend an estrous female against other contenders (Craighead and Mitchell 1982).

D. Age at Sexual Maturity

The age when successful conception occurs varies from coastal to interior areas. On the Alaska Peninsula and Kodiak Island, it was observed to be between 3.5 and 6.5 years (Hensel et al. 1969, Glenn et al. 1976). In the Nelchina basin, most brown bears appear to conceive first at 4.5 years. Some females first conceive at 3.5 years and others at 5.5 years (Ballard et al. 1982). In the eastern Brooks Range, maturity was attained between 6.5 and 12.5 years. The maximum observed age of reproductive females was found to be at least 23.5 years on the Alaska Peninsula (Aumiller, pers. comm.), 25.5 years in the western Brooks Range (Reynolds 1980), 22.5 years in the eastern Brooks Range (Reynolds 1976), and 21.5 years in the northern Yukon (Pearson 1976).

E. Fecundity

Average brown bear litter sizes vary from one geographic area to another. The reported litter size of cubs of the year ranges from 1.73 to 2.46 (table 1). Modafferi (1984) suspected that the average size of cub-of-the-year litters on the Alaska Peninsula was greater than what the field data indicated. The data in table 1 should be interpreted cautiously because some of the values represent averages for many years or are derived from a single sample or from a variety of sampling methods (Modafferi 1984). After six years of data collection, Reynolds and Hechtel (1984) found the average cub-of-the-year litter to range from 1.67 to 2.50. Obviously, separate analyses of these two extremes would produce different results.

Table 1. Litter Size for Brown Bears as Determined in Various Studies in North America

Location	Age of Young (Yr)	No. Litters	Mean Litter Size (Age Class)			Source
			0.5	1.5	2.0	
Yellowstone Natl. Park	0.5	213	2.12	1.88 ^a	1.47 ^a	Craighead et al. 1976
	1.5					
	2.5					
Glacier Natl. Park, B.C.	0.5	81	1.94	1.84	1.82	Mundy 1963
	1.5	45				
	2.6	17				
Kodiak Island, AK	0.5	39	2.36	2.17		Troyer and Hensel
	1.5	58				
Kodiak Island, AK	0.5	98	2.23	2.00		Hensel et al. 1969
	1.5	103				
Kodiak Island, AK	0.5	52	2.31	2.29		Klein 1958
	1.5	41				
Alaska Peninsula	0.5	77	2.17	2.08		
	1.5	50				
Southeast Alaska	0.5	25	2.16	1.89		
	1.5	35				
McNeil River, AK	0.5	108	2.46	2.48		
	1.5	95				
Northeast Alaska	0.5	13	1.77	2.00	2.00	Reynolds 1976
	1.5	7				
	2.6	1				
Northwest Alaska	0.5	44	2.00	2.29	2.00	Reynolds and Hechtel 1984
	1.5	28				
	2.5	34				
Southcentral AK	0.5	19	2.05	1.64	1.70	Miller 1984
	1.5	22				
	2.5	14				
Southwest Yukon	0.5	11	1.73	1.45		Pearson 1975
	1.5	7				
McNeil River, AK	0.5	41	2.1*	1.8		Glenn et al. 1976 and Modafferi 1984
	1.5	69				
McNeil River, AK ^a	0.5	26	2.15	1.75	1.75	
	1.5	20				
	2.5	4				
Black Lake, AK ^a	0.5	19	2.11	2.10	2.22	
	1.5	51				
	2.5	18				
Black Lake, AK ^d	0.5	66	2.36			
Alaska Peninsula ^e	0.5	180	2.06			

Source: Adapted from Modafferi 1984.

a Captured and marked family members and/or ground surveys.

b Mean litter size for 5.6-year-old litters.

c Mean litter size for 3.5-year-old litters.

d Aerial surveys along salmon streams.

e Aerial surveys along salmon streams, excluding the Black Lake area.

* Because of a misprint in Glenn et al. (1976), a mean litter size of 2.5 is frequently used for comparison in other reports; however, the value should be 2.1 (Glenn, pers. comm.).

Estimates for survival of cubs of the year to yearling (1.5 years old) vary greatly, depending on the particular study. Most data are wrongly based on comparisons of cub-of-the-year litter sizes with yearling litter sizes. Frequently, mortality occurs to an entire litter of cubs of the year (Reynolds 1980, Miller 1984). A sow who has lost an entire litter will either produce new cubs the following year or the year following that. In either instance, she would not be included in the calculation of survivorship for the age class of young her original litter represented.

Reported mortality of cubs of the year to yearlings, based on data collection for known family groups, ranges from 31% to as high as 47%. Comparing two study areas on the Alaska Peninsula, Modafferi found mortality to range from 31 to 43%. Reynolds and Hechtel (1984) reported a mortality rate of 44% in the western Brooks Range. Miller (1984) reported that cub-to-yearling mortalities ranged between 41 and 47% in his study area in Southcentral Alaska.

F. Frequency of Breeding

Female brown bears generally breed and produce cubs every three to four years (Reynolds 1980). Frequently, the interval is greater than four years (Glenn et al. 1976, Reynolds 1980).

G. Gestation Period

Including delayed implantation, gestation lasts about six months (Craighead et al. 1969).

VI. FACTORS INFLUENCING POPULATIONS

A. Natural

Availability of food, such as a salmon-spawning stream or other sources of rich protein, can influence local bear densities. Adult males may cause significant mortality of cubs (Reynolds 1980, Miller 1983). Climatic conditions that cause the failure of spring, summer, or fall vegetation food sources or an extremely low salmon escapement also appear to influence survival of bears through winter denning and reproductive status the following year (Miller 1983; Sellers, pers. comm.).

B. Human-related

A summary of possible impacts from human-related activities includes the following:

- Pollution of water and/or food supply
- Reduction in food supply
- Disturbance leading to abandonment of habitat, especially areas of concentrated food sources
- Disturbance during denning/abandonment of young
- Illegal hunting/killed in defense of life and property

(See the Impacts of Land and Water Use volume of this series for additional information regarding impacts.)

VII. LEGAL STATUS

Brown bears are managed by the Alaska Department of Fish and Game.

VIII. LIMITATIONS OF INFORMATION

There is a considerable amount of information about the basic biology of brown bears; however, more information is needed in order to identify the potential impacts of development on brown bear populations. Among these needs is the necessity to develop sampling techniques capable of providing accurate abundance information. In conjunction with this is the need to identify discrete bear populations.

Population dynamics are not clearly understood. Although substantial cub mortality occurs in some areas, the cause and effects are not adequately documented. Brown bear energetics, especially in relationship to its food base, are only partially understood. There is a need to identify limiting factors affecting brown bear populations in relation to their habitats. Adequate techniques have yet to be developed for Alaska to identify and classify the relative quality of brown bear habitat.

IX. SPECIAL CONSIDERATIONS

A. Homing

Homing of transplanted nuisance brown bears has been documented by several authors (Craighead and Craighead 1976, Cole 1972, Pearson 1972, Craighead 1976, Miller and Ballard 1982). Studies conducted in Alaska by Miller and Ballard (1982) found strong homing ability by brown bears in the Nelchina basin. Sixty percent of adult nonnuisance bears transplanted an average of 198 km from their capture sites successfully returned to or near their original home ranges. They concluded that transplanting of nuisance bears would have a high probability of failure.

B. Nuisance Bears

Brown bears often become "nuisance" bears in the vicinity of villages, remote cabins/lodges, and work camps. These animals can cause extensive damage and may be dangerous to humans. Factors such as improper garbage disposal and poor siting of camps often intensify the problem, but proper procedures can often prevent the occurrence of the problem.

C. Importance of Species

Because the brown bears that occur in the Southwest Region are among the largest in the world they attract particular interest from hunters and viewers. The bears are considered a very important species economically to the guiding industry, air taxi services, and other related industries.

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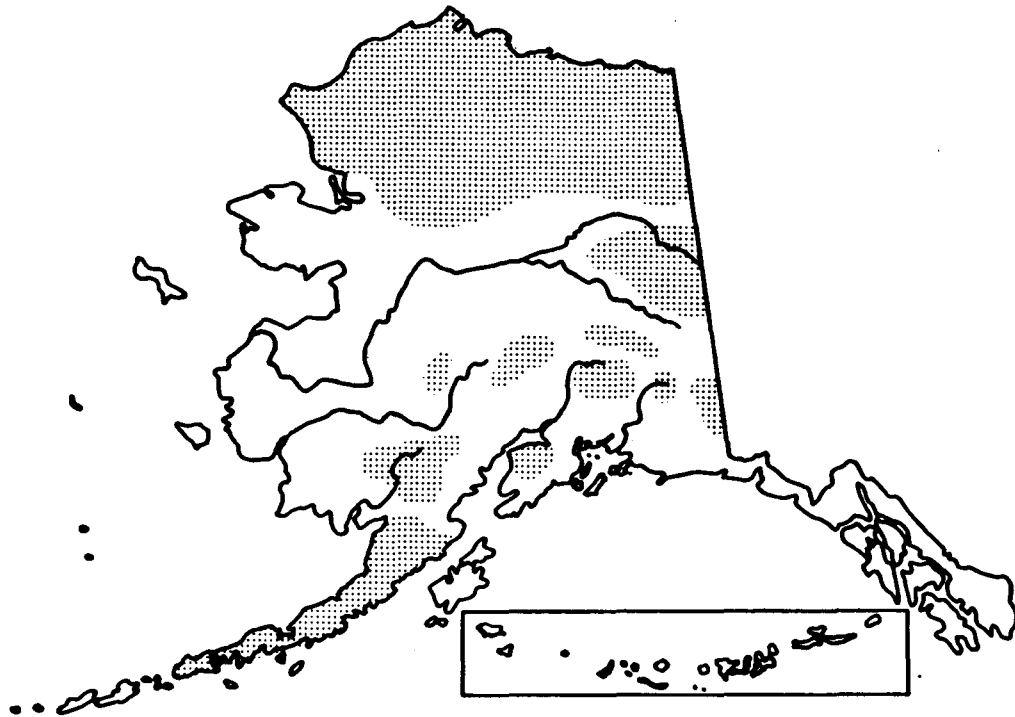
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Caribou Life History and Habitat Requirements
Southwest, Southcentral, Arctic, Western, and Interior Regions



Map 1. Range of caribou (ADF&G 1973)

I. NAME

- A. Common Names: Caribou
- B. Scientific Name: Rangifer tarandus granti (Banfield 1961)
- C. Native Names: See appendix A.

II. RANGE

- A. Statewide
Caribou are distributed throughout Alaska except on the southeastern panhandle and along the Gulf of Alaska coast from southeast Alaska to the Alaska Peninsula and most offshore islands (Hemming 1971).
- B. Regional Distribution Maps
To supplement the distribution information presented in the text, a series of blue-lined reference maps were prepared for the

Southcentral, Southwest, Arctic, Western, and Interior regions at 1:250,000 scale. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of caribou distribution has been prepared and may be found in the Atlas that accompanies the Southwest, Southcentral, Arctic, Interior, and Western regional guides.

C. Regional Distribution Summary

1. Southwest. Four distinct herds exist in Southwest Alaska: the Northern Alaska Peninsula, Southern Alaska Peninsula, Mulchatna, and Adak herds (Sellers, pers. comm.). The Northern Alaska Peninsula Herd ranges from the Naknek River south to Port Moller. The Southern Alaska Peninsula Herd ranges generally from Herendeen Bay south to and including Unimak Island (Hemming 1971). The Mulchatna Herd ranges in an area generally west of the Alaska range, Iliamna Lake, and the Kvichak River to the lower Nushagak River, throughout the upper Nushagak River country, including the King Salmon River drainage, and as far north as the Taylor Mountains and Stony River (Taylor, pers. comm.). (See volume 1 of the Alaska Habitat Management Guide for the Southwest Region for specific distribution and abundance information.)
2. Southcentral. There are three caribou herds that occupy the Southcentral Region year-round. The largest, the Nelchina Herd, occupies the upper Copper, Nelchina, and Susitna river basins. The Mentasta Herd ranges along the northwest slopes of the Wrangell Mountains and the headwaters of the Copper River. A small herd of caribou occupies portions of the Kenai Peninsula, having been transplanted there in the mid 1960's. This herd is composed of two relatively distinct subherds. The Kenai Lowlands Herd utilizes the muskeg areas in the vicinity of the Kenai airport and the Moose River flats. The Kenai Mountains Herd occurs in the northern Kenai Mountains south of Hope, between the headwaters of Resurrection Creek and the Chickaloon River. The Mt. McKinley Herd seasonally occurs in the Southcentral Region during calving and winter (ADF&G 1976). (See volume 2 of the Alaska Habitat Management Guide for the Southcentral Region for specific distribution and abundance information.)
3. Arctic. Four caribou herds occupy the Arctic Region. The Western Arctic Herd, the largest caribou herd in Alaska, occupies a range of 362,000 km² (140,000 mi²) in northwest Alaska, including the arctic coastal plain and the Colville, Noatak, Kobuk, and Koyukuk river drainages. The Central Arctic Herd ranges between the Canning and Colville rivers, including the arctic coastal plain and the northern foothills of the central Brooks Range. The Porcupine Herd ranks as Alaska's second largest subpopulation of caribou. The majority of animals from this herd spend only the spring and

summer months in Alaska, although portions of this herd do remain in the state throughout the year, and it is not uncommon for much of the herd to winter in Alaska. The Teshekpuk Herd is a subpopulation that occupies the area surrounding Teshekpuk Lake year-round. (See volume 2 of the Alaska Habitat Management Guide for the Arctic Region for more detailed specific distribution and abundance information.)

4. Western and Interior. In recent years, the population identities of the many small caribou herds have been better defined within the Western and Interior regions. Caribou are generally scarce in Western Alaska but can be found in the Andreafsky Mountains and the Kilbuck Mountains. The Sunshine Mountain, Beaver, Big River, Rainy Pass, and Tonzona herds are distributed in drainages such as the Holitna, Stony, Swift, Big, and Tatlawiksuk rivers, the many forks of the upper Kuskokwim drainage, as well as the Innoko, Dishna, Iditarod, and Nowitna rivers, which drain into the Yukon River. The Denali Herd ranges in the vicinity of Denali National Park. The Delta, Macomb, and Yanert herds occupy the northern slopes of the Alaska Range. The Fortymile Herd is distributed throughout the Tanana Hills between the Yukon and Tanana rivers and may also range into adjacent Canada. The Chisana Herd is found mainly in the Nutzotin Mountains and may also cross the Canadian border occasionally. The Porcupine and Western Arctic herds seasonally occupy portions of the Western and Interior regions. Spring and fall migration through and winter use of the south slopes of the Brooks Range in the Arctic Village area bring the Porcupine Herd into the region. The same holds true for the Western Arctic Herd as well. (See the Alaska Habitat Management Guide for the Western and Interior regions for more detailed distribution and abundance information.)

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

During summer, except for the arctic herds, which avoid marshy areas during mosquito season, caribou tend to concentrate their feeding activity in moist boggy areas where sedges (Carex spp.) predominate. Riparian areas are also important during mid summer. During winter, aquatic vegetation, such as sedges and horsetails (Equisetum spp.), are heavily used along lake margins and streams. Muskrat pushups, which consist of a variety of aquatic vegetation, are frequented by wintering caribou (Skoog 1968), but the total food content is negligible (Valkenburg, pers. comm.).

B. Terrestrial Cover Requirements

The use of ridge tops, frozen lakes and bogs, and other open areas for resting may be learned behavior related to predator avoidance that may have resulted from wolf-caribou interactions. The caribou's apparent reluctance to enter riparian willow (Salix

spp.) stands and other heavy brush cover and its state of alertness when passing through such areas suggest that caribou associate such cover with attacks by wolves and bears (Miller 1982). On the arctic coastal plain, where riparian stands are sparse, caribou do not show any apparent avoidance behavior of heavy brush cover types (Cameron, pers. comm.).

During the spring calving period, caribou tend to occupy open terrain with gentle slopes affording a wide field of view, which again may be related to predator avoidance (ADF&G 1976). Calving areas are also characterized by their close proximity to insect relief habitat and are usually well drained (Cameron, pers. comm.).

During summer, caribou make extensive use of windswept ridges, lingering snow drifts, glaciers, gravel bars, and elevated terrain to avoid insects (Skoog 1968, Kelsall 1968, Hemming 1971, Bergerud 1978, Miller 1982). Arctic coastal areas (sand dunes, beaches, river deltas, and points of land) are used as insect relief habitat.

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used (from Skoog 1968, unless otherwise noted)

1. Winter (mid October to mid April). Fruticose lichens (Cladonia spp. and Cetraria spp.), sedges, and grasses are heavily utilized. Willow (Pegau et al. 1973), horsetails, and dwarf shrubs (e.g., Vaccinium uliginosum) may be used to some extent. Although these plants may be used less by caribou during winter, they may be nutritionally significant.
2. Spring (mid April to mid June). The catkins of willow (especially Salix alaxensis, S. planifolia ssp. pulchra, and S. glauca) are among the first of the new-growth vegetation to be eaten. Various grasses and sedges (notably Carex bigelowii, C. membranacea, C. podocarpa, and Eriophorum vaginatum) are also used extensively. Fruticose lichens continue to be eaten during spring if available and especially if the growing season is late. Resin birch (Betula glandulosa), dwarf birch (B. nana), and especially willow leaves become the favored foods as the season progresses, as do horsetails, which are especially attractive. (See Kuropat 1984 for information on early summer food habits of the Western Arctic Herd.)
3. Summer (mid June to mid August). Caribou continue to eat the leaves of willow, resin birch, and dwarf birch extensively during June and July. Many species of sedge and grass (especially those of the genera Alopecurus, Arctagrostis, Dupontia, Festuca, Poa, Puccinellia, Calamagrostis, and Hierochloa), forbs, and horsetails are used extensively, depending upon their growth stage, annual differences in weather, and the particular area being used by the caribou. Legumes are especially important; species of particular note include Astragalus umbellatus, Lupinus arcticus, Hedysarum

alpinum, and Oxytropis nigrescens. The herbs Gentiana glauca, Swertia perennis, and Sedum roseum are highly palatable.

Other species known to be grazed include Antennaria monocephala, Artemisia arctica, Epilobium latifolia, Pedicularis spp., Petasites frigidus, Polygonum bistorta, Rumex arcticus, and Saxifraga spp.

4. Fall (mid August to mid October). During the fall, the quality and palatability of the summer forage decrease, and the caribou's diet gradually shifts toward the more restrictive winter forage. Willow leaves are heavily utilized as long as they are available. Grasses and sedges are eaten throughout the fall period. Lichens are increasingly used as the fall progresses. Carex aquatilis, which lines the shores of lakes, ponds, and sloughs, appears to be an especially favored food item.

B. Types of Feeding Areas Used

1. Winter. Depending on the availability and location of habitat, spruce forests (primarily spruce/lichen associations), bogs, and lake shores are used extensively (ADF&G 1976). On the Alaska Peninsula's poorly drained coastal plains, areas where sedges are abundant are used (Hemming 1971). Ridge tops and high plateaus are also important.
2. Spring. Open terrain with gentle slopes and shallow U-shaped valleys are used (Bos 1974). Vegetation falls primarily into grass meadow (Hemming 1971), shrub birch, dwarf heath types, and sedge meadows (Skoog 1968).
3. Summer. Areas of use consist primarily of treeless uplands where heath tundra, alpine tundra, and sedge wetland associations dominate. In response to insect harassment, caribou frequently use wind-swept ridges and coastal areas (ibid.).
4. Fall. Caribou remain on or near summer ranges until the quantity and quality of forage significantly decreases and/or weather forces them to begin migration toward the wintering grounds (Hemming 1971). Because fall migration generally occurs during this period and feeding often occurs on the move, it is difficult to relate specific feeding locations to this period (Skoog 1968).

C. Factors Limiting Availability of Food

1. Winter. Snow depth of 50 cm (20 inches) is generally considered the upper limit for use of areas by caribou. Ice crust of 4 to 6.5 cm (1.5-2.5 inches) on top of the snow is considered the upper limit caribou can paw through to obtain food (Pruitt 1959, Skoog 1968, Pegau 1972, LaPerriere and Lent 1977).
2. Spring. Calving area selections by caribou have been, in part, attributed to early snowmelt and the consequent availability of new vegetation (Lent 1980). Should a late snowmelt or a late snowstorm occur, use of otherwise

preferred early green-up vegetation may be restricted (Skoog 1968). (Also see Kuropat 1984 for information on the North Slope area.)

3. Summer. Insect harassment can restrict caribou feeding by causing them to move about constantly or occupy areas such as snowdrifts, where food is unavailable (Skoog 1968, Miller 1982). In the arctic, coastal beaches, river deltas, and sand dunes are heavily used for relief from insect harassment.
4. Fall. Increasing frost and/or snow in the high country decrease the quantity and quality of forage, in part triggering fall migration (Skoog 1968).

D. Feeding Behavior

1. Winter and fall. Feeding generally occurs during the mid portions of the day and night. Caribou prefer the finer parts of plants, such as the upper portions of lichens, leaves and stem tips of sedges and grasses, and the stem tips and buds of willows. Their cursory grazing habits help reduce the possibility of overgrazing the range (ibid.).
2. Spring. Feeding behavior is similar to winter, with an increased use of leaves of willow and dwarf birch (ibid.).
3. Summer. Caribou select plant species according to the occurrence of greening leaf and flower buds (ibid.). Feeding occurs throughout the day, but because of insect harassment most feeding takes place during the cooler twilight hours (Miller 1982). (See Kuropat 1984 and White et al. 1975 for more detailed information on the North Slope area.)

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

1. Breeding areas. The rut usually takes place during fall migration and is sometimes accompanied by a pause or slowdown of movement. Breeding usually takes place in areas above timberline (Skoog 1968), although this has not been the case during most recent years for the Nelchina Herd (Pitcher 1984).
2. Parturition areas. (See III.B., PHYSICAL HABITAT REQUIREMENTS, and IV.A.2., NUTRITIONAL REQUIREMENTS, Spring.)

B. Reproductive Seasonality

1. Breeding. Breeding seasonality varies in different parts of the caribou range. In central and southern Alaska, caribou breeding occurs primarily during the first two weeks of October (ibid.).
2. Parturition. In southwestern and southcentral Alaska, parturition generally occurs from early May through the first week of June (ibid.).
For the arctic herds, calving begins in late May, peaks around the end of the first week of June, and is completed by mid June.

C. Reproductive Behavior

1. Breeding. Bulls do not gather harems but rather join existing bands of cows and young. Bulls tend to become dominant within bands, depending on the size of the group (ibid.). As the rut peaks, dominant bulls reduce their foraging markedly, concentrating instead on tending estrous females. Copulation is brief and generally occurs at dawn or dusk (Espmark 1964). By the end of the rut, breeding adult bulls have depleted their fat reserves and enter winter in lean condition (Skoog 1968).

2. Parturition. According to Lent (1966), Kelsall (1968), and Skoog (1968), cows do not actively seek isolation to give birth. Bergerud et al. (1984), however, indicated that caribou in Spatsizi Provincial Park, British Columbia, dispersed to high south slopes in mountains for calving as an antipredator tactic. The mother-young bond is initiated within the first minutes of the calf's life and is necessary for the survival of offspring during the first six months of life (Miller 1982).

After calves are mobile, "nursery bands" of cows and calves are formed (Pruitt 1959). In central Alaska, most cows do not regroup or join mobile bands until their calves are older than two days (Skoog 1968).

D. Age at Sexual Maturity

Most cows conceive at 2.5 years of age. A few will conceive at 1.5 years, however, if in good condition. Bulls are sexually mature at 1.3 to 2.3 years of age (Skoog 1968, Dauphine 1976).

E. Fecundity

Adult females (3+ years) have pregnancy rates of about 80% and produce one offspring per year (Skoog 1968, Miller 1982).

F. Gestation Period

Gestation takes 225 to 235 days (Skoog 1968, Bergerud 1978).

G. Lactation Period

Little is known about the actual weaning process (Miller 1982). Kelsall (1968) concluded that weaning must occur during July because biting insects would greatly disrupt nursing after July. Skoog (1968) suggested that weaning takes place between September and December and mostly occurs prior to November. However, empirical evidence exists indicating most cows still lactate in August and September, with some individuals lasting into October (Valkenburg, pers. comm.).

VI. FACTORS INFLUENCING POPULATIONS

A. Natural

Emigration, which may be density-related, can cause large fluctuations in herd sizes; however, this phenomenon has never been documented. Weather, particularly precipitation, cold, and wind, are a deadly combination for newborn calves, often resulting in hypothermia (Banfield 1954). Wolf and bear predation, in some areas, can be an important factor in population regulation (Skoog

1968, Bergerud 1978, Miller 1982, Gasaway et al. 1983). Fire has changed successional stages in large expanses of winter range but in fact may not have caused major fluctuations in population numbers. It is possible, however, that fire has caused shifts in habitat use by caribou herds (Skoog 1968).

B. Human-related

A summary of possible impacts from human-related activities includes the following:

- Competition with introduced (wild or domestic) animals
- Increased susceptibility to predation
- Alteration of habitat
- Harrassment, active and passive
- Barriers to movement, physical and psychological
- Overharvest, expecially when associated with high predation rates
- Direct mortality associated with collisions with trains and cars
- Vegetation damage/destruction due to air pollution

(See the Impacts of Land and Water Use volume of this series for additional information regarding impacts.)

VII. SPECIAL CONSIDERATIONS

Food supply, population density, weather, snow conditions, insects, man, and a variety of other factors can alter caribou movement patterns seasonally and perhaps for several years (ibid.).

VIII. LEGAL STATUS

The Alaska Department of Fish and Game has regulatory authority over caribou.

IX. LIMITATION OF INFORMATION

Because caribou are nomadic and therefore occupy various kinds of habitat at different times, it is difficult to accurately describe caribou habitat requirements. Causes of large population fluctuations in many instances are also still unclear.

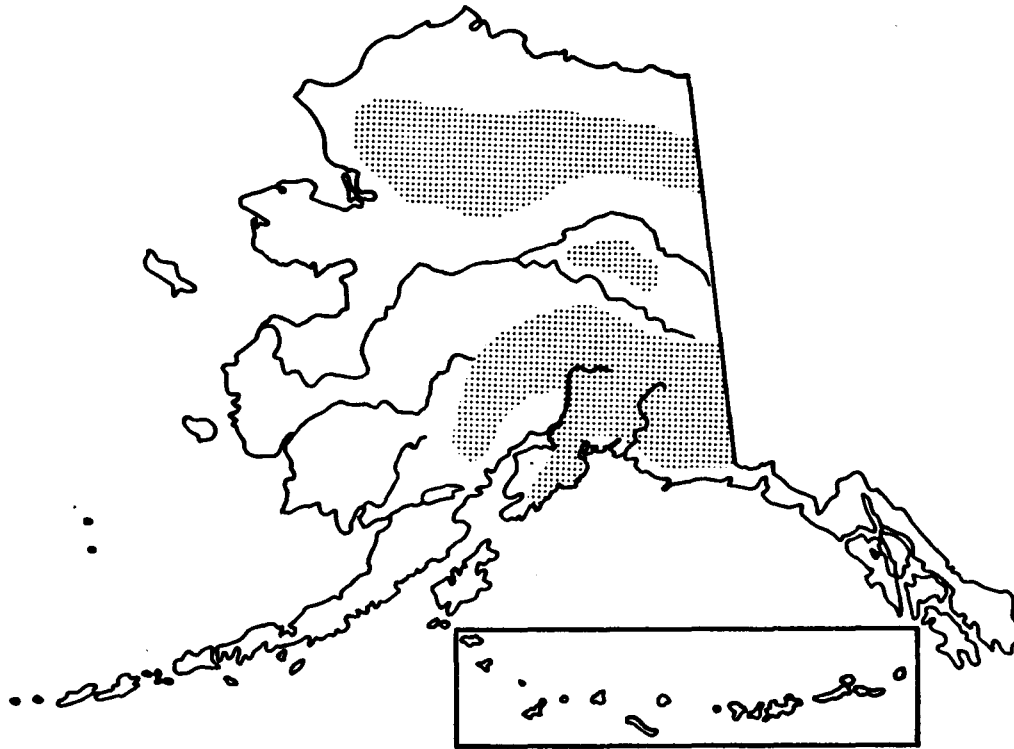
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Dall Sheep Life History and Habitat Requirements
Southcentral, Arctic, Western, and Interior Regions



Map 1. Range of Dall sheep (Nichols 1978a, Heimer and Smith 1975)

I. NAME

- A. Common Names: Dall sheep, Dall's sheep, Alaskan white sheep, thinhorn sheep (Nichols 1978a, Bee and Hall 1956)
- B. Scientific Name: Ovis dalli dalli
- C. Native Names: See appendix A.

II. RANGE

- A. Worldwide
Dall sheep occur in North America throughout the major mountain ranges of Alaska, east through the northern and southwestern mountain ranges of the Yukon Territory, through the mountains of the Northwest Territories, and in the mountains of the northwest corner of British Columbia (Nichols 1974).

- B. Statewide
Dall sheep are distributed throughout suitable alpine habitat, generally above 2,500 ft, in major mountain ranges of Alaska, including the Brooks Range, the Alaska Range from the Canadian border to Lake Clark, the Wrangell Mountains, Chugach Mountains, Talkeetna Mountains, and portions of the Kenai Peninsula Mountains. Small discontinuous populations exist in the Tanana/Yukon uplands (Nichols 1978a, Heimer and Smith 1975).
- C. Regional Distribution Maps
To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for the Southcentral, Arctic, Western, and Interior regions at 1:250,000 scale. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of sheep distribution has been prepared and may be found in the Atlas that accompanies the Southcentral, Arctic, and Western and Interior regional guides.
- D. Regional Distribution Summary
1. Southcentral. Dall sheep are found in the Kenai Peninsula, Chugach, Wrangell, and Talkeetna mountains. Population densities and compositions vary through the range. (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)
 2. Arctic. Dall sheep are distributed throughout the Brooks Range. In some areas, Brooks Range sheep are found at lower elevations than sheep found in other Alaskan mountain ranges. During aerial surveys in 1983, researchers observed sheep at elevations as low as 700 ft (Singer et al. 1983). Also, sheep have been observed at low elevations along the Noatak River (James, pers. comm.). Population densities and compositions vary by area; however, densities are generally higher on the North Slope and in the eastern portion of the Brooks Range. (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Arctic Region.)
 3. Western and Interior. In the Interior Region, Dall sheep are distributed throughout suitable habitat in the Alaska Range and in the Tanana/Yukon uplands. Habitat in the Alaska Range consists of almost continuous alpine areas on the northern slope, from the Canadian border to the area west of the south fork of the Kuskokwim River. Sheep habitat on the south slope of the Alaska Range is discontinuous, with severe winter weather conditions limiting sheep distribution to a large extent. Distribution of sheep in the Tanana/Yukon uplands is disjunct, with areas of alpine habitat separated from adjacent range by wide, timbered valleys. This area of fairly low, rolling hills contains only sparse areas of escape habitat, which may further limit sheep distribution.

Sheep distribution in the Western Region occurs in the southwest portion of the Alaska Range, as far as Lake Clark. Sheep distribution is continuous in areas of alpine habitat and occurs on both slopes of the range, with possible interchange between areas. (For more detailed narrative information, see the Alaska Habitat Management Guide for the Western and Interior regions.)

III. PHYSICAL HABITAT REQUIREMENTS

A. Terrestrial

Sheep are capable of using all suitable habitat in the mountain ranges they occupy. On a seasonal basis, there is generally little difference in the physical habitat parameters that sheep prefer. Typically, precipitous terrain with rocky slopes, ridges, and cliffs is used; this habitat preference is most likely related to predator avoidance (Geist 1971, Murie 1944).

1. Winter. In winter, sheep utilize windward southern exposures where available, which provide areas of shallow snow and maximum solar radiation for warmth (Murie 1944, Geist 1971). In some locations, however, sheep utilize other exposures where the wind exposes forage on ridges (Nichols, pers. comm.; Murie 1944). They will sometimes move from exposed slopes to protected cliff areas prior to storms (Heimer, pers. comm.) and occasionally gather together in cliff crevices or caves for warmth and to avoid strong winds (Geist 1971, Hoefs and Cowan 1979).
2. Spring/lambing. The spring range of Dall sheep is in general similar to their winter range, except that they move to lower elevations and more southerly exposures when possible (Heimer, pers. comm.). Near Cooper Landing and at Indian, south of Anchorage, for example, sheep are known to use the low- elevation, south-facing slopes in the spring (Nichols, pers. comm.). South-facing cliffs and slopes are apparently very important in spring, affording maximum solar radiation for warmth and faster snowmelt (Geist 1971, Nichols 1978b). Preferred lambing areas are on the most precipitous, inaccessible cliffs available (Pitzman 1970, Hoefs and Cowan 1979).
3. Summer. Dall sheep habitat requirements during summer are essentially the same as at other periods, although they may tend to utilize shady areas and ridge tops more frequently to obtain relief from insect harassment (Murie 1944).

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

Heimer (1983), in his study of different quality sheep populations in the Alaska Range, determined that selection of forage species by sheep is seasonal and location-specific, indicating that caution should be used when extrapolating sheep food species from area to area. He concluded that sheep select different forage plants on different ranges, partly on the basis of their avail-

ability. Therefore, groups of plants, rather than individual plant species, offer a more tenable means of categorizing the forage used by sheep. Heimer (1983) classified these plant groups as follows: grass and sedge/leaves and stems; woody stems and associated green leaves; leaves of willow (Salix spp.) and mountain-avens (Dryas spp.); forb basal parts (mainly Oxytropis spp. in the Alaska Range); and lichens and mosses.

1. Winter:

- a. Alaska Range. In the Alaska Range, Dall sheep prefer the leaves and seed heads of grasses available above the snow (Calamagrostis spp., Festuca spp., Agropyron spp., Poa spp.), sedges (Carex hepburnii), and lowbush cranberry stems (Vaccinium vitis-idaea) (Murie 1944, Heimer 1983).

Murie (1944) found that the winter diet of sheep in McKinley Park averaged 81.5% grasses and sedges.

- b. Kenai Mountains. Nichols (1974) found that relatively few plant species comprise most of the winter sheep diet on the Kenai Peninsula. Grasses (primarily Festuca altaica and F. rubra) and sedges (Carex spp.) were most commonly used, with occasional use of crowberry (Empetrum nigrum), willow (Salix spp.) and forbs (Erigeron spp., Dryas spp., false hellebore [Veratrum viride]).

- c. Yukon Territory. Hoefs and Cowan (1979) found that sage (Artemisia spp.) was an important winter food, along with grasses and sedges.

2. Spring/lambing. As mentioned, sheep generally move to lower elevations in early spring (April) to take advantage of vegetation exposed by the snowmelt. Overwintered snow-cured grasses and sedges and cranberry leaves and berries are important forage items at this time (Heimer 1983). As vegetation begins to grow again, grasses (Festuca spp.) and sedges are initially sought, and mountain-avens, willow, and Vaccinium spp. are utilized as soon as they leaf-out (Whitten 1975).

3. Summer:

- a. Alaska Range. Whitten (1975) observed that sheep during summer feed primarily on the most palatable and nutritious plant parts, the leaves, buds, flowers, and herbaceous stems.

Winters (1980) found that relatively few plant species formed the major portion of the summer diet. The most commonly used food species during summer in the Alaska Range included Dryas octopetala; several grasses, notably Festuca altaica and Hierochloe alpina; sedge (Carex microchaeta); willows (Salix polaris pseudopolaris and S. reticulata); and forbs, Epilobium latifolium, Oxyria digyna, and Geum rossii).

- b. Kenai Mountains. Nichols (1974) found on the Kenai Peninsula that sedges were occasionally more abundant and made up a larger portion of the summer diet than other commonly utilized grasses (Hierochloe alpina and Festuca spp.) and willows.
- B. Types of Feeding Areas Used
- Sheep use areas where forage quality and quantity is the most available during that time period. Areas of use change throughout the year in order to meet these requirements.
1. Winter. In early winter, sheep use lower-elevation slopes (Murie 1944). These slopes provide forage of good quality and quantity, even though they are snow-covered (Whitten 1975).
As winter progresses and snow becomes deeper and/or more crusted by the wind, sheep move to exposed wind-blown, snow-free ridges (Murie 1944, Geist 1971, Whitten 1975, Nichols 1978a).
Hoefs and Cowan (1979), observing Dall sheep in the Yukon Territory, found that 49% of all winter feeding occurred in areas of no snow, 21% in areas with snow less than 5 cm (1.9 inches), and 17% in areas with snow up to 10 cm (3.9 inches). About 9% of all feeding occurred in areas with snow up to 15 cm (5.9 inches), 2.4% in snow depths up to 20 cm (7.9 inches), and less than 1% in areas where snow depths were between 20 and 30 cm (7.9 to 11.8 inches).
2. Spring. Sheep move to lower-elevation, snow-free southern slopes and even into shrub tundra areas at the base of mountains to utilize early plant growth (Whitten 1975, Murie 1944). The winter-cured vegetation may have nutritional values comparable to late-summer vegetation (Whitten 1975; Heimer, pers. comm.).
3. Summer. Virtually all sheep range is available at this time; however, a general trend is for the sheep to move gradually up-slope, following the new plant growth, which is highly nutritious, mainly using southern slopes but also other aspects. In late summer, feeding is extended to northern slopes, where green plant growth occurs later (Whitten 1975).
- C. Factors Limiting Availability of Food
1. Winter. Heimer (pers. comm.), during his observations of Dall sheep in the Alaska Range, found that sheep avoided areas where snow was over 18 inches deep and foraged on wind-swept higher ridges for more readily available, less nutritious food species.
Nichols (1974), in his study on the Kenai Peninsula, determined that snow hardness appeared to be more important than snow depth; however, both factors combine to limit digging activity by sheep. Most digging for forage occurred in areas where snow was less than 1 ft deep. Wind-blown snow develops a crust that is difficult for sheep to paw through (Geist and Petocz 1977, Nichols and Erickson 1969).

B. Types of Feeding Areas Used

Sheep use areas where forage quality and quantity is the most available during that time period. Areas of use change throughout the year in order to meet these requirements.

1. Winter. In early winter, sheep use lower-elevation slopes (Murie 1944). These slopes provide forage of good quality and quantity, even though they are snow-covered (Whitten 1975).

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Thaw-freeze conditions during winter can develop an ice layer sometimes several inches thick, which sheep cannot paw through (Geist 1971). Unusually warm winters with heavy wet snow and/or rain can cause these icing conditions (Nichols 1978a), as happened in late winter 1969-1970 in the Kenai Mountains (Nichols, pers. comm.) and in December 1981 in the Alaska Range (Heimer, pers. comm.).

2. Spring. Whitten (1975) speculated that sheep utilize areas of early green-plant growth to maximize their nutrient uptake.

D. Feeding Behavior

Sheep are selective in their foraging pattern, concentrating on what is most palatable, nutritious, and available to them in the area (Geist 1971, Whitten 1975). (See IV.A., above.)

1. Winter. Pawing or cratering in snow by sheep allows access to forage plants underneath. Sheep will feed in one crater, enlarge it, gaining access to all forage plants, then move to another site and create another crater (Geist 1971, Nichols and Heimer 1972). Smaller or less dominant animals are sometimes forced to move from feeding craters by older or larger sheep (Nichols and Heimer 1972).

Feeding craters on the Kenai were dug in snow up to 10 inches deep (ibid.). Murie (1944) reported that sheep had pawed through snow up to 14 inches deep.

Sheep show a pattern of limited energy expenditure during winter, with less feeding activity in the morning and more in the warmer afternoon periods (Geist 1971, Hoefs and Cowan 1979).

2. Spring/summer. Whitten (1975) found that during spring and summer sheep selected high-quality, new-growth vegetation and chose the most nutritious species within mixed stands.

E. Mineral Licks

Heimer (1973), in his study of Dall sheep mineral lick use in the Alaska Range, recommended that mineral licks be considered critical habitat areas for Dall sheep populations in interior Alaska. This recommendation resulted from a study showing that all segments of the study population utilized the licks with a high degree of fidelity, that there was preferential use by lactating ewes, and that sheep travel significant distances (12+ mi), sometimes out of their way, to visit licks (Heimer 1973). Mineral licks provide physiologically important ions for sheep, including calcium, magnesium, sodium, and potassium (ibid.).

The extent and dependency of lick use has not been documented for all Dall sheep populations in Alaska. It is not known, therefore, whether the above findings are true for all sheep populations. Until further studies are conducted to document additional lick sites and the degree of utilization by different populations, the importance of all mineral lick areas should be recognized by managers.

1. Interior: Alaska Range-Dry Creek. Seasonal use of this lick occurs from mid May through early July, with the peak of use varying but usually occurring from the first to the third week of June (ibid.). Ewe fidelity, or annual return to the lick, was 100%; ram fidelity was 80% (ibid.). Rams begin use in mid May-early June, followed by juveniles and then ewes and lambs in late June-early July (ibid.). Rams and ewes without lambs spent an average of four days at the lick. Ewes with lambs spent an average of six and one-half to seven days (ibid.).
2. Southcentral: Watana Hills-Jay Creek. Seasonal use of this lick occurs from early May through at least mid August, with peak use occurring from mid May through June (Tankersley 1984). Rams begin lick use in early May, followed by ewe-yearling groups in late May and ewes and lambs in mid June (ibid.). At least 31% (a minimum of 46 of 149 sheep) of the observed 1983 area sheep population visited this lick (ibid.).
Another mineral lick located near the east fork of Watana Creek was also utilized seasonally by Watana Hills sheep. A minimum of 47 different sheep utilized the east fork lick, which is at least 31% of the observed population (ibid.). The exact number of different sheep visiting both licks is undetermined. However, it appears that most of the population is using one or both of these licks.
3. Arctic: Brooks Range-Hulahula River. Seasonal lick use occurs from April through October and perhaps all year, with peak use occurring in June (Spindler 1983). Rams utilized the lick primarily before 26 June, with ewes, lambs, and yearlings increasing after that (ibid.).
Spindler (ibid.) observed a major change in the lick use pattern during 1980. Prior to 26 June, rams composed a substantial portion of the total sheep observed at the lick; after that date rams were seen less frequently. Spindler thought that increased daily temperatures and insect activity caused rams and other sheep to use higher elevations (greater than 1,400 m), away from the lick.

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Breeding occurs on the winter range in high cliff terrain or on broken, steep slopes. Occasional breeding takes place away from normal breeding areas, usually following a ram/ewe chase (Geist 1971).

Lambing occurs on portions of the winter range, in areas of steep, broken, precipitous terrain (Nichols 1978b). Areas where protection from wind and other weather factors is available are favored (Pitzman 1970).

- B. **Breeding Seasonality**
The peak of breeding activity extends approximately from mid November through mid December (Nichols 1978b). The lambing period extends from late May through mid June (ibid.). The estimated peak date of lambing on the Kenai Peninsula was 24 May (ibid.).
- C. **Breeding Behavior**
Breeding is polygamous and is conducted mostly by ewes with dominant rams (Geist 1971, Nichols 1978b). Dominance among rams is determined in September and October by a complicated display ritual and occasional combat (Geist 1971). The physical effort expended by dominant rams during breeding depletes their energy reserves, leaving them in poor physical condition. A severe winter will probably result in high mortality among these individuals (ibid.).
- D. **Age at Sexual Maturity**
Rams are sexually mature at 18 to 30 months; however, dominance order usually prevents breeding until rams are six to eight years old (Nichols 1978b). Ewes are sexually mature at 18 months (Heimer and Watson, in prep.).
- E. **Fecundity**
Single births are usual, although twinning has very rarely been reported and never documented (ibid.). The gestation period is approximately 171 days (ibid.).
- F. **Frequency of Breeding**
Ewes can produce one lamb a year (ibid.). Under some conditions, ewes produce only one lamb every other year (Heimer 1983).

VI. FACTORS INFLUENCING POPULATIONS

- A. **Natural**
Deep snow and severe icing conditions appear to be major factors in limiting sheep populations in maritime areas (Nichols 1978a, Murie 1944). Wolves are a major predator in areas where the wolf population is high and/or escape terrain is limited (Murie 1944, Heimer and Stephenson 1982). Predation by bears, coyotes, lynx, and other predators occurs, but the extent is unknown (ibid.). Golden eagles are thought to be serious predators of lambs during their first few weeks of life (Heimer, pers. comm.; Hoefs and Cowan 1979). Major diseases and parasites associated with Dall sheep in Alaska include contagious ecthyma, lungworm-pneumonia complex, mandibular osteomyelitis (lumpy jaw), and several species of gastro-intestinal helminth worms (Neiland 1972).
- B. **Human-related**
The most serious human-related threat to Dall sheep in Alaska comes in the form of introduced diseases from domestic sheep. Wild animal populations seldom have the defenses necessary to withstand introduced diseases. These introductions were responsible for most of the decimation of wild sheep populations in the

western United States (Heimer 1983). Other human-related factors influencing sheep populations are the following:

- ° Competition with introduced (wild or domestic) animals
- ° Harassment, active
- ° Harassment, passive: construction noise, aircraft traffic
- ° Hunting
- ° Vegetation damage/destruction due to grazing by domestic animals

(See the Impacts of Land and Water Use volume of this series for additional information regarding impacts.)

VII. LEGAL STATUS

Dall sheep in Alaska are managed as a game animal by the Alaska Department of Fish and Game.

VIII. LIMITATIONS OF INFORMATION

Information is needed on the relationships of breeding success of rams vs. hunting mortality of older age classes.

Information is also needed on factors influencing winter survival of younger age classes and whether mineral licks are necessary for sheep survival.

Critical habitat components for sheep populations should be delineated (e.g., mineral licks), and further research on mineral lick relationships should be conducted. Basic research on the population dynamics of Dall sheep is needed.

Description and delineation of breeding and lambing habitats, as well as of winter ranges, is needed.

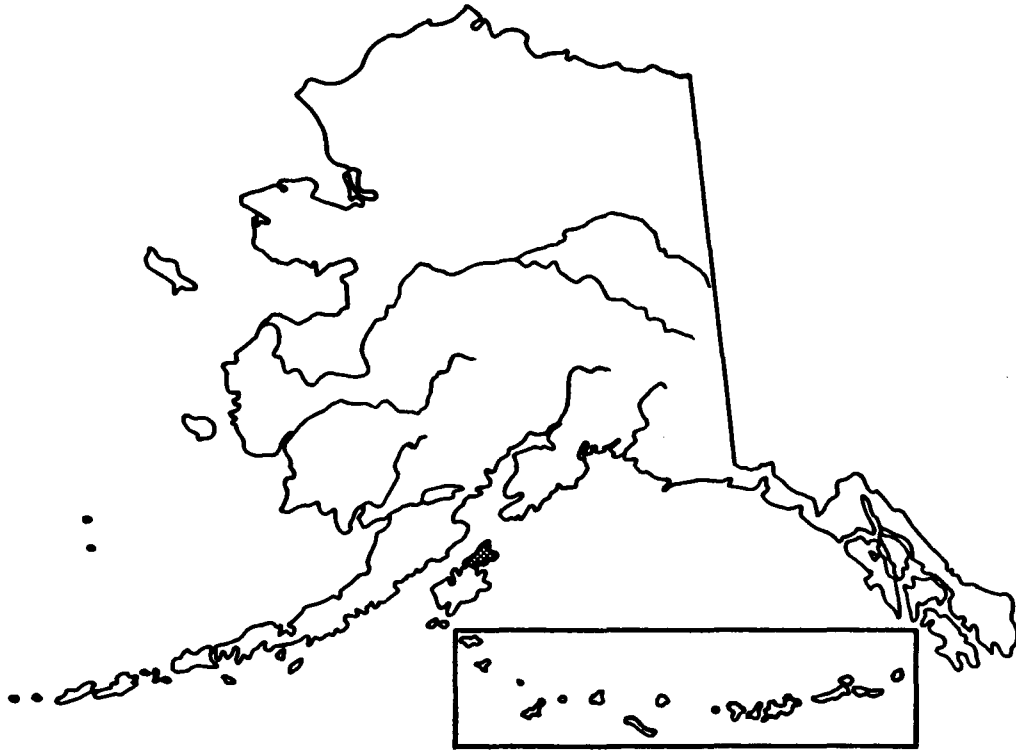
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Elk Life History and Habitat Requirements
Southwest Region



Map 11. Range of elk (ADF&G 1973)

I. NAME

- A. Common Names: Elk, Roosevelt elk, red deer, wapiti
- B. Scientific Name: Cervus elaphus roosevelti
- C. Native Names: See appendix A.

II. RANGE

A. Worldwide

The species Cervus elaphus occurs in North America and Eurasia and was introduced to New Zealand. The subspecies Roosevelt elk inhabits the timbered Pacific coast of Washington, Oregon, northwestern California, and Vancouver Island and was introduced to Afognak Island (Bryant and Maser 1982).

B. Statewide

Elk are found primarily on Afognak and Raspberry islands, although there have been several reports of elk on the northern part of

Kodiak Island. Transplants have been attempted in Southeast Alaska but with limited success (Burris and McKnight 1973, Eide 1977).

C. Regional Distribution Maps

To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for the Southwest Region at 1:250,000 scale. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of elk distribution has been prepared and may be found in the Atlas that accompanies the Southwest Region guide.

D. Regional Distribution Summary

See above.

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

Because of its widespread availability, water does not appear to be a limiting factor for elk on Afognak Island.

B. Terrestrial

1. Conditions providing security from predators or other disturbances. A wide variety of vegetation and terrain can be used by elk as escape cover. Use of escape cover varies seasonally and by sex and reproductive status. Brown bears are the only animal on the islands capable of preying on elk. Although predation of elk by brown bears currently does not appear to be a major mortality factor, Alexander (pers. comm.) has documented the killing of an adult female elk by a brown bear. Smith (pers. comm.) has observed on two occasions brown bears that were apparently stalking elk herds.

2. Conditions providing protection from natural elements. Where available, spruce-timbered areas are used by elk most during December through March, apparently because they provide extra cover and because snow depths are less (Troyer 1960, Alexander 1973).

IV. NUTRITIONAL REQUIREMENTS

A. Preferred Foods

Relatively little quantitative information exists concerning seasonal diets of elk on Afognak Island. According to Batchelor (1965), food preferences of these elk have been found to be quite diverse. There is a great abundance of vascular plants on Afognak Island; because of this, the elk's diet includes a large variety of succulent and woody plant species.

During summer feeding observations conducted on southwestern Afognak, Batchelor (1965) found that the following plants are utilized by grazing elk: fireweed (Epilobium angustifolium), lupine (Lupinus nootktensis), burnet (Sanguisorba sitchensis), cow

parsnip (Heracleum lanatum), sea lovage (Ligusticum hultenii), hellebore (Veratrum eschscholtzii), and water chickweed (Montia spp.).

Consumption of grasses and forbs begins to decrease with the arrival of fall because then species become dry and apparently less palatable. Gradually the fall diets of elk begin to include a few perennial forbs, notably fireweed, and an abundance of browse species, including elderberry (Sambucus racemosa) and highbush cranberry (Viburnum edule) (Batchelor 1965).

Batchelor (1965) indicates that during winter months elk on Afognak feed almost exclusively on browse, with elderberry and willow (Salix spp.) the most important species. During late winter, elk have been observed to heavily utilize the cured tops of hairgrass (Deschampsia caespitosa), which occurs in scattered stands in some of the lowland valleys, but grasses are not generally regarded as a major food item in the winter diet of these elk.

During spring, the consumption of grasses and grasslike plants and perennial forbs increases with the development of new growth. Sedges (Carex spp.), horsetail (Equisetum spp.), wild celery (Angelica lucida), bluejoint (Calamagrostis canadensis), and cow parsnip are also heavily utilized, as are the buds of fern (Anthyrum cyclosorum) and devil's club (Oplopanax horridus) (ibid.).

- B. Feeding Locations (from Alexander 1973, unless otherwise noted)
 - 1. There is considerable overlap in the use of habitat during spring, winter, and fall, depending on snow conditions.
 - a. Spring: Alder (Alnus spp.) communities
 - b. Summer: Alpine habitat
 - c. Fall: Alder communities
 - d. Winter: Spruce (Picea sitchensis); timbered areas typically on south and southeast-facing slopes adjacent to beach fringes where available
 - 2. Elk wintering on Tonki and Raspberry islands use heath-type habitat, which grows at or near sea level on windblown capes and bluffs.
- C. Factors Limiting Availability of Food
Heavy snowfall and overgrazing by elk can sufficiently reduce forage to cause malnutrition, resulting in severe winter mortality.

V. REPRODUCTIVE CHARACTERISTICS

- A. Reproductive Habitat
 - 1. Calving. Most calving occurs at lower elevations in spruce timber (Troyer 1960).
- B. Reproductive Seasonality
 - 1. Calving. Most calving occurs in early June, although calf tracks have been observed as early as 23 May (ibid.).

2. Rutting. Bulging begins in early September and continues through early October. Most breeding activity occurs during the last two weeks of September (ibid.).
- C. Reproductive Behavior
Currently, little pertinent breeding behavior information exists concerning Afognak elk.
- D. Age At Sexual Maturity
 1. Females. Female elk can successfully breed at 1.5 years, although the frequency of successful breeding in yearling cows varies among populations and from year to year in the same population (Flood 1970).
 2. Males. Male elk can successfully breed at 1.5 years (Harper 1971), but because of behavioral patterns larger bulls tend to do most of the breeding. Bulls generally are in their prime at ages 6 to 11.
- E. Fecundity
Elk generally produce one calf per year, although twinning is not unknown.

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

Alexander (1973) identified nine distinct herds on Afognak and Raspberry islands. Home range sizes varied between 13.7 and 39.4 mi² and averaged 22.8 mi². Winter home ranges were smaller, ranging from 1.2 to 7.3 mi² and averaging 3.2 mi². However, there appears to be some overlap between the ranges of adjacent herds, and some interchange of animals is suspected. The herds delineated by Alexander appear to have changed somewhat. Currently, seven herds are identified by Smith (pers. comm.). These changes in herd identities may be associated with population increases or declines.

VII. FACTORS INFLUENCING POPULATIONS

- A. Natural
Severe winter weather, as was documented by Alexander (1973), can cause severe losses of elk.
- B. Human-related
A summary of possible impacts from human-related activities includes the following:
 - Pollution of water and/or food supply
 - Reduction of food supply
 - Alteration of habitat
 - Disturbance/displacement
 - Barriers to seasonal movement
 - Overharvest(See the Impacts of Land and Water Use volume of this series for additional information regarding impacts.)

VIII. SPECIAL CONSIDERATIONS

1. Elk on Raspberry and Afognak islands are the result of transplants in 1928.

2. Drastic declines in elk numbers as a result of severe winters were documented. The decline was from 1,200-1,500 elk in 1965 to an estimated 500 animals by 1976 (Eide 1977). However, the elk population has since increased to over 1,200 animals (Smith, pers. comm.).
3. Sitka black-tailed deer (Odocoileus hemionus sitkensis) feed on many of the same food plants as elk on Afognak, which could lead to increasing competition as populations increase.
4. Much of the land occupied by elk is privately owned and may be subject to logging. The effect of logging and associated road access on elk habitat on Afognak and Raspberry islands is not clearly understood.
5. State and borough land sales on Raspberry Island may be detrimental to elk where changes in land use result in habitat deterioration or loss.

IX. MANAGERIAL AUTHORITY

The Alaska Department of Fish and Game manages elk.

X. LIMITATION OF INFORMATION

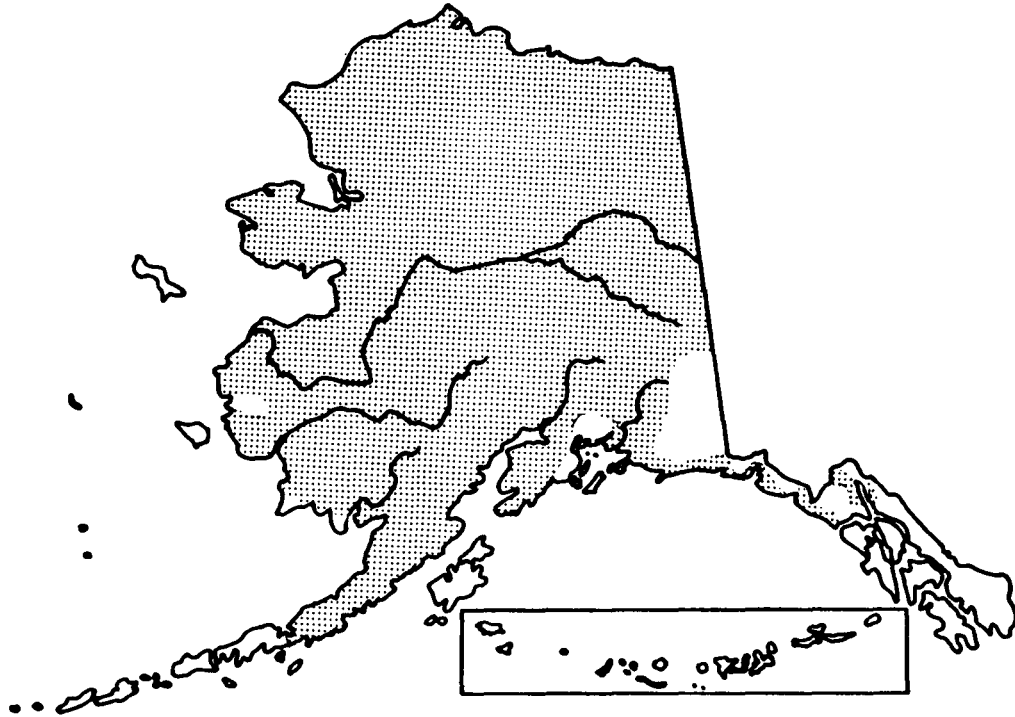
Data regarding seasonal ranges and habitat preferences for elk on Afognak and Raspberry islands are limited.

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Moose Life History and Habitat Requirements
Southwest, Southcentral, Arctic, Western, and Interior Regions



Map 1. Range of moose (ADF&G 1973)

I. NAME

- A. Common Name: Moose, Alaskan moose
- B. Scientific Name: Alces alces gigas (Peterson 1955)
- C. Native Names: See appendix A.

II. RANGE

- A. Worldwide
The Alaskan moose (Alces a. gigas) is distributed throughout most of Alaska, western Yukon Territory, and northern British Columbia (Franzmann 1978).
- B. Statewide
Moose are distributed throughout Alaska except for portions of the southeastern Panhandle, the southwestern Alaska Peninsula, most offshore islands, and glaciated areas. Moose are generally found

at or below 4,000 ft elevations (Ballard and Taylor 1980, Ballard et al. 1984).

C. Regional Distribution Maps

To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for each region at 1:250,000 scale. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of moose distribution has been prepared and may be found in the Atlas that accompanies each regional guide.

D. Regional Distribution Summary

1. Southwest. Moose are present throughout the Southwest Region mainland, generally below elevations of 4,000 ft. Few moose exist south of Port Moller on the Alaska Peninsula (ADF&G 1976a, Ballard and Taylor 1980, Ballard et al. 1984). (For more detailed narrative information, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)
2. Southcentral. Moose are distributed throughout much of the Southcentral Region mainland, generally below elevations of 4,000 ft (ADF&G 1976b, Ballard and Taylor 1980, Ballard et al. 1984), except in glaciated areas, such as occur in the Wrangell Mountains. They are also absent from western Prince William Sound from Valdez to Kings Bay. Moose are also found on Kalgin Island in Cook Inlet, as a result of transplants in 1957, 1958, and 1959 (Burris and McKnight 1973). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)
3. Arctic. Moose are distributed throughout the Arctic Region. In forested areas, such as those that occur in the middle and upper Kobuk River and its tributaries, moose are widely distributed during spring and summer. In treeless areas, such as coastal areas and the Arctic Region north of the Brooks Range, distribution is keyed to major floodplains and riparian areas along rivers and streams, where moose congregate during winter because of the available food (ADF&G 1976d,e).

Coady (1980), in a detailed historical review, reported that moose were not observed north of the Brooks Range before 1880 and were considered scarce until the 1940's. This does not suggest a total absence of moose on the North Slope, because Hall (1973) described prehistoric evidence of moose at several archaeological sites in that area. He suggested the expansion of moose range into that part of Alaska over time. During the late 1940's and 1950's, moose apparently began to increase in numbers and expanded their range dramatically (ADF&G 1976d,e). On the Seward Peninsula, this increase was most apparent during the late 1960's (Grauvogel 1984). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Arctic Region.)

4. Interior and Western. Moose are distributed throughout the Interior and Western regions, with the exception of the Yukon-Kuskokwim delta, where they are infrequently seen (LeResche et al. 1974, ADF&G 1976f). Moose were generally unknown to most early residents of the Kuskokwim River drainage and were rarely seen along the middle Yukon until the early 1900's. During the 1920's and 1930's, the moose population gradually expanded throughout the upper Kuskokwim and middle Yukon (ADF&G 1976f). (For more detailed narrative information, see the Alaska Habitat Management Guide for the Western and Interior regions.)
5. Southeast. In Southeast Alaska, moose are found on the Malaspina forelands, Yakutat forelands, the river valleys between Haines and the Canadian border, Berners Bay and Taku River, the Stikine River valley, and other drainages abutting Canadian herds (ADF&G 1976a,b,c).

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

Moose feed on aquatic vegetation during spring and summer. They may also seek relief from insects in deep water (Flook 1959). (For further discussion, see Terrestrial Cover Requirements, below, and IV. A.2. and 3.)

B. Terrestrial Cover Requirements

1. Winter. Willow (Salix spp.) shrub communities in alpine and riparian environments are very important habitats for moose during winter, supplying most of its winter food (see IV. A. 1., below). Coniferous tree stands may also provide needed food and cover, especially for cows with calves, which seek denser cover than do other moose, presumably for greater protection from predators (Peterson 1977) and lower snow depths (Coady 1982).
2. Spring. Moose typically begin feeding upon grasses, sedges, and aquatic and semiaquatic vegetation as soon as snow- and ice-melt permits. In many areas, cows usually select well-drained, dense islands of trees and shrubs as secluded birth sites, which probably serve as protective cover for their calves (Peterson 1955, Rausch 1967). These calving areas are characterized by dense clumps of spruce (Picea spp.) interspersed with alder (Alnus spp.) and willow, which very likely serve as protective cover from the natural elements (ADF&G 1973), as well as from predators or other disturbances. Modafferi (1982, 1983) described calving areas for radio-collared moose from a subpopulation along the Susitna River north of Talkeetna that were grossly different from those described above. He found that spruce was the least common and abundant of four major tree types present that were used by this subpopulation. Use of muskeg meadows was not observed. Cottonwood (Populus trichocarpa) was the most commonly occurring vegetation type associated with calving areas and dominated the canopy coverage. It is

likely that calving areas vary greatly throughout the state and are often widespread.

3. Summer. Generally, moose feed in open areas and use the bordering shrubs and forest for cover (LeResche 1966). Calves, however, tend to avoid exposed areas in which cows browse and graze (Stringham 1974). Moose only occasionally bed down in open wet meadows, preferring the drier ground among hummocks near the edges of willow, spruce, and mixed forest stands (LeResche 1966).
4. Fall. Generally, moose tend to occupy higher open areas during the rut. Ballard and Taylor (1980) found that moose occupied willow habitats more during September, October, and December than through the remainder of the year in the upper Susitna valley. Most moose collared during the winter along the lower Susitna River floodplain did not spend the rut period in or near their winter ranges. Most rutted to the west of the floodplain, with some individuals as far as 40 km away from the Susitna River (Modafferi 1984). Generally, rutting concentrations of moose occur at or above timberline, but they occur at lower elevations also. Early snows may force moose to move to wintering areas, and, conversely, warm weather may enable them to linger in summering areas.

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

1. Winter. Deciduous shrubs and trees protruding through accumulated snow on the ground and within reach of moose are the primary food in winter. In some areas, however, moose crater in snow to obtain nonbrowse forage such as ferns (LeResche and Davis 1973, Modafferi 1984). Several willow species are preferred, but the order of preference varies from area to area (Scott et al. 1958, Peek 1974). On the Kenai Peninsula, littletree willow (*S. arbusculoides*) is most preferred, followed by scouler willow (*S. scouleriana*) and bebb willow (*S. bebbiana*) (Machida 1979). Barclay willow (*S. barclayi*) was least preferred. In Interior Alaska, the order of preference is feltleaf willow (*S. alaxensis*), diamondleaf willow (*S. planifolia* ssp. *pulchra*), with scouler willow and halbred willow (*S. hastata*) preferred least (ibid.). After willow, the most preferred browse is paper birch (*Betula papyrifera*) (LeResche and Davis 1973). Because of the quantity of forage it produces, quaking aspen (*Populus tremuloides*) is also considered important in certain areas (Aldous 1944). Foliose lichens (*Peltigera* spp.) may serve as an important alternate winter food source (LeResche et al. 1974). In areas of low snow cover and on depleted winter ranges, lowbush cranberry and foliose lichens can support high densities of moose (LeResche and Davis 1973).

2. Spring. Willows are the most important food in spring. Horsetails (Equisetum spp.), sedges (Carex spp.), and aquatic plants are also important (Rausch 1967). On the Kenai Peninsula in late April and during May, foliose lichens and fruticose lichens (Cladonia spp.) made up more than half the diet of tame moose, with lowbush cranberry making up the remainder of the diet (LeResche and Davis 1973).
 3. Summer. Variety in the diet is greatest during summer. During this period, emergent vegetation and other herbaceous plants may be grazed, but leaves and succulent leaders on shrubs and trees are also used (Coady 1982). Newly emergent aquatic and marsh plants, including sedges, horsetails, and pondweed (Potamogeton spp.), are consumed in wetlands and lakes and ponds up to 8 ft deep (LeResche and Davis 1973, LeResche 1966).
During early growth stages, forbs such as fireweed (Epilobium spp.) and lupine (Lupinus spp.) are heavily used. Mushrooms are eaten in summer when encountered (LeResche and Davis 1973).
In late summer, emergent plants are used less, and the diet includes more browse (Bishop, pers. comm.).
 4. Fall. During fall, the transition from summer forage to winter forage occurs. The use of browse increases as fall progresses because many herbaceous plants become unpalatable.
- B. Types of Feeding Areas
1. Winter. Shrub communities, such as alpine and lowland willow stands, are the most important winter habitat for food (LeResche et al. 1974, Peek 1974). When snow depths are minimal, moose generally prefer more open shrub-dominated areas and sedge meadows (Coady 1982). As snow depths increase, moose shift to coniferous and deciduous forests with closed canopies, when available, where snow accumulation is less (Coady 1976, Gasaway 1977) and understory vegetation more available (LeResche and Davis 1973).
Mature, undisturbed plant communities, occurring both in upland areas near timberline and in lowland areas, are important late winter habitat, as are areas recovering from man-caused or natural disturbances. Moose may remain on their summer range if not forced out by deep snow (Ballard and Taylor 1980). During late winter, some moose may remain at higher elevations, where wind action or temperature inversions reduce snow depth. Moose may crater through snow up to 40 cm deep (Coady 1982, Modafferi 1984).
Generally, upland areas of winter habitat are dominated by willow or shrub birch (Betula glandulosa) and lowland areas by stands of spruce interspersed with deciduous tree stands and wetland areas (ibid.).
 2. Spring. Expanses of wetlands interspersed with dense stands of trees and shrubs, which are typically used for calving, provide abundant early spring forage (ibid.). Moose use

natural mineral licks in some areas of Interior Alaska, mostly in spring and early summer to obtain sodium (Tankersley and Gasaway 1983). Mineral licks used by moose occur in some areas of Southcentral Alaska also; however, there are no detailed reports on these areas (Tankersley, pers. comm.). No licks are known in Southwest Alaska.

Studies in Michigan and Canada indicate that aquatic vegetation eaten by moose in the summer is an alternate and sometimes better source of sodium and other mineral elements (Botkin et al. 1973, Fraser et al. 1982). Moose lick use declined when aquatic feeding increased in Interior Alaska (Tankersley and Gasaway 1983).

3. Summer. Timberline shrub thickets (LeResche et al. 1974) and lowland areas with ponds containing preferred aquatic species (LeResche 1966) comprise primary feeding locations during the summer. (See comment on salt licks under B. 2.)

In mid-to-late summer, moose tend to move to upland areas away from bog areas with standing water and to use browse in drier areas (Bishop, pers. comm.; Didrickson and Taylor 1978; Ballard et al. 1984).

4. Fall. Both lowland and upland shrub communities may be heavily used during fall (Coady 1982). In Southcentral Alaska, moose typically use upland areas (Ballard and Taylor 1980, Didrickson and Cornelius 1977).

C. Factors Limiting Availability of Food

Coady (1974) considered snow depth the most important limiting factor for moose. Migration between summer and winter range and daily winter activity may be influenced by initiation of first snow, snow depth, day length, and persistence of snow. Snow depths greater than 40 to 70 cm are generally considered the upper limit for areas utilized by moose (Coady 1974). Snow depths of 90 to 100 cm are considered critically limiting (Nasimovitch 1955, Kelsall 1969, Telfer 1970, Kelsall and Prescott 1971), because at these depths movement is restricted and adequate food intake may be impossible. Deep snow may also cover low-growing browse species, reducing their availability and requiring moose to exert greater effort to feed (Coady 1974). The next most important property of snow is hardness, which determines the force necessary for moose to move through the snow and their ability to crater for food.

The density, height, and distribution of forage plants determine how much a particular area and vegetation type is utilized (Milke 1969).

In Southcentral Alaska, moose generally confine their winter movements to areas less than 3,600 ft in elevation (Ballard et al. 1984).

D. Feeding Behavior

Peak feeding activity occurs at dawn and dusk. During fall, more feeding activity occurs throughout the day. Fall feeding activity is usually influenced by the rut, reflecting greater social

contact (Best et al. 1978). Schwartz et al. (1981) found that bull moose at the Kenai Moose Research Center quit eating entirely during the rut and that food intake decreased in females. Geist (1963) found that 79% of summer activity involved feeding. Cratering in snow to reach plants is common throughout Alaska during fall and winter (LeResche and Davis 1973).

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

1. Breeding areas. There are little descriptive data regarding moose rutting habitat. Use of habitat during the rut may be influenced by whether particular groups of moose are migratory or nonmigratory. Use of upland willow shrublands reaches a peak during the breeding period, corresponding with elevational movements of moose (Didrickson and Cornelius 1977; Ballard and Taylor 1980; Ballard et al. 1982a, 1984).
2. Parturition areas. Most studies conducted in the South-central Region have found calving to be widely dispersed (Didrickson and Cornelius 1977, Ballard et al. 1982a, Modafferi 1982) (see III. B. 2.).

B. Reproductive Seasonality

1. Breeding. Breeding occurs during fall, with the peak of rutting activity occurring between late September and early October (Lent 1974). The timing of the rut is remarkably synchronous among moose in different areas and years in North America (ibid.); this synchronism is reflected in the consistency in calving dates observed throughout the range of moose (Coady 1982).
2. Parturition. Parturition generally occurs between late May and early June. As a consequence of conception during later estrus periods, some calving may occur later, which is disadvantageous to calves because their reduced size in fall may lessen their ability to survive the winter (ibid.).

C. Reproductive Behavior

Moose often form large aggregations during the rut (Best et al. 1978). These rutting groups range in size from male and female pairs to 30 or more adults (Coady 1982). There may be movement of both bulls and cows to and from groups (ibid.).

D. Age at Sexual Maturity

Moose breed annually. Females may breed as yearlings (16 to 18 months) and are capable of reproducing annually until at least year 18 (Houston 1968). Bulls are also physically capable of breeding as yearlings (ibid.).

E. Pregnancy Rate/Number of Young Born

Natality rates for adult females range from 1.00 to 1.20. Eighty to 90% of adult females in most moose populations in North America become pregnant annually (Pimlott 1959, Schladweiler and Stevens 1973, Simkin 1974). The birth rate for two-year-old females in North America was found to be 0 to 0.47 (Pimlott 1959, Schladwiler

and Stevens 1973, Blood 1974, Simkin 1974). In the development of their moose population model, Ballard et al. (1984) used Blood's (1974) estimate of .29 calves/two-year-old female.

The lowest reported pregnancy and twinning rates for moose in North America were 60% (Franzmann 1981) and 2% (Pimlott 1959), respectively; the highest rates were 98% and 70%, respectively (Franzmann et al. 1983, Modafferi 1984). Moose populations in Alaska tend to be on the higher end of this scale.

F. Gestation Period

The gestation period is approximately 240 to 246 days (Peterson 1955).

G. Lactation Period

Cows lactate until fall, then gradually wean their calves (Franzmann 1978).

VI. FACTORS INFLUENCING POPULATIONS

A. Natural

1. Severe winters. Winter mortality results from factors related primarily to snow depth, density, hardness, and the persistence of these conditions over time (Franzmann and Peterson 1978).

Winter severity often manifests itself first in terms of reduced food availability and restriction of movements and later in terms of increased calf and adult mortality because of starvation and increased vulnerability to predators (Pimlott 1959, Peek 1974, Peterson and Allen 1974, Bishop and Rausch 1974, Sigman 1977).

Recently conducted predator-prey-relationship studies in Alaska suggest that moose mortality because of wolf predation is additive rather than compensatory. After a moose population has declined from factors such as severe winters, overharvest, declining range-carrying capacity, and/or predation, limits on moose population growth because of wolf predation can occur. In simple wolf-moose systems, predators can maintain moose at low levels for decades (Gasaway et al. 1983, Ballard et al. in press).

Prior to the mid 1970's, both brown and black bears were thought to be scavengers rather than predators of moose. Studies of neonatal moose mortality indicate that both species of bear can be successful ungulate predators (Franzmann et al. 1980, Ballard et al. 1981). Bear predation is the primary cause of mortality in some moose populations and, similarly to wolf predation, is an additive source of mortality. Experimental bear-reduction programs have demonstrated that calf moose survival can be improved by temporarily reducing bear numbers (Ballard et al. 1982b).

Most moose populations produce adequate numbers of calves to enable population growth. When growth fails to occur, it usually is the result of high neonatal mortality. The relationship between habitat carrying capacity and ungulate

density is confounded by predation. Managers attempting to provide sustained yields of moose for human use may find predator management a necessity in systems containing naturally regulated predator populations.

3. Disease and parasitism. Moose are subject to a large number of diseases and parasites; however, usually they are not important factors in population dynamics (Franzmann 1978; Zarnke, pers. comm.).
4. Competition. Competition for food between moose and hares is usually prevented by habitat segregation; moose, for example, prefer open seral communities, whereas hares inhabit dense black spruce (Picea mariana) or willow-alder (Salix-Alnus spp.) thickets, which provide more cover (LeResche et al. 1974, Wolfe 1974). In general, direct competition is minimal except in areas where forage has been extensively depleted or when deep snow forces hares to feed at higher levels on shrubs (Wolfe 1974).

B. Human-related

A summary of possible negative impacts from human-related activities includes the following:

- Collision with vehicles
- Pollution of water and/or food supply
- Reduction of food supply
- Vegetation composition change to less preferred or useable species
- Vegetation damage/destruction due to grazing by domestic animals
- Vegetation damage/destruction due to mechanical removal of material
- Barriers to movement, physical and behavioral
- Harvest, change in level
- Harassment or mortality caused by domestic dogs, especially in deep-snow conditions
- Competition with introduced animals
- Predation, increases
- Disease transmission from susceptibility to introduced diseases and/or domesticated animals
- Harassment, active

(See the Impacts of Land and Water Use volume of this series for additional information regarding impacts.)

VII. LEGAL STATUS

The Alaska Department of Fish and Game manages moose.

VIII. SPECIAL CONSIDERATIONS

A. Habitat Protection and Management

To sustain a moose population, high-quality habitat is essential. Habitat protection and management may consist of the following

(Franzmann 1978):

- Setting aside large areas such as the Kenai National Wildlife Refuge, and the Matanuska Valley Moose Range
- Limiting construction and other activities that restrict moose movements between traditional seasonal home ranges and within critical use areas of a seasonal home range
- Enhancing selected habitats to improve the carrying capacity for moose by prescribed burning, logging in small blocks, land-clearing, and mechanical rehabilitation that returns vegetation to early successional stages (Oldemeyer et al. 1977)

These practices should be subject to total resource planning and be compatible with other resource management considerations (Franzmann 1978).

IX. LIMITATIONS OF INFORMATION

Data are sparse concerning annual and seasonal habitat use by moose, and area-specific information is needed regarding these seasonal habitat requirements. Population identity and movement studies need to be completed in order to identify migrational patterns and habitats important to the maintenance of specific subpopulations of moose.

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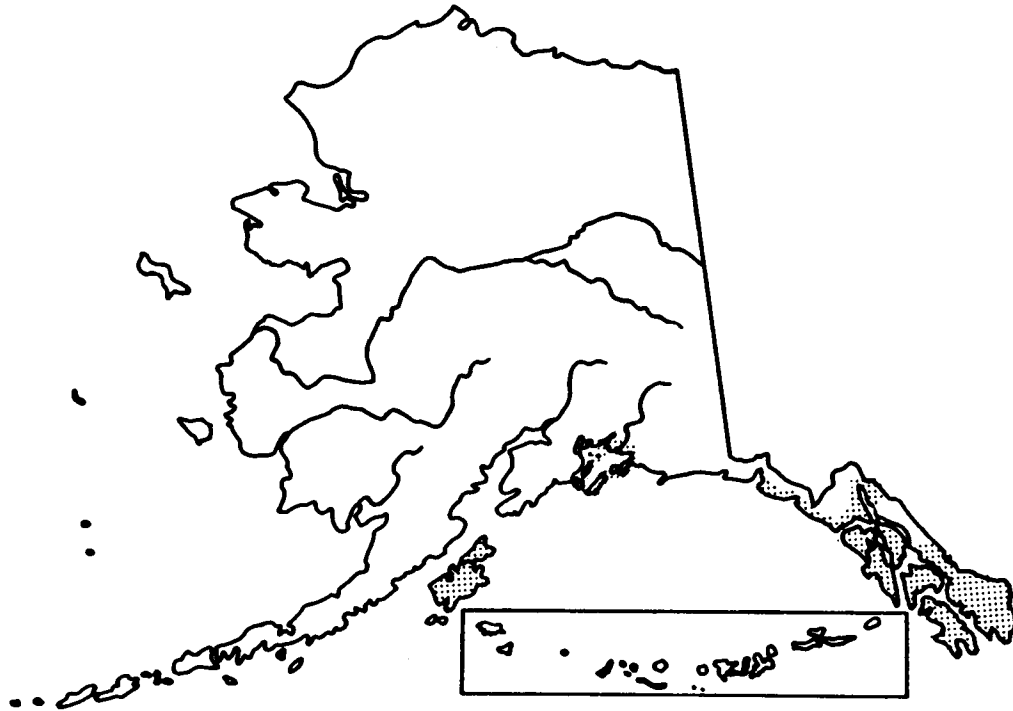
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Sitka Black-tailed Deer Life History and Habitat Requirements
Southwest, Southcentral, and Southeast Regions



Map 1. Range of Sitka black-tailed deer (ADF&G 1973)

I. NAME

- A. Common Name: Sitka black-tailed deer
- B. Scientific Name: Odocoileus hemionus sitkensis
- C. Native Names: See appendix A.

II. DISTRIBUTION

- A. Worldwide
Sitka black-tailed deer are found in the heavily timbered regions of the north coast of British Columbia and Southeast Alaska. Several transplants have increased deer range throughout the northeast Gulf of Alaska.
- B. Statewide
Deer are indigenous to the dense coastal forests of the southeastern Alaskan mainland and most islands as far north as

Glacier Bay. Several successful transplants have extended deer range to include most of the Kodiak archipelago, Prince William Sound (PWS), and the Yakutat area.

C. Regional Distribution Maps

To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for the Southwest and Southcentral regions at 1:250,000 scale. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of deer distribution has been prepared and may be found in the Atlas that accompanies the Southwest and Southcentral regional guides.

D. Regional Distribution Summaries

1. Southwest. Deer have been reported throughout the Kodiak archipelago, with low density deer populations becoming established in the previously unoccupied southwest portion of Kodiak Island. (For more detailed narrative information, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)
2. Southcentral. Deer have been reported throughout the PWS area, occurring primarily on the larger islands. Some deer populations, however, occupy small mainland areas adjacent to PWS. (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)
3. Southeast. Deer occur naturally throughout the coastal islands of Southeast Alaska (Alexander archipelago) and in a narrow strip along the adjacent mainland. The precipitous Coast Mountains, with extensive ice fields, constitute an eastern barrier to deer. The continental, subarctic climate terminates the natural northern distribution of deer above Juneau (Wallmo 1981). Deer were transplanted to Yakutat and to several areas around Lynn Canal (Burris and McKnight 1973). A persistent population was established in Yakutat and on Sullivan Island. Deer occur in very limited numbers along the Chilkat Peninsula and along the Chilkat River.

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

1. Water quantity. Dietary water is obtained from snow in winter, dew-laden succulent vegetation in rainy periods, and occasionally from water bodies in dry periods (Cowan 1956).

B. Terrestrial Cover Requirements

1. Conditions providing security from predators or other disturbances:
 - a. Southwest Region. Smith (1979) described how deer often avoid pursuit by swimming.
 - b. Southeast Region. Clear-cutting adjacent to major roads or timber haul roads without a buffer zone results in a

reduction of the use of cuts by deer because of the continual disturbance (Taber and Raedeke 1980).

2. Conditions providing protection from natural elements:
 - a. Southwest Region. Cottonwood (Populus sp.), birch (Betula papyrifera), scattered spruce (Picea sp.) patches, and dense alder (Alnus sp.) thickets along steep draws are used for cover by deer on Kodiak Island (Smith 1979). Low-elevation coastal Sitka spruce (Picea sitchensis) stands are used to some extent throughout the year. Deer use the coastal fringe Sitka spruce forests in varying amounts every winter, although these areas become very critical in winters of deep snow. Afognak, Shuyak, Raspberry, and several other adjacent islands, including northeast Kodiak, have extensive coastal spruce forests.
 - b. Southcentral Region. In PWS, deer cannot survive without the climax coniferous forest along the beach fringe, which provides essential shelter and forage during the winter period (Reynolds 1979).
 - c. Southeast Region. Mature, old-growth stands with a well-developed canopy intercept snowfall (Merriam 1971, Jones 1975, Weger 1977, Bloom 1978, Barrett 1979, Harestad 1979, Taber and Raedeke 1980, Rose 1982, Wallmo and Schoen 1980, Kirchhoff and Schoen 1985). Winter use of forest stands has been correlated with high volume (greater than 30 mmbf/acre) timber stands during moderate-to-hard winters (Schoen et al. 1981, Schoen and Kirchhoff 1983a). In milder winters, use is more dispersed and includes lower volume stands (less than 30 mmbf/acre) (Schoen and Kirchhoff 1983a).

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

1. Southwest Region. See table 1.
2. Southcentral Region. See table 1.
3. Southeast Region. Deer utilize a variety of forage species throughout the year but prefer herbaceous forage when available. They substantially increase their use of conifers, shrubs, and lichens when herbaceous species are unavailable (e.g., under deep snow). Preference for herbaceous species appears related proportionally to forage quality. Winter is the period when forage availability is most limited and when two plant foods, bunchberry (Cornus canadensis) and five-leaved bramble (Rubus pedatus), are highly preferred where available (Schoen and Kirchhoff 1983b, Schoen et al. 1982).
 - a. Winter (December-March):
Bunchberry and five-leaved bramble are primary foods on Admiralty and Chichagof islands under winter conditions of both little snow accumulation and of snow

Table 1. Food Species Used by Sitka Black-tailed Deer in the Kodiak and Prince William Sound Areas

Food Species Name		Kodiak Area				Prince William Sound			
		Primary Food Source		Secondary Food Source		Primary Food Source		Secondary Food Source	
		Seasonal ^a	Source	Seasonal ^a	Source	Seasonal ^a	Source	Seasonal ^a	Source
Common	Scientific	Use		Use		Use		Use	
Fireweed	<u>Epilobium angustifolium</u>	W,S	ADF&G 1976b	EW	ADF&G 1976b				
		S	Merriam 1965,1966						
Elderberry	<u>Sambucus racemosa</u>	EW	Merriam 1968						
		W,S	ADF&G 1976b	EW	ADF&G 1976b				
Crowberry	<u>Empetrum nigrum</u>	W	Smith 1979						
		W	ADF&G 1976b	S,EW	ADF&G 1976a				
		W	Smith 1979						
		EW	Merriam 1968						
Cow parsnip	<u>Heracleum lanatum</u>			S	ADF&G 1976a				
Willow	<u>Salix spp.</u>	W	ADF&G 1976b	EW	ADF&G 1976b				
		W	Smith 1979						
Sitka spruce	<u>Picea sitkensis</u>	EW	Merriam 1969	W	ADF&G 1976b				
Nootka rose	<u>Rosa nutkana</u>	S	ADF&G 1976b						
		W	Smith 1979						
		W	ADF&G 1973	S	ADF&G 1976a				
Reedgrass	<u>Calamagrostis spp.</u>	EW	Merriam 1968						
Hairgrass	<u>Deschampsia spp.</u>	EW	Merriam 1968						
Highbush cranberry	<u>Viburnum edule</u>	W	ADF&G 1973						
False hellebore	<u>Veratrum viride</u>	S	Merriam 1966						
Lady fern	<u>Athyrium filix-femina</u>	W	Smith 1979						
Lowbush cranberry	<u>Vaccinium vitis-idaea</u>	W	Smith 1979						
Lichens	<u>Unspecified species</u>			W	Smith 1979				
Ground dogwood	<u>Cornus canadensis</u>			S	ADF&G 1976a	W	Shishido 1984	S,F	ADF&G 1976b
				W	ADF&G 1973	SP,S,F	Reynolds 1979		
Bearberry	<u>Arctostaphylos spp.</u>	W	Smith 1979						
		EW	Merriam 1968	S	ADF&G 1976a	F,EW	Reynolds 1979		
Salmonberry	<u>Rubus spectabilis</u>	S	ADF&G 1976b			SP	Shishido 1984		
		W	Smith 1979						
Early blueberry	<u>Vaccinium ovalifolium</u>	W	Erickson 1958	S	ADF&G 1976b	W	Reynolds 1979	S	ADF&G 1976b
						W	Shishido 1984		
						W	Merriam 1965		
						SP,F,W	ADF&G 1976b		

(continued)

Table 1 (continued).

Food Species Name		Kodiak Area				Prince William Sound			
		Primary Food Source		Secondary Food Source		Primary Food Source		Secondary Food Source	
		Seasonal ^a Use	Source	Seasonal ^a Use	Source	Seasonal ^a Use	Source	Seasonal ^a Use	Source
Alaska blueberry	<u>Vaccinium alaskensis</u>					W	Shishido 1984		
Alder	<u>Alnus spp.</u>	W	Smith 1979	EW	Merriam 1968	W	Reynolds 1979	W	Reynolds 1979
Kelp	Unspecified species	W	Smith 1979	W	ADF&G 1976b	W	ADF&G 1976b		
Cold thread	<u>Coptis asplenifolia</u>					S,F,EW	Reynolds 1979	S	ADF&G 1976b
Trailing bramble	<u>Rubus pedatus</u>					S,F,EW	Reynolds 1979	S	ADF&G 1976b
Ferns	Unspecified species							F	ADF&G 1976b
False lily-of-the-valley	<u>Maianthemum dilitatum</u>					S	Reynolds 1979		
Yellow shunk cabbage	<u>Lysichiton americanum</u>					SP	ADF&G 1976b		
						SP	Shishido 1984		
						S	Reynolds 1979		
Rusty menziesia	<u>Menziesia ferruginea</u>							W	Reynolds 1979
Beach rye	<u>Elymus arenarius</u>							SP,W	ADF&G 1976b
Goose tongue, plantain	<u>Plantago maritima</u>							SP	ADF&G 1976b
Sedges								SP,W	ADF&G 1976b
Marsh marigold	<u>Caltha leptosepala</u>					S,F	ADF&G 1976b		
Deer cabbage	<u>Fauria crista-galli</u>					S	ADF&G 1976b		
Black durrant	<u>Ribes hudsonianum</u>							S,F	ADF&G 1976b
Orchid	<u>Listera cordata</u>							SP,S	Shishido 1984

^a W = Jan., Feb., Mar.; SP = Apr., May; S = June, July, Aug.; F = Sept., Oct.; EW = Nov., Dec.

accumulation in open areas with snow-free areas common under the canopy of an old-growth, uneven-aged spruce hemlock forest (Schoen et al. 1983b, Hanley and McKendrick 1985). Under the conditions of little snow accumulation, fern-leaved goldthread (Coptis aspleniifolia) is a primary food, as is yellow cedar (Chamaecyparis nootkatensis), where it occurs on Chichagof Island (Schoen et al. 1982). Under more severe conditions of deeper snow accumulation and persistence, hemlock (Tsuga spp.), arboreal lichens (Usnea spp. and Alectoria spp.), and blueberry stems (Vaccinium spp.) are also primary foods (Schoen and Kirchhoff 1983b, Hanley and McKendrick 1985). On Prince of Wales Island, yellow cedar, hemlock, blueberry, cedar (Thuja spp.), and bunchberry are important winter foods (Pierce 1981).

Under mild winter conditions, blueberry, spreading wood-fern (Dryopteris dilatata), deerflower (Tiarella trifoliata), Labrador tea (Ledum palustre), salmonberry (Rubus spectabilis), hemlock, and rockweed (Fucus fucus) are secondary foods on Admiralty and Chichagof islands (Schoen et al. 1982). During moderate-to-severe winters on Admiralty and Chichagof islands (Schoen and Kirchhoff 1983b) and on Prince of Wales Island, mosses, ferns, and ground lichens are secondary foods where available (Pierce 1981).

b. Spring (April-mid June):

In the spring, bunchberry, five-leaved bramble, blueberry, devil's club (Oplopanax horridus), skunk cabbage (Lysichiton americanum), arboreal lichens, and fern-leaved goldthread are primary foods (Schoen and Kirchhoff 1984, Hanley et al. 1984).

Secondary foods are Aleutian heather (Phyllodoce aleutica), western hemlock (Tsuga heterophylla), Labrador tea, and rockweed (Hanley et al. 1984).

c. Summer (mid June-September):

In the summer, bunchberry, five-leaved bramble, skunk cabbage, devil's club, and deer cabbage (Fauria crista-galli) are primary foods (Schoen and Kirchhoff 1983b). A variety of other foods have been reported eaten by deer (summary in Hanley et al. 1984). Klein (1963, 1965) also described deer cabbage, skunk cabbage, and sedges (Carex biflora, C. lyngbyei spp., cryptorarpa, and C. macrochaeta) as the most important summer forage species.

Secondary foods are plantain (Plantago maritima), Sitka vetch (Vicia gigantea), early blueberry (Vaccinium ovalifolium), seaside arrowgrass (Triglochin maritimum), swordfern (Polystichum munitum), beach rye-grass (Elymus arenaria spp. mollis), and Pacific reed-grass

(*Calamagrostis nutkaensis*), (Klein 1963, 1965). Only early blueberry and Pacific reed-grass are widespread throughout Southeast Alaska.

B. Types of Feeding Areas Used

1. Summer/fall:

- a. Southwest Region (May-October). In the Kodiak area, feeding occurs in willow and alder thickets, among grass-shrub vegetation, and in alpine areas (higher than 1,000 ft) (Smith 1979).
- b. Southcentral Region (May-October). The following limited observations partially describe deer feeding areas in Southcentral Alaska:
In PWS, deer feed along the margins of muskeg openings interspersed within the climax spruce-hemlock forest (ADF&G 1976b).
On islands that are large and high enough to have alpine areas, deer feed on the abundant high-quality alpine plants.
Deer often frequent slide areas, which are common in the alpine zone.
- c. Southeast Region (mid June-November). Deer range widely from sea level to alpine areas. Resident deer continue to utilize lower-elevation winter range, while migratory deer move to alpine and subalpine habitats (Schoen and Kirchhoff 1985). Alpine and subalpine habitat is preferred during summer. Clear-cuts are used but not preferred, and use of old-growth forest is extensive (Schoen et al. 1979, 1981). Alpine areas are avoided in fall (Schoen et al. 1981).

2. Winter:

- a. Southwest Region (September-April). On Kodiak Island, feeding activities occur in grass-shrub thickets composed of cottonwood, alder, and willow; in spruce forests; along windblown capes and bluffs with scattered heath patches; on steep, windblown, and southerly exposed hillsides; near beach-timber fringes during severe winters; and within intertidal areas (Smith 1979).
- b. Southcentral Region (November-April). Winter feeding areas in PWS are generally more limited than in the remainder of Alaska's deer range because a higher proportion of land is muskeg, the timberline is lower, and the beach-fringe area is narrower (ADF&G 1976b). Deer remain just below the snow line, moving up or down with the changing snow depths (Reynolds 1979). When snow depths increase and preferred evergreen forbs become unavailable, deer are forced to lower elevations to feed in the coniferous forests adjacent to beaches. Shishido (1984) found that deer use the forest's edge more than its interior. If snow depths increase and

beach-fringe feeding areas become depleted, deer are forced to feed on the beaches (ibid.).

During a winter of extremely mild snow conditions, Shishido (1984) noted that mountain hemlock forests (where at least 50% of the net timber volume is mountain hemlock) in PWS received more deer use than the spruce, western hemlock, or spruce/western hemlock forest types. However, Shishido points out that when the mountain hemlock component of this forest type is beyond 50% of the net timber volume, deer use may decline rapidly because of the more closed canopy. The transition forest type, a mix of western hemlock, mountain hemlock, and Sitka spruce, found in marginal or extreme site conditions (such as along muskeg edges or beach-fringe stands), was also used heavily by deer.

Shishido (1984) reported that deer preferred to use stands with a relatively low tree basal area (and, therefore, with an open tree canopy), large amounts of Vaccinium spp. stems and Coptis aspleniifolia biomass, a heterogeneous canopy structure (usually associated with uneven-aged old-growth forest), and relatively greater net timber volume.

- c. Southeast Region (December-March). Optimum deer winter range consists of high-volume (greater than 30 mmbf/acre) old-growth stands on productive, well-drained sites with large, irregularly spaced trees and abundant bunchberry, blueberry, and salmonberry in the understory (Schoen et al. 1981a, Schoen and Kirchhoff 1983b). Winter use is correlated with the abundance of blueberry, bunchberry, and fern-leaved goldthread. (Rose 1982). Dispersal of deer is greater during mild winters, with greater use of low-volume (less than 30 mmbf/acre) timber stands (Schoen and Kirchhoff 1983b). Use of regrowth stands of 0-147 years is proportionately low (Wallmo and Schoen 1980, Rose 1982). Low-elevation (less than 1,000 ft) old-growth forests are preferred, whereas clear-cuts, muskegs, and upper forest areas that accumulate deep snow are avoided (Schoen et al. 1981, Schoen and Kirchhoff 1983b).

3. Spring:

- a. Southeast Region (April-mid June). On Annette Island, Rose (1982) found deer using young (3 to 25 years old) snow-free clear-cuts during spring. Schoen et al. (1981a) and Schoen and Kirchhoff (1983b) observed radio-collared deer using a variety of old-growth stands, including low-volume sites, during spring.

C. Factors Limiting Availability of Food

- 1. Winter. Excessive snowfall (deeper than 10-12 in or 25-30 cm) can prevent deer from obtaining critical food resources (Hanley 1984, Reynolds 1979). Snow is the major factor

limiting availability of forbs (Jones 1975, Weger 1977, Bloom 1978, Harestad 1979, Barrett 1979, Schoen and Wallmo 1979, Schoen et al. 1981b, Rose 1982, Schoen and Kirchhoff 1983b). Overstory characteristics determine snow interception by forest stands (Jones 1975, Bloom 1978, Harestad and Bunnell 1979, Kirchhoff and Schoen 1985). Snow is substantially deeper in muskegs, clear-cuts, and other open areas than in old-growth forests (Merriam 1971, Bloom 1978, Barrett 1979, Schoen and Wallmo 1979). High-volume old-growth stands with large, irregularly spaced trees provide an optimum winter habitat because of the quantity and availability of nutritious evergreen forage under severe winter conditions (Schoen et al 1985, Kirchhoff and Schoen 1985).

Harvesting old-growth stands by clear-cutting results in reduced forage availability even where or when snow accumulations do not limit availability. Clear-cuts (0 to 30 years old) are characterized by high understory plant biomass, with the major component being shrubs (Alaback 1982). Second-growth stands (30 to 150 years old) have depauperate, unproductive understory vegetation (Jones 1975, Robuck 1975, Alaback 1980, Wallmo and Schoen 1980, Schoen et al. 1981b, Alaback 1984).

Silvicultural thinning of second-growth stands maintains a more open canopy and may increase understory productivity. Silvicultural objectives may be incompatible with habitat improvement, however, because maintaining lower timber stand density may conflict with silvicultural objectives of full site utilization for timber production (Harris and Farr 1979). The degree to which improved understory production is negated by increased snow accumulation in thinned stands is not known (Kessler 1982). Alaback and Tappeiner (1984) found generally poor and variable understory response to precommercial thinning after five-to-seven years, with productivity often decreasing at the expense of tree-seedling productivity. Secondary hemlock canopies appeared to be one result of thinning that is likely to shade out understory species. Stands thinned at varying intensities on Heceta Island were similarly unproductive (Kessler 1982).

Logging slash can also limit food availability. The effects of slash and deep, soft snow in limiting food availability and increasing energy requirements for locomotion are similar and can be additive (Parker et al. 1984). The depth and amount of logging slash and regrowth shrub biomass have interactive effects (i.e., each exaggerates the effect of the other). As logging slash increases and the level of shrub biomass increases over that which is optimal for access to portions of the summer range, the difference between energy expenditure for foraging and resultant energy intake per unit of expenditure increases (Hanley 1984.)

Low coastal winter ranges may be depleted when population densities increase as a result of a trend of several years of mild winter weather (Reynolds 1979).

An intensive logging program creating extensive clear-cuts could reduce food accessibility because of the resultant greater snow depths in the clear-cuts attributable to the removal of the forest canopy (ibid.).

Competition with cattle and elk can lead to winter range deterioration (Erickson 1958).

Oil contamination of kelp on critical winter beaches could remove a life-sustaining food item (Reynolds 1979).

2. Spring. Persistence and depth of snow cover, reduced productivity of forage in even-aged stands, and logging slash affect food availability, as described for winter conditions.
3. Summer/fall. Logging slash can restrict access to forage plants (Hanley et al. 1984, Wallmo and Schoen 1980).

D. Factors Affecting Quality of Food

1. Late fall/winter. Vaccinium ovalifolium growing under mature-canopy conditions have higher protein values than in clear-cuts (Billings and Wheeler 1979). The quality of Cornus canadensis was highest in high-volume old-growth forest stands and lowest in clear-cuts in late fall (Schoen and Kirchhoff 1984). Many plants remain green under mature forest canopies during winter. Herbaceous plants and evergreen forbs are highly digestible compared to hemlock and to deciduous shrubs. Usnea spp. lichens are also highly digestible but have low protein content (Schoen and Wallmo 1979).
2. Spring/summer/early fall. Long photosynthetic periods and alpine plant adaptations result in high nitrogen levels in alpine vegetation. Plants in early growth stages are most nutritious. Topographic variation affects plant phenological succession. The degree of topographic variation influences the extent and location of variation in nutritional values over the growing period, with a high degree of topographic variety resulting in high-quality forage being available over longer periods (Klein 1979).

E. Feeding Behavior

1. Movements. Deer make elevational movements seasonally in response to snow conditions and forage availability (Barrett 1979, Schoen and Kirchhoff 1985). Elevational movements can be hampered by the presence of clear-cuts adjacent to beach fringe habitat (Schoen and Kirchhoff 1985).
2. Use of edge. Deer winter use of edge habitats does not increase between clear-cuts and old-growth habitat types (Kirchhoff et al. 1983).
3. Snow conditions. Deer will pass through up to 12-to-18 inches of snow (to feed on ferns) (Smith 1979), depending on the snow conditions.

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

1. Southwest Region. Because deer on Kodiak Island are usually found from sea level to 1,000 ft during late May/early June, it appears that they give birth at relatively low elevations in heavy cover (Smith 1984).
2. Southcentral Region. Fawns are usually born in fringes of trees adjacent to lowland muskegs or beaches (ADF&G 1976a).
3. Southeast Region. Fall habitats of migratory and resident deer overlap enough to provide regular genetic interchange (Schoen and Kirchhoff 1985). Deer exhibit increased use of muskeg habitats during the rut in fall (ibid.).

B. Reproductive Seasonality

The breeding season begins at mid October and peaks in mid November, with fawns born from late May to early June.

C. Reproductive Behavior

Bucks are polygamous and establish dominance by mild pushing contests, antler presentation, pawing, and stamping. From October to March, females are receptive to breeding for 24 to 36 hours during estrus. The estrus cycle of female deer is 24 to 28 days and may be repeated several times if conception does not occur (ADF&G 1976a). Bucks incur large weight losses during the rut, and by December their fat reserves are often depleted.

D. Age at Sexual Maturity

Most does breed at 1.5 years (their seasonal fall). The quantity and quality of available forage can affect the age at which they first breed (Cowan 1956).

1. Southeast Alaska. In general, fawns and older female does do not breed (Johnson 1985).

E. Litter Size/Pregnancy Rate

Data describing litter size are not available for Kodiak or PWS.

1. Southeast Alaska. Female fertility rates are considered to be similar to those of Columbian black-tailed deer (*Odocoileus hemionus columbianus*) on Vancouver Island; the subspecies is less fecund and attains maximum fertility more slowly than other deer species (Thomas 1983). In-utero pregnancy rates are generally high, averaging nearly two fetuses per adult doe in areas on Admiralty and Chichagof islands (Schoen et al. 1982, Johnson 1985).

F. Gestation Period

The average gestation period is 203 days, with a range of 183 to 212 days (Cowan 1956).

VI. FACTORS INFLUENCING POPULATIONS

A. Natural

1. Winter severity (temperature, frequency of severe winters, snowfall, and duration of winter season). Mortality during winter is generally recognized as the most significant regulating factor on deer populations (Merriam 1968, 1970, 1971; Jones 1975; Taber and Hanley 1979). Starvation

accounts for 80% of winter mortality, with fawns and animals in age classes over five years old comprising the bulk of mortality and a higher proportion of fawn losses on ranges in good (vs. heavily used) condition (Klein and Olson 1960). Mainland deer populations, though seldom as high as island populations, are more static than island populations, probably due to uniformly more severe winter conditions and mortality factors (Olson 1979).

2. Availability and quantity of critical old-growth winter habitat. The availability and quantity of critical old-growth forest is a factor that limits deer populations (Hanley 1984, Schoen et al. 1985).
3. Quantity and quality of summer range. Winter survival also depends on the ability of deer to accumulate fat during summer (Regelin 1979). The condition and extent of summer range are primary factors affecting the size of animals and the population density and age structure. Primary factors influencing the quality and quantity of available deer forage are the degree of altitudinal and topographic variation and the relative proportions of alpine and subalpine areas over the range of a population (Klein 1963, 1965, 1979).
4. Predation. Predation by brown bears, wolves, black bears, and coyotes can reduce deer numbers (ADF&G 1976b, Reynolds 1979). Wolf predation can reduce numbers and delay population recovery following heavy winter losses on larger islands or on the mainland and is considered a factor that can accelerate population trends (Merriam 1970; Jones and Maser 1983; Van Ballenberghe and Hanley, in press). Wolves were introduced on Coronation Island, a small previously wolf-free island, where they reduced the deer population to a very low level (Merriam 1970). The retention of "islands" of deer winter range surrounded by clear-cuts and regrowth could result in concentrating deer during severe winter conditions and making populations more vulnerable to predation (Schoen et al. 1985).
5. Disease. Disease is not considered a limiting factor on deer abundance (Klein and Olson 1960, Klein 1965, Merriam 1970). Lungworm infections, however, can be a significant mortality factor for fawns and is thus a population-regulating factor (Johnson 1985).
6. Competition. Competition with elk for available winter range can limit deer populations (Taber and Raedeke 1980).
7. Habitat deterioration. Habitat deterioration due to natural disasters such as earthquakes, fires, and landslides can remove important areas of habitat (e.g., beach-fringe timber, which is valuable winter range).

B. Human-related

A summary of possible impacts from human-related activities includes the following:

- ° Alteration of habitat

- Reduction of food supply
- Harassment resulting in disturbance/displacement
- Barriers to seasonal movements
- Competition for available winter range with cattle
- Overharvest
- Predation by domestic dogs
- Pollution of water and/or food supply

(See the Impacts of Land and Water Use volume of this series for additional information regarding impacts.)

1. Southeast Region. The projected impacts of clear-cut logging on deer populations are a result of 1) significant reduction of forage supplies and impeded access to deer for one to two years after clear-cutting, 2) reduced summer use of clear-cuts from 4 to 15 years due to dense shrub growth and residual slash, 3) reduced summer use of clear-cuts from 15 to 30 years due to closing of stands, shading out of forbs, and dense shrub production, 4) reduced summer use of regrowth stands for approximately 160 to 200 years due to shading out of forage, and 5) reduced winter use of clear-cuts and regrowth stands through the length of a timber rotation due to high snow accumulations in open clear-cuts and lack of winter foods in closed regrowth stands for approximately 160 to 200 years (Schoen and Wallmo 1979, Wallmo and Schoen 1980).

In summary, "secondary succession of western hemlock-Sitka spruce forest in Southeast Alaska depicts a 15-to-20-year postlogging period with abundant but largely inaccessible forage, followed by perhaps two centuries of usable habitat with sparse forage" (Wallmo and Schoen 1980). Schoen et al. (1985) have developed a model to predict relative changes in deer populations resulting from planned timber harvesting in Southeast Alaska with a 100-year rotation schedule. Reductions of deer populations below 50% of current levels in 74% of drainages to be logged are predicted at the end of the planned rotation.

Deer densities and harvests have declined up to 75% in drainages on Vancouver Island following logging (Hebert 1979). Deer population declines of 25 to 75% are projected in western Washington in areas slated for intensive logging within the next 50 years (Taber and Raedeke 1980). Schoen et al. (1981b) suggest that early theories that deer responded positively to logging of old-growth throughout North America were based on inadequate data or faulty assumptions.

VII. SPECIAL CONSIDERATIONS

Deer populations are often geographically isolated on small islands. Elk transplants are being proposed for the Southeast Region. Elk compete for many of the same food plants as deer in other areas of Alaska.

Retention of only small areas of critical deer winter range from logging could result in overbrowsing of these areas, concentration of predation, and reduction of carrying capacity during severe winters (Schoen et al. 1982).

VIII. LEGAL STATUS

See the Human Use section in volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.

IX. LIMITATIONS OF INFORMATION

Because deer populations have been moderately high and are still expanding in Southcentral Alaska, the need to gather basic biological data on deer in Southcentral Alaska has been difficult to justify. Quantitative data describing deer distribution and abundance, habitat use and requirements, food habits, and reproductive activities in Southcentral Alaska are therefore lacking or minimal.

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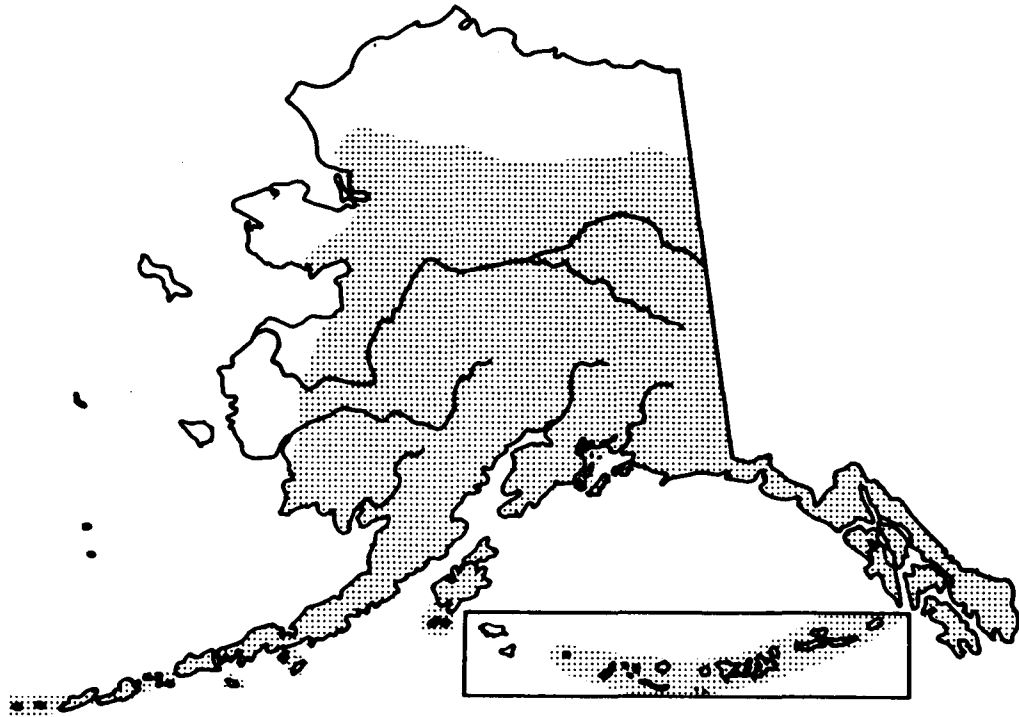
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Bald Eagle Life History and Habitat Requirements
Southwest and Southcentral Regions



Map 1. Range of Bald Eagle (ADF&G 1978)

I. NAME

- A. Common Name: Bald Eagle
- B. Scientific Name: Haliaeetus leucocephalus alascanus
- C. Native Names: See appendix A.

II. RANGE

- A. Worldwide
Bald Eagles are known to occur from northwestern Alaska, through the Alaskan interior, across interior Canada (Mackenzie, Manitoba, southern Ontario, southeastern Quebec, and Newfoundland), south to the Aleutian Islands, Southeast Alaska, Baja California, Arizona, New Mexico, Gulf Coast of southern Texas, Florida, and occasionally in northeastern Siberia (Terres 1980, Gabrielson and Lincoln 1959).

B. Statewide

The largest concentrations of Bald Eagles are found along the coastal areas of Southeast Alaska, the Gulf of Alaska, the Alaska Peninsula, and the Aleutian Islands (excluding the Near Islands). Although not in the densities present in the maritime regions, Bald Eagles are also found along major river drainages of Southwest, Southeast, Western, Interior, and Southcentral Alaska and along the Bering Sea coast north to the Noatak River (Gabrielson and Lincoln 1959). Approximately 45% of the breeding population occurs in Southeast Alaska, 25% in Southcentral Alaska, 20% in the Aleutian Islands, and 10% in the remainder of the state (Hodges 1982).

Bald Eagles normally winter along the southern coasts of Alaska, with some movement of birds, especially immature birds, into British Columbia and the continental United States (ibid.).

C. Regional Distribution Maps

To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for the Southwest and Southcentral regions. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of Bald Eagle distribution has been prepared and may be found in the Atlas that accompanies the Southwest and Southcentral regional guides.

D. Regional Distribution Summary

1. Southwest. Bald Eagles are distributed throughout Kodiak Island, Bristol Bay, the Alaska Peninsula, and the Aleutian Islands (excluding the Near Islands). They breed abundantly from Kiska Island eastward throughout the Aleutian Islands, the Pacific coast of the Alaska Peninsula, and Kodiak Island. They also breed commonly along the shores of Bristol Bay, Iliamna Lake, and Lake Clark (Gabrielson and Lincoln 1959). Although some birds overwinter along the Pacific coast of Southwest Alaska, the majority are thought to migrate east and then south along the Pacific coast, feeding wherever food is plentiful, returning to breed in Southwest Alaska the following spring (USFWS 1980, Beebe 1974). (For more information, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)
2. Southcentral. In Southcentral Alaska, the majority of Bald Eagles are found in the highly productive maritime areas. Eagles also nest along major inland water courses and lakes, with densities declining markedly in the more interior portions of the region. Densities likely reflect differences in food abundance. Seabird colonies, waterfowl concentrations, large fish resources, including frequent salmon runs and even garbage dumps in the coastal region, provide a greater concentration and abundance of food than is found in the interior areas (Mindell 1983). Although some birds overwinter along the Pacific coast, the majority are

thought to migrate south along the coast of the northwestern United States before returning in the spring to breed in Southcentral Alaska (USFWS 1980, Beebe 1974).

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

Over its entire range, the Bald Eagle is typically associated with land/water interfaces - shorelines and riverine areas. This association appears to be related to food sources, but other factors may also be important (Hughes, pers. comm.).

B. Terrestrial Cover Requirements

Bald Eagles are also associated with prominences, which are used for perches and nests; typically, these are the largest trees near land/water interfaces, although cliffs and sea stacks may also be utilized, especially along the steep, rugged coastline of the Aleutians (White et al. 1971, Beebe 1974). Where foliage is available, Bald Eagles show a strong preference for nest sites with overhead and surrounding foliage providing shelter from wind, rain, and sun; large old-growth trees are strongly preferred sites (U.S. Army Corps of Engineers 1979, USFWS 1980).

During harsh weather in the Chilkat Valley in Southeastern Alaska, eagles abandon primary roost areas and seek shelter in conifers and cottonwoods to reduce heat loss (Waste 1982).

In Southwest Alaska, Bald Eagles' preferred habitat lies within several hundred meters of the coastline or along rivers (ADNR/USFWS 1983). In Southcentral Alaska, eagles prefer nest sites along lakes, rivers, and sloughs close to the ocean (Bucaria 1979) or where ice breakup occurs in early spring (Bangs et al. 1982).

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

Throughout their habitat, Bald Eagles are highly opportunistic feeders. They may scavenge various forms of carrion and/or prey upon fish, small mammals, or birds (Beebe 1974). Fish, however, appear to be the preferred food item of Bald Eagles (Wright 1953). In coastal areas, shorelines are often searched for stranded or dead fish (Beebe 1974). Winter-killed deer carcasses are scavenged in late winter-spring in Southcentral and Southeast Alaska (Hughes, pers. comm.). According to Beebe (1974), in coastal areas crabs, octopi, and other tidepool animals are often prey for Bald Eagles.

1. Southwest Region. In the Aleutians, Murie (1940) found the food items of Bald Eagles to be 81% birds (73% of which were seabirds), 8.5% fish, and 7% mammals (none of which included sea otters). Sherrod et al. (1976), however, found that sea otter pups were regularly depredated by nesting adult Bald Eagles. Gabrielson and Lincoln (1959) reported that in the Aleutians eagles feed mainly on seabirds (e.g., murrelets, shearwaters, and fulmars). White et al. (1971) discovered

that on Amchitka Island the Bald Eagle's diet consisted of 26% birds, 28% fish, and 46% mammals.

Inland in Southwest Alaska, food is probably a limiting factor, as it is in the interior for breeding Bald Eagles. During late June on the Tatlawiksuk River, an adult Bald Eagle was seen eating lungs from a moose carcass (Mindell and Dotson 1982).

2. Southcentral Region. On the Kenai NWR, salmon comprised a major portion of the summer diet of Bald Eagles. Also, eagles were found to utilize streams where spawning rainbow trout (Salmo gairdneri) and longnose suckers (Castostomus castostomus) occurred. Eagles hunt and scavenge in both summer and winter. Eagles were observed feeding on dead moose in the winter and were often caught by trappers using exposed baits (Bangs et al. 1982).

B. Types of Feeding Areas Used

Eagles often congregate in large numbers along salmon-spawning streams to feed on spawned-out fish, and in coastal areas, as previously noted, shorelines are often searched for stranded or dead fish (Beebe 1974). Occasionally, Bald Eagles take live fish from lakes and streams (Grubb 1977) and from the ocean surface (Westlund, pers. comm.).

Lakes with potential food supplies bordered with strips of mature timber and small knolls for observational sites are probably very attractive to foraging eagles (Bangs et al. 1982).

C. Factors Limiting Availability of Food

High prey visibility is important for foraging success. Fishing success is reduced on lakes with turbid water, and the effect of wind on water also lowers fish-capture rates (Grubb 1977).

D. Feeding Behavior

Bald Eagles frequently locate a fish from a conspicuous perch, then swoop down and strike. They may also locate fish while flying over the water, then swoop and strike. They also wade into shallow water and catch fish with their beaks, characteristically submerging their heads or standing on ice and reaching into the water with talons or beaks (Southern 1963).

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

As previously mentioned, Bald Eagles typically nest in large trees, although they may nest on rocky cliffs, pinnacles of rock, and occasionally on the ground (Gabrielson and Lincoln 1959). Nests are usually situated within a few hundred meters of water in sites that afford both security and isolation (Sherrod et al. 1976). The nest is usually a large structure of sticks lined with seaweed, vines, grass, plant stalks, and sod. The center of the nest is lined with leaves, mosses, straw, and feathers, usually to a depth of four inches (Gabrielson and Lincoln 1959). Kalmbach et al. (1964) computed nests in Alaska to average about 1.7 m high and 2.1 m in diameter. They are generally used by a mated pair in

successive years and added to each year. Bald Eagles normally will not begin a nest where human disturbance is evident (Call 1978).

Throughout the range of the Bald Eagle the general attributes of nesting trees are similar, although the preferred species of nesting tree varies with location (Lehman 1978).

Nest trees are usually close to water, have a clear view of the water, are the oldest and largest living members of the dominant overstory, and often provide a sparse cover above the nest (Hensel and Troyer 1964, Lehman 1978, Bangs et al. 1982). Bald Eagles prefer to nest in trees, even if the tops may be dead (Call 1978).

1. Southwest Region. In the Aleutians, where trees are absent, Bald Eagles nest on coastal ridges, sea stacks, and hillsides (Gabrielson and Lincoln 1959, White et al. 1971, Early 1982). Nests on Amchitka Island are unusual in that they are virtually rebuilt every year (Sherrod et al. 1976). Murie (1940) found eagles in the Aleutians using dried grasses, stems of wild parsnip (Heracleum lanatum), moss, kelp, vegetable debris, and driftwood from the beaches to build nests. In this region, eggs are occasionally laid on bare ground, with little evidence of nest construction. Nests on Kodiak Island occur in isolated cottonwood stands (Populus balsamifera) and on cliffs (Troyer and Hensel 1965).
2. Southcentral Region. On the Kenai NWR, the majority of Bald Eagle nests were in cottonwood trees (Populus trichocarpa), although aspen (Populus tremuloides) was also commonly used (Bangs et al. 1982). In Kachemak Bay and Prince William Sound, eagles were found nesting in large cottonwood trees adjacent to a river or tidal slough and in large sitka spruce (Picea sitchensis) trees close to the coast (Shea, pers. comm.).

B. Reproductive Seasonality

Bald Eagle nesting occurs at roughly similar times in much of the state. Nesting activity begins in mid-to-late April in Southeast Alaska (Hensel and Troyer 1964, Robards and Hodges 1977) and Kodiak Island (Chrest 1964) and late April or early May along the Tanana River (Ritchie 1982). All birds have begun incubating by the end of May. Incubation lasts about 35 days. The young fledge after approximately 72-75 days and have fledged most nests by late August.

In the Aleutians, a somewhat different pattern occurs (Bangs, pers. comm.).

1. Southwest Region. On Amchitka, nest building may begin as early as late January (White et al. 1971, Sherrod et al. 1976). Egg laying takes place in mid May. Most eaglets fledge by the first week of July (Early 1982).
2. Southcentral Region. On the Kenai Peninsula, nest building begins in April, and egg laying occurs in early May. Most eagles fledge by mid-to-late July (Bangs, pers. comm.).

C. Reproductive Behavior

Aerial displays thought to be associated with mating or pair formation have been observed during the last few weeks prior to the northward migration and during migration itself (Ingram 1965, Grewe 1966). Breeding Bald Eagles establish territories during early spring and vigorously defend them against other Bald Eagles until their young become independent (Hensel and Troyer 1964).

D. Age at Sexual Maturity

Bald Eagles usually do not breed before they have acquired the white head and tail plumage characteristic of adults at about five years of age (Brown and Amadon 1968). Four-year-old birds, which do not have a pure white head, are often classified as mature birds regardless of whether they breed or function as adults (ibid.).

E. Fecundity

In most regions, only two eggs are produced, but in some areas the full clutch is often three and, rarely, four eggs (Beebe 1974). Although all eggs may hatch, often only the largest chick survives to maturity (Bent 1937). Production for Bald Eagle populations in varying portions of Alaska has been reported to range from .74 to 1.96 young per active nest (Bangs, pers. comm.).

1. Southwest Region. Sherrod et al. (1976) reported 1.25 young per active nest on Amchitka Island in 1971 and 1972. On Kodiak Island, the number of young per active nest ranged from .74 to 1.20 between 1963 and 1970 (Sprunt et al. 1973).
2. Southcentral Region. On the Kenai National Wildlife Range in 1979 and 1980, Bangs et al. (1982) found 1.0 and 1.4 eaglets per active nest, respectively.

VI. FACTORS INFLUENCING POPULATIONS

A. Natural

1. Habitat. Nesting habitat may be potentially limiting. Bald Eagles, as noted, prefer large trees near water. Over 4,000 nest trees have been recorded in Southeast Alaska, and none was located in a young stand of timber (USDA/USDI 1972). High winds may cause a loss of nesting trees through windthrow (Truslow 1961). Windthrow of old growth is relatively common in Southeast Alaska (USDA 1974). Forest fires also can destroy nesting habitat. For instance, Bangs et al. (1982) note that eagle nests are absent from burn areas except where mature stands have escaped extensive fire damage; over 35% of the boreal forest of the Kenai NWR has burned in the last 40 years. Beavers have been known to cut down nest trees in Interior Alaska (Ritchie 1982).
2. Fatricide. Several observers have noted that fratricide among nestlings is not uncommon and may be an important source of mortality among the young (Dixon 1909, Brown and Amadon 1968, Bent 1937). Bent reported that frequently only one nestling survives, although two or three or, more rarely, four eggs may be laid. This appears to be a less important

factor in Alaska, where as many as 35% of successful nests produce two young (Sprunt et al. 1973).

3. Productivity:

- a. Weather. In Alaska, it is not known whether severe weather may affect the productivity of eagles. It is known that severe storms may result in temporary nest abandonment, causing destruction of eggs or young (Evans 1982). Postupalsky (1967) believes winter severity has an impact on the reproductive success of eagles, and Bangs et al. (1982) believe this could be a factor on the Kenai Peninsula.
- b. Food resources. Food availability may also influence production. Food availability seems to affect the number of eaglets surviving to fledge in each nest, rather than the number of pairs that nest (Bangs et al. 1982).
- c. Intermittent breeding. Intermittent breeding has been observed in Bald Eagles (Broley 1947, Chrest 1964, Brown and Amadon 1968). Mated pairs may occupy and defend a territory but not lay eggs that season. The cause is unknown. Speculations include physiological upset, production of fewer eggs with increasing age, or an increase in eagle density, with a resulting decline in the food supply (Chrest 1964).
- d. Accidents. Young eagles may sometimes fall from their nests and perish. Birds younger than seven-to-eight weeks probably will not survive if they land in dense growth where adults cannot reach them (Dunstan 1978). The first flights of fledglings are also hazardous (Sherrod et al. 1976).
- e. Infertility. A proportion of all eggs laid are infertile, which may be a result of pesticides, disturbance, or an inability to reproduce (Brown and Amadon 1968).
- f. Smoke. Smoke from fires is also a potential hazard to nesting eagles (Ritchie 1982). This disturbance factor may cause abandonment of the nest, because they are unable to see adequately.

4. Disease and parasites. A variety of diseases and parasites are reported to infect eagles in other states. In Alaska, none occurs frequently or is considered a limiting factor (Hughes, pers. comm.).
5. Predation. Occasionally ravens, crows, magpies, and, under unusual circumstances, gulls prey on eggs and small young (Chrest 1964, Hensel and Troyer 1964, Sprunt and Ligas 1964, Fyfe and Olendorff 1976).
6. Mortality. Sherrod et al. (1976) estimated adult mortality to be 5.4% per year and a collective mortality of 90% or more for subadult birds before reaching breeding age on Amchitka Island, Alaska.

B. Human-related

A summary of possible impacts from human-related activities includes the following:

- Pesticide pollution of water and/or food
- Reduction of food supply
- Disturbance during nesting/abandonment of young
- Destruction of nesting habitat
- Electrocution on transmission wires
- Illegal shooting

(See the Impacts of Land and Water Use volume of this series for additional information regarding impacts.)

VII. LEGAL STATUS

A. Federal

Bald Eagles, their nests, and nest trees are fully protected under the Bald Eagle Protection Act of 1940. In addition, Bald Eagles in the continental United States are protected as an endangered species. Bald Eagles in Alaska are not currently endangered, and the Alaska subspecies is not on the endangered species list.

B. State

The state has no additional laws regarding Bald Eagles.

C. Population Management

The USFWS has a statewide raptor management plan; however, the Southwest and Southcentral regions have no Bald Eagle management programs in progress.

VIII. SPECIAL CONSIDERATIONS

The following problems should be given special consideration in Alaska:

- Disturbance - timing clauses
- Silvicultural options for maintaining nest trees
- Loss of habitat due to recreational and industrial development
- Prey populations
- Water quality
- Shooting

IX. LIMITATIONS OF INFORMATION

Only limited information on Bald Eagles is available for the Southwest and Southcentral regions of Alaska.

Specifically, there is insufficient information on the following:

- Age-specific mortality
- Longevity
- Natality
- Prey populations - seasonal food items
- Information on the timing of molting is limited and contradictory (U.S. Army Corps of Engineers 1979)

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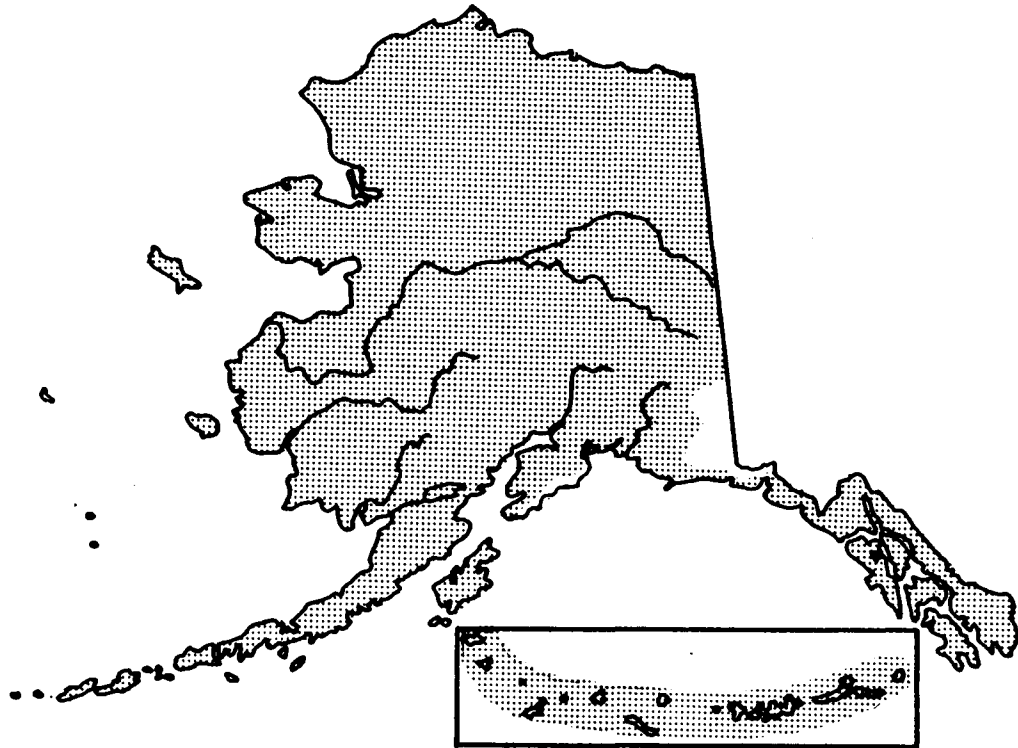
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Dabbling Ducks Life History and Habitat Requirements
Southwest, Southcentral, Arctic, Western, and Interior Alaska



Map 1. Range of dabbling ducks (Bellrose 1976)

I. NAME

- A. Common Names: Dabbling ducks, puddle ducks, or surface-feeding ducks
- B. Scientific Classification
 - 1. Family. Anatidae
 - 2. Subfamily. Anatinae
 - 3. Tribe. Anatini
- C. Native Names: See appendix A.
- D. Species Commonly Occurring in the Southwest Region
 In the Southwest Region, the dabbling duck population consists of northern pintail (Anas acuta), mallard (A. platyrhynchos), American wigeon (A. americana), green-winged teal (A. crecca), northern shoveler (A. clypeata), and gadwall (A. strepera) (Gabrielsen and Lincoln 1959). Lesser numbers of other dabbling

duck species such as Eurasian wigeon (A. penelope), use the area as well (ibid.).

- D. Species Commonly Occurring in the Southcentral Region
In the Southcentral Region, the dabbling duck population consists primarily of American wigeon, mallard, northern pintail, and green-winged teal. Lesser numbers of northern shoveler, gadwall, and other dabbling duck species use the region as well (ibid.).
- E. Species Commonly Occurring in the Arctic Region
In the Arctic Region, the dabbling duck population consists primarily of northern pintail, American wigeon, and northern shoveler. Lesser numbers of mallard and green-winged teal also occur (Rothe, pers. comm.).
- F. Species Commonly Occurring in the Western and Interior Regions
In the Western and Interior Regions, the dabbling duck population consists primarily of American wigeon, northern pintail, and mallard. Lesser numbers of green-winged teal, northern shoveler, and other dabbling duck species use the area as well (Gabrielson and Lincoln 1959).

II. RANGE

- A. Worldwide
Dabbling ducks are cosmopolitan in distribution, with variations in abundance related to seasonal changes in habitat conditions (Terres 1980).
- B. Statewide
Dabbling ducks are abundant and widely distributed seasonally throughout the state wherever habitat conditions are favorable (Gabrielson and Lincoln 1959).
- C. Regional Distribution Maps
To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for each region at 1:250,000 scale. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of selected fish and wildlife species has been prepared for all regions except Southeast and may be found in the Atlas that accompanies each regional guide.
- D. Regional Distribution Summary
 - 1. Southwest. In general, dabbling ducks are found throughout the Southwest Region at elevations below 1,200 ft. Major concentrations, however, occur in estuaries, lagoons, river deltas, tidal flats, and lowland ponds. In the Bristol Bay area, the largest concentrations of dabblers occur during the spring and fall migrations, whereas Kodiak and the Aleutian Islands are important wintering areas (King and Lensink 1971). (For more detailed narrative information, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)
 - 2. Southcentral. Dabbling ducks are found in favorable habitat throughout the Southcentral Region. Because of the lateness

of snowmelt and vegetation growth at higher elevations, the most favorable habitat is located below 1,000 ft elevations. In the Southcentral Region, major concentrations of dabbling ducks occur during the spring and fall migrations along the tidal marshes of Cook Inlet (map 2). During a 1962 spring survey, an estimated 100,000 birds were observed utilizing the Susitna Flats area (Sellers 1979). The many estuaries and tide flats of Prince William Sound (PWS) and the extensive tidelands of the Copper River Delta (CRD) are also important concentration areas. Estuarine and tidal flat areas of PWS and the CRD are important wintering areas for some species (Timm 1977). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)

3. Arctic. In the Arctic Region, major concentrations of dabbling ducks occur during the spring and fall migrations along the coast, in the major river valleys, and through the major mountain passes that connect the Arctic Region drainages to the Yukon River (King, pers. comm.). Dabbling ducks breed throughout the arctic coastal plain (Derksen et al. 1981), the lowland areas of the Seward Peninsula, and the Kobuk, Noatak, and Selawik drainages (Grauvogel, pers. comm.). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Arctic Region.)
4. Western and Interior. Dabbling ducks are found throughout the Western Region in areas of favorable habitat. This habitat consists primarily of numerous thaw lakes scattered across lowland tundra and the tidally influenced coastal zone (King Lensink 1971). The Yukon-Kuskokwim delta (YKD) is the largest and most productive area of habitat in the region; however, duck populations are usually less dense than in the Interior Region (ibid.). Favorable habitat for dabbling ducks within the Interior Region is associated with river valleys, which in many locations expand into broad floodplains of relatively low elevation. These floodplains contain innumerable lakes and streams that provide habitat for large populations of waterfowl (ibid.). Major areas of concentration include the Minto flats (King, pers. comm.), the Yukon Flats, the Koyukuk and Kanuti flats, the Innoko flats area, and the Tetlin-Northway area (ibid.).

III. PHYSICAL HABITAT REQUIREMENTS

Dabbling ducks are very mobile and opportunistic, characteristics that allow them to take advantage of a wide variety of habitat types, depending upon need and availability (Bellrose 1976). Preferred habitat types are closely associated with water, ranging from fresh water to salt and/or brackish water (King and Lensink 1971). Dabblers, in particular, are frequently found on shallow, small ponds or lakes bordered by shrubs, trees, or aquatic plants (Bellrose 1976).

Coastal habitats are also frequently used by dabblers. A study of coastal habitats in Alaska (Arneson 1980) found that dabbling ducks are the most ubiquitous of waterfowl. In the coastal zone, they are found most abundantly on protected delta water, lagoon water, and salt marshes, but they are also found on eight other habitats. During the study, only subtle differences in habitat selection among species were evident. Pintails, for instance, frequent lagoon island sand much more than other dabblers; green-winged teal are often on exposed mud flats; and American wigeon are more abundant on protected delta water and mud. Quimby (1972) studied waterfowl use of different plant communities at Chickaloon Bay in upper Cook Inlet (map 2). Waterfowl use occurred in 8 of 10 types, with most use occurring in the marsh, floating marsh, and mud flat community types (ibid.). The marsh community contains permanent brackish ponds of various sizes and depths bordered by sedges (Carex spp.) and bulrushes (Scirpus spp.). The ponds contain food plants and are good feeding, nesting, and resting areas (ibid.). The floating marsh community is similar but has fewer, deeper open-water areas, greater plant species diversity, and mats of floating vegetation. This type provides large areas of suitable habitat, but less nesting occurs because there is less open water. The mud flat community was near the upper limit of the tide and was utilized mostly by fall-migrating ducks resting and feeding in that type (ibid.).

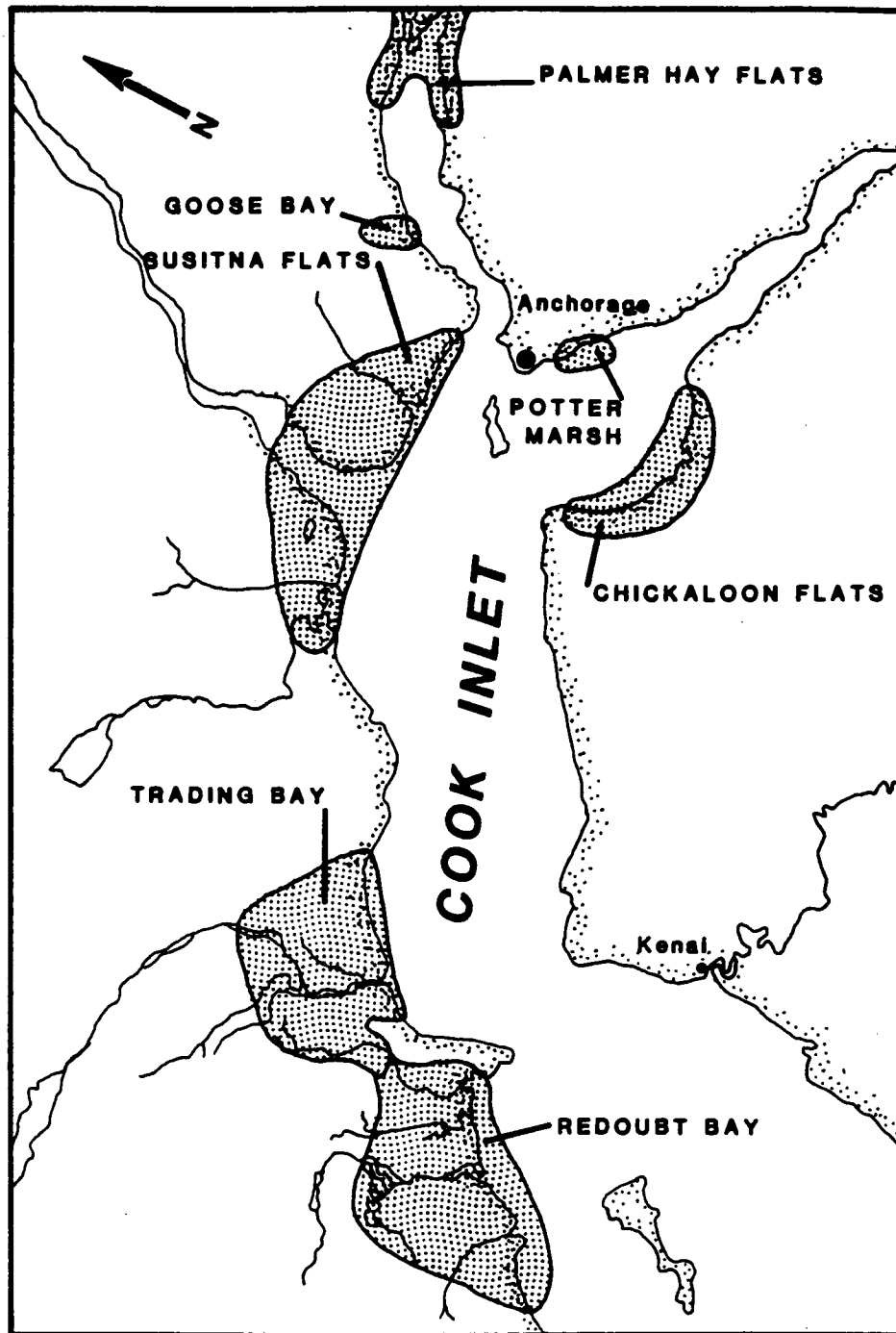
A. Arctic Region

1. Pintail. Pintails at Icy Cape were observed more frequently in shallow and deep Arctophila (Class III and IV) wetlands in June and July; shallow Carex (Class II) wetlands were used frequently in August. At Storkersen Point, habitat use by pintails was not limited to any particular wetland type, although shallow Arctophila (Class III) and basin-complex (Class IV) wetlands were used significantly more (Bergman et al. 1977). Arctophila wetlands have been found to be preferred in some areas (Derksen et al. 1979).
2. Green-winged teal. At Icy Point, migrating birds, which landed in the area, were noted to feed along pond edges in the salt marsh (Lehnhausen and Quinlan 1981).
3. Northern shoveler. At Icy Cape, migrating birds were noted to land in the mainland marsh and feed in the brackish ponds; shovelers were also observed on the tundra on shallow and deep Arctophila ponds (Class III and IV) (ibid.).
4. American wigeon. At Icy Cape, migrating birds were noted to feed and rest in the salt marsh; two pairs were also observed in the tundra, feeding on shallow Arctophila ponds (Class III) (ibid.).

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

Dabbling ducks have a wide seasonal variety of food items. They are highly opportunistic and will concentrate on food items most readily available to them (Peret 1962, Timm 1975). The following food items are known to be utilized by dabbling ducks during



Map 2. Major coastal marshes of Upper Cook Inlet (Campbell 1984).

portions of the year (Bellrose 1976, Bartonek 1972, Quimby 1972, Sugden 1973). This list is incomplete but shows the wide diversity of food items utilized by ducks.

Animal species - larval and flying forms of invertebrates, including:

Water fleas (Cladocera)
Amphipods (Amphipoda)
Mayflies (Ephemeroptera)
Dragonflies (Odonata)
Water striders (Hemiptera)
Caddis flies (Trichoptera)
Black flies (Diptera)
Mosquitoes (Diptera)
Snails (Gastropoda)
Spiders (Arachnoidea)
Salmon carcasses
(Onchoryhnchus spp.)
Crustaceans (Crustacea)
Mollusks (Mollusca)
Earthworms (Oligochaeta)
Stickleback (Gasterosteus aculeatus)

Plant species - vegetative parts and seeds of numerous plants, including:

Pondweeds (Potamogeton spp.)
Cattails (Typha spp.)
Bulrush (Scirpus spp.)
Sedges (Carex spp.)
Horsetails (Equisetum spp.)
Algae (Cladophoraceae)
Grasses (Graminae)
Mares-tail (Hippuris spp.)
Cultivated
grains (e.g., barley)
Buttercup (Ranunculus spp.)

Dabbling ducks prefer an early season diet high in animal matter, changing to a diet high in plant matter as the season progresses (Bartonek 1972, Sugden 1973). This seasonal change is related to both the availability and the nutritional value of food items (Sugden 1973, Krapu 1974). The rapid early growth of juveniles and the nutritional requirements of prebreeding and breeding adults require food sources high in protein. Krapu (1974) observed that female pintails fed heavily on invertebrates before and during egg laying. Esophageal contents before egg laying averaged $56 \pm 27.1\%$ animal matter and during egg laying $77.1 \pm 11.6\%$. Invertebrate consumption declined sharply after the laying period (ibid.).

Bartonek (1972) found that juvenile American wigeons (Class IIa) contained an average of $66 \pm 22\%$ animal matter in their esophagi, whereas older juveniles (Class IIIa and flying) had only $12 \pm 20\%$ animal matter in their diet. Adult American wigeons examined during the same study contained an average of $31 \pm 34\%$ animal matter (ibid.). This represents significantly more animal matter in the diet of the adult wigeon than had been previously recorded (Bellrose 1976, Johnsgard 1975). Sugden (1973) found similar results in the American wigeon, with animal food dominating the diet at first, being largely replaced by plant food after three weeks of age.

Mallards also have a high percentage of animal material in their early season diets (Bartonek 1972). A small sample of juvenile

mallards (class IIc) had 99% animal matter in their esophagi, whereas a flying juvenile had only 35% animal matter (ibid.). Sugden (1973) found that juvenile northern pintails followed a similar pattern, with up to 98% of their early diet comprised of animal matter. The percentage of plant material in the diet increased as the ducks grew (ibid.).

1. Southcentral Region: Cook Inlet (from Timm and Sellers 1979). During the summer and fall of 1978, a food habits study of dabbling ducks (mallard and pintail) was conducted by the ADF&G on tidal marshes of Cook Inlet (Palmer Hay Flats, Susitna Flats, Goose Bay, Chickaloon flats, and Trading Bay). Four genera of plants (Carex, Scirpus, Potamogeton, and Hippuris) comprised between 82 and 96% of gullet contents.

Seeds of these plants were dominant in both summer and fall, although tubers of Scirpus paludosus and Potamogeton were important in the fall on the Susitna Flats and Goose Bay. Seeds of Potamogeton and Hippuris were more abundant, and therefore more important, during summer than during fall, whereas the inverse was true for Carex seeds. Mallards relied more heavily on Carex and less heavily on Scirpus seeds than did pintails.

The Chickaloon flats and Trading Bay marshes do not have extensive stands of bulrush (Scirpus validus), and consequently birds collected there were nearly devoid of bulrush seeds. Palmer Hay Flats contain more bulrush than any other marsh in Cook Inlet, and the ducks collected there fed more heavily on this food item than did birds elsewhere. Because of biases in procedures for collecting and processing samples, the importance of animal foods was undoubtedly underestimated.

Although not reflected in this study, ducks spent more time on intertidal areas as the hunting season progressed. Because birds were relatively invulnerable while feeding on the tide flats, few were included in the sample. Small crustaceans, mollusks, and algae are probably the major foods consumed by ducks in the exposed tidal zone.

2. Southcentral Region: Copper River Delta. Dabbling ducks on the CRD apparently rely more on soft vegetation and less on seeds than do mallards and pintails in Cook Inlet coastal marshes (ibid.). Seeds are an important part of the fall duck diet in Alaska because their high carbohydrate content helps to provide the energy necessary for migration (Campbell and Timm 1983).

The 1981 autumn diet of four species of dabbling ducks (pintail, mallard, green-winged teal, and wigeon) was comprised of 36% vegetation, 33% seeds, and 29% animal matter. Pintails consumed the greatest amount of seed, as well as of animal matter, followed by mallards and green-winged teal. Wigeons consumed the least amount of seed and

animal matter but the most vegetation (ibid.). (See table 1.)

B. Types of Feeding Areas Used

Dabbling ducks feed in the shallow waters of small lakes, ponds, and other bodies of water and at the tide line in Alaska coastal waters (Timm 1975).

C. Factors Limiting Availability of Food

Lingering snow and ice from a late spring prevent ducks from foraging in all areas, especially upland areas. Early cold weather and accompanying ice conditions eliminate food resources in most freshwater areas in the fall (Rothe, pers. comm.). Feeding activity under these conditions usually occurs at or along ice-free coastal areas.

D. Feeding Behavior

Dabbling ducks feed either at the surface, where they skim the water at the edges of the shores and banks, or by "tipping" tail up in shallow places, reaching down to obtain food items from the bottom (ibid.).

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Dabbling ducks generally require lowland ponded areas for nesting; however, some have been found over 500 yd from water (Sowls 1955). In areas where choice nesting habitat is limited, nests may be located up to 5 mi from water (Duebbert 1969).

Nesting pairs of dabblers (and other species) are known to claim and defend areas of territory adjacent to their nest site (Sowls 1955). Defense of these areas by the territorial drake can be quite vigorous but usually lasts only until the last egg is laid and the female starts incubation (ibid.).

B. Reproductive Seasonality

The span of nest initiation depends on local temperatures and water conditions and varies among species. The initial nesting period usually occurs from mid April to mid June (Sellers 1979).

Ducks are persistent nesters and will attempt to nest again, sometimes several times, if their first attempt is destroyed (Sowls 1955). Initial destruction by fluctuating water levels, mammalian or avian predators, and man-caused disturbance can be quite severe, and during some years renesting may account for the total production (ibid.).

C. Reproductive Behavior

Dabblers have new mates each season. Courtship takes place during late winter and early spring. On arrival at their nesting grounds, the females immediately search for a suitable nesting site and then commence nest construction (Timm 1975). As mentioned, males defend both the females and the nesting territory (Sowls 1955). This defense lasts until the eggs are laid and the males retreat to molting areas.

D. Age At Sexual Maturity

All dabblers mature at one year of age (Timm 1975).

Table 1. Diet Composition of 62 Dabbling Ducks on the West Copper River Delta, September through October 1981

Item	Aggregate % Volume	% Occurrence
Vegetation		
Water buttercup (<u>Ranunculus</u> spp.)	13.6	16.9
Pondweed (<u>Potamogeton</u> spp.)	11.6	13.8
Unidentified grass CRD #3	5.1	10.8
Misc. foliage	5.6	---
Seeds		
Sedge (<u>Carex</u> spp.)	12.4	38.5
Rushes (<u>Eleocharis</u> spp. & <u>Scirpus</u> spp.)	8.1	16.9
Unidentified seed #7	7.1	16.9
Marestail (<u>Hippuris</u> spp.)	3.3	16.9
Pondweed (<u>Potamogeton</u> spp.)		
Animals		
Diptera larvae (<u>Chironomidae</u> , <u>Ceratopogonidae</u> , <u>Tipulidae</u>)	13.4	29.2
Unidentified invertebrate eggs	4.2	4.6
Trichoptera larvae (<u>Brachycentridae</u> , <u>Limnephilidae</u> , <u>Polycentropodidae</u>)	3.8	23.1
Pelecypods (<u>Sphaeriidae</u>)	3.1	9.2
Gastropods	2.5	15.4
Stickleback (<u>Gasterosteus aculeatus</u>)	1.4	3.1
Miscellaneous (Hirudinids, Arachinids, Odonatids)	1.0	---

Source: Campbell and Timm 1983.

--- means no data were available.

- E. Fecundity
The number of eggs per clutch varies among species but ranges between 1 and 18 eggs, the average being between 6 and 9 eggs (ibid.). (See table 2.)
- F. Incubation Period
The incubation period varies by species but usually averages between 21 and 29 days (ibid.). Hatching generally coincides with the longest days of the year and the peak production of aquatic invertebrates in late June.
- G. Rearing of Young
As soon as the females are well into incubation, the males withdraw into flocks by themselves and proceed to molt. They take no part in raising young (ibid.).

VI. FACTORS INFLUENCING POPULATIONS

- A. Natural
Species composition and numbers for the Alaska population of dabbling ducks can change dramatically. Production is influenced primarily by spring weather and flooding. Production is less in years with "late" springs than in years when snow and ice disappear early in the season. Flooding in river valleys or from storm tides on coastal wetlands can delay nesting or destroy nests and significantly reduce production. Flooding in river valleys, however, causes beneficial effects from nutrient exchanges, which fertilize ponds, increasing the food they produce for waterfowl (ADF&G 1980).
A phenomenon that has occurred at least twice during the last 25 years is the drought displacement of millions of waterfowl from the southern Canada and northern United States prairie pothole area to the arctic coastal plain (Hansen and McKnight 1964, Derksen and Eldridge 1980).
During the first drought period (1956-1960), several duck species were recorded in Alaska for the first time or at much greater abundance than formerly (Hansen and McKnight 1964). In some areas, waterfowl population indices were three times the average (ibid.).
During 1977, surveys indicated the highest duck population index ever recorded in Alaska, a 61% increase over 1976 and 46% above the 10-year average (King and Bartonek 1977). The greatest increase was recorded for northern pintails, which increased 123% over 1976 and 87% over the 10-year average (ibid.). The 1978 population index was lower but still 5% above the 10-year average (ibid.).
These drought-related duck population increases did not result in increased production in Alaska. Although limited evidence indicates that some displaced duck species will increase their nesting attempts, there appears to be no related increase in production (Hansen and McKnight 1964, Derksen and Eldridge 1980).

Table 2. Breeding Biology of Dabbling Ducks

Species	Nest Locations	Mating	Incubation	Clutch Size		Sexual Maturity
				Range	Average	
Northern pintail	Dry ground, usually away from water	Late winter; arrive mated	22-24 days	1-12	6	1 yr
Mallard	Ground, edges of of ponds, much variation	Late winter; arrive on breeding grounds mated	23-29 days, usually 26	1-15	8	1 yr
American wigeon	Dry ground, away from water, usually brushy area	May-June	24-25 days	1-12	6	1 yr
American green-winged teal	Dry ground, tall grass, bordering marshes	Late winter	21-23 days	1-18	9	1 yr
Northern shoveler	Hollows, on ground	May-June, with two males occasionally	21-23 days	1-14	7	1 yr

Source: Timm 1975, and Bellrose 1976.

Hansen and McKnight (1964) and Derksen and Eldridge (1980) both concluded that drought-displaced ducks arrive in northern areas with depleted energy reserves, resulting in minimal nesting success. Also, late arrivals would have to compete for nesting sites with already established pairs, adding to poor nesting success (Calverley and Boag 1977).

B. Human-related

A summary of possible impacts from human-related activities includes the following:

- Pollution of water and/or food
- Reduction of food supply
- Alteration of freshwater habitat

- Dredging/filling/draining of wetlands
 - Disturbance of fall/spring staging areas
 - Oiling of feathers
 - In-flight hazards (e.g., transmission lines, towers)
 - Alteration of nesting habitat
 - Lead poisoning in heavily utilized hunting areas
- (See the Impacts of Land and Water Use volume of this series for additional information regarding impacts.)

VII. LEGAL STATUS

In Alaska, waterfowl are managed by the U.S. Fish and Wildlife Service and the Department of Fish and Game. Waterfowl are protected under international treaties with Canada (Great Britain) 1916, Mexico 1936, Japan 1972, and the Soviet Union 1976.

VIII. SPECIAL CONSIDERATIONS

- A. Molting
- Male dabbling ducks begin flocking by mid June and are flightless by late June and early July. Flight feathers are generally regained by early August (Bellrose 1976). The wing molt of females is delayed to coincide with the development of the young.

IX. LIMITATIONS OF INFORMATION

1. Southcentral Region. Surveys of nesting habitat need to be repeated for the Cook Inlet area. Information on ecological requirements is needed, especially in Cook Inlet, Alaska Peninsula coastal lagoons, and the Copper River delta. The relationship between drought-displaced birds and total annual production is unknown and needs investigation.
2. Arctic Region. Very few scientific studies have been done on dabbling ducks in the Arctic Region. Therefore, there is little specific life history information available.

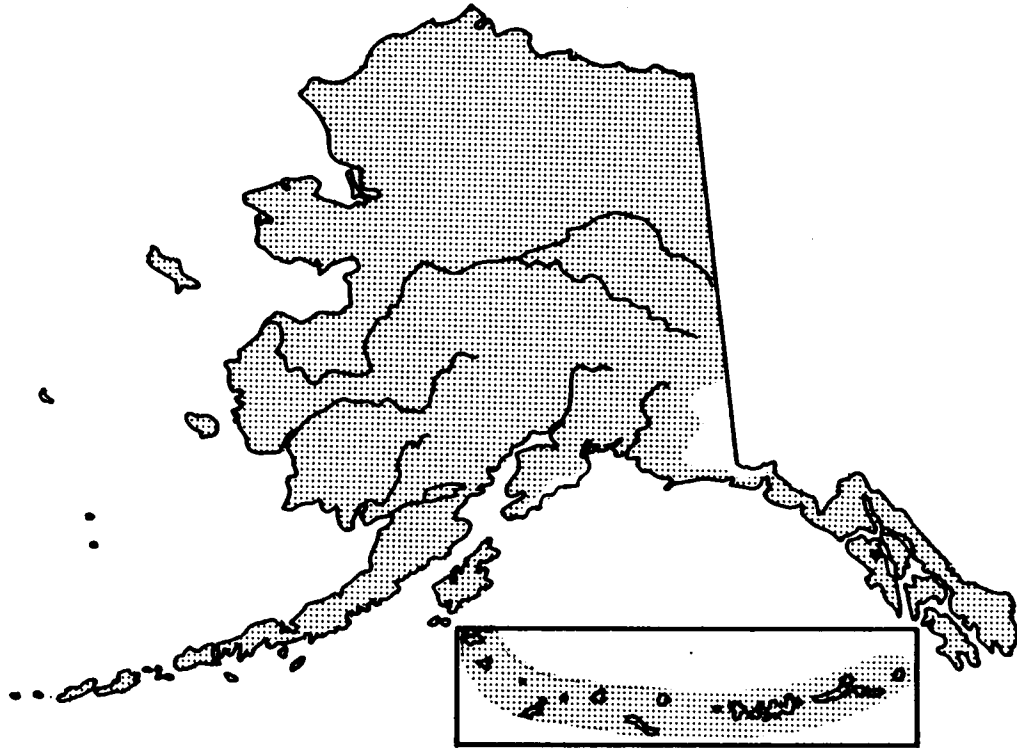
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Diving Ducks Life History and Habitat Requirements
Southwest, Southcentral, Arctic, Western, and Interior Regions



Map 1. Range of diving ducks (Bellrose 1976)

I. NAME

A. Common Names: Diving ducks, bay ducks, sea ducks

B. Scientific Classification

1. Family. Anatidae

2. Subfamily. Anatinae

3. Tribe:

a. Bay ducks or inland diving ducks. Aythyini.

b. Sea ducks. Mergini.

C. Native Names: See appendix A.

D. Species Commonly Occurring in the Southwest Region

The Southwest Region diving duck population is comprised of the greater scaup (Aythya marila); harlequin duck (Histrionicus histrionicus); oldsquaw (Clangula hyemalis); surf scoter (Melanitta perspicillata); white-winged scoter (M. fusca

deglandi), and black scoter (M. nigra); Barrow's goldeneye (Bucephala islandica) and common goldeneye (B. clangula); bufflehead (Bucephala albeola); red-breasted merganser (Mergus serrator) and common merganser (M. merganser); and Steller's eider (Polysticta stelleri), Pacific common eider (Somateria mollissima v-nigra), and king eider (S. spectabilis) (Gabrielson and Lincoln 1959).

- E. Species Commonly Occurring in the Southcentral Region
In the Southcentral Region, the diving duck population consists primarily of scaup, scoter, goldeneye, bufflehead, and oldsquaw. Lesser numbers of canvasbacks (Aythya valisineria), ring-necked duck (Aythya collaris), mergansers, and other diving duck species use the region as well (*ibid.*).
- F. Species Commonly Occurring in the Arctic Region
In the Arctic Region, the diving duck population consists primarily of oldsquaw, Pacific common eider, king eider, spectacled eider (Somateria fischeri), and lesser scaup (Aythya affinis) (Rothe, pers. comm.).
- G. Species Commonly Occurring in the Western and Interior Regions
In the Western Region, the diving duck population consists primarily of scaup, oldsquaw, Steller's eider, and scoters. Lesser numbers of goldeneyes, bufflehead, canvasback, and mergansers utilize the area as well (Gabrielson and Lincoln 1959). In the Interior Region, common diving ducks include scaup, both species of goldeneye, white-wing and black scoters, and mergansers. Less common species include canvasback, redhead, and surf scoter (*ibid.*).
Scaup are sometimes very abundant in the Interior Region. Between 1960 and 1969, they represented over 30% of all ducks identified by the USFWS during breeding-ground surveys (Johnsgard 1975).

II. RANGE

- A. Worldwide
Diving ducks occur in suitable habitats throughout the northern hemisphere.
- B. Statewide
Diving ducks occur throughout the state, generally near the larger and deeper inland bodies of water and along the sea coast (Timm 1975).
- C. Regional Distribution Maps
To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for each region at 1:250,000 scale. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of diving duck distribution has been prepared for all regions, except Southeast, and may be found in the Atlas that accompanies each regional guide.

D. Regional Distribution Maps

1. Southwest. In general, diving ducks are distributed throughout the Southwest Region at elevations below 1,200 ft. Major concentrations, however, are found in coastal and riverine habitats. In the Bristol Bay area, the largest concentrations of diving ducks occur during spring and fall migrations, whereas Kodiak and the Aleutian Islands have their highest concentration of birds during the winter (ADNR/USFWS 1983, Gabrielson and Lincoln 1959). (For more detailed narrative information, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)
2. Southcentral. Diving ducks are found in favorable habitat throughout the Southcentral Region. In general, this habitat is located at elevations below 1,000 ft. Large concentrations of diving ducks overwinter in coastal areas of Southcentral, in Cook Inlet, especially Kachemak Bay, and in the many protected bays and estuaries of Prince William Sound (PWS) (Timm 1975). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)
3. Arctic. In the Arctic Region, diving ducks are distributed primarily along the sea coast and near the larger and deeper inland bodies of water (Johnsgard 1975; Rothe, pers. comm.). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Arctic Region.)
4. Western and Interior. In the Western Region, diving ducks frequent coastal areas and associated lowland areas (Gabrielson and Lincoln 1959). The Yukon-Kuskokwim Delta (YKD) provides nesting and other habitat for a wide variety of diving duck species (ibid.). Diving ducks are also distributed along the major river valleys of this region. In the Interior Region, diving ducks are distributed in lowland ponded areas and in association with larger water bodies and river valleys. Areas of concentration include the Tetlin-Northway area, the Yukon Flats, Minto flats, and the Innoko River area (King, pers. comm.). (For more detailed narrative information, see the Alaska Habitat Management Guide for the Western and Interior regions.).

III. PHYSICAL HABITAT REQUIREMENTS

King (pers. comm.) indicated that any coastal water within the 60-ft depth contour could be considered important diving duck habitat. Diving ducks generally prefer protected estuarine areas, as opposed to the open ocean (King and Lensink 1971). Diving ducks generally frequent the larger and deeper inland bodies of water and the sea coast (Timm 1975).

A. Arctic Region

Important diving duck habitat in the Arctic Region is tundra in the vicinity of lakes or ponds, coastlines or islands. Where shrubs are available for nesting cover, they are preferentially

utilized, but grasses and sedges may also be used. Forests, however, are apparently avoided (Johnsgard 1975).

1. Oldsquaw. At Icy Cape, birds began using the salt marsh as soon as meltwater ponds formed in spring. In contrast, use of lagoons was very slight until mid July. Shallow Carex (Class IIb) was the most frequently used wetland, although deep Arctophila (Class IV) ponds were also used heavily (Lehnhausen and Quinlan 1981). To some extent, oldsquaw used all wetland types at Storkersen Point (Bergman et al. 1977). Before and during nesting, shallow Carex (Class II) and deep Arctophila (Class IV) wetlands were used significantly more than other types. After nesting, deep, open (Class V) lakes were used most frequently at Storkersen Point. Derksen et al. (1977) obtained similar results for wetland use by oldsquaw, although they recorded prenesting congregations on deep, open lakes.

At Icy Cape lagoon, molting started in mid July and declined in late August and September. Starting in late August, many birds regained flight and dispersed to offshore areas (Lehnhausen and Quinlan 1981). At Simpson Lagoon, a major oldsquaw concentration area, Johnson and Richardson (1980) reported the activities of these birds for nesting, feeding, and molting (but not nesting) to be largely restricted to the shallow bays, lagoons, and beaches from mid summer to early fall.

2. Common eider. At Icy Cape, birds started using the salt marsh on 8 June and use was highest just after mid June. Breeding activity probably started then, inasmuch as many birds were in pairs and males were displaying. No salt marsh use was observed in August or September (ibid.). Common eiders also used lagoon areas from early June to mid August (Lehnhausen and Quinlan 1981).

B. Western and Interior Regions

Specific information regarding habitat requirements of diving duck species in these regions is relatively scarce; however, there are studies that provide some information.

Generally, diving duck habitat in the Western Region is lowland tundra associated with lakes and/or the coast (Johnsgard 1975, Gabrielson and Lincoln 1959, Rowinski 1958). Cover of grasses or sedges is usually available, and shrubs are sometimes utilized (Johnsgard 1975).

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

Diving ducks utilize a wide variety of plant and animal species. Animal species, however, comprise the majority of their diet during most of the year (Bartonek and Hickey 1969, Johnsgard 1975, Dirschl 1969). This preference can be related to the habitats diving ducks occupy during most of the year: coastal marine areas, estuaries, and large, deep lakes (Johnsgard 1975).

Locally abundant plant foods are also utilized by diving ducks. Aquatic plants, including pondweed (Potamogeton spp.), muskgrass (Chara spp.), and bulrush (Scirpus spp.) are extensively used by some species (ibid.).

Table 1 presents food species known to be utilized by diving ducks. This list is incomplete but shows the wide diversity of food species utilized by diving ducks.

Bartonek and Hickey (1969), studying diving duck food habits in Canada, reported that juvenile and adult canvasbacks, redheads, and lesser scaup had a high proportion of animal food species in their spring and summer diet. Juvenile and adult female canvasbacks had 87% and 92% animal matter in their diets, respectively (ibid.). Conversely, adult male canvasbacks had 97% vegetative material in their summer diets (ibid.). Age and sex class differences are probably attributable to nutritional requirements. Fall-collected canvasbacks had only 22% animal matter in their diets (ibid.). Juvenile redheads have a varied summer diet, with only 43% animal matter observed in esophageal contents. Adult redheads had a higher percentage of animal species in their summer diet, with 86% and 81%, respectively, for males and females (ibid.). Lesser scaup juveniles and adults had an average of 98 to 99% animal matter in their summer diet (ibid.). The diets of fall-collected lesser scaup remained high in animal matter (ibid.).

Diving duck species that are primarily associated with coastal habitats have a high percentage of animal foods in their diet also (Johnsgard 1975). This category includes eiders, scoters, and oldsquaws.

The common eider has a reported winter diet of mussels (70.3%), barnacles (40.5%), and other mollusks (24.3%) (Dementiev and Gladkov 1967). The summer diet of juveniles and females showed that amphipods, mollusks, periwinkles, and crowberries (Empetrum nigrum) were important food sources (ibid.). The diet of king eider appears to be similar to the common eider (Johnsgard 1975). Juvenile spectacled eiders had a high percentage of insects in their summer diet. Pondweeds and crowberries were important plant foods during this period (Cottam 1939).

Adult and juvenile oldsquaws feed extensively on amphipod crustaceans, mollusks, insects, and fish (Johnsgard 1975). Insects, both larval and flying forms, are important food sources for juveniles during summer months (ibid.). Crabs, shrimp, and other crustaceans averaged almost 50% of the food consumed by adults (ibid.).

In the Arctic Region, oldsquaws eat primarily mysids and amphipods, and, to a lesser extent, bivalves (Gabrielson and Lincoln 1959).

B. Types of Feeding Areas Used

Inland diving ducks rarely feed on land. They generally frequent the larger and deeper inland bodies of water and protected estuarine habitats (ibid.). Marine diving species frequent

Table 1. Plant and Animal Species Utilized by Diving Ducks

Plant Species	Animal Species
Muskgrass (<u>Chara</u> spp.)	Caddis fly (<u>Trichoptera</u>)
Pondweed (<u>Potamogeton</u> spp.)	Midges (<u>Tendipedidae</u>)
Bulrush (<u>Scirpus</u> spp.)	Mayfly (<u>Ephemeroptera</u>)
Sedge (<u>Carex</u> spp.)	Dragonfly (<u>Odonata</u>)
Milfoil (<u>Myriophyllum</u> spp.)	Flies (<u>Diptera</u>)
Duckweed (<u>Lemna</u> spp.)	Flies (<u>Hemiptera</u>)
Buttercup (<u>Ranunculus</u> spp.)	Leech (<u>Hirudinea</u>)
Ditch grass (<u>Ruppia maritima</u>)	Water strider (<u>Corixidae</u>)
Cattail (<u>Typha</u> spp.)	Mysids (<u>Mysidae</u>)
Pond lily (<u>Nuphar</u> spp.)	Amphipods (<u>Amphipoda</u>)
Bur reed (<u>Sparganium</u> spp.)	<u>Gammarus</u> spp.
Green algae (<u>Chlorophyceae</u>)	<u>Hyallolella</u> spp.
	Crayfish (<u>Crustacea</u>)
	Water flea (<u>Daphnia</u> spp.)
	Snails (<u>Gastropoda</u>)
	Blue mussel (<u>Mytilus edulis</u>)
	Mussel (<u>Unio</u> spp.)
	Freshwater shrimp
	(<u>Palaemonetes</u> spp.)
	Clam (<u>Macoma</u> spp.)
	Clam (<u>Mulina lateralis</u>)
	Razor clam (<u>Solen sicarius</u>)
	Crab (<u>Cancer</u> spp.)

Source: Bartonek and Hickey 1969, Johnsgard 1975.

coastal habitats. Shallow coastal waters of bays, inlets, and estuaries, with a variety of substrates, are favored feeding areas for these species (Johnsgard 1975, Gabrielson and Lincoln 1959). Most diving duck species have somewhat unique water/substrate/food preferences (Rothe, pers. comm.). Buffleheads and mergansers are usually associated with river systems, especially during winter (ibid.). Eiders, scoters, oldsquaws, and scaups are associated with coastal marine areas in winter (ibid.), except where ice conditions prevent feeding in open water. Oldsquaws typically utilize the nearshore marine waters for feeding (Johnson and Richardson 1980).

C. Factors Limiting Availability of Food

Lingering snow and ice from a late spring may prevent diving ducks from utilizing lowland ponded areas. Cold weather, with accompanying ice conditions in the fall, prevents divers from using freshwater areas. Feeding activity under these conditions usually occurs in coastal marine waters.

The abundant bogs and muskeg wetlands common in the Southcentral Region are acidic and are therefore low in productivity. Nutrients and food species are more abundant in river systems, deltas, and coastal zones (Rothe, pers. comm.).

D. Feeding Behavior

Diving ducks usually dive for their food and will feed submerged. The depths to which they dive are generally between 2 and 10 ft; however, some may feed at greater depths. Oldsquaws, for example, have been recorded at depths of over 200 ft (Timm 1975, Johnsgard 1975).

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Most diving ducks require lowland pond habitats for nesting. Nest locations vary according to species (see table 2). The majority of diving ducks build their nests over shallow water in emergent vegetation or along the shorelines. The common and Barrow's goldeneyes and the bufflehead, however, are habitually tree nesters (Timm 1975). Ponds with good escape cover and high aquatic invertebrate populations are preferred.

In the Arctic Region, diving duck breeding habitat includes grasslands, coastal sedge meadows, upland tundra, coastal deltas, and inland lakes. Breeding habitat varies, however, by species.

1. Oldsquaw. Oldsquaw breeding was observed at Icy Cape in a salt marsh pond (Lehnhausen and Quinlan 1981).
2. Common eider. At Icy Cape, common eiders were observed using salt marshes for breeding (ibid.). Elymus coastal sites with grass were found to be preferred by nesting eiders (Schamel 1974, Lehnhausen and Quinlan 1981). Other types of sites utilized for nesting included sticks and logs, barren substrate, beaches covered with Honckenya spp., and old gull nests. Elymus grass appears to provide a camouflage protection, whereas sticks and logs may provide mainly a

Table 2. Reproductive Characteristics of Diving Ducks

Species	Region	Nest Location	Mating	Incubation	Clutch Size		Sexual Maturity*
					Range	Average	
Greater scaup	SW, SC	Not far from water; concealed in tufts of grass; close to shore of ponds	May-June	25-28 days	5-22	7-10	Breed at two years
	A W&I	--- Floating mat vegetation***	---	---	7-22**	8*	---
Lesser scaup	SW, SC	Ground; near marshy creeks, sloughs, ponds; concealed in tall grasses	May-June	25-28 days	6-15	9-12	"
	A W&I	Close to water (within 39 ft)**	---	25 days**	---	9**	---
Canvasback	SW, SC, I	Just clear of high water; in bulrushes and reeds in sloughs and marshes	May-June	24-28 days	---	7-9	"
Ringneck	SW, SC W&I	Wet, boggy areas bordering marshes, ponds, sloughs; most barely above level of water	May-June	24-28 days	---	8-12	"
Bufflehead	SW, SC I	Tree nester; usually placed in deserted hole of woodpecker or flicker; may nest in banks	April-May	20-28 days	6-14	10-12	"
Harlequin	SW, SC	Ground or in holes in trees or cliffs	March-May	24-26 days	5-10	6-7	Do not breed until their second year
Oldsquaw	SW, SC	Ground: small hollows, sometimes in grass; might be near water or away from it	---	24-29 days*	5-17	5-7	Most do not breed until they are at least two years

(continued)

Table 2 (continued).

Species		Nest Location	Mating	Incubation	Clutch Size		Sexual Maturity*
					Range	Average	
Oldsquaw*	A, W&I	Usually on islands, either offshore along the coasts or in tundra ponds and lakes. Nests are placed in natural depressions or former nest sites; mosses, sedges, grasses, dwarf willow and dwarf birch leaves are used	---	24-29 days	2-11	7	Two years
Pacific common eider*	A, W&I	Close to the sea, usually on small islands or islets, but sometimes located on tundra ponds distant from coast	---	21-28 days	1-14	4	---
Surf scoter	SW, SC, W	Ground: carefully concealed, lined with a small amount of grass; will breed inland	Usually June	---	5-9	7	---
White-winged scoter	SW, SC, W&I	Ground: in hollow lined with sticks, leaves, and rubbish; concealed under shrubs or bushes	Usually June	25-31 days*	9-14	12	Probably reach breeding age in second year
Black scoter	SW, SC, W&I	Ground: well hidden in hollows of steep banks of lake; lined with grass	Usually May	27-28 days*	6-10	7-8	Reach breeding age in second year
Barrow's goldeneye	SW, SC, W&I	Cavity of trees, dead stumps; preferably near water; from ground to 50 ft up	March-June	19-22 days	6-15	10	Most breed at two years
Common goldeneye	SW, SC, W&I	Cavity of trees, or dead stump; preferably near water; from ground to 50 ft up	March-June	20 days	5-19	8-12	Initially breed in their second or third year

(continued)

Table 2 (continued).

Species	Nest Location	Mating	Incubation	Clutch Size		Sexual Maturity*
				Range	Average	
Red breasted merganser*	SW, SC, I Ground; close to water	April-May	30 days	5-11	7-8	Not known to breed before their second year
Common merganser*	SW, SC, W&I Cavities of trees; from ground to 50+ ft up; usually close to water	April-May	30-35 days	6-17	9-12	

Source: Timm 1975, unless otherwise noted.

--- means no data were available.

* Bellrose 1976.

** Johnsgard 1975.

*** Rowinski 1958.

wind-break protection. Island sites appear to be preferred to mainland sites (Lehnhausen and Quinlan 1981).

3. King eider. King eider breed on inland ponds (Johnsgard 1975).
4. Spectacled eider. Spectacled eider breed in the grassy tundra (ibid.).

B. Reproductive Seasonality

Most diving ducks have arrived at their breeding range by mid-to-late May (ibid.) in Southwest and Southcentral Alaska (Bellrose 1976). Nest initiation extends from early to late June, depending on the species and weather conditions, with scoters generally the last to nest. In the Western and Interior regions, weather is an important factor in determining breeding activities and nest initiation. Late springs can delay these activities for several weeks, resulting in lower total production (ibid.).

In the Arctic Region, most diving ducks have arrived at their breeding range by late May to late June (Bellrose 1976).

1. Oldsquaw. Oldsquaw mating was observed on 17 June at Icy Cape (Lehnhausen and Quinlan 1981).
2. Common eider. Common eider pairs and displaying males were observed around mid June at Icy Cape (ibid.). Nesting dates appear to be at least partially the result of weather conditions. Lehnhausen and Quinlan (1981) estimated egg-laying dates on two islands off Icy Cape to be from 23 June to 12 July. Schamel (1977) observed similar nesting chronology on the Beaufort Sea coast. Divoky (1978) reported that eider egg laying at Icy Cape occurred between 18 and 27 June in 1976 - about 10 days earlier. Lehnhausen and Quinlan (1981) suggest this difference from Divoky's observation was due to the cold and late spring that occurred in their study and in Schamel's (1977).

C. Reproductive Behavior

Diving ducks have new mates each season. Birds that have mated before arrival begin nesting as soon as a suitable site has been selected. Birds that have not mated begin to pair off soon after arriving at their breeding grounds; they court and then begin nesting activities (ibid.). In the Arctic, oldsquaw males leave females after the start of nesting in mid June (ibid.).

D. Age At Sexual Maturity

Diving ducks usually mature at two years of age, but it varies by species (ibid.).

E. Fecundity

The number of eggs per clutch varies among species. Clutch size ranges between 5 and 22 eggs, with the average between 7 and 12 eggs (ibid.).

1. Common eider. On the Beaufort Sea coast, Schamel (1977) found a mean clutch of 5.1 in 1976 at Icy Cape. Lehnhausen and Quinlan (1981) found a mean clutch size of 2.9 on Amaulik Island and 3.8 on Tern Island (both near Icy Cape), with an overall range of 1 to 11 eggs.

Smaller clutch sizes are typical of birds that must renest (Schamel 1977). Lehnhausen and Quinlan (1981) suggest that the smaller mean clutch size on Amaulik Island may be due to the number of renests resulting from predation during early egg laying. On Tern Island, nest success (nests producing young) was 34%. Similar success was found by Schamel (1977) (34%, 1974) for Pacific (common) and king eider.

F. Incubation Period

The incubation period varies by species but usually averages from 19 to 28 days (Rothe, pers. comm.).

1. Common eider. Schamel (1977) found the incubation period for common eiders along the Beaufort Sea to be 26 days.

In the Arctic Region on June 28, Lehnhausen and Quinlan (1981) noted that male/female common eider pairs were breaking up and the males leaving.

G. Rearing of Young

As soon as the female is well into incubation, the males withdraw into flocks by themselves; they take no part in the rearing of young (ibid.). In the Southwest and Southcentral regions, brood rearing occurs throughout July and August. In the Arctic Region, oldsquaw brood rearing occurs from mid to late June (Bellrose 1976) or later (Lehnhausen and Quinlan 1981).

VI. FACTORS INFLUENCING POPULATIONS

A. Natural

Species composition and numbers for the Alaska populations of diving ducks can change dramatically. Production is influenced primarily by spring weather, flooding, and predation. Production is less in years with "late" springs than in years when snow and ice disappear early in the season. Flooding in river valleys or from storm tides on coastal wetlands can delay nesting or destroy nests and significantly reduce production. Flooding in river valleys, however, causes beneficial effects from nutrient exchanges, which fertilize ponds, increasing the food they produce for waterfowl (ADF&G 1980).

1. Common eider. Predators may play an important role in influencing population size. Lehnhausen and Quinlan (1981), who found 479 nests on Amaulik Island, reported that no nests survived to hatching as a result of predation by an Arctic fox, which apparently swam out from the mainland and destroyed the colony late in the season. Evidence of avian predation of eggs, apparently by parasitic jaegers and glaucous gulls, was also noted.

B. Human-related

A summary of possible impacts from human-related activities includes the following:

- ° Aquatic substrate alteration (e.g., from accelerated aufeis, mechanical removal)
- ° Chronic debilitation due to ingestion or contact with petroleum or petroleum products

- Electrocution, contact with powerlines
- Entanglement in fishing nets or marine debris
- Harvest, change in level
- Interference with reproductive behavior
- Interruption of ongoing behavior (alarm, flight)
- Water level or water quality fluctuations (including changes in drainage patterns, long-term increase or decrease in water levels)
- Terrain alteration or destruction (e.g., shoreline habitat, estuarine, and lagoon)
- Vegetation composition change to less preferred or useable species (See the Impacts of Land and Water Use volume of this series for additional information regarding impacts.)

VII. LEGAL STATUS

In Alaska, waterfowl are managed by the U.S. Fish and Wildlife Service and the Alaska Department of Fish and Game. Waterfowl are protected under international treaties with Canada (Great Britain) 1916, Mexico 1936, Japan 1972, and the Soviet Union 1976.

VIII. SPECIAL CONSIDERATIONS

A. Molting

The requirements of molting adults vary by species.

1. Scoters. Scoters leave the nesting areas in mid July to molt at sea, often near estuaries.
2. Scaup and goldeneye. These divers molt on large inland lakes that are perennial molting areas. The molt extends from mid July to the end of August (Bellrose 1976).
3. Steller's eiders. Steller's eiders migrate to their wintering areas at Izembek and other Alaska Peninsula lagoons prior to their molt. The molt period is variable, ranging from August through November (Johnsgard 1975).
4. Oldsquaw. Oldsquaws leave their nesting areas in mid July to molt at sea, often near estuaries (Bellrose 1976). Oldsquaws in the Simpson Lagoon area utilize the nearshore area for molting (Johnson and Richardson 1980, Martin and Moitoret 1981). At Icy Point, Lehnhausen and Quinlan (1981) noted an increase in lagoon use around the beginning of molt in mid July.
At Icy Cape, 10% of male birds were flightless on 16 July; about 50% were flightless on 12 August; and in late August many birds regained flight (Lehnhausen and Quinlan 1981). Derksen et al. (1979a) noted that molting begins around mid July.
2. Common eider. At Icy Cape, molting birds were noted from mid July to about mid August (ibid.).

IX. LIMITATIONS OF INFORMATION

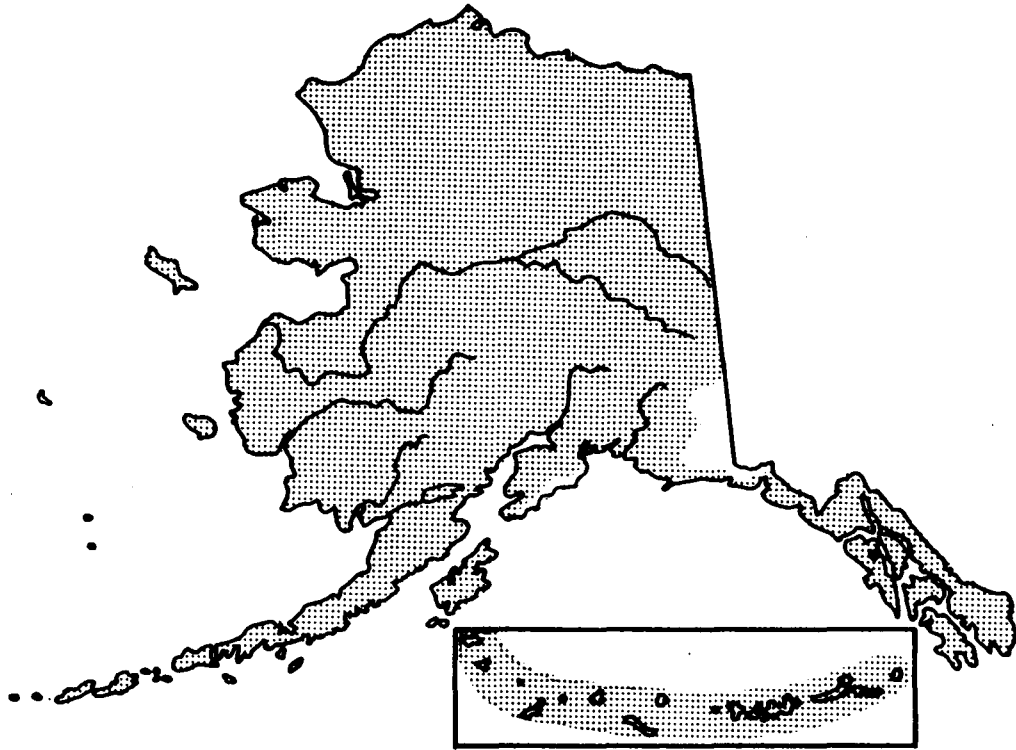
Few scientific studies have been conducted on diving ducks in Alaska, and there is a need for much more life history information on these species.

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Geese Life History and Habitat Requirements
Southwest, Southcentral, Arctic, Western, and Interior Regions



Map 1. Range of geese (Bellrose 1976)

I. NAME

A. Common Name: Geese, brant

B. Scientific Classification:

1. Family. Anatidae.

2. Subfamily. Anserinae.

3. Tribe. Anserini.

C. Native Names: See appendix A.

D. Species Commonly Occurring in the Southwest Region

In the Southwest Region, goose populations are comprised primarily of the Pacific flyway population of the greater white-fronted goose (Anser albifrons frontalis); the emperor goose (Chen canagica); the Pacific black brant (Branta bernicla nigricans); and three races of Canada goose: the cackling Canada goose (Branta canadensis minima), Aleutian Canada goose (B. c. leucopareia), and Taverner's Canada goose (B. c. taverneri) (Gabrielson and Lincoln

- 1959). The lesser snow goose (C. caerulescens) occurs during migration (*ibid.*).
- E. Species Commonly Occurring in the Southcentral Region
Goose species that commonly occur in the Southcentral Region include the lesser Canada goose (B. c. parvipes), the dusky Canada goose (B. c. occidentalis), possibly the Vancouver Canada goose (B. c. fulva), the tule white-fronted goose (A. a. gambeli), and, during migration, the lesser snow goose, greater white-fronted goose, and cackling Canada goose (Gabrielson and Lincoln 1959; Rothe, pers. comm.).
 - F. Species Commonly Occurring in the Arctic Region
Goose species that commonly occur in the Arctic Region include the lesser Canada goose (Branta canadensis taverneri and B. c. parvipes, collectively), the Pacific black brant, the white-fronted goose, and the snow goose (Rothe, pers. comm.).
 - G. Species Commonly Occurring in the Western and Interior Regions
Goose species that commonly occur in the Western Region include the cackling Canada goose, the Pacific black brant, the greater white-fronted goose, and the emperor goose. The lesser snow goose occurs during migration (Gabrielson and Lincoln 1959).
Goose species commonly occurring in the Interior Region include the lesser Canada goose (B. c. parvipes and B. c. taverneri, collectively) and, less commonly, the white-fronted goose (*ibid.*).

II. RANGE

- A. Worldwide
Geese are found in nearly all northern temperate and arctic zones.
- B. Statewide
Geese are found throughout the state where suitable habitat is available. In general, geese are distributed throughout the Southwest Region at elevations below 500 ft (Sellers, pers. comm.). In Southcentral Alaska, geese are found in suitable habitat at elevations up to 1,000 ft (Timm 1977). Estuaries, lagoons, river deltas, marshes, and tidelands, however, support the largest concentrations of geese. In the Arctic Region, geese are generally found on the coastal plain (Johnsgard 1975) and along the Colville River (King, pers. comm.). In the Western Region, geese are found in suitable habitat along the coast and major river valleys, with nesting concentrations of worldwide importance located along the coastal fringe of the Yukon-Kuskokwim delta (YKD) (Gabrielson and Lincoln 1959; Rothe, pers. comm.).
- C. Regional Distribution Maps
To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for each region at 1:250,000 scale. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of selected fish and wildlife species has been prepared for all regions, except Southeast, and may be found in the Atlas that accompanies each regional guide.

D. Regional Distribution Summary

1. Southwest. The largest concentrations of geese occur in the Bristol Bay and Alaska Peninsula areas during spring and fall migrations; Kodiak and the Aleutian Islands remain important wintering areas for some species (Gabrielson and Lincoln 1959, ADNR/USFWS 1983). (For more detailed narrative information, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)

2. Southcentral. The largest concentrations of geese in the Southcentral Region occur during spring and fall migrations. The tidal salt marshes and extensive mud flats of Cook Inlet, the numerous small mud flats of Prince William Sound (PWS), and the large alluvial floodplain and delta of the Copper River all provide important spring and fall habitat for geese (Timm 1977).

Additionally, important world populations of the tule goose and the dusky Canada goose are found in Cook Inlet and the Copper River delta, respectively. The tule goose has been found nesting along the west side of Cook Inlet, which is the only known breeding area. This subspecies winters in northern California (Timm 1975).

The world population of the dusky Canada goose is known to breed only on the Copper River delta. The wintering area for this subspecies is in the Willamette Valley, Oregon, and southwest Washington (ibid.). Additionally, Canada geese breed in the small bays and islands of PWS. This population is generally believed to be a small population of Vancouver Canada goose (*B. c. fulva*) (ibid.). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)

3. Arctic. Geese in the Arctic Region are concentrated along and on the coastal plain (Johnsgard 1975).

- a) Canada goose. Because of the great subspecific diversity in breeding habitats and the extensive breeding range of the collective races, no concise summary of distribution and habitat is possible for the Canada goose. Virtually all of the nonmountainous portions of the Arctic Region can be considered breeding range for the Canada goose (ibid.). The following is as specific information as possible for the two primary subspecies found in the Arctic Region:

- 1) Cackling Canada goose. The cackling Canada goose breeds along the coast of Western Alaska (ibid.).

- 2) Taverner's Canada goose. The Taverner's Canada goose is distributed along the coastline from the Seward Peninsula to Point Lay, where it probably intergrades with minima (ibid.).

- b. Black brant. Black brant breed abundantly from the Kuskokwim delta and Nelson Island northward along the

- coastline and east to the Alaska-Canada border (Johnsgard 1975, Gabrielson and Lincoln 1959).
- c. Snow goose. Snow geese historically breed in the vicinity of Barrow and recently on Howe Island near Prudhoe Bay (Johnsgard 1975; Rothe, pers. comm.). Scattered and isolated broods of snow geese are observed each year on the arctic coast (King, pers. comm.).
 - d. White-fronted goose. White-fronted geese breed primarily along the arctic coastal plain and nest mainly near the coast. At Barrow and to the east, it is a common coastal breeder, extending in marshy areas from 1 to 20 mi inland, with apparent centers of abundance at Smith Bay and the Colville delta. In the Kotzebue Sound region along the Noatak and Kobuk rivers, white-fronts are also common nesters (Johnsgard 1975).
4. Western and Interior. The majority of geese in the Western Region are concentrated along the coastal fringe of the YKD (Gabrielson and Lincoln 1959, Mickelson 1975).
- a. Cackling Canada goose. The coastal fringe of the YKD is the chief breeding ground for this subspecies (Mickelson 1975). Nesting densities of this goose can range from 82 to 146 nests/mi² (ibid.).
 - b. Black brant. Black brant are abundant breeders on the coastal fringe of the YKD (Johnsgard 1975). Approximately half of the total population of brant nest on the YKD (Mickelson 1975). Nesting densities of up to 4,275 nests/mi² have been observed near the mouth of the Kashunuk River (Lensink 1968).
 - c. Emperor goose. Approximately 80 to 90% of the world's population of emperor geese nest on the YKD, mainly confined to the coastal fringe between Nelson Island and Cape Romanzof (Eisenhauer and Kirkpatrick 1977).
 - d. White-fronted goose. Most of the Pacific Flyway populations of white-fronted geese nest on the YKD (Gabrielson and Lincoln 1959, Mickelson 1975). Little information is available on distribution and concentration areas for geese in the Interior Region. Areas of abundance include the Yukon Flats near Ft. Yukon, the Minto flats near Fairbanks, and the Innoko River basin near McGrath. All major river valleys within the Interior Region provide habitat for nesting and breeding geese (King, pers. comm.).

III. PHYSICAL HABITAT REQUIREMENTS

A. Southwest

Geese in the Southwest Region are usually found where lagoon water and embayment habitat are plentiful, particularly on the north side of the Alaska Peninsula. Brant are primarily restricted to lagoon water where eelgrass is found. Canada and snow geese use

Table 1. Preferred Foods and Breeding Habitat of Geese in the Southcentral Region

Species	Preferred Food	Breeding Habitat
Lesser snow goose	In marine areas: salt marsh vegetation; in upland areas: berries and grasses (Bellrose 1976)	Seasonal migrants in SC Region; none known to breed there (Timm, pers. comm.)
Tule goose	On west side of Cook Inlet: sedges (<u>Carex</u> <u>Lyngbyaei</u> and <u>C. Ramenskii</u>), arrow grass (<u>Triglochin palustris</u> and <u>T. maritimum</u>), and alkali grass (<u>Puccinellia nutkaensis</u> & <u>P. phryganodes</u>) (Timm 1982)	Apparently limited to saline sedge-grass meadows of western Cook Inlet; additional breeding areas possibly occur farther inland, in <u>Carex</u> & <u>Equisetum</u> riparian meadows and outwash plains (Timm 1982)
Lesser Canada goose	Wide variety of foods eaten, including cattails (Typhaceae), grasses, algae, waste grains, bulrushes, (<u>Scirpus</u> sp.), and clover; marine invertebrates utilized in coastal areas (Terres 1980); also sedges (<u>Carex</u> sp.), alkali grass (<u>Puccinellia</u> sp.), seeds of mare's tail (<u>Hippuris</u> sp.), goose foot (<u>Atriplex</u> sp.), tubers of arrow grass (<u>Triglochin</u> <u>palustris</u>), and crowberries (<u>Empetrum</u> sp.) (Sellers, pers. comm.)	Have greater diversity of nest sites than all other species of waterfowl; nest in dense marshes, on islands, cliffs, elevated platforms in trees, in muskeg, and on tundra
Dusky Canada goose	Similar to above	World's population nests on CRD; vegetative and other changes since 1964 earthquake have apparently influenced nesting habitat: shrubland and sedge meadows type are utilized as nesting habitat
Vancouver Canada goose	Plant material comprises bulk of summer food, with skunk cabbage (<u>Lysichiton</u> <u>americanum</u>) heavily utilized; also sea lettuce (<u>Ulva</u> sp.), blueberry (<u>Vaccinium</u> sp.), horsetail (<u>Equisetum</u> sp.), and grasses and sedges; winter foods probably include more animal matter (Lebeda 1980)	Majority of nests in dense conifer forest, at base of large trees; one nest reported in tree top, and nearby trees used for perching (Lebeda 1980)

Table 2. Preferred Foods and Breeding Habitat of Geese in the Southwest, Western, and Interior Regions

Species	Preferred Food	Breeding Habitat
Pacific white-fronted goose	Vegetative parts of various native grasses and sedges (Johnsgard 1975)	Nests on both coastal and upland areas, typically in tall grass bordering tidal sloughs or in sedge marshes and less often in grass-covered pingos or margins of tundra hummocks; infrequently, nests on heath tundra, sometimes as far as 50 to 100 yd from water (Bellrose 1976)
Lesser snow goose	Primarily salt marsh vegetation; berries and grasses often important diet in upland areas (Bellrose 1976)	Usually locate nesting colonies on low grassy tundra plains within few miles of sea, along broad shallow rivers near coast, and on islands in shallow lakes 10-80 mi inland (Bellrose 1976); most snow geese in the SW and SC regions nest on Wrangell Island in USSR
Emperor goose	Major food sources: algae, eelgrass, pond-weeds, grasses, sedges, and other plant fibers; mollusks, crustaceans, and other animal materials make up smaller portions of diet (Johnsgard 1975); young birds feed on aquatic insects and marsh grass and later may consume berries	Tend to nest on coastal fringe slightly inland from black brant; almost all nest within several hundred yd of tide waters that may extend up to 30 or 40 mi inland along tidal grass lands, low pingo tundra, and sedge marshes (Bellrose 1976); most nesting occurs on the Y-K delta
Pacific black brant	Eelgrass most important food in Western Alaska; when scarce or unavailable, brant use rockgrass and sea lettuce (Bellrose 1976); saltmarsh grasses (<u>Puccinellia</u> sp) are preferred in other areas	Nesting on Yukon delta confined either to extreme coastal rim or to areas along major estuaries flanked by tidal meadows; nests on delta most frequently established on small islets or on shores of tidal ponds but sometimes as far as 30 yd from nearest water; nests placed in either short sedge or, rarely, in clumps of wild rye (Barry 1966)

(continued)

Table 2 (continued).

Species	Preferred Food	Breeding Habitat
Canada goose	Cackling geese feed predominately on sedges and creeping alkali grass (<i>Puccinellia phryganodes</i>); also seeds of <i>Hippuris</i> and <i>Atriplex</i> and tubers of <i>Triglochin palustris</i> (Sellers, pers. comm.). Major foods of Taverner's Canada geese: berries (especially crowberries) and other upland vegetation and eelgrass in marine system	Cackling geese use pond-studded tundra of coastal Yukon delta; select islets for 81% of nest sites; islets average 5-11 ft in size and 8 inches in height; 16% nested on small peninsulas extending into tundra ponds, but only 3% placed nests on mainland shore (Mickelson 1973)

Table 3. Nesting, Rearing, and Molting Biology of Geese in the Southcentral Region

Species	Nest Location	Incubation	Clutch Size	Sexual Maturity	Fledging Period	Molting	
						Initiation	Flightless Period
Lesser snow goose	Seasonal migrants to SC Region; none known to breed in region						
Tule goose	Favored nest sites on slight elevation in saline sedge-grass meadows (Timm 1982)	App. 26 days (Timm 1982)	4-7 eggs; avg. 5.6 (Timm 1982)	Usually 3 yr, sometimes 2 (Bellrose 1976)	App. 55-65 days (Bellrose 1976)	Late June (Bellrose 1976)	App. 35 days (Bellrose 1976)
Dusky Canada goose	Nest locations vary; most preferred is grassland; increase in nesting in sedge meadows observed since 1964 earthquake (Bromley 1976)	25-31 days (Bromley 1976)	1-8 eggs; avg. 5.2 (Bromley 1976)	Usually 3 yr; some 2-yr-olds breed (Bromley 1976)	App. 48 days (Bromley 1976)	App. 2nd week July (Bromley 1976)	App. 4 weeks; birds gather in large flightless flocks (Timm 1975)
Vancouver Canada goose	At base of trees; nest is a scrape depression, with vegetation around rim (Lebeda 1980)	App. 25-31 days (Lebeda 1980)	2-6 eggs; avg. 4.4 (Lebeda 1980)	No specific info., 3 yr common for other Canada goose subspecies	Late Aug. (Lebeda 1980)	Late June-early July (Lebeda 1980)	4-6 weeks (Lebeda 1980)
Lesser Canada goose	Most nests are a depression on ground, with vegetation around rim (Bellrose 1976, Timm 1980) (Bellrose 1976, Timm 1980)	24-30 days (Terres 1980)	1-12 eggs; avg. 4.3 (Terres 1980)	Some mature at 2 yr but most at 3 (Terres 1980)	40-46 days (Terres 1980)	Adults begin molt when young are 1-2 weeks old (Terres 1980)	3-4 weeks (Bellrose 1976)

Table 4. Nesting, Rearing, and Molting Biology of Geese - Southwest, Western, and Interior Regions

Species	Nest Location	Mating	Incubation	Clutch Size		Sexual Maturity	Fledging Period	Molting	
				Range	Average			Initiation	Flightless Period
Pacific white-fronted goose	Female selects shallow depression, building nest from nearby plant material as eggs are laid (Barry 1966)	Probably Feb. and Mar. (Dau, pers. comm.)	23-25 days (Bellrose 1976)	2-10 (Bellrose 1976)	4.75	First breed at 3 yr; favorable nest conditions may induce some 2-yr-olds to breed	55-65 days	Adult molt begins when goslings about 3 weeks old (Bellrose 1976)	4 weeks (Mickelson 1973)
Lesser snow goose	No nesting occurs in SW Alaska	Mating apparently occurs during northward migration, particularly at rest stops immediately preceding their last passage to nesting grounds (Bellrose 1976)	23 days (Cooch 1958)	2-10 (Bellrose 1976)	3.9	Reach sexual maturity at 2 yr; majority do not breed until 3rd yr and in some seasons not until 4th yr (Bellrose 1976)	45 days (Cooch 1958)	Adults molt about 2.5 weeks after young hatched (Barry 1966)	About 24 days (Cooch 1958)
Emperor goose	Prefer to nest on an elevated site near tidal pond; nest is a scrape lined with grass, sedges, or other adjacent vegetation, and small amount of down (Bellrose 1976)	Arrive on nesting grounds on Yukon Delta in May, mated and ready to begin nesting (Headley 1967); mating occurs probably Feb./Mar. (Dau, pers. comm.)	23-27 days (Eisenhauer & Frazer 1972)	1-12	4.83	The age at breeding unknown, but most probably do not nest until 3rd yr (Bellrose 1976)	50-60 days (Mickelson 1973)	Adults molt when young are 20-25 days old (Headley 1967)	Third week of July to 3rd week of Aug. (Mickelson 1973)

(continued)

Table 4 (continued).

Species	Nest Location	Mating	Incubation	Clutch Size		Sexual Maturity	Fledging Period	Molting	
				Range	Average			Initiation	Flightless Period
Pacific black brant	Nest placed in depression or scrape, with grass foundation and symmetrical ring of down (Bellrose 1976)	Courtship known to occur on winter grounds between mid Jan. and Apr. (Einarsen 1965)	23-25 days (Mickelson 1973)	1-10 (Barry 1966)	3.52	Most breed at 3 yr, but good seasons encourage perhaps 10% of 2-yr birds to nest (Barry 1966)	40-45 days (Barry 1966)	Adults molt 2 weeks after eggs hatched (Barry 1966)	3 weeks, controlled by day length (Barry 1966)
Canada geese	If females do not use old scrapes, new ones are wallowed out in earth; usually female reaches out from saucer-shaped depressions to gather vegetation for bases and rims (Bellrose 1976)	Probably Feb./Mar. (Dau, pers. comm.)	24-30 days (Mickelson 1973)	1-12 (Bellrose 1976)	4.27	A few yearling geese have attempted to nest, but none have hatched a clutch successfully; some 2-yr and probably all 3-yr-olds nest (Hall and McGilvrey 1971, Mickelson 1973)	40-46 days (Mickelson 1973)	Adults molt when goslings are 1 to 2 weeks of age (Mickelson 1973)	3-4 weeks (Mickelson 1973)

uplands, lagoons, and alluvial floodplains, whereas emperors use lagoon island sand and protected delta mud (Arneson 1980). (See tables 2 and 4 for additional information on habitat preference.)

B. Southcentral

Geese are found in a wide variety of habitats but are most common in alluvial floodplains, lagoons, and tidal mud flats. Canada geese use alluvial floodplains and coastal salt marshes extensively during their migrational stopovers (ibid.). Additionally, the saline sedge-grass wetlands of Cook Inlet are thought to be important nesting habitat for tule geese (Timm 1982). (See tables 1 and 3 for additional information on habitat preferences.)

C. Arctic

In spring and during the molt, white-fronted geese in the Teshepuk Lake area use flooded tundra and shallow Carex areas (Derksen et al. 1979). Brant commonly feed in salt marshes and lagoons (Lehnhausen and Quinlan 1981, Kiera 1979, and Seaman et al. 1981) and have been observed on barrier island beaches (Bailey 1948).

Molting geese in the National Petroleum Reserve-Alaska (NPR-A) showed a definite preference for deep, open lakes as opposed to those with emergent vegetation. Derksen et al. (1979) found 96% of the observed brant, 85% of the Canada geese, and 57% of the white-fronted geese to be associated with deep, open lakes. White-fronted geese clearly preferred smaller waterbodies than the other species, which preferred flooded tundra and braided streams. At Storkersen Point, however, white-fronted geese used deep, open lakes almost exclusively, with minimal use of shallow Arctophila and basin complexes (Bergman et al. 1977). Escape cover may be an important factor in selection of deep open lakes, because of the security provided from terrestrial predators, such as arctic fox (Derksen et al. 1979). Low-relief shorelines that support grasses and sedges are used more frequently by molting geese than precipitous shorelines with adjacent uplands, apparently because of greater food availability in the former. Following molt, Canada geese and brant utilized coastal areas, whereas white-fronted geese did not (ibid.).

Lehnhausen and Quinlan (1981) found brant at Icy Cape using deep Arctophila lakes primarily and shallow Arctophila ponds occasionally during the molt.

D. Western and Interior

In the Western Region, preferred goose nesting habitat consists of lowland floodplains interspersed with shallow ponds and meandering tidal sloughs. Most ponds are small (less than two acres), with many small islands and irregular shorelines (Mickelson 1975).

Generally, black brant nest up to 5 mi inland, cacklers from 3 to 15 mi inland, and emperors overlap these two areas. White-fronted geese have the highest densities in this zone but also nest farther inland (ibid.).

During the brooding season, cackling geese prefer sedge meadows for feeding and nesting, whereas black brant rear their young

along tidal sloughs and rivers (ibid.). Emperor geese prefer to feed and nest near ponds with grass and sedge shorelines, whereas white-fronted geese utilize the heads of smaller sloughs with more and taller vegetation (ibid.). (See tables 2 and 4 for additional information on habitat preferences.)

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

Geese are predominantly vegetarians and consume the leaves, roots, and seeds of a wide variety of plants. Cultivated grains comprise a large percentage of their diet in wintering areas of the continental United States (Bellrose 1976). Along coastal areas, geese are known to feed on mollusks, crustaceans, and other animal materials (table 1) (Terres 1980). Black brant feed almost exclusively on eelgrass (Bellrose 1976). During fall migration on the Alaska Peninsula, Canada geese feed extensively on crowberries (*Empetrum nigrum*) (Rothe, pers. comm.). (See tables 1, 2, and 3 for further information on food.)

1. Arctic Region

(See table 5 for additional information.)

- a. Geese. Derksen et al. (1979) noted that geese utilize grasses and sedges.
- b. Canada geese. Derksen et al. (1979) observed occasional feeding on emergent *Arctophila fulva*. *Deschampsia* spp. and *Carex* spp. were the most important grass and sedge, respectively, for molting Canada geese at Teshepuk Lake; mosses were also evident in droppings (Derksen et al. 1982).
- c. Black brant. Derksen et al. (1979) observed that brant in the NPR-A feed mainly on *Dupontia fischeri*. Derksen et al. (1982) found that, for molting birds around Teshepuk Lake, *Deschampsia* spp. and *Carex* spp. were the most important grass or sedge, respectively, based on analysis of brant droppings. Mosses were also eaten. In a salt marsh near Prudhoe Bay, Kiera (1979) found brants to feed predominantly on *Carex subspathacea*. Also, Kiera (1979) observed brant, prior to nesting, feeding on mosses, freshwater algae, *Equisetum variegatum*, and old seed heads of *Carex aquatilis*. During nesting, however, they fed primarily on *C. aquatilis* and *Dupontia fischeri*. Chironomids were taken on days of peak emergence. Kiera (1979) determined that brant consumed an average of 1,207 kcal/goose/day.

2. Western and Interior regions:

- a. Cackling Canada geese. On the YKD, adults and newly hatched young feed on crane flies and midges (Mickelson 1975). In mid July, cackling geese feed almost exclusively on seeds of sedges and grasses, (*Carex Mackenziei*, *C. rariflora*, and *Calamagrostis*

deschampsoides). From mid August to the time of migration, crowberries (Empetrum nigrum) and cloudberries (Rubus chamaemorus) are important foods (ibid.).

- b. Emperor geese. On the YKD, sedges (Carex rariflora) and grasses (Elymus sp. and Puccinellia sp.) are important foods in early spring (Eisenhauer and Kirkpatrick 1977). Invertebrates are also consumed, including mosquitos, midges, mollusks, and crustaceans (ibid.).

B. Types of Feeding Areas Used

Geese are opportunistic and forage in areas providing plentiful food supplies. Coastal salt marshes and adjacent shallow water areas, cultivated fields, freshwater marshes, and a variety of other habitats all provide feeding areas for geese (Johnsgard 1975).

In the Arctic Region, salt marshes and lagoons appear to be commonly used feeding areas (Seaman et al. 1981, Kiera 1979, Lehnhausen and Quinlan 1981, Derksen et al. 1982). Kiera (1979) observed black brant feeding in salt marshes in the Prudhoe Bay area in mid August.

C. Feeding Behavior

Geese are essentially grazers and crop vegetation with their bills. During spring, they often dig up tubers and rhizomes, and in fall they often select berries. When eating submerged vegetation, they reach below the surface with their head and neck, tail tipped up, similarly to dabbling ducks. Geese feed primarily in the early morning and late afternoon (table 1) (Timm 1975). Except during nesting, geese feed socially in flocks that move and react to disturbance as a unit (Johnsgard 1975).

1. Black brant. Kiera (1979) reports that brant begin arriving in salt marshes near Prudhoe Bay in mid August just after salt marsh vegetation reaches peak production. He found no relationship between food preferences and the nutritional characteristics of the graminoid vegetation they ate. He observed brant to spent 77% of the daylight hours feeding and noted distinct daily patterns of feeding at different times of the summer. During nesting, he found brant exhibited a bimodal pattern in early evening. By late summer, when geese were migrating, he noted that they fed most heavily in the morning, with feeding gradually tapering off through the day. Kiera (1979) also found that females during nesting fed significantly faster than males and that during migration juveniles fed at a significantly higher rate than adults.

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Nesting sites vary by species, but there are three standard prerequisites for all geese: 1) proximity to water, 2) cover for the nest itself, and 3) an exposed view of the surrounding area

for the incubating bird (Bellrose 1976, Johnsgard 1975). (See tables 1, 2, 3, 4, and 5.)

B. Reproductive Seasonality

The span of nest initiation, which begins in early May, varies among species and is dependent on weather conditions. In years when snow cover and cold conditions persist later into the season, nesting efforts may be delayed for several weeks (Johnsgard 1975).

1. Arctic Region. On the NPR-A and adjacent areas, Derksen et al. (1979) observed brant and white-fronted geese arriving in late May and early June to nest, with the peak hatch occurring in early July.

At Storkersen Point, estimated egg-laying dates for brant ranged from 5 to 18 June (Bergman et al. 1977).

Mating was observed between brants at Icy Cape on 9 June (Lehnhausen and Quinlan 1981).

2. Western and Interior regions. On the YKD, emperor geese normally begin nesting during the first week of June (Eisenhauer and Kirkpatrick 1977). There is a high degree of synchrony within the species and 80% of nest initiation occurs within a two-week period (ibid.). The peak of hatching depends on the season but is generally the last half of June to the first half of July (ibid.).

Mickelson (1975) observed white-fronted geese arriving on the YKD during the first or second week of May, with other geese arriving soon after. Nest initiation begins soon after arrival, and egg laying usually occurs from late May to mid June.

C. Reproductive Behavior

Geese appear to form pair bonds that remain steadfast throughout life, but when separated by death, the survivor seeks a new mate. Most species of geese return to the same breeding grounds or nesting colonies each year, where they establish a territory prior to nesting. The size of the territory varies by species and within the species, according to the demands made upon the available space (ibid.). Brant and snow geese are colonial nesters, and their nests may cover large areas. Some Canada goose subspecies and emperors may nest in loose aggregations, whereas white-fronted geese are solitary nesters (Rothe, pers. comm.). (See table 2.)

D. Age at Sexual Maturity

On the average, geese reach sexual maturity at two years of age, although the majority do not breed until their third year (Terres 1980, Bellrose 1976).

E. Fecundity

The number of eggs per clutch varies among species but ranges between 1 and 12 eggs, the average size being 4 eggs (Johnsgard 1975).

Table 5. Preferred Foods and Breeding Habitat of Geese in the Arctic Region

Species	Preferred Food	Breeding Habitat
Black brant	Mostly plant materials: eelgrass (<u>Zostera marina</u>) and sea lettuce (<u>Ulva</u> spp., especially <u>U. lactuca</u>)	High arctic coastal sedge tundra; lowland coastal tundra, usually just above high tide line, nesting grounds highly susceptible to flooding by storm tides; low islands of tundra lakes and dry inland slopes well covered with vegetation
Canada goose	Mostly plant materials, particularly root stocks of many marsh plants	High arctic grassy tundra; virtually all nonmountainous portions of the arctic region
Snow goose	Mostly plant materials: salt marsh rootstocks	High arctic coastal deltas; low grassy tundra associated with islands in braided deltas, usually near salt water, ponds or lakes
White-fronted goose	Mostly plant materials: vegetative parts of native grasses, some horsetail (<u>Equisetum</u> spp.) and cotton grass (<u>Eriophorum</u> spp.) and sedges	High arctic upland tundra; coastal tundra with little surface relief; gently rolling upland tundra 50-700 ft above sea level, with lakes and ponds in the depressions; also willow and shrub-fringed streams and ponds

Source: Johnsgard 1975.

F. Incubation Period

The incubation is conducted solely by the female, with the male on guard nearby (Terres 1980). The incubation period varies by species but usually averages between 25 and 30 days (ibid.).

G. Rearing of Young

Both parents are attendant to their young, the male principally assuming the role of guarding them from predators (Bellrose 1976).

VI. FACTORS INFLUENCING POPULATIONS

A. Natural

Species composition and numbers of geese in areas of Alaska can change dramatically. Production is influenced primarily by spring weather and flooding. Production is less in years with "late" springs than in years when snow and ice disappear early in the season. Flooding in river valleys or from storm tides on coastal wetlands can delay nesting or destroy nests and significantly reduce production. Flooding in river valleys, however, causes beneficial effects from nutrient exchanges, which fertilize ponds and thus increase the food they produce for waterfowl (ADF&G 1980).

The 1964 earthquake uplifted parts of the Copper River delta by as much as 1.89 m. This has apparently resulted in drier, less saline soils, with subsequent changes in vegetation communities on the delta, including those utilized for nesting by dusky Canada geese. An increase in the use of sedge as a nesting cover type during the mid 1970's was due to 1) an increase in the suitability of that cover type (less flooding) and 2) high population levels and increased nesting density, which may have caused nesting to occur in less favorable habitat (Bromley 1976). In addition, increased nest predation, particularly by mammalian predators, appears to be a factor in the reduced nesting success of dusky Canada geese (Campbell and Timm 1983).

B. Human-related

The dusky Canada goose population, which winters almost exclusively in the Willamette Valley, Oregon, is probably the most heavily harvested Canada goose population in North America (Timm 1975). The intermixing of wintering populations of the more numerous lesser Canada geese (B. C. parvipes and B. C. taverni) with the less abundant dusky Canada goose complicates censusing and harvest management. Although duskys are diluted among more numerous subspecies, their high vulnerability to hunting causes a disproportionately high harvest of this subspecies compared to others (Simpson and Jarvis 1979).

Populations of four goose species (emperor, brant, white-fronted, and cackling Canada) that nest on the YKD have declined dramatically over the last decade. Reasons for these declines are still not clearly defined; however, most researchers agree that fall hunting along the Pacific Flyway and spring/summer subsistence hunting by Natives on the YKD are the major causes.

Other human-related factors influencing goose populations include the following:

- Aquatic substrate alteration (e.g., from accelerated aufeis, mechanical removal)
- Chronic debilitation due to ingestion or contact with petroleum or petroleum products
- Collision with vehicles (including automobiles, boats, aircraft) or structures
- Electrocution, contact with powerlines
- Entanglement in fishing nets or marine debris
- Harassment, passive (e.g., construction noise, vehicle noise, human scent)
- Interference with reproductive behavior
- Interruption of ongoing behavior: alarm, flight
- Terrain alteration or destruction (e.g., raptor cliffs)
- Vegetation composition change to less preferred or useable species
- Water level or water quality fluctuations (including changes in drainage patterns, long-term increase or decrease in water levels)

(See the Impacts of Land and Water Use volume of this series for additional information regarding impacts.)

VII. LEGAL STATUS

In Alaska, waterfowl are managed by the U.S. Fish and Wildlife Service and the Alaska Department of Fish and Game. They are protected under international treaties with Canada (Great Britain) 1916, Mexico 1936, Japan 1972, and the Soviet Union 1976.

VIII. SPECIAL CONSIDERATIONS

A. Molting

The first geese to molt are usually the subadults, followed by mature breeders that failed to nest successfully, and then by successful breeders. For breeding birds, the molt is initiated when the goslings are between one and three weeks old, varying by species. Geese are flightless for approximately three to four weeks (Bellrose 1976). During this period, geese are vulnerable to predation and are very sensitive to disturbance. Molting flocks are often found on large lakes and protected coastal waters away from nesting areas (Johnsgard 1975, Bellrose 1976).

In the Arctic Region, nonbreeding brants are in full molt in the first week of July; some individuals regain flight by the last week in July, indicating the molt lasts three to three-and-one-half weeks. Canada geese molt slightly earlier, with some birds flying by 18-16 July (Derksen et al. 1979).

B. Disturbance

In the Western Region, goose nesting populations are highly sensitive to disturbance, and efforts should be made to minimize human activities in nesting and breeding areas. Additionally, nesting and other habitat along the coast is vulnerable to environmental damage, especially that resulting from oil spills.

The bays, lagoons, and other tidal areas are necessary for the survival of these species.

IX. LIMITATIONS OF INFORMATION

The breeding grounds of the tule goose have only recently been partially delineated, and additional data on nesting areas and habitat requirements are needed.

Studies to determine mammalian depredation of dusky Canada geese nests are ongoing and will continue. Additional studies to determine utilization of new nesting habitat created by the 1964 earthquake are being conducted by the ADF&G and the USFWS. The importance of Cook Inlet and Alaska Peninsula staging habitats needs to be further described. Banding studies and research on nesting areas needs to be increased substantially to determine movements and mortality sources. Increased banding efforts for cackling Canada and emperor geese need to be initiated. Banding of these species must be greatly increased to determine survival rates, migration routes, and mortality factors. Also, efforts should be made to determine the total population size of the emperor goose.

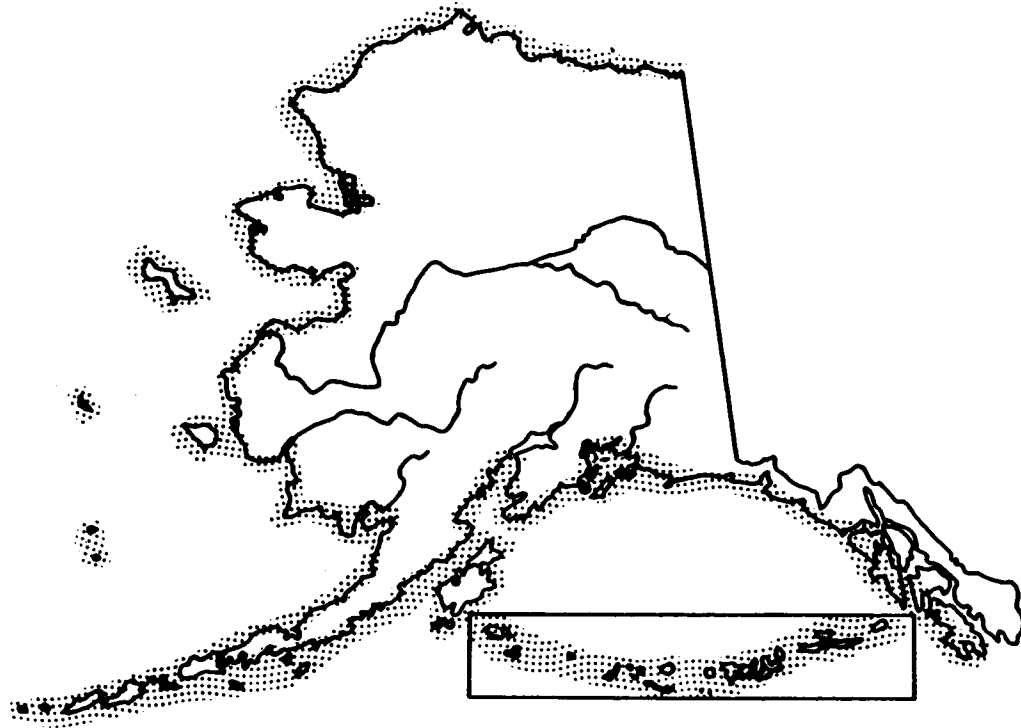
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Seabird Life Histories and Habitat Requirements
Southwest and Southcentral Regions



Map 1. Range of seabirds (ADF&G 1973, SOWLS et al. 1978)

I. NAME

Seabirds known to occur in Alaska are separated into the following general categories: albatrosses (Diomedidae), shearwaters and fulmars (Procellariidae), storm-petrels (Hydrobatidae), cormorants (Phalacrocoracidae), gulls and terns (Laridae), and alcids (Alcidae), which include murrelets, guillemots, murrelets, auklets, and puffins (Quinlan, pers. comm.; SOWLS et al. 1978; Nelson 1979).

II. RANGE

A. Worldwide

Approximately 260 species of seabirds occur worldwide. Their range extends virtually from pole to pole and throughout the expanses of the world's oceans. Some species of seabirds may occur anywhere on the open ocean; however, they more commonly

occur near favorable areas of current upwelling and convergence. These areas provide concentrated food sources for large numbers of seabirds (Nelson 1979).

B. Statewide

At least 65 species of seabirds migrate, breed, or visit along Alaska's coastline and adjacent waters (Trapp, pers. comm.). Seabird colonies appear to be most numerous in the Gulf of Alaska, along the Alaska Peninsula, in the Kodiak archipelago, and in Prince William Sound (PWS). In the Bering and Chukchi seas region, fewer colonies are found; however, all are very large, many containing breeding populations exceeding a million birds (King and Lensink 1971, Sowls et al. 1978).

In late fall, most seabirds migrate south, and populations in Alaskan waters become much reduced from those of summer (ADF&G 1978).

C. Regional Distribution Maps

To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for the Southwest, Southcentral, and Southeast regions. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of seabirds has been prepared for the Southwest and Southcentral regions and may be found in the Atlas that accompanies each regional guide.

D. Regional Distribution Summary

Because of a greater variety of favorable habitats in Southwest and Southcentral Alaska, seabird populations there exhibit greater species diversity than those found in the remainder of the state (ibid.).

1. Southwest. In Southwest Alaska, over 560 colonies or colony complexes, with breeding populations including over 23 species of seabirds, have been recorded (Sowls et al. 1978). In Southwest Alaska, the common murre represents over half the total population of colonial birds in the region. Other species of importance include the black-legged kittiwake, tufted puffin, pelagic cormorant, and glaucous-winged gull (ADNR/USFWS 1983). (For more detailed narrative information, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region and the USFWS Catalog of Alaskan Seabirds Colonies [Sowls et al. 1978].) Computerized distribution and abundance information on seabirds, which is annually updated, is available from the USFWS in Anchorage, Alaska.

2. Southcentral. In Southcentral Alaska, over 216 colonies, including at least 26 species, have been documented (ibid.). The majority of these colonies occur in the PWS area (including Middleton Island and Blying Sound), with over

400,000 birds nesting there during the breeding season (ibid.).

Along the southern outer Kenai Peninsula coast and the lower Cook Inlet area, over 73 colonies are documented (ibid.), with over 43,000 breeding birds.

In Southcentral Alaska, the black-legged kittiwake is the most abundant species of nesting seabirds. Other seabird species with large breeding populations in Southcentral Alaska include tufted puffin, common murre, and pelagic cormorant. A small colony of fork-tailed storm petrels is located on Wooded Island in PWS.

(For more detailed narrative information, see the USFWS Catalog of Alaskan Seabird Colonies [ibid.].) Computerized distribution and abundance information on seabirds, which is updated annually, is available from the USFWS in Anchorage, Alaska (Sowls, pers. comm.).

III. PHYSICAL HABITAT REQUIREMENTS

Alaska's vast coastal zone and continental shelf provide abundant feeding, molting, migrating, and wintering habitat for seabirds. These marine habitats can be categorized as inshore, nearshore, and offshore waters (including mid continental shelf, outer continental shelf, shelfbreak, and oceanic waters). (See table 1.)

IV. NUTRITIONAL REQUIREMENTS

(See table 1.)

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Nesting habitat for seabirds in Alaska is largely confined to islands, cliffs, bluffs, and beaches of the coastal zone. Seabirds, however, show considerable flexibility in adapting to available nesting habitat by utilizing a wide variety of habitats, including man-made structures (shipwrecks, building ledges, etc.). Natural nesting habitat within the coastal zone includes boulder rubble, talus slopes, rock cliffs, rock crevices, cliff ledges, soil burrows, and flat ground (Trapp, pers. comm.). A few seabirds, such as jaegers, glaucous gull, mew gull, and arctic tern, are widely distributed throughout the interior along lakes, streams, and in areas of moist tundra (table 1).

VI. FACTORS INFLUENCING POPULATIONS

A. Natural

Disease and parasites have the potential to kill many birds, although study of this phenomenon is in its infancy in Alaska (ibid.).

Increasing gull populations could cause substantial damage (through food-robbing and egg and young predation) to specific

Table 1. Seabird Life Histories

Species	Preferred Foods	Feeding Location	Feeding Behavior	Incubation	Clutch Size	Nest Location	Sexual Maturity
Albatross, black-footed and Laysan	Fishes, amphipods, and squids	Pelagic ocean surface	Feeds at night from the ocean surface	63-68 days; incubation by both sexes	1	Nests in colonies on islands in southern hemisphere; nest is shallow scrape on the sand; does not breed in Alaska	Approximately 9 yr
Northern fulmar	Fishes, mollusks, crustaceans; offal from off-shore fishing ships	Pelagic ocean surface; reported to dive up to 6 ft below surface	Single birds wander widely; large, noisy flocks gather at areas of high food concentration; float or swim on surface while eating	16-51, avg. 48 days; by both sexes	1 egg only; 1 brood/yr	Nests in colonies, sometimes very large; nest is usually in hollow on cliff or moist vegetation; also on small islands	6-12 yr of age; do not come to land until 3-4 yr old
Storm-petrel, fork-tailed, and Leach's	Small fishes and crustaceans, plankton, drifting marine mammal carcasses, and offal from offshore fishing vessels	Ocean surface and below	Birds hover close to surface and occasionally dive beneath the surface	37-68, avg. 49 days	Average 1	Nests in dense colonies in burrows on islands or in deep holes in rocks; also on grassy slopes up to 1 mi or more inland	---
Shearwater, slender-billed	Fishes	Ocean surface	Shallow dives or catches fish on the surface	52-55 days	1	In colonies, in burrows on coastal islands near Australia (does not breed in Alaska)	---
Gulls, glaucous, and glaucous-winged	Barnacles, mollusks, and sea urchins; they are scavengers, feeding on carrion, fishes, and garbage	Garbage dumps, docks, along shore, near ships; seabird colonies	Opportunistic feeding; will scavenge on land and in/near water; are predators of colonial seabird eggs and young	28-29 days	2-3, usually 3	Nests usually built of grass, moss, and seaweed, on narrow ledges of steep cliffs facing the sea, usually near colonies of murre; also nests near tundra lakes or on coastal dunes and sandbar islands	---

(continued)

Table 1 (continued).

Species	Preferred Foods	Feeding Location	Feeding Behavior	Incubation	Clutch Size	Nest Location	Sexual Maturity
Tern, Aleutian & arctic	Capelin, sand lance, or small crustaceans	Ocean or freshwater surface	Hovers 30-40 ft over water, then dives, often submerging	21-22 days	Usually 2, sometimes 3	Nests on the ground in loose colonies on or near the coast in sand pits, sand bar islands, or the flat vegetated tops of rugged islands	---
Kittiwake, black-legged & red-legged	Small fish, crustaceans, or other invertebrates	Feeding occurs at or near the pelagic ocean surface during and outside the breeding season	Hovers briefly before landing on ocean surface, or dives shallowly; flocks to forage on scraps from ships	Avg. 27 days; by both sexes	Black-leg: usually 2; red-leg: usually 1	Nests in colonies on cliffs; some are found along fjords, often near glaciers	---
Pelagic cormorant	Sculpins, herring, tomcod, sand lances, sea poachers, flounders; also crabs, shrimps, crayfishes, amphipods, and marine worms	Ocean surface or diving in inshore waters or surf; rarely observed farther than a few kilometers from land	Dives from surface, even into rough seas and surf near boulders to catch food; attracted to schools of fish by actions of gulls	20-32, avg. 31 days; by both sexes	3-7, usually 3-5	In colonies on remote and precipitous cliffs with other cormorants and seabirds; changes in colony location are well documented in the western Gulf of Alaska	---
Double-crested cormorant	Salt water: fishes, crustaceans, mollusks, seaworms; fresh water: fishes, salamanders, reptiles, crustaceans	Surface of salt, brackish, and inland fresh waters	Dives from surface to depths of 5-25 ft; swims underwater from 30-70 seconds	20 days; by both sexes	2-7, sometimes 9 but usually 3-4; usually single brood, but may re-lay if nest is destroyed	Nests in colonies on rocky islands, on cliffs facing water, or stands of trees near water; ground nest material is seaweeds & trash; tree nest materials are twigs and grass	---

(continued)

Table 1 (continued).

Species	Preferred Foods	Feeding Location	Feeding Behavior	Incubation	Clutch Size	Nest Location	Sexual Maturity
Red-faced cormorant	Small fishes, crabs, shrimps	In inshore waters, rarely observed far from land	Dives from surface	32-34 days	Usually 3-4	Nests in colonies on ledges of steep cliffs; nests are large and built of grasses, seaweed, and sod	---
Puffin, tufted and horned	Fish (8-10 in. long) such as smelts, sardines, herring, perch, squid, some small invertebrates and mollusks	At sea, primarily below ocean surface	Dives and uses wings to fly underwater to catch small fish; quite maneuverable	41-54, avg. 45 days; incubation by both sexes	1	Puffins nest in burrows on rounded tops of islands, in sandy bluffs above beaches, under loose rocks or in crevices in rocks and cliffs; return to same burrow and mate the 15-20 yr it nests	3-4 yr
Murre, common and thick-billed	Feeds on polar cod, capelin, lances, Atlantic cod, herring, marine worms, amphipods, shrimp, and arctic squid	Ocean surface and below	Congregates where food is and dives up to 240 ft from surface; best diver among alcids	28-34 days; incubation by both sexes	1	Nests in dense colonies on bare rock ledges and high rocky coastal cliff tops; often associated with other seabirds	Breeds for 1st time in 3rd summer
Pigeon guillemot	Bottom-dwelling small fishes, mollusks, crustaceans, and marine worms	Nearshore waters; rarely observed far from land	Dives from surface, and uses wings to "fly" underwater	30-32 days	1-2, usually 2	Solitary nests or in small colonies up to 50 pairs; nests in crevices, caves, talus slopes of cliffs, or abandoned burrows of puffins or rabbits	---
Auklet, least	Amphipod crustaceans	Primarily in near-shore waters on the ocean surface	Dives in little leaps below surface	20-36 days; incubation by both sexes	1	Least auklets lay eggs on bare rocks or beds of small stones in rocky crevices on inaccessible cliffs or under loose boulders on rocky beaches	---

(continued)

Table 1 (continued).

Species	Preferred Foods	Feeding Location	Feeding Behavior	Incubation	Clutch Size	Nest Location	Sexual Maturity
Ancient murrelet	Small marine invertebrates, small fish	Pelagic ocean surface in winter; near shore in spring/summer	Nocturnal; dives from surface and flies underwater	By both sexes, which exchange places at night; precocious young leave nest after 2-3 days	1-2, usually 2	Small burrow or hollow under grass clumps, in natural rock crevices, or abandoned burrows of other alcids	---
Parakeet auklet	Amphipods or other small crustaceans	Ocean surface or rocky bottom at moderate depths	Flies out to sea in morning and returns to nest at night; carries food to young in mouth pouch	Probably by both sexes	1	Nests in scattered pairs, or sometimes in large colonies; in rubble of talus slopes or in deep crevices or holes of rocky cliffs	---
Crested auklet	Amphipod crustaceans	Nearshore waters	Surface dives or with dives as deep as 200 ft; parents carry food to young in pouch under the tongue	34-47 days;	1	Nests in colonies in crevices in cliffs, talus slopes, or under beach boulders	---
Whiskered auklet	Amphipods, snails and crabs	Nearshore waters and passes in breeding season and winter	Surface dives preceded by a small leap on surface	35-36 days	1	Nests in rock crevices and holes of steep rocky shores of remote islands; nocturnal or crepuscular in colony attendance	---
Rhinoceros auklet	Small fish and crustaceans	Nearshore waters during breeding season	Dives from surface and uses wings to fly underwater	By both sexes, which exchange places at night; 31-33 days	1	Nests in burrows from near shoreline to 400-500 ft up banks; uses sticks and grasses for material; same mates and burrows are maintained from year to year	---

Source: Terres 1980.

--- means no data were available.

colonial species (such as terns and puffins), as they have on the Atlantic coast (ibid.).

B. Human-related

Predators, mainly foxes, introduced for fur-farming in the late 1800's and early 1900's have had a devastating and long-lasting impact on Alaska seabird colonies throughout Southcentral and Southwest Alaska (ibid.).

Oil and gas developmental activities and the related possibility of marine oil pollution pose a threat to seabirds. If properly regulated, however, offshore oil and gas development may not severely impact seabirds (ibid.).

Commercial exploitation of North Pacific fish populations may result in a serious reduction in fish numbers, which in turn might reduce the food supply of seabirds (ibid.).

Toxic chemical contamination of seabirds is a serious threat. The widespread distribution of a variety of pollutants in marine ecosystems affecting seabirds is well documented (Nelson 1979).

In Alaska, human disturbance in the form of tourism has not yet been a problem (Trapp, pers. comm.). Properly organized and regulated visits to seabird colonies by tour groups can actually benefit seabirds by promoting public support for managerial efforts (ibid.).

VII. LEGAL STATUS

All seabirds are protected by the Migratory Bird Treaty Act of 1918. Seabirds in Alaska are managed by the U.S. Fish and Wildlife Service.

VIII. LIMITATIONS OF INFORMATION

Current abundance information for many species and some areas is needed: outer Aleutian Islands, some areas of PWS, and Southeastern Alaska.

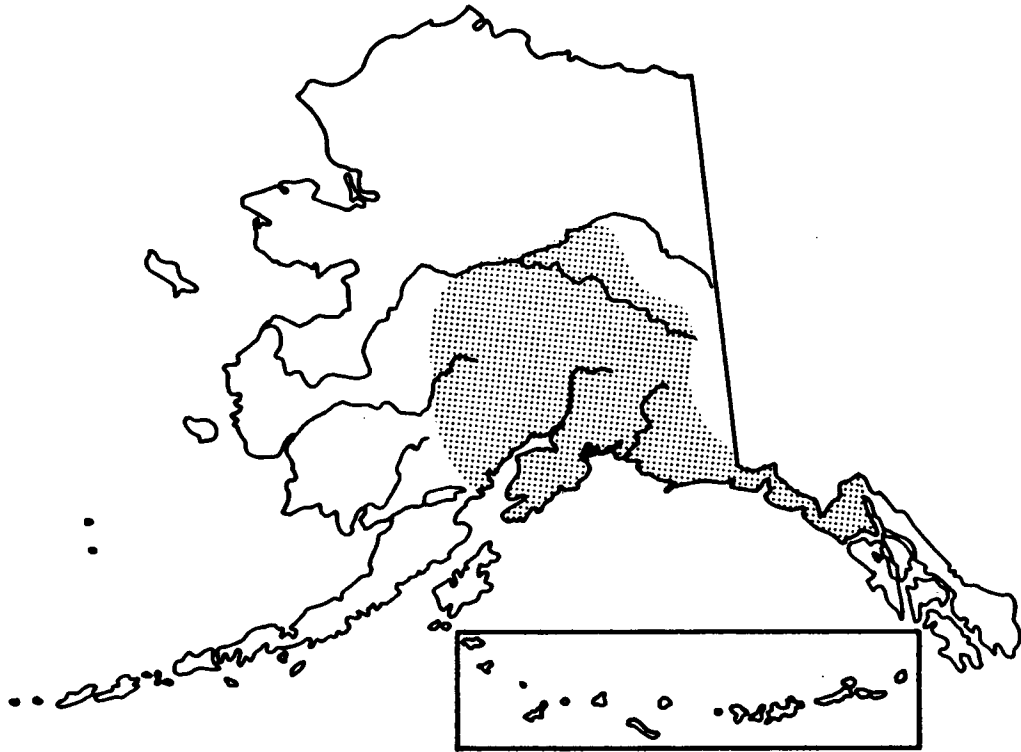
Nesting habitat and behavior of some species, especially marbled and kittlitz's murrelets, is little known.

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Trumpeter Swan Life History and Habitat Requirements
Southcentral Region



Map 1. Range of trumpeter swan (Bellrose 1976)

I. NAME

- A. Common Name: Trumpeter swan
- B. Scientific Name: Cygnus buccinator
- C. Native Names: See appendix A.

II. RANGE

A. Worldwide

The present range of the trumpeter swan is only a vestige of the once vast region of North America that it frequented in both summer and winter (Bellrose 1976).

1. Breeding range. The trumpeter swan breeds in central and southern Alaska, British Columbia, Alberta, southwestern Montana, and Wyoming (Gabrielson and Lincoln 1959).
2. Wintering areas. The southern portion of the trumpeter swan population is more or less nonmigratory, whereas the northern

portion migrates to the coast of southeastern Alaska and British Columbia, Washington, Oregon, Idaho, Montana, and Wyoming (ibid.).

B. Statewide

1. Breeding range. According to King and Conant (1980), nesting trumpeter swans in Alaska are distributed along the North Pacific coastal plain from Yakutat to Cook Inlet, through the forested valleys of the Copper, Susitna, and Yukon rivers to the vicinity of the Arctic Circle at elevations below 3,000 ft. (See map 1 in the trumpeter swan Distribution and Abundance section of volume 2 of the guide for the Southcentral Region.)
2. Wintering areas. Trumpeter swans that breed in Alaska winter along the Pacific Coast from the Alaska Peninsula to the mouth of the Columbia River (Bellrose 1976).

C. Regional Distribution Maps

To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for the Southcentral and Southeast regions. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a colored 1:1,000,000-scale index map of trumpeter swan distribution may be found in the Atlas that accompanies the guide for the Southcentral Region.

D. Regional Distribution Summary

1. Southcentral:

- a. Breeding range. The trumpeter swan is a locally common summer resident of the freshwater areas of the northeastern coast of the Gulf of Alaska, an uncommon migrant and visitor in Prince William Sound, and an occasional visitor along the northwestern coast of the Gulf of Alaska (Timm 1975).
- b. Wintering areas. Birds winter on the open, freshwater outlets of Eyak Lake and Martin Lake near Cordova and on Skilak Lake on the Kenai Peninsula if suitable conditions exist (Timm 1975; Spraker, pers. comm.). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

Trumpeter swans prefer secluded regions, where they frequent shallow bodies of water (Timm 1975).

Along the coast in late summer and early fall, large numbers of trumpeter swans congregate on ponds and marshes (ibid.). Birds winter on ice-free freshwater outlets, although sometimes they are temporarily driven to salt water during extremely cold periods when freshwater locations freeze (ibid.). Palmer (1976) defines the wintering habitat of trumpeter swans in Alaska as unfrozen ponds, lakes, sluggish-moving waters, marsh meadows, and inner brackish reaches of coastal fjords and bays (see section V.A. below for a discussion of additional water requirements).

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

Adult trumpeter swans prefer wild celery (Angelica lucida) and other freshwater plants, but they also eat grain, grasses, insects, snails, and small invertebrates when available. Trumpeter swans normally consume succulent green vegetation when available, with all parts of the aquatic plants being utilized (Banko 1960). Pondweed (Potamogeton spp.) tubers are used extensively as food (Hansen et al. 1971). Young cygnets in their first three weeks feed primarily on animal matter, with plant life becoming increasingly more important with age (Banko 1960).

In Southcentral Alaska, preferred foods include maretail (Hippuris spp.), horsetails (Equisetum spp.), sedges (Carex spp.), and buckbean (Menyanthes trifoliata). Communities dominated by these species also contain most nest sites (Hansen et al. 1971; Campbell, pers. comm.).

B. Types of Feeding Areas Used

Most feeding occurs in shallow water areas, although immature and adult swans may feed or graze to a limited extent upon land; cygnets feed solely in water (Banko 1960). Large lakes in Alaska that lack emergent vegetation and are therefore unsuitable for breeding are often used by nonbreeding swans when pondweed is common (Hansen et al. 1971). Generally during their first two weeks, young cygnets feed in very shallow waters of six inches to one foot in depth. When feeding occurs in deeper waters, they gather foodstuffs brought to the surface by their parents (Banko 1960).

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Alaska trumpeters require a minimum of 140 and up to 154 ice-free days to complete a reproductive cycle. This requirement precludes use of otherwise suitable habitat above approximately 2,700 ft elevation and dictates that most nesting occurs below 500 ft (King 1968, Hansen et al. 1971). Specific physical features of the trumpeter swan breeding habitat include the following requirements:

- Stable waters that possess a relatively static level, not exhibiting marked seasonal fluctuations
- Quiet lake, marsh, or slough waters, not subject to obvious currents or constant wave action
- Shallow waters of lakes or open marshes that do not preclude considerable digging and foraging for lower aquatic plant parts (roots, tubers, etc.) (Banko 1960)

Trumpeter swans build their nests in extensive areas of marsh vegetation. The nests are built directly on the marsh bottom (Hansen et al. 1971) in water 1 to 3 ft deep (Bellrose 1976). In Alaska, sedges and horsetails predominate where nests are found. Trumpeter swans also utilize muskrat houses and beaver lodges for nesting (Arneson, pers. comm.).

B. Reproductive Seasonality

Most breeding pairs are at their nest sites by early May, and the first egg appears some time between April 28 and May 11 (Timm 1975). The first hatching dates range from June 16 to June 29 (ibid.). In Alaska, cygnets are unable to fly until 13 to 15 weeks of age (Bellrose 1976). After leaving the breeding areas, larger numbers of trumpeter swans congregate on ponds and marshes along the coast in late summer and early fall. Most swans depart by mid October but some years may remain until freeze-up in November (Timm 1975).

C. Reproductive Behavior

Swans usually mate for life; however, if one of the pair is lost, the other may subsequently mate again (Bellrose 1976). Territorial behavior is strikingly evident among trumpeter swans; a mated pair vigorously defends the mating, nesting, and cygnet feeding grounds (Banko 1960). A pair occupies its territory as soon as there is open water in the spring, and some pairs defend their territories until late summer, when the cygnets are half grown (Bellrose 1976).

In Alaska, Hansen et al. (1971) found only one pair of territorial trumpeters on each small water area ranging from 6 to 128 acres. Only a few large lakes, 1 to 4 mi long, were occupied by two or three breeding pairs.

D. Age at Sexual Maturity

Banko (1960) concluded that trumpeters may begin nesting as early as their fourth year or as late as their sixth year. Perhaps the density of territorial pairs accounts for some of the variation (Bellrose 1976).

E. Clutch Size

From 2 to 10 eggs are laid, usually 5 to 8 (Timm 1975). In Alaska, the clutch size ranges from 4.9 to 5.2 eggs but may vary as a result of early and late springs (Timm 1975, Hansen et al. 1971).

F. Incubation Period

The period of incubation varies from 33 to 37 days (Banko 1960, Hansen et al. 1971).

G. Rearing of Young

The female usually broods her newly hatched young on the nest for the first 24 hours, longer if the weather is inclement (Hansen et al. 1971). Both parents are solicitous of their young; the family forms a tightly knit group, with the actively swimming or feeding young flanked by each parent (Bellrose 1976). The offspring are usually left by their parents upon approach of the breeding season, at least until their first flightless molt in late June or early July (Banko 1960).

VI. FACTORS INFLUENCING POPULATIONS

A. Natural

Survival of young to the flight stage (90-100 days) is greatly affected by severe weather, predator populations (coyotes and

eagles) (Banko 1960), and diseases (Sarvis, pers. comm.; Banko 1960). Mortality of adult trumpeter swans is caused primarily by weather (freezing of feeding areas for extended periods causing starvation) and infrequently by mammalian predation (coyotes and river otters) (Banko 1960) and avian predation (golden eagles) (ibid.).

B. Human-related

Activities having the greatest potential for causing future population declines are those that alter or eliminate swan habitat, particularly nesting and molting areas, or that disturb swan use areas, such as the following:

- Aquatic substrate alteration (e.g., from accelerated aufeis, mechanical removal)
- Chronic debilitation due to ingestion or contact with petroleum or petroleum products
- Chronic debilitation due to ingestion or contact with chemicals
- Harassment, active (e.g., intentional hazing, chasing)
- Harassment, passive (e.g., construction noise, vehicle noise, human scent)
- Interruption of ongoing behavior: alarm, flight
- Terrain alteration or destruction
- Vegetation composition change to a less preferred or usable species
- Vegetation damage/destruction due to contact with petroleum, petroleum products, or chemicals (limited to plant species/associations important to swans)
- Vegetation damage/destruction due to hydraulic or thermal erosion and/or deposition (limited to plant species/associations important to swans)
- Vegetation damage/destruction due to mechanical removal or material overlay (limited to plant species/associations important to swans)
- Poisoning due to lead shot introduced in marsh habitat by hunters (King, pers. comm.)
- Loss of security due to establishment of human recreational activity introduced to swan nesting territories, including boating and floatplane activity, camping, and cabin sites (ibid.)
- Illegal hunting
- Water level or water quality fluctuation, including changes in drainage patterns, long-term increase or decrease in water levels
- Accidents (striking power, telephone, or fence wires in flight)

(See the Impacts of Land and Water Use volume of this series for additional information regarding impacts.)

VII. LEGAL STATUS

In Alaska, waterfowl are managed by the U.S. Fish and Wildlife Service and the Alaska Department of Fish and Game. They are protected under international treaties with Canada (Great Britain), 1916, Mexico, 1936, Japan, 1912, and the Soviet Union, 1976.

VIII. SPECIAL CONSIDERATIONS

1. Nest disturbance. When trumpeter swan nests have been disturbed, the birds frequently abandon their nest sites and sometimes walk overland to another lake, which makes them much more subject to predation (Hughes, pers. comm.). On the Copper River delta, pairs of trumpeter swans with nests or young were more sensitive to human disturbance than adults without young (Timm and Sellers 1979). Also the timing of egg removal is a critical factor in renesting (Banko 1960). Even aircraft flying at 2,000 ft can cause trumpeter swans to abandon their lake (Portner, pers. comm.).
2. Molting and staging areas. Most nonbreeding birds in Alaska begin their molt in late June or early July. For breeding pairs, males usually molt first (Hansen et al. 1971). Birds are flightless for about 30 days (Hansen et al. 1971, Bellrose 1976).
3. Migration stops (resting and feeding areas). Trumpeter swans travel in family groups, and having adequate resting and feeding areas is especially critical to the young, which cannot travel as far (Hughes, pers. comm.).
4. Wintering habitat. Good swan wintering habitat usually contains a certain amount of level and open terrain allowing trumpeter swans to loaf or fly without restriction of visibility or movement. On smaller streams, where air space over water is limited, this requirement becomes especially important, because trumpeters need ample unrestricted air space for take-off (Banko 1960). Unobstructed snowfields or meadows adjacent to open streams or ponds are regularly used for loafing sites, especially in late winter, when the snow hardens with settling (ibid.). On streams, water movement is important in keeping such waters open during moderately cold weather, but some source of warm water is a necessity during prolonged periods of cold weather in the winter (ibid.).
When freshwater locations along the eastern North Gulf Coast freeze, swans are sometimes driven to salt water during extremely cold periods (Timm 1975).

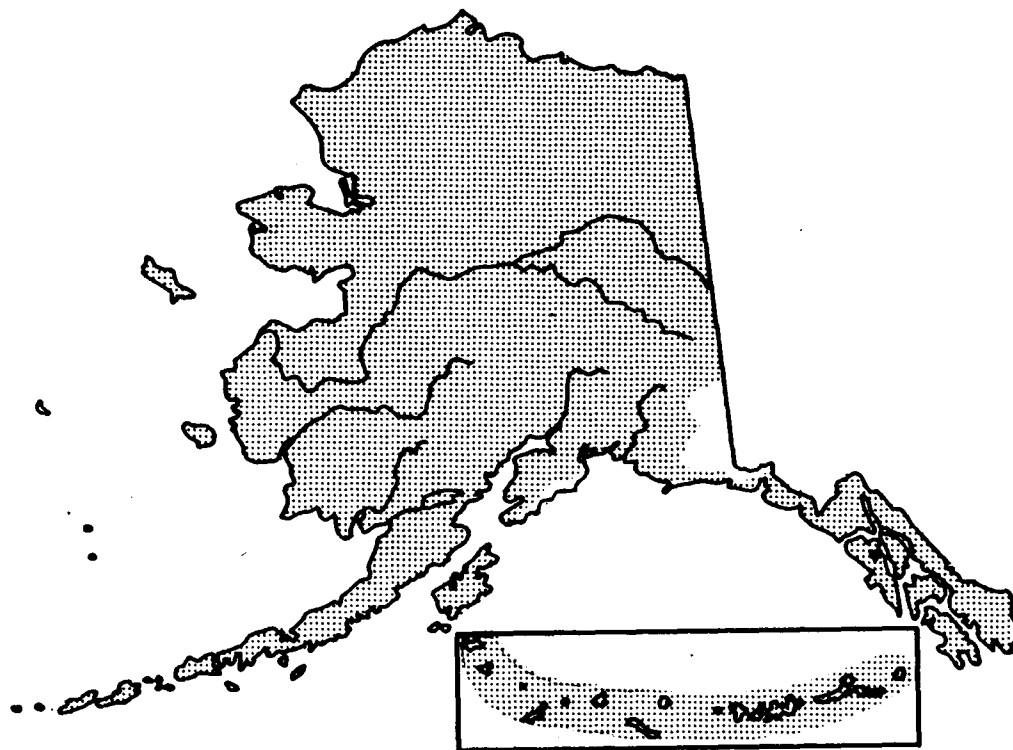
IX. LIMITATIONS OF INFORMATION

Molting and brood-rearing areas are not well documented. Basic research information has been collected only occasionally (usually one survey per year every five years) in the Copper River delta and Cook Inlet basin. Also, all wintering areas south of Alaska for Gulf Coast trumpeters have not been found (Timm 1975).

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Tundra Swan Life History and Habitat Requirements
Southwest Region



Map 17. Range of tundra swan (Bellrose 1976)

I. NAME

- A. Common Names: Tundra swan, whistling swan
- B. Scientific Name: Olor columbianus
- C. Native Names: See appendix A.

II. RANGE

A. Worldwide

- 1. Breeding range. Tundra swans nest in arctic North America, with the greatest density along the arctic coastal strip from the west side of Mackenzie River delta to the east side of Anderson River delta. Swans also nest on islets off the shores of shallow lakes or flooded tundra from north Alaska south to the Alaska Peninsula (Terres 1980).

2. Wintering areas. Tundra swans winter from the Aleutians south along the Pacific Coast to extreme northern Baja California; and on the Atlantic coast rarely from Massachusetts, New Jersey, and Long Island, N.Y., but mainly Chesapeake Bay, Md., south to Currituk Sound, North Carolina; rarely to Florida and the coasts of Louisiana and Texas (ibid.).
- B. Statewide
1. General distribution. Tundra swans are found throughout the state where conditions are suitable. Records extend from Attu Island on the west to Demarcation Point on the east (Gabrielson and Lincoln 1959).
 2. Breeding range. The breeding range is from Unimak Island, Kodiak Island, and the northern part of the Alaska Peninsula north and west to Cape Prince of Wales, Meade River, the Colville River delta, and Camden Bay (ibid.).
- C. Regional Distribution Maps
- To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for the Southwest Region at 1:250,000 scale. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of tundra swans has been prepared and may be found in the Atlas that accompanies the guide for the Southwest Region.
- D. Regional Distribution Summary
- In general, tundra swans are distributed throughout the Southwest Region east of Unimak Pass at elevations below 1,200 ft (Sellers, pers. comm.). Major concentrations, however, are found in coastal and riverine habitats. Two populations of tundra swans utilize the area, one migratory, the other nonmigratory. When a majority of the swans have migrated to warmer climes, usually by mid September, a population of approximately 400 to 700 birds remains in the region, wintering primarily at Peterson Lagoon in Uria Bay, Unimak Island (Sarvis, pers. comm.).

III. PHYSICAL HABITAT REQUIREMENTS

In the summer, tundra swans occur primarily on coastal tundra areas dotted with small lakes (Timm 1975). During spring and fall migrations, swans utilize river deltas and outlets as well as lagoons and estuaries. Recent studies on coastal migratory bird habitats showed that of the available habitat types swans preferred protected delta water and salt marshes (Arneson 1980).

IV. NUTRITIONAL REQUIREMENTS

A. Preferred Food

Tundra swans feed largely on the leaves, stems, and tubers of aquatic and marsh plants (Bellrose 1976). Berries, particularly lowbush cranberry (Vaccinium vitis-idaea) and blueberry (Vaccinium uliginosum), are also important (Sellers, pers. comm.).

B. Feeding Locations

Swans usually feed in shallow water where immersion of the head and neck is sufficient to enable them to obtain the desired food items (Bellrose 1976). They also graze along the margins of lakes and ponds (Scott 1972); during the spring and fall, tundra areas near lakes are used for foraging on berries (Sellers, pers. comm.).

C. Feeding Behavior

When feeding, large flocks of swans will usually break up into family units of three-to-six individuals (Bellrose 1976).

V. REPRODUCTIVE CHARACTERISTICS

A. Breeding Habitat

Hummocks located on peninsulas and islands are preferred nesting areas. Most swan nests are in heath tundra, which not only dominates the nesting grounds but also provides most of the elevated sites used by swans. The nest is an elaborate platform 12 to 18 inches high composed of moss, grass, and sedges and resembling a muskrat house surrounded by a moat (Lensink, pers. comm.).

B. Breeding Seasonality

According to Lensink (pers. comm.), the first swans reach their breeding grounds on the Yukon delta in late April, and almost all have arrived by mid June. During warm years, when the snow melts early, nesting begins soon after the arrival of the flocks on the outer delta, usually by mid-to-late May (Bellrose 1976). Tundra swans, however, frequently arrive on breeding grounds before the snow has melted (Scott 1972), and in those years the date of nesting is delayed, perhaps until early June. Inland from the coast, where the snow melts earlier, nesting occurs earlier (Bellrose 1976).

C. Breeding Behavior

1. Swans are territorial in their nesting behavior. In Alaska, tundra swans nest at densities varying between 0.4 and 1.0 pairs/km² (King and Dau 1981).
2. Sexually mature adults normally pair for life, sharing the responsibilities of nest care, incubation, and rearing of the young.
3. Traditional ponds and lakes are used for nesting, with birds often returning to the same nest sites. In making the nest, swans pluck the vegetation from around the nest site, creating a circle of open water or disturbed ground up to 15 ft in diameter (Bellrose 1976; Sarvis, pers. comm.).

D. Age At Sexual Maturity

Although swans mature in their third year, most do not establish a territory and breed before their fifth or sixth summer (Scott 1972; Sarvis, pers. comm.).

E. Fecundity

The average number of eggs per clutch is three to five, with a hatch success of approximately 75%. Differences in clutch size

appear attributable to the timing of the snowmelt. The later the birds commence nesting, the smaller the clutch (Bellrose 1976). In the Izembek area, clutch size is from three to nine eggs, with hatching success varying from 36 to 50% (Sarvis, pers. comm.).

F. Incubation Period

The incubation period is approximately 30 to 33 days; peak hatching occurs about mid June (Bellrose 1976; Sellers, pers. comm.; Sarvis, pers. comm.).

G. Rearing of Young

Both parents guard the welfare of their young. On the Yukon delta, broods stay within 100 to 400 yd of their nests for a considerable length of time after hatching (Bellrose 1976). In the Izembek area, some broods travel up to 2 mi from the nest lake to the brood rearing lake, whereas others raise broods on the same lake where they hatched (Sarvis, pers. comm.).

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

A. Staging

In late August, when the birds have regained their flight capabilities, they congregate along the coast or near large inland lakes in preparation for the move to wintering areas. River outlets and deltas, such as those of the Naknek River, as well as the lagoons and estuaries in Bristol Bay, are used by spring and fall migrants. In the fall in the Izembek area, the nonmigratory swans gather into flocks and begin a gradual shift to Peterson Lagoon on Unimak Island (ibid.).

B. Migration Behavior

Tundra swans migrate as family units, with several families and probably some nonbreeding birds combining into a single flock (Bellrose 1976).

C. Migration Routes

1. Fall migration. The migrating population of tundra swans leaves the Southwest Region from September through October (Sellers, pers. comm.). The peak fall migration occurs in mid October (ibid.). They move south along the coast to Vancouver Island and the small bays along the coasts of Washington and Oregon. Tundra swans begin arriving at their wintering grounds about mid-to-late November (Bellrose 1976).
2. Spring migration. Swans begin leaving their central California winter grounds in mid February. By mid March they are leaving the Klamath basin, and by late March, the higher Malheur and Great Salt Lake basins. The western population of tundra swans migrates earlier and more swiftly than its eastern counterpart. The Naknek River near King Salmon supports 1,000 or more swans in early spring (King, pers. comm.). According to Lensink (pers. comm.), the first swans reach their breeding grounds on the Yukon delta in late April, and almost all have arrived by mid May (Bellrose 1976).

VII. FACTORS INFLUENCING POPULATIONS

- A. Natural 312
Survival of young to the flight stage (60 to 70 days) is greatly affected by severe weather, predator populations, and possibly diseases (Sarvis, pers. comm.).
- B. Human-related
A summary of possible impacts from human-related activities includes the following:
 - ° Pollution of water and/or food
 - ° Reduction of food supply
 - ° Alteration of freshwater habitat
 - ° Alteration of nesting habitat
 - ° Dredging/filling/drainage of wetlands
 - ° Disturbance of fall/spring staging areas
 - ° Oiling of feathers
 - ° In-flight hazards (e.g., transmission lines, towers)

VIII. SPECIAL CONSIDERATIONS

- A. Molting
Molting is a once-a-year phenomenon that occurs in the mid-to-late summer, following the nesting period. The birds are flightless for a period of 20 to 25 days (ibid.).

IX. LEGAL STATUS

In Alaska, waterfowl are managed under the International Migratory Bird Treaty Act of 1918 as implemented by the U.S. Fish and Wildlife Service and the Department of Fish and Game.

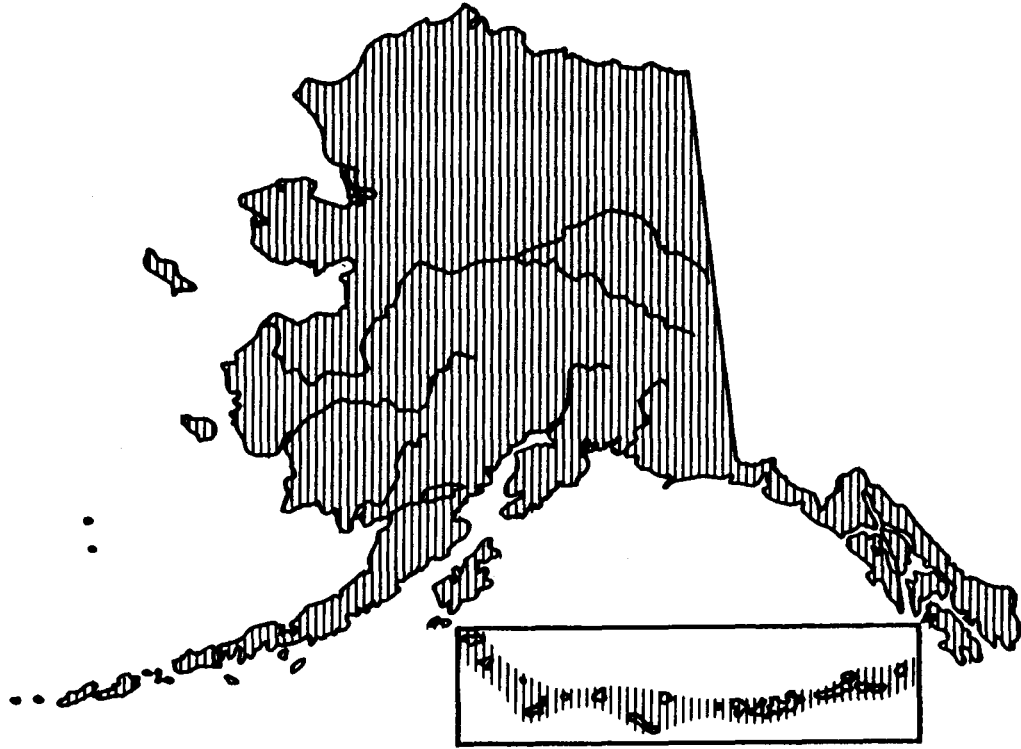
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Freshwater/Anadromous Fish

Arctic Char Life History and Habitat Requirements
Southwest, Southcentral, Arctic, Western, and Interior Regions



Map 1. Range of arctic char and Dolly Varden in Alaska (ADF&G 1978)

I. NAME

- A. Common Names: Dolly Varden, arctic char
- B. Scientific Names: Salvelinus malma (Walbaum), Salvelinus alpinus (Linnaeus)

Dolly Varden and arctic char are two closely related salmonids of the subfamily Salmoninae. Members of the genus Salvelinus are morphologically and ecologically very plastic species. Although this has allowed char to adapt to changing environmental conditions it has been a nightmare for taxonomists, who must attempt to compartmentalize a continuum of life history types and morphological forms into recognizable groups.

Morrow (1980a) stated that both Salvelinus malma and S. alpinus are valid species in Alaska, with S. malma composed of a northern form and a southern form. McPhail (1961) divided the North

American S. alpinus complex into an eastern arctic form and a western arctic-Bering Sea form. The MacKenzie River is the dividing line between the distributions of anadromous populations of the two forms in North America (Craig 1977a), and where the eastern arctic form occurs west of the MacKenzie River it is generally a freshwater lake resident (ibid.). Morrow (1980a) concluded that the northern form of S. malma and the western arctic-Bering Sea form of S. alpinus are identical and should be called S. malma. Within this narrative, we will circumvent the taxonomic problem by referring to all forms of S. malma and S. alpinus jointly as char.

Within each taxonomic form of char there are several different life history patterns. Char may be anadromous, nonanadromous stream residents, or nonanadromous lake residents (Craig 1977a, Morrow 1980a). In the arctic area, there are also a few populations of nonanadromous spring resident fish (Craig 1977a). Lake resident char may be subdivided into dwarf and normal size forms (ibid.). Nonanadromous stream residents may be predominantly dwarf male populations that mate with anadromous females or self-perpetuating populations of male and female fish (Craig 1977a, Morrow 1980a).

C. Native Names: See appendix A.

II. RANGE

A. Statewide

Anadromous and nonanadromous populations are found from the arctic coast south along the western, southwestern, southcentral, and southeastern coastal areas of Alaska. Isolated populations of resident (landlocked) char are found in lakes and streams scattered throughout Interior and Arctic Alaska and on the Kenai Peninsula and Kodiak Island (ADF&G 1978, Morrow 1980b).

B. Regional Distribution Maps

To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for each region. In this series, char distribution information is included on the series of 1:250,000-scale maps titled Distribution of Selected Freshwater Fish. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of selected fish and wildlife species has been prepared and may be found in the Atlas that accompanies each regional guide.

C. Regional Distribution Summary

1. Southwest. Char are widely distributed throughout most systems in the Southwest Region. Important drainages of Bristol Bay include the Togiak River, the Wood River Lakes system, the Tikchik-Nushagak system, the Iliamna-Kvichak system, the Naknek River and Lake, and the Becharof and Ugashik rivers. Some important lake-river systems in the Kodiak region include Uganik, Little River, Karluk, Ayakulik

(Red River), Akalura, Saltery, Buskin, and Barabara lakes. Char are also abundant in the Aleutian Islands (ADF&G 1976, 1977a, and 1977b). (For more detailed narrative information on char distribution in the Southwest Region, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)

2. Southcentral. Char are widely distributed throughout the Southcentral area. They are found in the Klutina and Tonsina river drainages and small tributary streams of the Copper River (Williams, pers. comm.). In the Prince William Sound area, nearly all freshwater systems, with the possible exception of short glacial streams on the southeast side of the Kenai Peninsula, contain char. Char are found in lakes and streams on the Kenai Peninsula, most notably the Kenai River, Kasilof River, Deep Creek, Stariski Creek, Anchor River, and lakes in the Swanson River drainages. Char are also found in many streams draining into the west side of Cook Inlet and in the Susitna River drainage (ADF&G 1978). (For more detailed narrative information on char distribution in the Southcentral Region, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)
3. Arctic. Char are found in every major watershed in the Northwest Alaska area, including the Selawik, Kobuk, Noatak, Wulik, and Kivalina rivers (ADF&G 1978, 1984). On the North Slope from Cape Lisburne to Demarcation Point, char are found in most rivers and many lakes. Char have not been reported from rivers or lakes on the arctic coastal plain west of Teshekpuk Lake (Hablett 1979, Bendock and Burr 1984); much of this area, however, has not been extensively surveyed. (For more detailed narrative information on char distribution in the Arctic Region, see volume 2 of the Alaska Habitat Management Guide for the Arctic Region.)
4. Western and Interior. Anadromous char are found south of the Kuskokwim River in Kuskokwim Bay drainages such as the Goodnews, Arolik, and Kanektok rivers (ADF&G 1978, Alt 1977). Dwarf stream resident char and lake resident char are also found in Kuskokwim Bay drainages (Alt 1977). Stream resident char are found in tributaries of the Yukon and Kuskokwim rivers, but they rarely enter the main stem of these rivers (Alt 1980, 1977). Anadromous char are not found in the Yukon or Kuskokwim rivers (ibid.). Lower Kuskokwim tributaries supporting fairly large populations of resident stream char include the Aniak, Kisaralik, Kwithluk, and Tuluksak rivers (ADF&G 1978, Alt 1977). In the Yukon River drainage, char are present as resident species in streams flowing into the Yukon River, from the Andreafsky River upstream to the Melojitna River. The Melojitna River is the furthest upstream where large-size resident char have been found, but dwarf-size resident char are present in small tributary streams further up the Yukon

and in the Upper Tanana drainage (Alt 1981, 1980). (For more detailed narrative information on char distribution in the Western and Interior regions, see Volume 2 of the Alaska Habitat Management Guide for the Western and Interior regions.)

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

Char are found in clear and glacial rivers and lakes, brackish deltas and lagoons (ADF&G 1977a), and nearshore marine waters (Morrow 1980b).

1. Water quality:

a. Temperature. Recorded water temperatures during the spawning period range from 0.5 to nearly 13°C (Morrow 1980b, Moore 1975). In Southeast Alaska, spawning occurs when water temperatures are 5.5 to 6.5°C (Morrow 1980b). Water temperatures on char spawning redds in the Wulik and Kivalina river drainages in Northwest Alaska in August ranged from 6.5 to 11°C (Alt 1978). Egg hatching and alevin development are quite slow but do appear to be dependent upon temperature, with warmer-than-normal temperatures accelerating hatching and resulting in earlier-than-normal fry emergence. Blackett (1968) determined that Southeast Alaska anadromous char eggs held in a hatchery began hatching after 129 days in water with a temperature range of 8.3 to 0.6°C. No upper or lower temperature tolerance limits of char eggs or alevins were found in the literature; however, eggs are frequently exposed to temperatures from 0.0 to 2.2°C during incubation, and Scott and Crossman (1973) report significant egg mortality at temperatures above 7.8°C. Juvenile char have been observed burrowing into the substrate when water temperatures decreased to 2°C (Elliott and Reed 1974). Emigration of char from overwintering areas to summer feeding areas usually occurs after ice breakup in lakes at about 4°C (Armstrong 1965, ADF&G 1977b). Fish reduce feeding and seek overwintering areas when temperatures decrease to or below 5°C (Krueger 1981, ADF&G 1977b). Vertical distribution in lakes appears to be temperature-dependent, with char preferring mid water and bottom depths with temperatures lower than 12.8°C (ADF&G 1976).

b. Dissolved oxygen (D.O). No information was found in the literature on the influence of dissolved oxygen levels on the survival and development of char; however, inferences can be made from work on other salmonid species. Sufficient transport of D.O. to, and metabolic wastes from, developing eggs and alevins by intragravel flow is crucial for survival of eggs and alevins (Vaux

- 1962, Wickett 1958). Relatively low intragravel D.O. levels during the egg development stage may increase egg mortality, influence the rate of egg development, or reduce the fitness of alevins (Alderdice et al. 1958, Silver et al. 1963).
- c. Turbidity. Little work has focused on the influence of turbidity on the survival and development of char; however, inferences can be made from work on other salmonid species. Deposition of fine sediments in spawning areas could reduce the water interchange in the redd and retard or prevent the emergence of fry (Koski 1966). Accumulation of organic debris can reduce dissolved oxygen below safe levels through oxidation (Reiser and Bjornn 1979).
 - d. Salinity. Physiological changes for salinity tolerance of anadromous char probably begin before emigration from freshwater overwintering areas to marine summer feeding areas (Conte and Wagner 1965, Johnson 1980). Roberts (1971), who conducted experiments with a nonanadromous population of char that had been isolated from sea water for about 12,000 years, concluded that nonanadromous char retain a certain degree of salinity tolerance. In the Beaufort Sea in summer, char have been observed in salinities ranging from 2 to 32 parts per thousand (ppt).
2. Water quantity. Sufficient water velocity and depth are required to allow adequate water flow during egg and alevin development. Low flows and cold winter temperatures could cause redds to desiccate or freeze (Krueger 1981). Excessive velocities or flooding can cause egg dislodgement and/or displacement of juvenile (presmolt) char from rearing areas as well as hinder upstream fish migration (ibid.). Juvenile char in the Terror River on Kodiak Island are associated with relatively slow current velocities in pools, quiet side channels, and sloughs and tributaries (Wilson et al. 1981). Habitat preference studies for juvenile char in streams along the route of the Trans Alaska Pipeline System (TAPS) indicated that juvenile char prefer pools with low current velocities, generally below 0.3 m/sec, located adjacent to swift-flowing water (DenBeste and McCart 1984). Anadromous char juveniles and fry in the Sagavanirktok River and neighboring drainages are most abundant in the vicinity of spring water sources (McCart et al. 1972). Proximity to perennial sources of water is probably important in assuring their overwinter survival without having to undertake extensive migrations (ibid.). Char have been observed spawning in water depths of 0.15 to 4.5 m (Krueger 1981, ADF&G 1977b, Alt 1978) and in slow-to-moderate current velocities ranging from 0.3 to 1.2 m/sec (1.0 to 3.8 ft/sec) (Blackett 1968, Scott and Crossman 1973, Alt 1978).

3. Substrate. Preferred spawning substrate is small-to-coarse (walnut-size) gravel (Scott and Crossman 1973, McPhail and Lindsey 1970). Blackett (1968) found char in Southeast Alaska spawning primarily in small gravels, 6 to 50 mm in diameter. Wilson et al. (1981) found char on Kodiak Island spawning on gravels ranging from 2 to 32 mm in diameter. In the Wulik and Kivalina river drainages in Northwest Alaska, char spawn over substrate that is predominantly medium and coarse gravel, with some fine gravel, sand, and boulders (Alt 1978). Char in the Anaktuvuk River also spawn over mixed substrate, ranging from sand to gravel up to three inches (8 cm) in diameter (Bendock 1981). A gravel layer over fertilized eggs in the redd protects eggs from sunlight and predation and reduces disturbance by ice and floods (Krueger 1981). In streams along the route of the TAPS, juvenile char prefer shallow pools with medium-to-coarse rock substrates (DenBeste and McCart 1984). Juvenile char burrow into substrate interstices and logging debris and slash to avoid cooling water temperatures (Elliott and Reed 1974).
- B. Cover Requirements
Rocks, logs, root balls, and undercut stream banks in pools, quiet side channels, and high-water overflow areas provide cover for young-of-the-year fish. Char seldom swim near the water surface, preferring to remain near the bottom (Krueger 1981, ADF&G 1977b, ADF&G 1977a). Larger char are most abundant in deeper water in pools, under cutbanks and in quiet water on the downstream side of large boulders (McCart et al. 1972). In-stream vegetation, bank vegetation, shade, in-stream tundra slumps, and rock cover are the most important cover features for juvenile char in streams along the route of the TAPS (DenBeste and McCart 1984). Char overwintering in North Slope streams apparently prefer ice-covered areas even when open-water areas are available (Bendock 1982).

IV. NUTRITIONAL REQUIREMENTS

A. Preferred Foods

Fry begin active feeding as soon as they emerge. Juveniles feed on various winged insects, larvae of mayflies (Ephemeroptera) and midges (Chironomidae), and various small crustaceans (Karzanovskii 1962, Krueger 1981). In the Bristol Bay drainages, fish (sticklebacks, sculpins, blackfish, and salmon fry), fish eggs, and invertebrates (snails, leeches, clams, insects, and insect larvae) are major food sources (Alt 1977, Moriarity 1977, Greenback 1967). Rearing char from the Noatak and Wulik rivers consume fly (Diptera), mayfly, and stonefly (Plecoptera) larvae (DeCicco 1983). Russell (1980) found that char in the Lake Clark area of Bristol Bay consumed gastropods, pelycopods, caddis fly (Trichoptera) larvae and adults, ants and small wasps (Hymenoptera), midge pupae and adults, adult aquatic beetles

(Coleoptera), and small crustaceans (amphipods, copepods, and cladocerans). In the Wood River Lakes system, char feed on sockeye salmon smolt during the smolt's summer migration to Nushagak Bay (Rogers 1972, Buklis 1979). Ruggerone and Rogers (1984) found that the number of smolt consumed in a 24-hour period increased when large smolt migrations occurred. When smolt migrations in excess of 80,000 smolts/24 hours took place, char consumption of smolts increased to 5.6 smolts/char per 24 hours. Palmisano (1971) studied the food habits of char in lakes on Amchitka Island. He found that in lakes with access to the sea, crustaceans and aquatic insects were the major foods. Char in landlocked lakes on Amchitka fed primarily on aquatic insects, fish, and fish eggs (ibid.). Stream resident (nonanadromous) char in the Sagavanirktok and Canning river drainages on the North Slope feed mainly on dipteran larvae (mostly chironomids), stonefly, nymphs, and caddis fly larvae (Craig 1977a, McCart et al. 1972). The diet of large fry in the Canning drainage is generally similar to that of older residents, although the fry feed on fewer kinds and smaller individuals (Craig 1977a). Craig (1977b) found that spring resident char in Sadlerochit Spring in the Arctic National Wildlife Range fed primarily on larvae of stream-dwelling benthic invertebrates, which have high densities in the spring.

In marine waters, smelt, herring, juvenile salmon, sand lance, greenling, sculpins, flounder larvae, and cod are major food components. Amphipods, decapods, mysids, euphausiids, brachiopods, polychaetes, and isopods are also included in their diet (Armstrong and Morrow 1980, Johnson 1980). Townsend (1942) found that char captured near the Shumagin Islands contained large numbers of flounder juveniles and larvae of the sand lance. Off Amchitka Island, char fed on a variety of items, mainly amphipods, mysids, and small fish (Neuhold et al. 1974). Once North Slope char enter coastal waters they feed on insects (chironomid larvae and diptera pupae), crustaceans (Amphipods and mysids), and fish, especially juvenile arctic cod (Boreogadus saida) and fourhorn sculpin (Myoxocephalus quadricornis) (Craig and McCart 1976). Anadromous char feed little while in fresh water. Those that had fed in the Sagavanirktok drainage most frequently consumed arctic char eggs and small arctic char (McCart et al. 1972). Craig and Poulin (1974) found that some char in Weir Creek in the Shaviovik River drainage consumed grayling, and char taken in the Anaktuvuk River during the seaward migration fed on slimy sculpin (Cottus cognatus) and caddis fly larvae (Bendock 1981).

B. Feeding Locations

Juveniles feed primarily from the benthos in low velocity areas along stream and lake margins (Armstrong and Morrow 1980, Johnson 1980). Older char move to deeper and faster stream reaches with higher densities of drifting invertebrates (Krueger 1981, ADF&G 1977b, ADF&G 1977a). Adult anadromous char appear to be equally capable of taking food from mid water or from the bottom (Johnson

1980). Resident char in lakes feed primarily on the lake bottom (Murray, pers. comm.; McCart et al. 1972). McBride (1979) estimated that 40% of the char population in the Wood River Lakes system feed at inlets and outlets of lakes or confluences of rivers and streams during sockeye smolt migrations. Morrow (1980b) states that adult anadromous char consume the majority of their annual diet of small fish and invertebrates in nearshore marine waters.

C. Factors Limiting Availability of Food

Excessive sedimentation may inhibit production of aquatic plants and invertebrate fauna (Hall and McKay 1983) and reduce visual references. While in fresh water, the char may compete directly for food and space with such fishes as grayling, whitefish, sculpins, salmon, and smelt (Armstrong and Morrow 1980). Competitive interactions between char and coho salmon juveniles have been well documented in southeastern Alaska streams (Armstrong 1970, Armstrong and Elliot 1972). Competition for food or space with other species is probably negligible in lakes during the winter (Armstrong and Morrow 1980).

D. Feeding Behavior

Char are carnivorous but have a varied diet, dependent on the size and age of the fish, location, and available food sources. Char may browse along the substrate or consume drifting invertebrates (Armstrong and Elliott 1972). Activity levels and digestive rates drop when freshwater temperatures decrease to or below 5°C (Krueger 1981, ADF&G 1977b). Mature spawners of anadromous populations feed little, if at all, when wintering in fresh water (Morrow 1980b, McCart et al. 1972, Craig 1977a). Stream resident fish feed year-round (McCart et al. 1972, Craig 1977a). When leaving lakes in spring and early summer, char also appear to feed very little (Armstrong 1965).

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Spawning site selection is influenced by current velocity, water depth, and substrate composition. Spawning sites are usually located in a fairly strong current near the center of the stream in riffles or spring areas at least 0.3 m deep or in gravel-bottomed lakes (Krueger 1981, ADF&G 1977a).

In the Sagavanirktok River and neighboring drainages, all known spawning areas for anadromous char are either in the vicinity of spring sources of mountain streams originating in the Brooks Range or spring-fed tributaries of mountain streams (McCart et al. 1972). Spawning sites in the Anaktuvuk River are also closely associated with spring areas (Bendock 1981). The eggs cannot tolerate freezing, and these are the only stream areas in which winter flow is assured (ibid.). In the Canning River, almost all spawning sites are located in the main channels of the river or in springs originating within or near the Canning floodplain (Craig 1977a). In the Noatak River system, some spawning takes place in

and around springs; however, most spawning occurs downstream of springs in the main channels of streams. The major spawning streams maintain limited flow throughout the winter and are under spring influence for much of their length (DeCicco 1982). Many spawning areas in the Kivalina River are near spring areas; however, in the Wulik River most spawning grounds are not directly influenced by groundwater (Alt 1978).

B. Reproductive Seasonality

All races of char spawn between early July and the beginning of December (Meacham 1977, Alt 1977, DeCicco 1982).

Char have been observed spawning in the Terror and Kizhuyak rivers on Kodiak Island between late August and the end of September (Wilson et al. 1981). On Amchitka Island, Neuhold et al. (1974) observed char spawning from mid October to late November. Char in the Wood River Lakes system spawn in September and October (McBride 1980). Char in the Susitna River drainage also spawn in September and October (ADF&G 1981), and spawning peaks in the Anchor River on the Kenai Peninsula in mid October (Hammarstrom and Wallis 1981) and in Valdez area streams in October and November (Dames and Moore 1979).

The peak of spawning activity in Southeast Alaska occurs between September and November (Blackett 1968, Blackett and Armstrong 1965).

In North Slope rivers, the char spawning period apparently extends over several months; however, the peak of spawning activity probably occurs during late September or early October (McCart et al. 1972, Craig 1977a). In the Anaktuvuk River, spawning has been observed from early September through early November (Bendock 1981). In the Noatak drainage, char are found in the vicinity of the spawning grounds from early July to mid October (DeCicco 1982). In the Noatak and Wulik and Kivalina drainages, char spawners may be divided into two groups: summer spawners that remain in fresh water after overwintering and occupy spawning grounds from early July through mid September, and fall spawners that in-migrate in the fall and spawn from mid September through freeze-up (DeCicco 1982, Alt 1978). In the Wulik and Kivalina rivers, the peaks of spawning appear to be in mid August and mid September (Alt 1978).

Spring resident char in most North Slope streams spawn in November and December (Craig 1977b).

C. Reproductive Behavior

Spawning behavior is similar to that of salmon. Fish are usually paired. The male usually takes no part in the nest-building and spends his time defending the redd from other male spawners. The female excavates the redd, often in typical salmonid fashion by turning on her side and thrashing the substrate with her tail. When the female is ready to deposit her eggs, the pair descend into the redd and press against each other laterally; sperm and eggs are released simultaneously into the redd. After completion of the spawning act, the female may move to the upstream end of

the redd and repeat the digging process, washing gravel downstream over the fertilized eggs. The spawning act may be repeated up to five times; several days are usually required for a female to deposit all her eggs (Morrow 1980b). Morrow (1980b) described the redds as varying from a deep pit to a clean spot on large stones. The dimensions of the redd vary with the size of the female, the substrate, and the current velocities. Male spawners may mate with more than one female; occasionally a female will mate successively with two or more males (Fabricus 1953, Fabricus and Gustafson 1954, Krueger 1981, ADF&G 1977a).

D. Age at Sexual Maturity

Char are an especially slow-growing fish and attain sexual maturity at different ages and sizes, varying with their life history and local environmental conditions. Three life forms of char occur in Alaska: resident lake char, resident stream char, and anadromous char. In general, resident stream char do not grow as large as resident lake or anadromous stream char. Resident stream char commonly occur in dwarf form (sexually mature and fully grown but only six to eight inches in length) (ADF&G 1977a, Russell 1980). Generally, northern populations grow slower, live longer, and reach a smaller maximum size than more southerly populations. Char populations in the south also attain sexual maturity earlier (Morrow 1980b). Males may mature before females. In Kuskokwim Bay drainages, char generally mature at 7 to 10 years (Alt 1977). In the Iliamna system, Metsker (1967) found mature char (life form unknown) as young as four years old. Russell (1980) noted that char in the Lake Clark area apparently become mature at six years of age. Most char in Southeast Alaska reach maturity by ages 4 or 5 (Blackett and Armstrong 1965). Most anadromous char in the Sagavanirktok and Canning river tributaries spawn for the first time at age 7 or 8 (McCart et al. 1972, Craig 1977a). Female char in the Anaktuvuk River mature as early as age 6, males as early as age 7. Stream resident males in these tributaries may mature as early as ages 2 or 3 (ibid.). Most anadromous char from the Wulik and Kivalina rivers in northwest Alaska are mature at age 9 (Alt 1978).

Age at maturity for northern populations of lake resident char is variable, ranging from ages 2 to 9 (Craig 1977a). Males in North Slope spring resident char populations begin maturing at age 2, whereas the youngest mature females are ages 3 or 4 (ibid.). The longevity of char is variable. Char have been found as old as 24 years (Grainger 1953), but most in Southeast Alaska live 8 to 12 years (Armstrong 1963, Heiser 1966, ADF&G 1978).

E. Fecundity

The fecundity of char varies by stock, location, and size of female. Eggs of anadromous stocks are much larger than those of nonanadromous fish and increase in size with fish age and length (Blackett 1968, Morrow 1980b). Fecundity of anadromous char is also higher than for nonanadromous stocks (McCart et al. 1972). In Alaska, the number of eggs generally ranges from 600 to 8,000

per female (ADF&G 1978, Morrow 1980b, McPhail and Lindsey 1970), though Russell (pers. comm.) has observed dwarf, prespawning females with as few as 20 mature eggs in the Tazimina Lakes in Southwest Alaska, and fecundity of female lake resident char from the Canning River drainage ranged from 54 to 1,600 eggs (Craig 1977a).

F. Frequency of Breeding

Though char do suffer a high postspawning mortality rate, a number live to spawn again in subsequent years. Armstrong (1974) found that in a Southeast Alaska population of char 73% spawned once, 26% twice, and 1% three times. Up to 50% of the females spawning for the first time survived to spawn again. In Southeast Alaska, males are much less likely to survive spawning than females. This may also be true of males in North Slope drainages (Armstrong 1974, Yoshihara 1975). Some char spawn in consecutive years; others spawn at two or three-year intervals. Most anadromous char in northern Alaska spawn only every second year (Yoshihara 1975). Craig (1977a), in studies of char in the Canning River, noted that only a small number of char beyond age 9 were found in the population. Because most anadromous char on the North Slope do not mature until ages 7 or 8, relatively few anadromous char may spawn more than twice during their lifetime. Stream resident char, in contrast to the anadromous type, almost always spawn annually (Armstrong and Morrow 1980, Craig 1977a); however, lake resident char from lakes in the Canning River drainage are not annual spawners (Craig 1977a).

G. Incubation Period/Emergence

The time of development varies widely with temperature and stock. Embryo development is slow in cold water temperatures. Eggs incubate over winter, generally four to five months; however, periods of up to eight months have been documented on the North Slope of the Brooks Range (ADF&G 1977a, Yoshihara 1973). The incubation time for char eggs in streambed gravels in the Sagavanirktok and Canning rivers on the North Slope has been estimated to be seven to nine months, though fry in perennial springs may emerge sooner (McCart et al. 1972, Craig 1977a). Eggs hatch as 15-to-20-mm-long alevins (yolk sac fry) in March or April. Yoshihara (1973) observed preemergent fry in the Sagavanirktok River drainage that had probably hatched in April. Alevins remain in the gravel for approximately 18 days while absorbing their yolk sac before they emerge as free-swimming fry (20 to 25 mm) in April to July (ADF&G 1977a, McCart et al. 1972, DeCicco 1982).

In Valdez area streams, fry emerge from the gravel in April and May (Dames and Moore 1979). Peak emergence of fry in the Canning River on the North Slope occurs during the end of May and early June, though fry have been observed in early April (Craig 1977a). In the Noatak drainage, young-of-the-year fry probably emerge sometime in mid July (DeCicco 1982).

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

A. Anadromous

1. Out-migration. Juvenile anadromous char rear in streams and lakes. After a variable number of years (usually at age four or five) most char juveniles undergo a physiological change and, in the spring, migrate seaward as smolts (ADF&G 1977a, 1977b). Most immature and mature char emigrate from overwintering areas to marine summer feeding areas following ice breakup from April to June. In the Sagavanirktok and neighboring North Slope drainages, it is likely that seaward migration occurs during the spring flood in late May and June (McCart et al. 1972). In the Canning River, char begin to leave overwintering areas in May, with a large scale emigration observed in late June and early July (Craig 1977a). In the Anaktuvuk River, char out-migrate in mid June (Bendock 1982). Departure from overwintering habitats may more closely coincide with breakup along the Beaufort Sea coast than with breakup near the overwintering site (ibid.) The char smolt migration in the Anchor River on the Kenai Peninsula takes place in late May and early June (Hammarstrom and Wallis 1983). Nonlake systems may support an additional autumn smolt out-migration (Armstrong 1965 and 1970, Armstrong and Kissner 1969, Dinneford and Elliott 1975, Elliott and Dinneford 1976). In the Noatak, Wulik, and Kivalina rivers, some fish that will spawn in the current year do not migrate seaward in the spring but rather go directly from overwintering to spawning grounds. Some of these summer spawners that spawn in early to mid August probably do migrate to sea for a month or two after spawning (DeCicco 1982, Alt 1978). Alt (1978) estimated that in the Wulik and Kivalina rivers probably in excess of 50% of the prespawning fish do not go out to the ocean at breakup.
2. Marine environment. Individuals remain at sea feeding in the estuary and along the coast for a period of a few weeks to seven months (Morrow 1980b). While in the marine environment, char stay in coastal areas. In some cases char in the Beaufort Sea may travel great distances along the coast (up to 300 km)(Craig and McCart 1976).
3. Spawning and overwintering. Char generally begin reentering fresh water in July and may continue through December, with spawners entering first, followed by immature fish and nonspawners (ADF&G 1977a). Mature anadromous char in the Sagavanirktok River have been taken in the vicinity of spawning tributaries as early as June 26. Mature migrants enter downstream spawning tributaries earlier than those further upstream (McCart et al. 1972). Immature migrants may make this return journey several times before they mature for the first time (ibid.). Although it appears that char return to their natal stream to spawn, nonspawners from Beaufort Sea drainages and from the Wulik and Kivalina river drainages may

overwinter elsewhere in the same drainage or in nonnatal drainages (Craig 1977a, Craig and McCart 1976, DeCicco 1984). Radio-tagging studies of char in the Anaktuvuk River indicate that during the ice-covered months (October to May) char are confined residents of limited overwintering habitat, and movement at this time is minimal (Bendock 1982). In the Chignik River system on the Alaska Peninsula, char, which migrate to sea from April through June, return to Chignik Lake and Black Lake from late July through September to spawn and overwinter (Roos 1959). Emigration of spawned-out char to overwintering areas usually occurs within two weeks after completion of spawning, typically during late October and November. Immature char move to overwintering areas earlier, primarily in July, August, and September (Blackett and Armstrong 1965, Krueger 1981). Adult char usually remain in fresh water through the winter months to avoid the cooler water temperatures of the marine environment (ADF&G 1977a). Overwintering sites include deep lakes, deep river pools, and groundwater spring areas.

B. Nonanadromous

1. Lake residents. Lake resident char move into streams for short periods of time. Studies in the Wood River Lakes system show that discrete subpopulations of resident lake char concentrate at inlets and outlets of the lakes during early summer to feed on out-migrating sockeye salmon smolt (McBride 1979). During late summer, char move to deeper lake waters, probably in response to a declining availability of sockeye salmon smolt and to escape warming surface waters (Nelson 1966). Mature spawners usually move back to the lake margins to spawn in the fall. Resident lake char in the Sagavanirktok drainage do not undertake any long migrations, though they do sometimes enter streams (McCart et al. 1972).
2. Stream residents. Little is known about the life history of resident stream char. In the Sagavanirktok River and neighboring drainages, they are common in mountain and spring streams. Overwintering of stream residents occurs in deep pools of streams and rivers (Morrow 1980b). In Minook Creek, a small tributary of the Yukon River near Rampart, the stream resident char leave smaller tributaries, such as Little Minook Creek and Ruby Creek, in late fall and early winter, apparently spending the winter in the lower reaches of Minook Creek itself (Armstrong and Morrow 1980). During the summer, stream residents in the Kuskokwim and Yukon river drainages congregate in areas where salmon spawn to feed on the salmon eggs (Alt 1980, 1977; ADF&G 1978). In the Sagavanirktok, Canning, Firth, and Babbage rivers, apparently all stream resident char are males;

however, stream resident females have occasionally been found in Fish Creek, Yukon Territory (Craig and McCart 1976). A consequence of this pattern is that female char are significantly more abundant in nearshore areas than are males (ibid.).

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

Natural mortality is largely a result of limited winter habitat. Char that hatch in surface runoff streams must find suitable overwintering areas with open water. Studies in Southeast Alaska indicated that populations of juvenile char suffered 51% mortality in small surface-water streams, versus about 31% mortality in spring-fed streams, from November to June (Elliott and Hubartt 1977). Severe stream flooding can harm developing eggs and embryos and hinder upstream fish migration (Krueger 1981). Low flows and cold winter temperatures could cause redds to desiccate or to freeze. Deposition of fine sediments in the spawning area could retard or prevent fry from emerging (ibid.). Deposition of fine sediments in streams with limited flushing abilities could embed the substrate material and significantly reduce the available overwintering habitat for juvenile char (Bjornn et al. 1977, Krueger 1981). Postspawning mortality is high and may account for the natural removal of up to 50% of a spawning population (Armstrong and Kissner 1969, ADF&G 1977a). Lake-dwelling populations are often heavily parasitized with nematodes and cestodes (Russell, pers. comm.) There is no significant natural predation on char except for cannibalism (Scott and Crossman 1973, Armstrong and Morrow 1980, Craig 1977a).

B. Human-related

In the Arctic Region, char rely extensively on spring-fed habitats at particular stages in their life cycle. Springs are used as spawning grounds, summer rearing areas of fry and juveniles, and as overwintering areas (Craig 1978). In smaller North Slope drainages, which have few areas suitable for overwintering, it is conceivable that a single spring-fed site might harbor virtually all members of a particular char population, from eggs to mature adults, during the winter period (ibid.). Because stream beds are frozen solid both above and below overwintering sites, char cannot avoid disturbances in their winter habitat (Bendock 1983). Thus any disturbances to spring-fed areas, such as water removal or siltation due to gravel extraction, may have severe deleterious effects on char populations in the entire drainage. The introduction of organic materials under the ice in overwintering areas may reduce dissolved oxygen below the lethal level for any of the life history stages inhabiting the affected stream section (Craig and McCart 1974). A summary of possible impacts from human-related activities includes the following:

- ° Alteration of preferred water temperatures, pH, dissolved oxygen, and chemical composition

- Alteration of preferred water velocity and depth
 - Alteration of preferred stream morphology
 - Increase in suspended organic or mineral material
 - Increase in sedimentation and reduction in permeability of substrate
 - Reduction in food supply
 - Reduction in protective cover (e.g., overhanging stream banks or vegetation)
 - Shock waves in aquatic environment
 - Human harvest
- (See the Impacts of Land and Water Use volume of this series for additional impacts information.)

VIII. LEGAL STATUS

A. Managerial Authority

The Alaska Board of Fisheries develops regulations governing the sport harvest of fish in Alaska. Research and monitoring of char populations is conducted mainly by the Alaska Department of Fish and Game, Division of Sport Fish.

IX. LIMITATIONS OF INFORMATION

Most life history information on char pertains to the sea-run variety. Little is known about the habits of nonmigratory char. There are very little data relating the various char life stages to the physical and chemical characteristics of their habitats.

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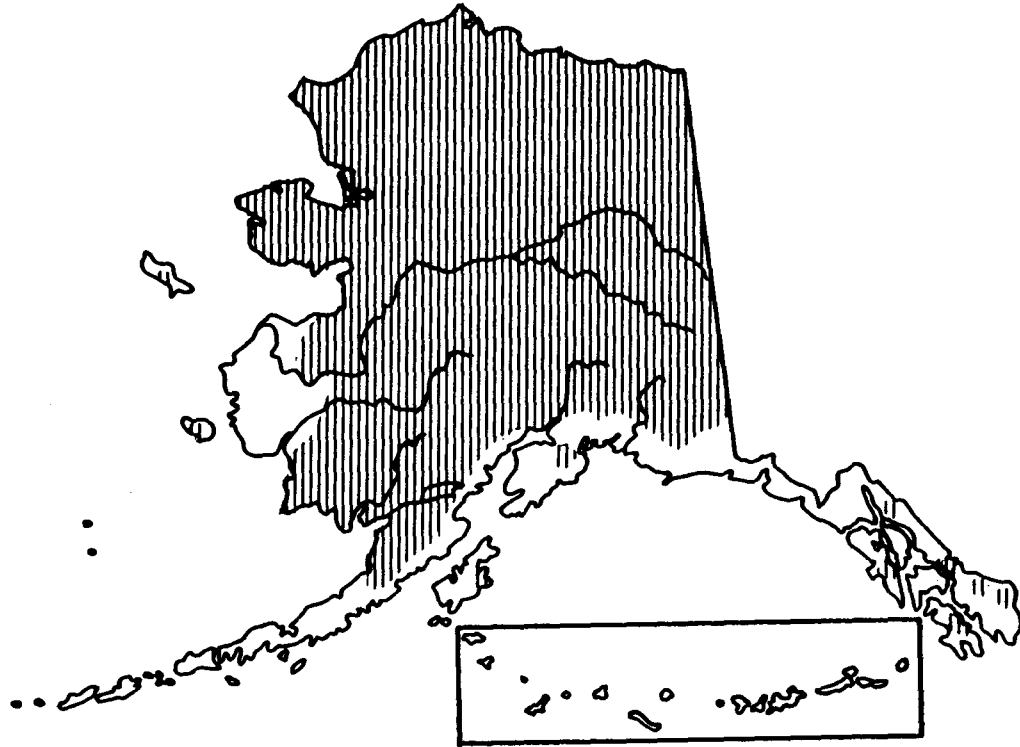
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Arctic Grayling Life History and Habitat Requirements
Southwest, Southcentral, Arctic, Western, and Interior Regions



Map 1. Range of arctic grayling (ADF&G 1978)

I. NAME

- A. Common Name: Arctic grayling
- B. Scientific Name: Thymallus arcticus (Pallas)
- C. Native Names: See appendix A.

II. RANGE

- A. Statewide
Native arctic grayling are distributed throughout the Interior and Arctic regions of Alaska as well as in Southwest Alaska north of Port Heiden and west of the Aleutian Range. Stocking programs have produced self-sustaining populations in Southeast Alaska, Prince William Sound, the Kenai Peninsula, and Kodiak Island (ADF&G 1978).

B. Regional Distribution Maps

To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for each region. Grayling distribution information is included on the 1:250,000-scale maps titled Distribution of Selected Freshwater Fish. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of selected fish and wildlife species has been prepared and may be found in the Atlas that accompanies each regional guide.

C. Regional Distribution Summary

1. Southwest. Arctic grayling are found in clearwater streams of Bristol Bay and Alaska Peninsula drainages south to approximately Port Heiden. Grayling have been stocked in selected lakes on Kodiak Island (Murray, pers. comm.). Grayling are not present on the Aleutian Islands or in streams on the south side of the Alaska Peninsula (ADF&G 1978). Large grayling are found in the Ugashik, Becharof, Nuyakuk, and Togiak river drainages (ADF&G 1978; Russell, pers. comm.). (For more detailed narrative information on grayling distribution in the Southwest Region, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)
2. Southcentral. Arctic grayling are found in several clearwater tributaries and lakes within the upper Copper River and Susitna River drainages and in a few clearwater tributaries of the lower Copper River. Grayling are not found on the west side of Cook Inlet south of Tyonek (ADF&G 1978). They are also not native to the Kenai Peninsula but have been stocked in several Kenai Peninsula lakes, which now contain self-sustaining populations (Engel 1971). (For more detailed narrative information on grayling distribution in the Southcentral Region, see volume 2 of the Alaska Habitat Management Guide for the Arctic Region.)
3. Arctic. Grayling are widely distributed throughout the Arctic Region. On the arctic coast, most of the freshwater drainages that have been surveyed contain grayling (USFWS 1982), and they are the principal species inhabiting foothill lakes and streams (Bendock 1982). Grayling are also found in lakes and streams on the Seward Peninsula and in lakes and streams draining into the Chukchi Sea between Kotzebue and Barrow (ADF&G 1978). (For more detailed narrative information on grayling distribution in the Arctic Region, see volume 2 of the Alaska Habitat Management Guide for the Arctic Region.)
4. Western and Interior. Arctic grayling are found in nearly all freshwater habitats of the Western and Interior regions, including Nunivak Island, with the exception of the Yukon-Kuskokwim delta plain (ibid.). Grayling are present in

both lakes and streams of the Western and Interior regions but are usually more abundant in streams (ibid.). (For more detailed narrative information on grayling distribution in the Western and Interior regions, see volume 2 of the Alaska Habitat Management Guide for the Western and Interior regions.)

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

1. Water quality. Grayling prefer clear, cold lakes and streams (ibid.), with different life stages frequently occurring in different locations within a drainage. Grayling generally feed during the summer in rivers and streams that may freeze solid or dry up during the winter, and they may overwinter, therefore, in areas unsuitable for summer feeding (Tack 1980). The basic water chemistry of streams that support grayling varies by geographic area and reflects the character of mineral types in the area (ibid.).
 - a. Temperature. Increasing water temperatures and spring flooding appear to stimulate spawning (Armstrong 1982). A water temperature of around 4°C triggers spawning in the Interior streams of Alaska (Tack 1973, ADF&G 1983) and in Western Alaska (Alt 1976); however, spawning activities have been observed at temperatures ranging from 3.3°C at the inlet to Fielding Lake in Interior Alaska (Wojcik 1954) to 16.7°C at Wier Creek in the western Arctic Region (Craig and Poulin 1975). Tack (1980) noted that grayling tend to spawn in the warmest areas of drainages, and that the use of bog or tundra streams for spawning is probably because of their favorable temperature regimes. Development of eggs to hatching is directly influenced by water temperatures. Bog and tundra streams warm rapidly, thus causing rapid development and early hatching of eggs spawned in these areas. Kratt and Smith (1977) and Bishop (1971) reported centigrade degree days required for hatching grayling eggs ranging from 177 to 230. Field observations indicate that juveniles and fry are tolerant of high temperatures but that small subadults and adults tend to avoid water temperatures above 16°C (Reed 1964, Wojcik 1955). Grayling in the Tangle Lakes area near Paxson displayed signs of stress and experienced unusually high mortality when seined from waters with a temperature of 17°C (Wojcik 1955, cited in Tack 1980). LaPerriere and Carlson (1973), in laboratory experiments with grayling from the Chena River, concluded that the median tolerance limit (temperature that will kill 50% of the fish exposed) for grayling larger than 10 cm was 20.0 to 24.0°C. No reference to

- upper or lower lethal temperature data for eggs was found in the available literature.
- b. The pH factor. No optimum pH value was found in the literature. Measured values of several Interior streams, however, ranged from 6.2 (Netsch 1975) to 9.0 (Hallberg 1978). Russell (1980) reports that Southwest Alaska waters are also naturally slightly alkaline (7.1-8.5).
 - c. Dissolved oxygen (D.O.). Some grayling can survive over winter in oxygen concentrations of less than 1 ppm (Roguski and Tack 1970); however, Tack (1973) and Williams and Potterville (1981) found that D.O.s of 0.6 ppm and 0.5 ppm, respectively, resulted in winter kills in several Interior and Southcentral lakes. No optimum D.O. value was found in the literature; however, measured concentrations during periods of observed grayling abundance have ranged from 0.6 ppm (Bendock 1980) to 21 ppm (Pearse 1974) in Interior streams. Measured D.O. concentrations during the summer months in several Southwest Alaska waters indicate an average D.O. of around 10 ppm (Russell 1980).
 - d. Turbidity. High levels of turbidity may abrade and clog fish gills, reduce feeding, and cause fish to avoid some areas (Reiser and Bjornn 1979). Turbidity and sedimentation may smother food organisms and reduce primary productivity (Bell 1973, LaPerriere et al. 1983). Turbid water may absorb more solar radiation than clear water and may thus indirectly erect thermal barriers to migration (Reiser and Bjornn 1979, Van Nieuwenhuysen 1983). Stomach analyses of caged grayling held in mined and unmined streams (LaPerriere et al. 1983) indicated that grayling in the turbid, mined waters were not capable of locating invertebrate prey. This may be due to the observed reduction of invertebrate abundance in the mined stream or to the inability of the grayling to locate prey in the turbid water. Grayling in arctic environments do most of their feeding under conditions of continuous daylight and very clear water and have been exposed to little or no selective pressure to increase their ability to feed in turbid or low light intensity conditions (Schmidt and O'Brien 1982). Studies conducted on the Susitna River indicate that grayling avoid high turbidity waters (Suchanek et al. 1984).
 - e. Salinity. Grayling have been taken in the spring from marine waters along the coastline adjacent to the Arctic National Wildlife Range around river mouths and behind barrier reefs (Roguski and Komarek 1971). The spring runoff from numerous rivers entering this area keeps the salinity at or below one part per thousand (ppt). No

grayling were found in salinities exceeding 1 ppt. In the Nome area, there is some movement of grayling into tidal areas of the Nome River, but grayling do not enter the ocean (Alt 1978).

2. Water quantity. Sufficient water velocity and depth are required to allow adequate intragravel water flow during egg and alevin development. Low flows during incubation could result in desiccation of developing eggs and alevins (Wojcik 1954). High velocities or flooding could cause low fertilization, egg dislodgement, or displacement of young-of-the-year (YOY) out of their rearing areas to less favorable sites, resulting in direct mortality (Nelson 1954; Tack 1971, 1974; Walker 1983). Holmes (1983, 1984) found a high correlation between numbers of grayling in an age class and the average rate of river discharge during May, June, and July of their natal years. As discharge increased, grayling abundance decreased. Excessive velocities may also impede migrating fish (Hallberg 1977, MacPhee and Watts 1976). The upstream migration of grayling usually coincides with high flows resulting from spring breakup (Krueger 1981). In studies of Deadman Creek, tributary to the Susitna River, the upper reach, which is characterized by an abundance of large, deep, pool-type habitats, contained a higher summer population of grayling than the middle and lower reaches, which were more shallow (Sautner and Stratton 1984). Arctic grayling spawn in a wide range of current velocities and depths. Wojcik (1954) reported spawning in "slow, shallow backwaters" in an inlet stream to Fielding Lake. Warner (1955) observed grayling in the same stream spawning in surface current velocities of about 120 cm/sec in depths of 0.2 m. Surface current velocities measured in territories of 22 males in the outlet of Mineral Lake (Interior Alaska) ranged from 34 to 146 cm/sec, and territorial depths ranged from 0.18 to 0.73 m (Tack 1971). Newly emerged fry are found in protected areas where current velocities are extremely low. Typical emergent fry-rearing areas include shallow backwaters and flooded stream margins and side channels (Krueger 1981, Walker 1983). In studies of 27 streams along the route of the Trans Alaska Pipeline System (TAPS), it was found that juvenile grayling select habitats with the lowest possible velocity (often where there is no detectable current) and pools with an average depth of 0.65 m (Denbeste and McCart 1984). Adult grayling in the study streams also preferred near zero velocity water, with an average depth of 0.8 m (ibid.). Both juveniles and adults frequently were found in areas with adjacent swift water (greater than 50 cm/sec) to provide a steady supply of stream drift for food (ibid.). Older YOY fish occupy progressively faster waters. Aquatic habitat occupied by rearing YOY fish in selected bog streams along the TAPS had mean column velocities of 0 to 15 cm/sec

and water depths ranging from 0.09 to 1.07 m (Elliott 1980). Juvenile and adult fish in bog streams along the TAPS were found holding in mean current velocities ranging from 18 to 26 cm/sec and were found at water depths ranging from 0.2 to 1.07 m. Juvenile grayling in tributaries to the Susitna River appear to rear in areas with water velocities under 46 cm/sec (ADF&G 1983). Preliminary results from winter tagging studies on the Chena and Salcha rivers indicate grayling in Interior Alaska overwinter in areas of moderate current (Holmes, pers. comm.).

3. Substrate. Arctic grayling have been reported to spawn over a wide range of substrates, including mud, silt, and gravel up to 4 cm in diameter (Krueger 1981). Gravel substrate provides cover, decreases the chances of dislodgement, and lessens swimming stresses in early life history stages, probably resulting in higher alevin survival than for those hatching on exposed substrate (Kratt and Smith 1977). The following are examples of observed spawning substrates in Alaska:

- Fine (1 cm) gravel (Warner 1955)
- "Pea-size" gravel in the outlet of Mineral Lake (Tack 1971)
- Sand-to-small-cobble, with coarse sand and gravel to about 2.5 cm in diameter, in four inlet tributaries to Tyee Lake near Ketchikan (Cuccarease et al. 1980)
- Relatively fine (3.8 cm diameter) gravel, with most material less than 1.25 cm, in outlets of two Kenai Peninsula lakes (Krueger 1981)
- Sand and fine gravel substrate, about 0.6 cm in diameter, in the outlet of Tea Lake near the TAPS (McCart et al. 1972)
- Silt and fine sand overlaid by organic detritus in Million Dollar Creek, along the TAPS (Elliott 1980)
- Silt overlaying gravel in the mainstem Colville River (Bendock 1979)
- Gravel 0.5 to 7.6 cm in diameter (Kratt and Smith 1977)
- Relatively uniform distribution of particle sizes from 0.08 cm to 3.8 cm at the outlet of Mineral Lake (Tack 1973)

Juvenile and adult grayling in 27 streams along the route of the TAPS were found to occupy pools with fine-grained substrates (DenBeste and McCart 1984), but adults also displayed a preference for coarse substrates, and both juveniles and adults used rocks as cover (ibid.). In the Susitna River, adult grayling use rocks with diameters over 8 cm for protective cover (Suchanek et al. 1984).

B. Cover Requirements

Newly emerged fry have limited swimming abilities, and they school in shallow, protected stream areas with cover, low current velocities, and an abundance of food items. Irregular banks, with

shadows from boulders and overhanging vegetation, contribute important cover for these rearing fry. Juvenile fish (age one year and older) progressively move to faster and deeper stream reaches (Vascotto 1970). Older fish commonly use logs, boulders, and turbulence for instream cover (Krueger 1981, Sautner and Stratton 1984). In streams along the TAPS, juvenile grayling were found to use rock cover most extensively, but to a lesser extent they also use habitats with cutbanks or loose gravel or rock banks providing cover, overhanging vegetation, deep water, instream vegetation, and shade (DenBeste and McCart 1984). Adult grayling preferred habitats with cover features typically associated with banks such as cutbanks, overhanging vegetation, instream vegetation, and shade but also use rock cover and deep water to some extent (ibid.).

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

Grayling are opportunistic feeders, able to use a wide range of food items, but they prey primarily on immature and emerging aquatic insects (Armstrong 1982). Elliott (1980) found that immature midges (Chironomidae) were the most frequently consumed taxon by YOY grayling in spring, rapid-runoff, and bog streams crossed by TAPS. Jennings (1983) found that chironomid pupae were the most important food item for yoy grayling (length range 40-48 mm) stocked in ponds near Delta, Alaska. In the Chena River, chironomid pupae and larvae made up 94% by volume of yoy grayling (length range 11-16 mm) stomach contents (ibid.). Engel (1973) found that grayling eggs comprised the bulk of the diet of juvenile grayling found downstream of spawning adults in Crescent Creek on the Kenai Peninsula. Adults feed primarily on immature mayflies (Ephemeroptera), stoneflies (Plecoptera), dipterans, and caddis flies (Trichoptera) (Bishop 1971, Bendock 1980, Craig and Wells 1975, McCart et al. 1972). In lakes, zooplankton may make a significant contribution to the diet (Yoshihara 1972 and Wojcik 1954, cited in Armstrong 1983; Schmidt and O'Brien 1982). In three lakes in Southwest Alaska, Russell (1980) found caddis fly larvae and adults and cyclopoid copepods to be the most common food items. Furniss (1974) found Diptera, stonefly, beetle (Coleoptera), caddis fly, and Hymenoptera (bees and wasp) larvae and adults, gastropods, and nematodes to be important food items for grayling from four mountain lakes on the north side of the Brooks Range. Salmon eggs, smelt eggs, and shrews have been observed in grayling stomachs from the Naknek River in the Bristol Bay area (Russell, pers. comm.). In the Chena and Delta Clearwater rivers near Fairbanks and in the Aniak River, tributary to the Kuskokwim, grayling have been observed concentrating at the downstream end of chinook and chum salmon spawning redds, feeding on the salmon eggs that drift down during spawning activity (Hallberg 1981, Schallock 1966a, Alt 1978). Whitefish eggs and mayfly and stonefly larvae are dominant grayling food items in the

Colville River during October (Bendock 1979, 1981). Other food items include isopods (ADF&G 1977), plant material (Craig and Wells 1975), fish (McCart et al. 1972, Williams 1969), and lemmings (Alt 1978, Reed 1964).

B. Types of Feeding Areas Used

Newly emerged fry have limited swimming abilities and spend the first summer near their hatch site (Tack 1980). They school and feed in shallow lotic habitats with low current velocities where production of aquatic invertebrates is high (Cuccarese et al. 1980). In the Arctic Region, YOY grayling rear in small tundra streams. The warm water and abundance of food in these small streams provide favorable conditions for growth. Grayling fry are able to equal the growth of char fry in the same river systems, although the char may emerge four to six weeks earlier and at a larger size (Craig and Poulin 1974).

Immediately after spawning, adults and large juveniles move to upstream locations or into tributary streams or lakes rich in food (Tack 1980). Tack (1980) found that in large, rapid-runoff rivers, grayling consistently home to their summer feeding streams and feeding locations. Vascotto (1970) observed that during the summer months grayling were found almost exclusively in pools, where they established feeding territories and, within each feeding territory, a feeding range where all feeding activities took place. In pools with a strong current, distribution was related to the strength of the current and the availability of food in the benthic drift, with the larger fish holding near the upstream end near the center and smaller fish distributed downstream and to the sides (Tack 1980, Vascotto and Morrow 1973, ADF&G 1983). Other literature also indicates that rearing grayling concentrate in the lower reaches of a stream and that larger (older) fish are found further upstream (Hallberg 1978, Tack 1971).

C. Factors Limiting Availability of Food

Grayling are visual feeders, relying primarily upon benthic drift for nutrition. During periods of high, muddy water, this drift is unavailable to them. Schallock (1966b) suggested that grayling and slimy sculpin (Cottus cognatus) may compete for food. Though some dietary overlap between the two species does occur (Sonnichsen 1981), it is unlikely that competition for food takes place (Moyle 1977).

D. Feeding Behavior

Most grayling feed on the water surface or on the drift at mid depth (Vascotto 1970); they also feed off the bottom during periods of reduced benthic drift (Morrow 1980, Wojcik 1954). Grayling in lakes tend to feed more on the bottom than those in streams (Armstrong 1982). Feeding behavior varies with the size of the individual and its hierarchical status (Vascotto 1970, Vascotto and Morrow 1973). Tack (1980) suggests that the out-migration of juvenile and spawned-out adult fish may allow YOY fish to rear and feed in natal streams without competition.

Grayling are active feeders during the summer, ceasing to feed only at darkness (Reed 1964). Grayling also feed during the winter (Alt 1976, Bendock 1980). Prespawning and spawning fish take food only casually as it drifts past; spent fish feed actively (Bishop 1971, Craig and Wells 1975).

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Grayling usually spawn in unsilted rapid-runoff streams, bog (tundra and foothill) streams, and lake inlets and outlets. Spawning does not occur to any extent in spring-fed streams or silted rapid-runoff streams (Tack 1980). Craig and Wells (1975) noted that grayling spawning in the Chandalar River drainage in Northeast Alaska tends to occur in small, clearwater tributaries with low stream gradients. These spawning tributaries tend to be warmer and less turbid than the main stem of the Chandalar River during the grayling spawning period (ibid.). Within rivers and streams, grayling usually spawn in riffles composed of gravel or rubble (see III.A.3., Substrate, this report). Tack (1980) suggests that because grayling adults home to the feeding stream annually they probably also home to their natal stream to spawn. Scale analysis indicates homing of grayling to Badger Slough on the Chena River for spawning (Holmes, pers. comm.). Tagging studies in the Susitna River drainage indicate that the majority of arctic grayling do return to the same stream year after year, in many cases returning to the same specific area within the stream (ADF&G 1983). Craig and Poulin (1975) also suggested that some grayling may return annually to a particular stream to spawn.

B. Reproductive Seasonality

Grayling populations in Alaska spawn between late April and early July, with most spawning taking place between mid May and mid June (Bendock 1979, Roguski and Tack 1970, Schallock 1966a, Warner 1955, Wojcik 1954). In the Bristol Bay area, grayling generally spawn in May (Russell 1980). In 1982 and 1983, grayling in the Susitna River drainage spawned from late May to mid June (ADF&G 1983, Sundet and Wenger 1984). Grayling in the Chandalar River drainage in northeast Alaska enter tributaries and spawn during the latter half of May (Craig and Wells 1975). In Weir Creek, tributary to the Kavik River in the Shaviovik River drainage on the arctic coastal plain, grayling spawn in mid June (Craig and Poulin 1974). Spawning time is also mid June in Happy Valley Creek, tributary to the Sagavanirktok River (McCart et al. 1972). Grayling spawning in small tributaries of the Colville River is completed by the end of June (Bendock 1979). The spawning period often coincides with the rising water temperatures and flooding of spring breakup. Grayling typically ascend to spawning sites as soon as flow conditions permit passage (Krueger 1981).

C. Reproductive Behavior

Males enter the spawning grounds and establish territories in riffle areas, which they vigorously defend against other males.

Females remain in deep pools and enter the riffles only for short periods to spawn (Tack 1971). The spawning act involves intensive simultaneous body-arching and vibrating; no redd is dug, but small depressions usually result from the spawning activity. During the spawning act, the posterior portion of the female's body may be forced into the gravel by the male's tail working vertically (ibid.). Eggs are simultaneously fertilized and deposited 2 to 3 cm below the gravel surface (Kratt and Smith 1977, Van Wyhe 1962). The eggs are adhesive prior to water-hardening and have a slightly higher specific gravity, enabling them to sink to the bottom rapidly, where they are covered by settling material loosened during the spawning act (Brown 1938, Warner 1955). The female resumes her former resting position after spawning. Both sexes may spawn more than once with various partners (Krueger 1981). The duration of spawning activity may range from four days to two weeks (Craig and Poulin 1975, McCart et al. 1972, Tack 1971, Warner 1955). Conflicting observations exist in the literature concerning an apparent diurnal pattern of spawning activity. Van Wyhe (1962) and Warner (1955) reported that most spawning activity occurred between 8:00 P.M. and 4:00 A.M. Russell (pers. comm.) has also observed grayling spawning at night in Lower Talarik Creek in Southwest Alaska. Other observations, however, indicate that spawning activity occurs only during daylight hours and probably ceases during the evening (Bishop 1971, Kruse 1959, MacPhee and Watts 1976, Scott and Crossman 1973, Tack and Fisher 1977). Williams (1968) noted that grayling from Tolsona Lake near Glennallen, Alaska, entered Bessie Creek to spawn only at dusk and after dark. In contrast, grayling from Moose Lake entered Our Creek during all hours (ibid). Williams hypothesized that the difference may be due to the lack of cover in Bessie Creek.

D. Age at Sexual Maturity

The point at which sexual maturity is reached varies and is probably more related to size than to age (Armstrong 1982). In the Interior systems and the lower Kuskokwim River, lower Yukon River, Seward Peninsula, and Tanana River, grayling reach maturity by ages 4, 5, or 6 (Alt 1977, 1978, 1980; Armstrong 1982; Wojcik 1955). Most grayling begin spawning in the Bristol Bay area at age 5 (Russell 1980). Grayling from Crescent Lake on the Kenai Peninsula mature at ages 3 or 4 (Engel 1973).

Grayling in the upper Susitna River mature at ages 4 or 5 (ADF&G 1983, Schmidt and Stratton 1984). In the North slope systems, most grayling appear to mature later, at ages 6 to 9 (Armstrong 1982). Craig and Wells (1975) noted that the age at which grayling reach sexual maturity in the Chandalar River drainage is highly variable, ranging from ages 5 to 10 in the Chandalar River, ages 6 to 8 in Monument Creek, and ages 4 to 9 in Strangle Woman Creek. Grayling in the Pilgrim River near Nome are nearly 100% mature by age 6 (Alt 1980). Grabacki (1981) found that upper Chena River (Interior Alaska) populations subject to heavy fishing

pressure showed slower individual growth rates, younger average age, and lower natural mortality than populations in areas free of fishing pressure. Longevity is variable, with northern populations generally living longer than southern populations. In some unexploited populations, a high percentage live beyond age 8, with some surviving up to at least age 22 (deBruyan and McCart 1974, Craig and Poulin 1975, Craig and Wells 1975).

E. Frequency of Breeding

Grayling spawn annually upon maturation (deBruyan and McCart 1974, Craig and Wells 1975, Engel 1973, Tack 1980, Williams 1969).

F. Fecundity

Fecundity varies, apparently depending on the size of the fish and the stock. Williams (1968) sampled eight grayling from Bessie Creek, which connects Tolsona and Moose lakes, and found an average fecundity of 4,490 eggs per fish. Schallock (1966a) found an average fecundity of 5,350 eggs from 24 Interior Alaska grayling. Individual fecundities ranged from 1,700 eggs for 267 mm-long fish (fork length) up to 12,350 for a 400 mm-long fish. An average fecundity of 8,968 was found for 20 grayling from the Yukon Territory (deBruyan and McCart 1974, cited in Armstrong 1982), with no significant correlation between fecundity and fish length.

G. Incubation Period and Time of Emergence

Embryo development is rapid (13 to 32 days) and is directly correlated with water temperatures (Bishop 1971, Kratt and Smith 1977). Kratt and Smith (1977) found that arctic grayling eggs in northern Saskatchewan hatched in 32 days at a mean daily temperature of 5.8°C. Field studies in Interior Alaska by Warner (1955) and Wojcik (1954 and 1955) indicated that at an average water temperature of 7.8°C eggs eyed in 14 days and hatched in 18 days, and eggs incubated at a mean temperature of 15.5°C hatched in 8 days. In another field study, eggs incubated at an average water temperature of 8.8°C eyed at 10 days and began hatching in 13.7 days (Bishop 1971). Alevins remain in the gravel and almost completely absorb their yolk sacs before emerging (Kratt and Smith 1977). Young-of-the-year are present by June 5 in the Bristol Bay area (Russell 1980). Fry were first collected by Craig and Wells (1975) in the Chandalar River drainage during the last week of June, but the authors note that it is likely that the fry had emerged one to two weeks earlier.

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

A. Home Territory

All life phases, including the life functions of spawning, rearing of young, feeding, and overwintering, usually take place within the semiconfined environment of one drainage or watershed system. Usually some locations within a drainage are better suited than others for supplying seasonal life-function needs, and grayling therefore often exhibit complex migrational patterns and require unrestricted movement within a system (Armstrong 1982). Spawning

territories vary in size, depending upon such factors as stream width, water depth, current velocity, channel configuration, and spawner density. Tack (1971) described 22 male territories as generally oval, 1.8 to 2.4 m wide and 2.4 to 3.0 m long.

B. Timing of Movements and Use of Areas

The seasonal pattern of grayling movements within a system is affected by each river or stream's source of water (Tack 1980) and therefore varies from system to system. A river or stream's source of water affects the migrational pattern of grayling within that system. Glacier-fed systems in the interior tend to be used mainly for overwintering or as migration routes to other systems; spring-fed systems are used primarily for feeding, with some overwintering for those systems entering the Arctic Ocean. Bog-fed systems may provide suitable spawning and feeding habitat; large unsilted runoff waters may be used for spawning, feeding, and overwintering (Tack 1980).

Tack (1980) and Armstrong (1982) provide detailed descriptions of grayling movements in several different stream types, which can serve as more complete references for the reader in need of extensive information on grayling movements. Generally, adults move from overwintering locations to begin an upstream prespawning migration under the ice in late winter or early spring. The prespawning migration typically lasts from two to six weeks, depending upon the distance traveled. In most cases, grayling move into bog streams or unsilted rapid-runoff streams to spawn (avoiding spring-fed streams and silted rapid-runoff streams) as soon as the ice is out and the water temperatures rise to about 1°C, usually in May or June (Tack 1980, Armstrong 1982, Sundet and Wenger 1984). Only in the case of large unsilted rapid-runoff rivers do grayling spawn in the same stream in which they overwinter, and even in these rivers there is a marked upstream migration to parts of the system not used for overwintering (Tack 1980). Immature fish generally follow closely behind adults. Immediately after spawning, many of the adults move to upriver summer feeding areas, but most juveniles remain in lower portions of unsilted rapid-runoff streams and associated tributaries until late August or September (Armstrong 1982). Young-of-the-year feed in the area near their hatch site and then migrate directly to overwintering areas (Tack 1980). From September through December, as temperatures drop and instream flow and food availability deteriorate, there is a general downstream movement of all age classes to more favorable overwintering areas (Grabacki 1981, Netsch 1975, Tack 1980). Common overwintering sites include intermittent pools, under the ice in large rivers, deep lakes, brackish river deltas, and spring- or ground-fed areas (Bendock 1980, Tack 1980). In the arctic area, spring areas in rapid-runoff (mountain) streams and isolated deep pools in the largest rapid-runoff rivers provide the only overwintering habitat other than a few lakes (Tack 1980). Lake-dwelling populations move into tributaries to spawn in the spring and may return to the

lakes shortly after spawning (Engel 1973), or they may remain in the tributaries until fall (Saunter and Stratton 1984). Grayling leave Deadman Lake in the upper Susitna River drainage in mid June and do not return until early September (ibid.).

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

Excessive water velocities can cause low fertilization, egg dislodgement, and alevin displacement (Nelson 1954; Tack 1971, 1974; Holmes 1983, 1984). Low water during the summer months will concentrate grayling, making their population more available to fishing pressure (Tack 1975). High water temperatures (above 16°C) during the summer and low water and D.O. levels during the winter can be detrimental. Predation on grayling eggs and alevins by other fish could significantly reduce population levels (Krueger 1981). Whitefish were reported preying upon arctic grayling eggs at the outlet of Mineral Lake (Tack 1971). Other fishes, including rainbow trout (Salmo gairdneri), arctic char (Salvelinus alpinus), round whitefish (Prosopium cylindraceum), northern pike (Esox lucius), and longnose suckers (Catostomus catostomus), also consume arctic grayling eggs and alevins (Bishop 1971, MacPhee and Watts 1976, Alt 1977). Grayling fry are often trapped in shallow pools that are cut off from main stream channels as water levels fall. Many fry perish as these shallow pools dry up or freeze with the onset of winter (McCart et al. 1972). Peterson (1968) suggested that grayling fry lack the behavioral mechanisms that prompt salmon and trout to escape entrapment.

B. Human-related

Any disturbances within a system that degrade grayling spawning, rearing, or feeding habitats, degrade water quality, or block fish migration routes may adversely affect population levels of grayling occupying that system. A summary of possible impacts from human related activities includes the following:

- Alteration of preferred water temperatures, pH, dissolved oxygen, and chemical composition
- Alteration of preferred water velocity and depth
- Alteration of preferred stream morphology
- Increase in suspended organic or mineral material
- Increase in sedimentation
- Reduction in permeability of substrate
- Reduction in food supply
- Reduction in protective cover (e.g., overhanging stream banks or vegetation)
- Shock waves in aquatic environment
- Human harvest

(For additional impacts information, see the Impacts of Land and Water Use volume of this series.)

VIII. LEGAL STATUS

The Alaska Board of Fisheries develops regulations governing the sport harvest of fish in Alaska. Research and monitoring of grayling populations is conducted by the Alaska Department of Fish and Game, Division of Sport Fish.

IX. LIMITATIONS OF INFORMATION

A great amount of information has been collected on the life history of arctic grayling in Alaska, particularly in the Interior Region and along the TAPS, but there are still gaps in our knowledge critical to the future management of grayling as resource development (habitat alterations) and angler pressure continue to increase. A better understanding of the dynamics of exploitation, early life history, stock separation, feeding habits, grayling stocking, the validity of aging by scale analysis, and the effects of various habitat alterations is necessary. There are very few studies on the effects of environmental changes on arctic grayling in Alaska (Armstrong 1982, Grabacki 1981).

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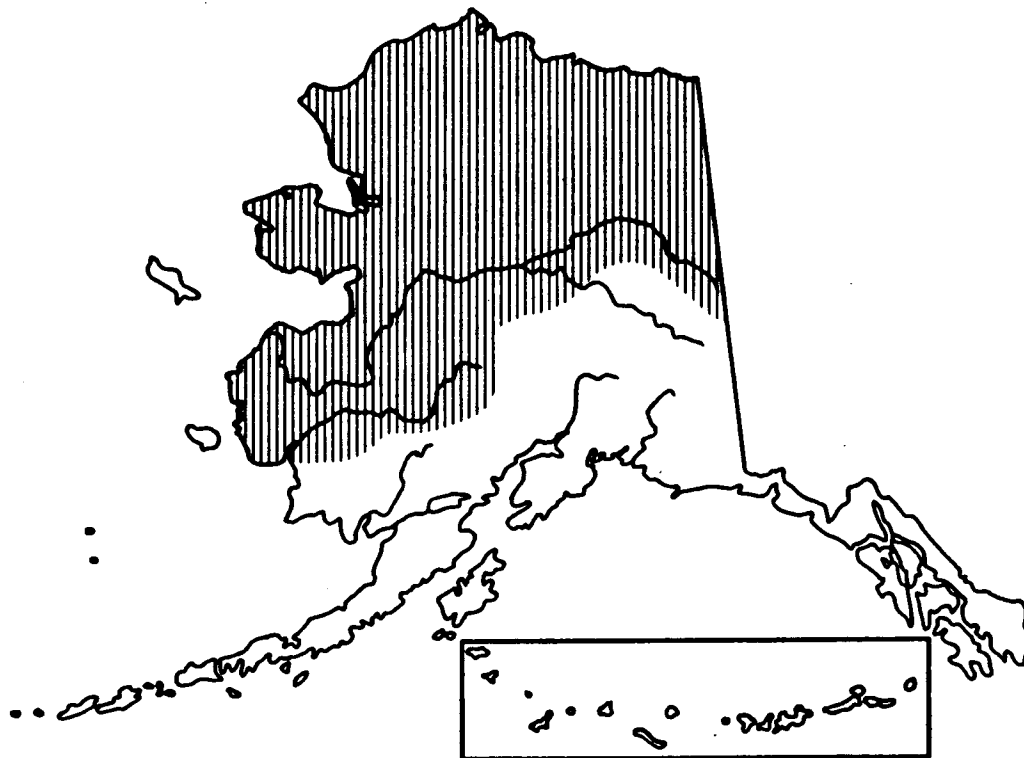
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Broad Whitefish Life History and Habitat Requirements
Arctic, Western, and Interior Regions



Map 1. Range of broad whitefish (Morrow 1980)

I. NAME

- A. Common Names: Broad whitefish, round-nose whitefish, sheep-nose whitefish, small-headed whitefish, Kennicott's whitefish
- B. Scientific Name: Coregonus nasus Pallus, 1776
Due to taxonomic confusion in identifying broad whitefish, the following scientific names have been used since 1883 to describe Coregonus nasus: Coregonus kennicottii, Coregonus nelsoni, Coregonus nasus kennicotti, Coregonus clupeaformis, Prosopium cylindraceum, and Prosopium kennicotti.
- C. Native Names: See appendix A.

II. RANGE

- A. Worldwide
Broad whitefish are distributed in the fresh and brackish waters of the arctic and subarctic drainages of northwestern North

America and northern Eurasia, south to about 60° north latitude (Baxter 1973, Scott and Crossman 1973). The western limit of the range is the Pechora River, USSR (52° E), just west of the Ural Mountains, from which they occur east to the Bering Sea, south to the Bay of Korf, and in the Penzhia River on the northeastern corner of the Sea of Okhotsk (Baxter 1973, Scott and Crossman 1973, Morrow 1980). In North America, broad whitefish occur in fresh water from the Perry River, Northwest Territories, west in numerous river systems of arctic Canada (such as the Coppermine and MacKenzie rivers) and along the arctic and northwest coast of Alaska to the Kuskokwim River (Scott and Crossman 1973). Anadromous populations have been observed in nearshore brackish water along the Beaufort Sea and as far offshore as Herschel Island, Yukon Territory (ibid.). A nonanadromous population exists in Teslin Lake at the headwaters of the Yukon River (ibid.).

B. Statewide

Broad whitefish are found throughout Alaska from the Kuskokwim River north to the arctic coast (Alt 1971, Morrow 1980). They are present throughout the Yukon River drainage from the mouth to the headwaters in British Columbia, including the Innoko, Koyukuk, and Porcupine river tributaries in Alaska (Alt 1971). In the Tanana River drainage (part of the Yukon River system), they are widespread in the Minto flats area and the lower Tolovana, Chatanika, and Tatalina rivers (Alt, pers. comm.). They are also found in most of the rivers draining into the Bering, Chukchi, and Beaufort seas (Alt 1971, Morrow 1980).

C. Regional Distribution Maps

To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for each region. Broad whitefish distribution information is included on the 1:250,000-scale maps titled Distribution of Selected Freshwater Fish. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of selected fish and wildlife species has been prepared and may be found in the Atlas that accompanies each regional guide.

D. Regional Distribution Summary

1. Arctic. Broad whitefish are widely distributed throughout the Arctic Region. They are frequently caught in nearshore waters of the Beaufort Sea. Anadromous runs occur in the Colville and Sagavanirktok rivers (Alt 1971, 1972; Bendock 1977, 1982). Small numbers were observed at stream and lake sites on the arctic coastal plain, including Teshekpuk Lake (Hablett 1979, Bendock 1982, Bendock and Burr 1985). Broad whitefish were observed in the lower Canning River and may possibly use other drainages to the east, although none have been reported in the Arctic National Wildlife Range (USFWS 1982).

In northwest Alaska, they are present in the Kobuk River (Alt 1971) as well as in the Imuruk Basin proper and the lower reaches of the major rivers flowing into the basin: the Agiapuk, Kuzitrin, and Pilgrim rivers (Alt 1972). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Arctic Region.)

2. Western-Interior. Broad whitefish are found in most major drainages where there is 1) summer access to tundra lakes and ponds, 2) suitable sand or fine gravel in moving water for spawning, and 3) adequate oxygenated water for winter survival (Baxter 1973). They are widely distributed in the Yukon River drainage from the mouth to the headwaters (Scott and Crossman 1973). Alt (1983) reported that broad whitefish were very abundant in the Innoko River system. They were taken in early September 1982 in all surveyed areas of the Iditarod River. They were also taken 7 mi up the Yentna River, near the mouth of the Dishna River, and 8 mi up the North Fork of the Innoko River (Alt 1983). Broad whitefish are found in the Porcupine and Koyukuk rivers and are widespread in the Minto flats region of the Tanana River drainage but apparently are rare farther upstream (Alt, pers. comm.). A single broad whitefish was captured in the Tanana River 14 km upstream from its confluence with the Chena River in September 1971 (Alt 1972). This represents the farthest upstream penetration of this species documented in the Tanana drainage (ibid.). They are also common in the entire Kuskokwim River system (Alt 1971, Baxter 1973). Alt (1972) reported that broad whitefish exist in Highpower Creek, 1,350 km up the Kuskokwim River. (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Western and Interior regions.)

III. PHYSICAL HABITAT REQUIREMENTS

A. Water Quality

1. The pH factor. In the Yukon-Kuskokwim delta, broad whitefish have been observed in tundra ponds containing a pH in the range of 5.5 to 6.0 (Hale 1981). They have been observed in the central arctic coastal plain lakes, where pH values ranged from 7.5 to 9.0 (Bendock and Burr 1985). Broad whitefish also were observed at stream survey sites in the Topagoruk and Ikpikpuk river drainages within the central arctic coastal plain, where pH values ranged from 8.0 to 9.0 (ibid.). However, the exact range they can tolerate or prefer is unknown (ibid.).
2. Dissolved oxygen (D.O.). Little information is available on the dissolved oxygen requirements of broad whitefish. Baxter (1973) reports that broad whitefish in the Kuskokwim River drainage appear to need at least 2 mg/l at a water temperature of 0°C to survive. Bendock (1980) found broad whitefish overwintering in deeper pools and depressions of the Colville

River, where D.O. levels ranged from 1.4 to 4.6 mg/l. Fish found at the lower D.O. level appeared healthy. Bendock (1977) also found late winter under-ice D.O. readings in the Sagavanirktok River that varied between 7 mg/l and saturation (in excess of 15 mg/l at 0°C).

3. Turbidity. Little information is available on the effects of turbidity on broad whitefish populations in Alaska. Craig and Haldorson (1980) report that Simpson Lagoon waters are turbid to varying degrees for almost the entire open-water period. Because of wind-generated turbulence of bottom sediments, nearshore turbidity readings fluctuated widely (1-146 NTU recorded 80 m from shore) from day to day. Divers observed that a vertical stratification of water currents occurred in the center of the lagoon even though the water depth was only 2 m. Currents were slower at the bottom, and thus the flocculent detrital layer often remained in place despite relatively high velocities of overlying water. Kogl (1971) reported turbidity readings taken during July 1970 in the Colville River drainage that ranged from 0 to 20 ppm. The highest reading occurred at the outlet of Nanuk Lake on the Nechelik Channel of the Colville River delta.

Most experimental work has shown that many species of fish can survive high concentrations of suspended matter for short periods. Prolonged exposure to some types of materials in most species, however, results in a thickening of the cells of the respiratory epithelium and the eventual fusion of adjacent gill lamellae, which definitely interferes with respiration. Fish do not have gill cleaners for removing foreign matter and rely on the flow of water through the gill chambers (Bell 1973).

Excess turbidity in the form of settleable solids can kill buried eggs and alevins by denying water interchange and can smother food organisms. Primary food production is lowered above levels of 25 NTU (ibid.). Alaska turbidity standards for anadromous waters are set at no more than 25 NTU over background levels (ADEC 1979).

4. Salinity. Broad whitefish have been caught in waters with salinities as high as 30 ppt during summer conditions and 0 ppt during winter conditions in the Beaufort Sea (Craig and Haldorson 1980). Bendock (1977) captured broad whitefish in open-water leads of Prudhoe Bay with a salinity of less than 2.5 ppt during the early spring when fresh river water mixes with the more saline water of the ocean.

In the arctic, broad whitefish are confined to fresh or slightly brackish water near coastal areas (Berg 1948, Muth 1969). Alt (1976) reports that broad whitefish are seldom taken in water with salinities greater than 20 ppt. Thus the Bering, Chukchi, and Beaufort seas should act as isolating barriers between fish of the Kuskokwim, Yukon, and Sagavanirktok river systems (Alt 1976).

B. Water Quantity

Broad whitefish in Alaska generally occur in streams where the gradient is less than 0.75 m/km (Kogl 1971). Current velocities for several bodies of water on the North Slope, where broad whitefish occur, range from 0 to approximately 180 cm/sec (ibid.). Hale (1981), based on information from Jones (n.d.), states that upstream migration might be inhibited by stream reaches longer than 100 m with velocities in the range of 40 cm/sec.

C. Water Temperature

Broad whitefish were captured in the Arctic Region and northwest Canada in water temperatures ranging from 0 to 16°C (Muth 1969, Bendock 1977). They overwinter at 0°C, with no apparent ill effects (Baxter 1973). They may also tolerate summer temperatures in shallow ponds of the Kuskokwim River delta up to about 20°C (Hale 1981).

There is little information on preferred temperatures, but fish from the MacKenzie River (0 to 15.5°C annual range) have a greater growth rate than fish from the Coppermine River (0 to 10°C annual range) (Muth 1969). The environmental factors (water temperature, longer ice-free period, and food availability) are suggested as the primary causes of growth differences between Coppermine and MacKenzie river fish (ibid.). Alt (1976) suggests that the slower growth rate of broad whitefish from the Sagavanirktok River and Imuruk Basin as compared to populations from the Yukon-Kuskokwim drainage may be the result of the shorter ice-free period in the Arctic Region. Food availability and genetic differences could be secondary factors (Alt 1976).

D. Substrate

Little information was found relating to the substrate required by broad whitefish. The lacustrine stock of broad whitefish in Lake Minchumina, northwest of Denali National Monument, evidently spawns on gravel and cobble along the lakeshore (Hale 1981). Baxter (1973) notes that they were found spawning in areas with sand and fine gravel in the Yukon-Kuskokwim delta. Broad whitefish were taken by Bendock and Burr (1985) in rivers draining the central arctic coastal plain, which were characterized by an unvegetated substrate of silt and mixed sand. He also captured broad whitefish in thaw lakes, with typically unvegetated or sparsely vegetated silt bottoms and in deflation lakes characterized by vegetated sandy bottoms (ibid.).

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

Broad whitefish are opportunistic feeders able to use a wide range of food items. Percy (1975) captured broad whitefish fry along the arctic coast, in streams, and in delta lakes, and the stomach contents were analyzed. He noted a distinct difference in the diets of these three groups. Coastal fry were principally feeding on chironomids (midges) and copepods. Stream specimens had fed on

plecopterans (stoneflies), crustaceans, and oligochaetes. Lake specimens had fed on mysids.

Stomach analysis of 136 broad whitefish (399 to 516 mm fork length) captured during the summers of 1974 and 1975 in the outer Mackenzie River delta revealed that 130 were empty. The stomach contents of the remainder included 60% plant remains, 35% gastropods, and 5% trichopterans (caddisflies) (ibid.). Stomach contents of broad whitefish sampled in Prudhoe Bay during late July revealed that 58% (n = 12) were empty; the remainder included 80% amphipoda, 20% pelecypoda, and 40% dipteran larvae and adults (Furniss 1973).

From stream surveys, Hablett (1979) found that 76% (n = 83) of the broad whitefish sampled in the Colville River had empty stomachs. Food items found in the remaining fish included snails, aerial insects, chironomid larvae, and zooplankton. Fifteen percent (n = 35) of the Innoko River broad whitefish stomachs sampled during the spring upstream migration contained food (Alt 1983). Food items of fish captured on summer feeding grounds were clams, caddisflies, snails, diptera larvae, and beetles (ibid.).

Bendock (1982) reports that 46% (n = 66) of the broad whitefish stomachs examined from coastal plain lakes contained food. Prey items in descending frequency of occurrence included clams, snails, chironomid larvae, and zooplankton (Bendock 1982).

B. Types of Feeding Areas Used

As is suggested by their short gill rakers and blunt snouts, broad whitefish are apparently bottom feeders (McPhail and Lindsey 1970).

Upon entering the Beaufort Sea when the larger rivers break up in early June, anadromous broad whitefish forage along the mainland coastline, inhabiting shallow bays and lagoons (Bendock 1977). In the Sagavanirktok and Colville river deltas, young-of-the-year and age 1 broad whitefish seldom travel beyond the waters adjacent to the rivers (ibid.). Overflow channels and oxbows connected to the Colville River are used extensively by young-of-the-year and immature broad whitefish (Hablett 1979).

In the Kuskokwim drainage, the nonanadromous broad whitefish usually feed in lakes that connect with river channels. The adult and young broad whitefish leave the tundra lakes, ponds, and sloughs in the fall to overwinter in the deeper river channels (Baxter 1973).

Alt (1983) reports that nonanadromous broad whitefish migrate upstream in early summer and move into the lake and slough environment to feed along the lower 140 mi of the Innoko River and lower Iditarod River. In 1982, they were captured in shallow lakes that in 1981 had been dry because of low water levels (ibid.).

C. Factors Limiting Availability of Food

Little documentation was found that discussed factors limiting the availability of food. In the Beaufort Sea, the primary food source of anadromous fish are marine-derived organisms (mysids,

amphipods, etc.). This is because of the low input of terrestrially derived carbons to the brackish water nearshore zone. The availability of suitable feeding habitat in the nearshore zone is limited by the thermoregulatory and osmoregulatory abilities of the anadromous broad whitefish. Therefore, the suitable feeding habitat for anadromous broad whitefish in the Beaufort Sea would be defined by high temperatures (less than 15°C), low salinity (15 ppt), and the availability of prey organisms recruited from the marine waters offshore (Johnson 1984).

D. Feeding Behavior

Broad whitefish do not feed in the Kuskokwim River from the time they leave their summer feeding areas in the fall until the next spring, when they return to the tundra lakes (Baxter 1973). For spawners, this is a period of eight to nine months without feeding. Baxter (1973) found no food in hundreds of broad whitefish that he examined during fall and winter months. Bendock (1977) reports that all of the spawning broad whitefish captured in the Sagavanirktok River during the last week of September had empty stomachs. Innoko River broad whitefish (in the Western Region) do not feed during the spring upstream migration (Alt 1983).

During the summer open-water season, the anadromous fish emerge from the overwintering areas and disperse along the coast of the Beaufort Sea. Their summer dispersal is predominantly for feeding purposes; in excess of 80% of the annual food budget is obtained during the summer open-water season (Johnson 1984).

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Little documentation was found on reproductive habitat characteristics. In the Yukon-Kuskokwim river drainages, with the possible exception of Lake Minchumina, all broad whitefish spawning areas reported by Baxter (1973) have been in moving water. Baxter (1973) states that adult broad whitefish require flowing water for their eggs to develop to the final stages before spawning.

Both anadromous and nonanadromous populations of broad whitefish travel up the main stem of larger rivers to spawn, sometimes traveling several hundred miles (Baxter 1973, Bendock 1977). Bendock 1977 also reports that anadromous adult broad whitefish reenter the Sagavanirktok River in late August and spawn in deep pools throughout the lower reaches of the delta. (Additional information on spawning substrate is discussed in the Physical Habitat Requirements section.)

B. Reproductive Seasonality

In the fall, broad whitefish leave their summer feeding areas and move toward the spawning grounds. Broad whitefish apparently move upstream in small groups, and the run is spread over several months. The peak catch at Umiat on the Colville River occurred at the end of July (Kogl 1971). An annual upstream spawning migration, peaking during September and October in the inner delta, has

been documented in the MacKenzie River (DeGraaf and Machniak 1977, Percy 1975). Adults apparently move downstream after spawning and overwinter in deeper parts of the rivers or in estuaries (Morrow 1980, Baxter 1973). Tag-return data indicate that the downstream run of spent fish in the MacKenzie River occurs during the first two weeks of November (Percy 1975).

All broad whitefish ($n = 12$) captured near the mouth of the Pilgram River, Imuruk Basin, on 19 September were in spawning condition (Alt 1980). Bendock (1977) captured ripe broad whitefish in the Sagavanirktok River during the last week in September. Baxter (1973) reported the following seasonal distribution for broad whitefish in the Kuskokwim River drainage:

1. June and July. The entire population spends summers feeding as a mixed-age-and-sex group on the tundra in the lakes and ponds and, to a lesser extent, in the tundra sloughs.
 2. August. Sexually mature females that will spawn in the fall start their out-migration from summer feeding areas and slowly ascend the Kuskokwim River, 5 to 10 mi per day. The earlier ripening fish spawn farthest upriver.
 3. September. Sexual development of males occurs more rapidly, and the males join the females in the upstream migration.
 4. Late September through October. The nonspawning adults leave the tundra feeding areas and apparently mill in the Kuskokwim River generally below the spawning population.
 5. October to December. The immature fish leave the tundra and mill with the nonspawning adults. The youngest fish leave last.
 6. October to early December. The only area surveyed in the main Kuskokwim River during the spawning season was at river mile 89. Spawning starts about the time the Kuskokwim River freezes over in this area.
 7. Mid December to May. After spawning, the entire broad whitefish population moves downstream and appears to be mixed for the rest of the winter in deeper pools of the lower Kuskokwim River.
 8. Late May or early June. As soon as the melting snow and ice flushes the Kialik River and it becomes oxygenated, broad whitefish populations enter the river and proceed upstream to their summer feeding areas. This migration occurs before the ice is out of the tundra lakes, ponds, and sloughs and will proceed above the anchor ice in the sloughs. The older fish appear in the upper reaches of the rivers first, with no apparent differences between spent and developing fish.
- In the Nizhnyaya and Tungusky rivers in the USSR, broad whitefish spawn from the end of October to the beginning of November at water temperatures close to 0°C (Berg 1948).

D. Age at Sexual Maturity

Limited data on the sexual maturity of Sagavanirktok River fish indicate that males mature at ages 7 to 9 and females at ages 8 to 10 (Alt 1976). Age at maturity for both sexes from the Colville

River samples was seven to eight years (Alt and Kogl 1973). Fifty percent ($n = ?$) of the age 9 broad whitefish sampled from the Colville River and the eastern margin of Foggy Bay in the Beaufort Sea during 1975 and 1976 were mature (Bendock 1977). Twenty-three ($n = ?$) of those fish between ages 11 and 13 had redeveloping gonads and would not spawn in the year of capture (ibid.). Broad whitefish captured from arctic coastal plain lakes ranged from 5 to 20 years. The age of sexual maturity was 10 years for both sexes (Bendock 1982).

In Imuruk Basin samples, males mature between ages 6 and 8, whereas females mature between ages 7 and 8 ($n = 53$) (Alt 1976). Gonad examinations of specimens from the Innoko River suggest that all age 6 and older fish, except for a 376-mm female, were mature (Alt 1983).

Data indicate a somewhat earlier age at maturity for Porcupine River broad whitefish. Males reach sexual maturity at age 5 and females at age 5 or 6 ($n = 32$) (Alt 1976). Minto flats samples ($n = 79$) ranged from ages 5 to 11, and all were mature except one age-5 400-mm male (ibid.).

Holitna River specimens ranged from ages 4 to 8 ($n = 73$). Examinations of the gonads of these fish indicate that males mature at ages 5 and 6 and females at ages 6 and 7 (ibid.).

The maximum age reported by Craig and Haldorson (1980) for broad whitefish from Simpson Lagoon in the Beaufort Sea was 22 years. Longevity is generally greater for broad whitefish of the arctic coastal plain lakes than for either their anadromous counterparts (from Prudhoe Bay) or Interior Alaska broad whitefish (Bendock 1982).

E. Frequency of Breeding

In the Kuskokwim and Yukon river systems, larger broad whitefish do not spawn every year after they become adults (Baxter 1973). During the winter, part of the population consists of large adult fish that have immature gonads. These fish are quite fat in physical condition, especially in the nuchal hump. The other part of the adult population consists of those that have spawned recently. These fish have lost almost all their abdominal fat, and the nuchal hump is lower than that of the nonspawning adults (ibid.).

Females in the Minto flats area are apparently nonconsecutive spawners because many large fish were found during the summer that contained tiny undeveloped eggs and residual eggs from the previous year's spawning (Alt 1972). Other investigators have noted the nonconsecutive spawning of northern fishes. Baxter (1973) presumes that it is possibly caused by the paucity of the food supply and the lack of trace elements and vitamins in the food.

Based on field examinations of fish in the Innoko River, consecutive spawning is probably the rule for broad whitefish in that system (Alt 1983).

F. Fecundity

An exceptionally large broad whitefish for the Kuskokwim River, fork length (FL) = 590 mm, had an estimated egg number of 127,700; a large fish, FL = 522 mm, had an estimated 71,480 eggs; and an average fish, FL = 476 mm, had an estimated 46,220 eggs (Baxter 1973). Age was not given for these fish. Berg (1948) reported the fecundity of broad whitefish up to age 8 in the Kara River, USSR. The fecundity of the fish varied from 14,000 to 29,000 eggs. The fecundity of a sample (n = 11) from the MacKenzie River ranged from 26,922 to 65,798 eggs/female, with a mean of 39,721 eggs/female (DeGraaf and Machniak 1977).

G. Incubation Period/Emergence

The timing and requirement for egg and fry development is largely unknown, but young-of-the-year fish have been documented in coastal waters in the summer (Bendock 1977, Craig and Haldorson 1980), indicating early movement away from spawning areas (USFWS 1982). Morrow (1980) states that the young hatch in the spring and move downstream.

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

Most of the natural mortality apparently occurs during the winter months that follow spawning (Baxter 1973). The exact cause of mortality was not given but may be any of several factors, including low D.O. or freezing (ibid.). Predation is also a major cause of mortality (Berg 1948). In the Kolyma River, Russia, the eggs of broad whitefish were found in the intestines of grayling, round whitefish, Siberian whitefish, dace, longnose sucker, and sturgeon (ibid.).

1. Overwintering. During the winter, the critical habitats are freshwater pools located under the ice that are fed by springs or the interstitial flow of the major rivers (Johnson 1984). As the river ice increases in thickness, it freezes into the substrate in shallow areas and riffles (Bendock 1977). By mid winter, this process has effectively created a series of discontinuous pools of water under the ice. This constitutes the only overwinter habitat for fish occupying the lower reaches of these rivers (ibid.).

Overwinter locations have been reported in pools from the lower Sagavanirktok River and from the Colville River in the vicinity of Umiat (Bendock 1977, 1980). Overwintering broad whitefish were also netted in several lakes in the inner MacKenzie delta (Percy 1975).

B. Human-related

Significant loss or reduction of overwintering habitats could result in populationwide reductions in numbers. Access to the overwintering pools is also essential if the populations are to be maintained (Johnson 1984). The overwintering and fall spawning areas within river deltas are extremely sensitive to disruption because concentrated numbers of fish are restricted to small

pockets of under-ice water in these areas (Bendock 1977). Large-scale gravel mining in river deltas can disrupt their hydrologic regime, thus affecting the availability of fall spawning and overwintering habitat (ibid.).

The start of intensive fishing may lead to sharp successional changes. From studies in Russia, Reshetnikov (1979) states that fishing usually reduces the abundance of large and old fishes and that at least 10 years are needed to allow the population to return to its original state. He also notes that overfishing leads to a change in the composition of the ichthyofauna and that valuable commercial fishes with a long life cycle (inconnu, whitefishes, trout) are replaced by species with a short life cycle. Such changes in the compositions of the ichthyofauna, attributed to fishing and the eutrophication processes, were recorded in Lake Imandra, Syamozero, and the Pskov-Chudskoye body of water in Siberia, USSR (Reshetnikov 1979).

1. Drilling fluids. An intensive investigation was conducted in the vicinity of Prudhoe Bay, Alaska, in early and mid 1979 to examine the environmental implications of offshore drilling fluid disposal in the arctic. Components of this investigation included measurement of environmental parameters, test discharges of freshwater drilling effluents (above and below ice), benthic studies, acute toxicity testing, and long-term biological effects studies. Ninety-six-hour LC50s values (concentrations at which 50% of the test organisms died over a 96-hour period) for broad whitefish varied from 6.4% for XC-Polymer drilling fluids (from mid-well depth) to greater than 20.0% for CMC/Gel drilling fluids (from upper portions of the well)(Tornberg et al. 1980).
2. Barriers. To date, the primary coastal developmental activity in the Alaskan Beaufort Sea is the 13,000-ft-long West Dock Causeway extending into the brackish nearshore zone of Prudhoe Bay (Johnson 1984). Baker (1985) states that the Prudhoe Bay Waterflood Studies have obtained sufficient data to clearly establish the negative effect of the West Dock Causeway on four species of anadromous fishes. The study of the effects of the West Dock Causeway on anadromous fish has been ongoing for over four years (Johnson 1984). Baker (1985) reports that it has been established that the causeway has degraded habitat and blocked the movement of anadromous fishes by creating thermal and salinity gradient barriers. A sharp decrease in temperature accompanied by an increase in salinity blocks the movement of fishes. It is the presence of these gradients, not the physical presence of the causeway, that results in the barrier to fish movement (Johnson 1984). These gradients may present a barrier that could delay the arrival of the anadromous fish to their overwintering habitat, resulting in high overwintering mortality (ibid.).

A summary of potential impacts from human-related activities in the Beaufort Sea estuary includes the following (Bendock 1977):

- A large-scale reduction in invertebrate fauna may have a profound effect on the fishery.
- Overwintering and fall spawning areas within river deltas are extremely sensitive to disruption because of the concentrated number of fish restricted to small pockets of under-ice water.
- Large-scale gravel mining in river deltas can disrupt their hydrologic regime, thus affecting the availability of fall spawning and overwintering habitat.

The following are other possible impacts:

- Changes in biological oxygen demand, nutrient loading
- Changes in chemical composition of water
- Changes in dissolved oxygen, temperature, pH, salinity
- Changes in flow or water level, entrapment
- Changes in sedimentation rates, turbidity, suspended solids
- Changes in substrate composition and location
- Competition with introduced species
- Increased susceptibility to harvest or predation
- Inducement of impingement or entrainment
- Physical barriers to movement
- Shock waves and blasting in aquatic environments

(For additional impacts information, see the Impacts of Land and Water Use volume of this series.)

VIII. LEGAL STATUS

The Alaska Board of Fisheries develops regulations governing the harvest of broad whitefish throughout its freshwater and coastal marine range. Because only localized harvesting by commercial, subsistence, and sport fishermen occurs, no statewide management plan has been formulated.

IX. LIMITATIONS OF INFORMATION

There are major gaps in our current knowledge critical to the future management of broad whitefish and their habitat requirements. More extensive information is needed on velocity, depth, temperature, and salinity requirements. Little information was found on the effects of environmental changes. A better understanding of early life history, population dynamics, population genetics, species identification, and spawning populations is necessary.

Russian scientists have conducted research on broad whitefish, including studies on hatchery production, that have been published in Russian language journals for which translations are not readily available.

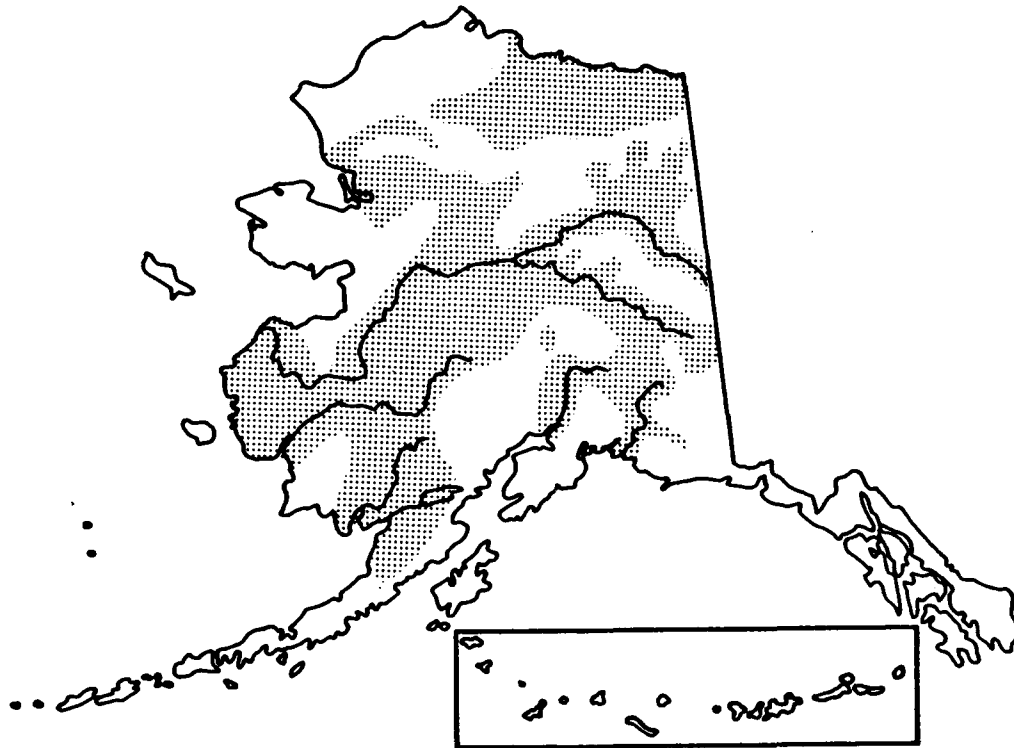
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Burbot Life History and Habitat Requirements
Southcentral, Western, and Interior Regions



Map 1. Range of burbot (ADF&G 1978)

I. NAME

- A. Common Name: Burbot
- B. Scientific Name: Lota lota (Linnaeus)
- C. Native Names: See appendix A.
- D. Species Group Representation: Burbot is a member of the codfish family (Gadidae) and is the only species in the family found strictly in fresh water.

II. RANGE

- A. Worldwide
Distribution of the burbot is circumpolar in the northern hemisphere. Several subspecies of burbot are present in fresh waters of Eurasia and North America from the Arctic Ocean southward to about 40°N. It is absent from Kamchatka, Scotland,

Ireland, Nova Scotia, most islands, and the west coast of Norway (Scott and Crossman 1973).

B. Statewide

Burbot occur throughout mainland Alaska, including nearly all of Interior, Western, and Arctic Alaska (map 1). Burbot are absent from most coastal watersheds of Southeastern Alaska, the Kenai Peninsula, Kodiak Island, and the Aleutian Islands chain (ADF&G 1978). Burbot are widely distributed in large glacial rivers of Interior Alaska, near the confluences of tributary streams, and in many lakes (Peckham 1979).

C. Regional Distribution Maps

To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for each region. Burbot distribution information has been mapped on the series of 1:250,000-scale maps titled Distribution of Selected Freshwater Fish. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of selected fish and wildlife species has been prepared and may be found in the Atlas that accompanies each regional guide.

D. Regional Distribution

1. Southcentral. Burbot occur throughout lakes and interconnecting waterways of the upper Copper-Susitna rivers area. The main Susitna River and its larger tributaries, the Yentna, Chulitna, Talkeetna, and Skwentna, support burbot populations (ADF&G 1978). On the Kenai Peninsula, burbot are present only in Juneau Lake, where they were probably introduced (ibid.). In the Prince William Sound area, a native population is present in McKinley Lake near Cordova (ibid.). (For more detailed information, see the burbot Distribution and Abundance narrative in volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)
2. Western and Interior. Burbot are abundant in the Yukon, Kuskokwim, Tanana, and Koyukuk rivers and occur in many low-lying lakes and interconnecting waterways of the Western and Interior regions (ibid.). Burbot are present in the lower Kuskokwim drainage in the lower reaches of streams (Alt 1977). Burbot are found in many tributaries of the Yukon and Koyukuk rivers and in a few lakes on the south slope of the Brooks Range (Chihuly et al. 1980, Netsch 1975, Pearse 1978). Burbot are widely distributed in the Tanana drainage in large glacial rivers and near the confluences of many tributaries (Peckham 1981). (For more detailed information, see the burbot Distribution and Abundance narrative in volume 2 of the Alaska Habitat Management Guide for the Western and Interior regions.)

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

1. Water quality:

- a. Dissolved oxygen (D.O.). Little is known about oxygen levels required by burbot. Sorokin (1971) reports that burbot eggs can develop only when the oxygen content in the water is fairly high and that spawning grounds usually have an undercurrent of fresh water ensuring a supply of oxygen. State of Alaska water quality standards for growth and propagation of freshwater fish call for D.O. levels greater than 7 mg/l (ADEC 1979).
- b. Turbidity. Prolonged exposure to turbidity can irritate fish gills, interfering with respiration (Bell 1973). Suspended material in water can smother food organisms and lower primary productivity, making spawning areas unusable (ibid.). Little is known about turbidity levels that are harmful to burbot. Chen (1969) reported that burbot in the Tanana and Yukon rivers were more abundant in the silty, main rivers than in the smaller, clear tributaries. Chen found that burbot ran up the tributaries more often during high water, when the tributaries' water turned silty. Burbot eggs are unable to develop on soft, silty bottoms (Volodin 1966).
- c. Salinity. Burbot is the only freshwater species of the cod family and generally avoids brackish waters. This fact is evident in its distribution, as it is absent from most islands within its range (Scott and Crossman 1973, ADF&G 1978). However, burbot have been reported in the brackish waters of the Yukon Territory's coast and in the MacKenzie River delta in Canada, where salinities were less than 5 ppt (parts per thousand) (Percy 1975, Kendel et al. 1975). The fish moved from the brackish water upstream to lakes and rivers in late fall for spawning.

Burbot eggs are more tolerant of brackish water and develop normally at 3 to 6 ppt salinity (Jager et al. 1979). Fertilization, embryonic development, and hatching were observed in salinities up to 12 ppt, but the mortality rate increased at later embryonic stages. At a salinity of 14 ppt no larvae hatched (ibid.).

2. Water depth and velocity. Adult burbot usually reside in deep lakes and rivers, especially in the southern part of their range, but they may also occur in small streams, elevated lakes, and low ponds (McPhail and Lindsey 1970). In Great Slave Lake, Canada, burbot are common at least to depths of 100 m (Rawson 1951). Burbot in lakes have been taken from as deep as 213 m and seem to be confined to the hypolimnion in summertime. River fish tend to congregate in deep holes except during the spawning period (Morrow 1980).

Burbot were taken from Harding Lake, in Interior Alaska, in depths from 18 to 33 m in August (Doxey 1983).

Susitna River adult burbot utilized deep eddies in the main river for summer habitat (ADF&G 1983a). After spawning, burbot appeared to use the main river and, to a lesser extent, the tributaries for overwintering habitats. Burbot were most often found in lower-velocity backwater areas (0.0-1.0 ft/sec) but were observed in areas of higher velocities (ibid.). Based on radio telemetry studies, most Susitna burbot overwintered in the main river in areas having relatively high specific conductances (above 200 umhos/cm) and water temperatures (above 0.5°C), indicating areas with an upward percolation of flow (ibid.).

Burbot spawn in streams or lake shallows under ice (McPhail and Lindsey 1970). The spawning site is usually in 0.3 to 1.3 m of water in shallow bays or on gravel shoals 1.5 to 3 m deep (Scott and Crossman 1973). Sorokin (1971) reports that burbot in the Lake Baikal system in southeast Siberia spawn as far as possible upstream in calm places where the depth does not exceed 10 cm and the stream width was 30 cm. Lake Baikal burbot spawned in areas with a weak current of approximately 3 cm/sec, which turned the eggs and cleansed them of silt (ibid.).

In Lake Michigan, high densities of burbot larvae were collected within the 3-m bottom contour, indicating that spawning may have occurred near shore (Mansfield et al. 1983). However, because larvae are more buoyant than their demersal eggs, distribution of burbot larvae throughout the water column in nearshore Lake Michigan demonstrates passive dispersal by currents shortly after hatching (ibid.).

3. Water temperature. Optimum temperatures for burbot range from 15.6 to 18.3°C, with 23.3°C as the upper limit (Scott and Crossman 1973). The surface water temperatures during winter spawning usually range from 0.6 to 1.7°C (ibid.), and in tributaries of the Lake Baikal system, spawning occurs at 0°C water temperature (Sorokin 1971). Burbot enter the Baikal tributaries in the fall when the water temperature drops to 10 to 12°C (ibid.).

Temperatures at which burbot eggs can develop range from 1 to 7°C, and survival decreases rapidly when the temperature deviates from 4°C (Jager et al. 1979). Larvae beyond metamorphosis survive in water temperatures from 8 to 20°C, and the larvae do not start feeding at temperatures lower than 8°C (ibid.). Larvae in Lake Michigan were collected most often in temperatures from 6 to 12°C. However, larvae are vulnerable to currents and may not be able to avoid less preferred temperatures (Mansfield et al. 1983).

4. Substrate. Scott and Crossman (1973) report that burbot spawn over sand or gravel bottoms in shallow bays or on gravel shoals. Sorokin (1971) described the substrate of

burbot spawning areas as large cobble with a small amount of silt, detritus, and organic debris. Burbot eggs are unable to develop on soft, silty bottoms (Volodin 1966). Burbot larvae in Lake Michigan showed a preference for rocky sites over sandy bottoms (Mansfield et al. 1983). Burbot in the main stem Susitna preferred areas with a rubble or cobble substrate (Suchanek et al. 1984).

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

The burbot is an omnivorous carnivore. The diet of burbot varies from place to place, but most studies show that young burbot eat mainly invertebrates, whereas adults feed mainly on fish (Bonde and Maloney 1960, Clemens 1950a, Hewson 1955, Hanson and Qadri 1980, Chen 1969). Young burbot in the Yukon and Tanana rivers feed mainly on insect larvae, especially Plecoptera, Ephemeroptera, and Diptera, and on slimy sculpins (Chen 1969). By ages 4 to 5, the burbot in Chen's study shifted to a diet of fish.

Adult burbot include a variety of fish in their diet. Burbot in Harding Lake, in Interior Alaska, consumed slimy sculpins, least ciscos, northern pike, burbot, and coho salmon (Hallberg 1979, Doxey 1983). In the Colville River of northern Alaska, burbot ate slimy sculpins, ninespine stickleback, round whitefish, and grayling, as well as snails, caddis fly larvae, and small mammals (Bendock 1979). Burbot in Moose Lake, near Glennallen, Alaska, ate whitefish, burbot, and mollusks (Williams 1970), whereas Yukon and Tanana river burbot included slimy sculpin, burbot, lamprey, round whitefish, longnose sucker, and northern pike in their diet (Chen 1969). Arctic and least cisco were the primary food of burbot inhabiting the coastal waters of the Yukon Territory, Canada (Kendal et al. 1975). Adult burbot in the MacKenzie River delta in Canada had a diverse diet, including a variety of insects, crustaceans, sculpins, burbot, and smelt (Percy 1975).

B. Types of Feeding Areas Used

Chen (1969) states that burbot are almost completely bottom feeders in the summer in the silty rivers he sampled. Chen found that bottomfish dominated the diet and noticed a frequent occurrence of bottom debris and drowned shrews or mice in the stomachs. Baily (1972) also noted the presence in burbot stomachs of rocks, wood chips, and plastic, which would indicate indiscriminate bottom feeding.

C. Factors Limiting the Availability of Food

Excessive sedimentation may limit the production of aquatic invertebrate fauna used especially by young burbot (Hall and McKay 1983).

D. Feeding Behavior

McPhail and Lindsey (1970) observed that burbot foraged actively in dim light and were quiet in bright light. Morrow (1980) also noted that burbot moved into shallow water to feed at night.

In the Great Lakes, burbot eat mainly fish during the winter and shift to a diet of invertebrates in the summer (Bailey 1972, Clemens 1950a). However, fish comprise most of the stomach contents of burbot in Alaska year-round (Chen 1969, Doxey 1983).

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Burbot spawn in streams or lake shallows, usually under ice in shallow water .3 to 3 m deep but sometimes 18 to 20 m deep (McPhail and Lindsey 1970, Clemens 1950b, Scott and Crossman 1973). The spawning substrate is clean sand, gravel, or large cobblestones with only a small amount of silt or detritus (Sorokin 1971, Morrow 1980). Sorokin observed spawning in a stream with partial ice cover, which was open in many places.

Burbot in the Susitna River appeared to mill in preparation for spawning in areas with an ice cover having low to medium (0.1-4.0 ft/sec) water column velocities (ADF&G 1983a). In areas of milling, moderately high specific conductances (70-150 umhos/cm) have been observed, suggesting that upwelling may be occurring (ibid.). Burbot spawn at Susitna tributary mouths, such as the Deshka River and Alexander Creek, and radio telemetry data suggest that burbot may also spawn in the main stem (ADF&G 1983c).

Tributaries of Lake Michigan serve as spawning sites or nursery areas for burbot (Mansfield et al. 1983). Rivers may provide sources of food for young burbot, making spawning near river mouths advantageous (ibid.). Juvenile burbot sampled in the Susitna River were most numerous in sloughs and tributaries, indicating that they were rearing near the hatching area (ADF&G 1983b). Juveniles were also found closely associated with the river bottom (ibid.).

B. Reproductive Seasonality

The burbot spawns from November to May over the whole of its world distribution and mainly from January to March in Canada (Scott and Crossman 1973). Spawning in the Lake Baikal area occurs in January and February (Sorokin 1971), and Chen (1969) also reports spawning in the Yukon and Tanana rivers in these months. Spawning in the Susitna River below Devil Canyon occurs between mid January and early February (ADF&G 1983d). In Harding Lake, in Interior Alaska, burbot spawning has been recorded in April (Hallberg 1979).

C. Reproductive Behavior

Male burbot reach the shallow spawning area first, followed in three or four days by the females, and spawning occurs at night (Morrow 1980, Scott and Crossman 1973). However, sampling in the Susitna River indicates that females may arrive first (ADF&G 1983c). Spawning takes place in a writhing ball about 2 ft in diameter that moves over the bottom (ibid.). The eggs are broadcast and then settle to the bottom. Sorokin (1971) notes that the spawning streams in the Lake Baikal area are so shallow that the fish are partly out of water during spawning.

D. Age at Sexual Maturity

Burbot mature from ages 2 to 4 in the southern part of their range but generally not until they reach ages 6 or 7 in interior Alaska (Chen 1969). Colville River burbot reach sexual maturity at age 7 (Bendock 1979), whereas most burbot in Moose Lake, near Glenallen, are sexually mature by age 5 (Williams and Potterville 1983). Clemens (1950b) found that growth of Lake Erie burbot slowed down during the third and fourth years and increased afterwards. He explained that this was due to their reaching sexual maturity and changing their food preference from invertebrates to fish. Chen (1969) did not observe this growth pattern in Alaskan fish.

E. Frequency of Breeding

Chen (1969) states that probably not all burbot spawn every year; it may take more than one year to store the nutrients necessary for gonadal development. Susitna River burbot appear to be nonconsecutive spawners (ADF&G 1983d).

F. Fecundity

A 10-year-old female burbot from the Tanana River produced over 738,000 eggs (Chen 1969). An average adult female produces from 500,000 to 750,000 eggs and occasionally as many as 1.5 million (Morrow 1980).

G. Incubation Period/Emergence

Development time of burbot eggs varies with the temperature and possibly with the population. At 6.1°C, hatching occurs in about 30 days, and at temperatures from 0 to 3.6°C about 71 days are needed (ibid.). Chen (1969) concludes that the incubation period of burbot eggs in the Tanana River, which has a water temperature close to 0°C in the winter, is probably less than three months.

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

During most of their life history, burbot are rather sedentary; however, there appear to be definite movements toward spawning areas. Observations of tagged burbot in the Susitna River indicate that whereas burbot are relatively sedentary, they are nevertheless capable of long-distance movements. (ADF&G 1983b, 1983c). One radio-tagged burbot moved downstream approximately 60 mi in the winter and then held its new position (ADF&G 1983b).

Four burbot were radio-tagged in the lower Chena and Tanana rivers in the fall to monitor their fall and winter movements (Hallberg 1984). All four fish showed some movement both upstream and downstream, moving from as far as 18 mi downstream to 7 mi upstream.

Generally, the spawning migration is one of individual movements, rather than of a whole school together (Morrow 1980). Lake Baikal burbot move into the tributaries in the fall when the water temperature drops (Sorokin 1971). This is initially a feeding migration to the lower reaches of the rivers. Slightly later, the burbot move farther upstream for spawning. The prespawning migration to the tributaries is believed to begin in mid September and last until mid January for burbot in the Susitna River (ADF&G 1983d).

Sorokin (1971) observed a downstream migration to the lower reaches of the rivers after spawning. A slight downstream postspawning movement was also observed in Susitna River burbot (ibid.). Burbot in Ontario, however, have been observed to make postspawning runs upriver, apparently for feeding (MacCrimmon 1959).

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

Burbot are prey to several species of fish, including smelt, perch, lake trout, and northern pike (Scott and Crossman 1973, Johnson 1975, Hallberg 1979). Adult burbot are also known to feed on smaller burbot (Williams 1970, Chen 1969, Hallberg 1979). Foxes sometimes take spawning burbot in shallow streams (Sorokin 1971).

Immature burbot compete for food with other invertebrate-consuming species (Clemens 1950a). Adult burbot can consume large numbers of fish and are potential competitors with other piscivorous fish (Scott and Crossman 1973, Bonde and Maloney 1960, Bailey 1972).

B. Human-related

Any disturbances within a system that degrade burbot spawning, rearing, or feeding habitats, degrade water quality, or block migration routes may adversely affect population levels of burbot occupying that system. A summary of possible impacts from human-related activities includes the following:

- Alteration of preferred water temperatures, pH, dissolved oxygen, and chemical composition
- Alteration of preferred water velocity and depth
- Alteration of preferred stream or lake morphology
- Increase in suspended organic or mineral material
- Increase in sedimentation
- Reduction in food supply
- Shock waves in aquatic environment
- Human harvest

(See the Impacts of Land and Water Use volume of this series for additional information regarding impacts.)

VIII. LEGAL STATUS

The Alaska Board of Fisheries develops regulations governing the sport harvest of fish in Alaska. Research and monitoring of burbot populations is conducted by the Alaska Department of Fish and Game, Division of Sport Fish.

IX. LIMITATIONS OF INFORMATION

The information collected on burbot in Alaska has concentrated on the food habits and age structure of populations. As angler pressure increases, especially winter ice-fishing, many gaps in the knowledge critical to management of this species become apparent. A better understanding of early life history, feeding and spawning habitats, nursery areas, migrational patterns, competition with other fish species, and the effects of various habitat alterations is necessary.

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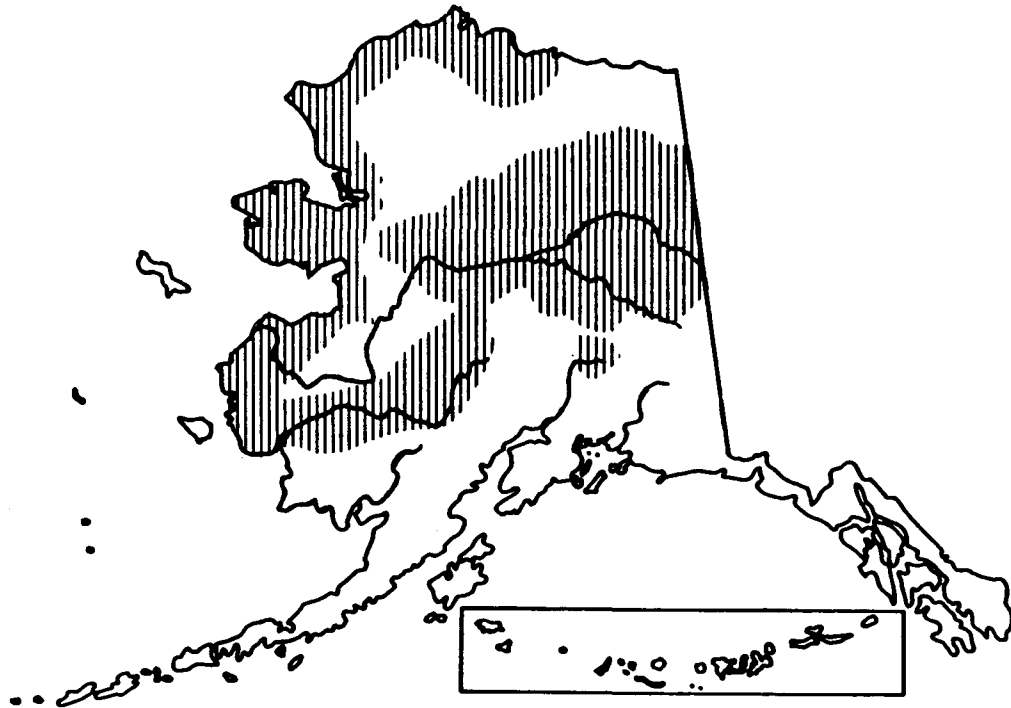
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Humpback Whitefish Life History and Habitat Requirements
Western and Interior Regions



Map 1. Range of humpback whitefish, Coregonus clupeaformis complex (Morrow 1980)

I. NAME

- A. Common Name: Humpback whitefish
- B. Scientific Name: Coregonus pidschian (Gmelin)
- C. Native Names: See appendix A.
- D. Species Group Representation

The humpback whitefish belongs to a group of three closely related species known as the Coregonus clupeaformis complex. McPhail and Lindsey (1970) and Morrow (1980) separate the complex into three species based on gill raker count, which is determined genetically. However, even gill raker numbers can change with environmental modification and selective pressures over a few generations (McPhail and Lindsey 1970).

The species in Alaska known as humpback whitefish, Coregonus pidschian, has average gill raker counts of 21 to 23, with a range from 17 to 25. The species called Alaska whitefish, C. nelsoni, averages 24 or 25 gill rakers, with a range of 22 to 27. Lake whitefish, C. clupeaformis, has average gill raker counts of 26, with a range of 24 to 33 (Morrow 1980).

Alt (1979a) noted few differences in life history parameters when populations of whitefish were separated by gill raker counts. The populations generally occupy a similar habitat and have similar growth, age at maturity, and spawning periods, with lake dwellers spawning later in the season than stream dwellers. Because little distinction exists between the forms in the Coregonus clupeaformis complex, Alt (ibid.) considers the humpback whitefish in Alaska a single species for management purposes, unless two forms occur sympatrically.

II. RANGE

A. Worldwide

The Coregonus clupeaformis complex is widely distributed in North American fresh waters from Atlantic coastal watersheds westward across Canada and the northern United States to British Columbia, the Yukon Territory, and Alaska (Scott and Crossman 1973). The humpback whitefish, C. pidschian, is distributed from Bristol Bay to arctic Alaska and eastward along the arctic coast to the lower Mackenzie River (McPhail and Lindsey 1970). The humpback whitefish is replaced by C. lavaretus in Russia and Europe (Alt 1979a).

B. Statewide

The humpback whitefish is found in most of the Alaskan rivers that empty into the Bering, Chukchi, and Beaufort seas (Morrow 1980). Humpback whitefish are found in waters south of the Alaska Range, such as the Susitna, Copper, and Alsek rivers, and Eyak Lake near Cordova (Alt 1979a). They are also present in waters of the Bristol Bay drainage (map 1).

C. Regional Distribution Maps

To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for each region. In this series, humpback whitefish distribution information is included on the series of 1:250,000-scale maps titled Distribution of Selected Freshwater Fish. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of selected fish and wildlife species has been prepared and may be found in the Atlas that accompanies each regional guide.

D. Regional Distribution Summary

1. Western and Interior regions. Humpback whitefish reach their greatest abundance statewide in the Yukon and Kuskokwim drainages. They are found in all major tributaries of the

Tanana drainage. Humpback whitefish are year-round residents of large deep lakes, such as Lake Minchumina, and are summer residents of smaller lakes (ibid.). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Western and Interior regions.)

III. PHYSICAL HABITAT REQUIREMENTS

A. Water Quality

Little information is available on the pH, turbidity, or dissolved oxygen tolerances of humpback whitefish. Humpback whitefish have been found overwintering in the Sagavanirktok River on the arctic coast, with dissolved oxygen near 7 ppm (Bendock 1977). In the spawning grounds of other whitefish species in Europe, the oxygen concentration of bottom water must be at least 8 mg/l so that viable larvae can develop in the eggs (Fluchter 1980).

Humpback whitefish can tolerate brackish water, and some populations may winter in the sea near river mouths (Morrow 1980, McPhail and Lindsey 1970). Studies in Kotzebue Sound, Hotham Inlet, and the Kobuk River delta found humpback whitefish in both fresh and brackish waters (Alt 1979b). Small rearing whitefish from one to three years old were captured only in brackish water. Immature and nonspawning fish were common in brackish water, and prespawning fish were captured mainly in fresh water (ibid.).

B. Water Velocity and Depth

Humpback whitefish in Great Slave Lake have been taken at depths from 10 to 100 m (Rawson 1951) and were most abundant near the bottom at all depths sampled in Squanga Lake, Yukon Territory (Lindsey 1963). Overwintering fish in the Sagavanirktok River were taken under the ice in water .5 m deep (Bendock 1977).

Spawning usually occurs in shallow water. Alt (1979a, 1983) reported whitefish spawning in a shallow riffle of the Yukon River, in water from 0.5 to 2.5 m deep in the Chatanika River, and in water from 1.5 to 3.0 m deep in the Innoko River. Current speed was 2 to 4 mph (approximately 50-100 m/sec) in spawning areas of the Innoko River (Alt 1983).

C. Water Temperature

Little information is available on the temperature tolerances of humpback whitefish. Humpback whitefish spawn in water temperatures ranging from 0 to 3°C in the Innoko, Kobuk, and Chatanika rivers (Alt 1979a, 1983).

For Coregonus lavaretus pidschian, a closely related form in Siberia, the main factor determining the growth rate of fingerlings is temperature (Protopopov 1982). The higher the temperatures rise during spring and summer, the larger the size of the young. Their length and weight during the first year are closely correlated with water temperature. In European whitefish species, the larvae were shown to be relatively insensitive to temperature (Fluchter 1980). However, temperatures ranging from 2 to 26°C were needed in order for production of the necessary

zooplankton species to provide sufficient food for the whitefish larvae (ibid.).

D. Substrate and Cover Requirements

Substrate requirements of humpback whitefish have not been noted, except for spawning. Whitefish spawn over a gravel bottom in the Chatanika River (Alt 1979a) and over small- and medium-size gravel in the Innoko River (Alt 1983). Humpback whitefish were captured in the lower Yukon River over a gravel bottom (Alt 1980).

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

Young humpback whitefish feed mainly on zooplankton, but adults feed primarily on benthic organisms such as mollusks, crustaceans, and chironomid larvae (Nikolskii 1961). In Alaska, snails and clams usually predominate in the diet of adult humpback whitefish. In the Innoko River, a tributary of the lower Yukon River, caddis flies and snails were found most often in whitefish stomachs, but beetles, clams, diptera larvae, and cladocerans were also eaten (Alt 1983). In the Andreafsky River, another tributary of the lower Yukon River, snails were eaten by whitefish (Alt 1981), and in tributaries of the lower Kuskokwim River, whitefish fed on snails, clams, and diptera larvae (Alt 1977).

In brackish water of Kotzebue Sound and Hotham Inlet, whitefish also fed primarily on snails, clams, and insects, but herring eggs on kelp and ninespine sticklebacks were seasonally important foods (Alt 1979b). In lakes on the south slope of the Brooks Range, snails and clams were eaten by whitefish (Roguski and Spetz 1968). In lakes of the Sheenjek River drainage, a tributary of the Porcupine River, whitefish fed on snails, clams, amphipods, corixids, chironomid larvae, and cladocerans (Craig and Wells 1975).

The feeding habits of humpback whitefish in a lake in northern Sweden were found to vary seasonally, annually, and with the size of the fish (Nilsson 1958). Whitefish switch prey types in response to seasonal and annual fluctuations in the abundance and availability of prey species.

B. Types of Feeding Areas Used

Coregonus lavaretus pidschian, the Siberian humpback whitefish, feeds primarily in shallow areas where benthic organisms are abundant (Kirillov 1982). Alaskan humpback whitefish may feed mainly during the summer in rivers such as the Andreafsky and Innoko (Alt 1981, 1983). Stomachs of whitefish migrating up the Innoko River in May were empty, as were the stomachs of whitefish near spawning grounds in September and October. Thus, the feeding period for these fish lasts about three months during the summer and may occur during the winter (Alt 1983).

C. Factors Limiting Availability of Food

Larval whitefish have specific food requirements, and growth is delayed if the required food species are not present. Adult

whitefish can select from a wider range of food species and can switch prey types seasonally and annually.

D. Feeding Behavior

Whitefish feed mainly on benthic organisms, but the species eaten varies in different rivers (Nikolskii 1961). Craig and Wells (1975) also note that whitefish feed on a variety of both benthic and planktonic species, indicating that the fish can adjust to changing availability of prey items. Whitefish feed primarily on a variety of benthic forms, and bottom feeding is evident from detritus found in stomachs of whitefish from the lower Kuskokwim River (Alt 1977). Siberian whitefish, Coregonus lavaretus pidschian, switch from benthic feeding in summer to preying on fish during winter (Kirillov 1982).

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Spawning of the Siberian humpback whitefish, Coregonus lavaretus pidschian, takes place on gravel at a water temperature below 4°C (Nikolskii 1961). Great Slave Lake humpback whitefish spawn over rocky reefs in lakes or the shallows of rivers (McPhail and Lindsey 1970).

Alt (1979a) reports that Alaskan humpback whitefish spawn in shallow riffles of the main Yukon River and in swift, shallow water over a gravel bottom in the Chatanika River. Water temperatures in these spawning areas ranged from 0 to 3°C. In the main Innoko River, Alt (1983) found spent and ripe humpback whitefish in areas with a gravel bottom, current speed of 3 to 4 mph, and a water temperature near 0°C with shore ice forming. Baxter (pers. comm.) captured ripe humpback whitefish in the main Kuskokwim River over sand substrate when the river was iced over, the water temperature was 0°C, and there was a slight downstream current.

B. Reproductive Seasonality

Spawning of whitefish in the Coregonus clupeaformis complex occurs from late summer to November or December (McPhail and Lindsey 1970). In Alaska, humpback whitefish usually spawn in October (Morrow 1980). The spawning period extends from late September through early October in the Chatanika (Alt 1979a) and Innoko rivers (Alt 1983) and from September through October in the Colville River (Bendock 1979). Ripe humpback whitefish have been found in the main Kuskokwim River near Bethel in early November (Baxter, pers. comm.).

C. Reproductive Behavior

Spawning behavior of humpback whitefish has not been described; however, Morrow (1980) notes that it may be similar to that of Alaska whitefish, Coregonus nelsoni. Alaska whitefish spawn actively both at night and in the daytime (ibid.). The females begin to swim vertically and are joined by one or two males. Eggs and milt are extruded as the fish approach the surface of the water (ibid.).

D. Age at Sexual Maturity

Humpback whitefish in Alaska generally reach sexual maturity by ages 4 to 7 (Alt 1979a, 1977; Kramer 1975). In some areas, however, whitefish grow more slowly. Humpback whitefish mature at age 8 in the Colville River (Alt and Kogl 1973) and in the Kotzebue Sound and Hotham Inlet area (Alt 1979b). In lakes of the Sheenjek River drainage, a tributary of the Porcupine River, whitefish mature at ages 9 to 15 (Craig and Wells 1975). Alt (1979a) notes that whitefish populations in Interior Alaska streams appear to be faster-growing than fish of coastal and arctic streams, probably because of the longer growing season of interior waters. However, genetic factors or low food availability could also reduce the growth rate.

E. Frequency of Breeding

Alt (1977, 1983) found that consecutive spawning is most common for humpback whitefish in the lower Kuskokwim system and the Innoko River, a tributary of the lower Yukon River. In Lake Minchumina, Kramer (1975) found it difficult to determine the age of maturity of humpback whitefish because of the presence of nonconsecutive spawners. McPhail and Lindsey (1970) suspect that in some northern lakes whitefish of the Coregonus clupeaformis complex spawn every other year.

F. Fecundity

Fecundity of humpback whitefish in Alaska has not been studied. Fecundity of the Siberian whitefish, Coregonus lavaretus pidschian, varies from one population to another and ranges from 8,000 to 50,000 eggs per female (Nikolskii 1961). The eggs measure about .12 cm in diameter (ibid.).

G. Incubation Period/Emergence

Little is known about the early stages of humpback whitefish in Alaska. Morrow (1980) assumes that the young hatch in late winter and spring, move downstream, and return as mature adults. Alt (1979b) found that the estuarine area of Kotzebue Sound was an important feeding and rearing area for humpback whitefish. Laboratory experiments with eggs of European whitefish species showed that water as cold as 1°C delayed hatching by eight weeks (Fluchter 1980). This delay in hatching allowed the release of whitefish larvae when the zooplankton density was higher, coordinating the larval release with their food supply.

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

Humpback whitefish migrate upstream to feeding areas in the early summer and move further upstream to spawning grounds in the fall (Alt 1979a). Some humpback whitefish are anadromous, but it is not known how far the wintering fish move from river mouths. They have been taken in the Beaufort Sea several miles offshore of the Colville and Sagavanirktok rivers, as well as in Kotzebue Sound, off the coast of Nome, and around the mouths of the Yukon and Kuskokwim rivers (Morrow 1980, Bendock 1977, Alt 1979b).

In the Kuskokwim River system, the fish move from the main river into tributaries, such as the Aniak River, in late May for summer feeding (Alt 1977). Catches in August indicate movements either back into the Kuskokwim River or further up the tributaries into feeding or spawning areas. Tagging studies by Baxter (n.d.) indicate that humpback whitefish may travel over 600 km up the Kuskokwim River to spawning grounds.

In the Innoko River, a tributary of the lower Yukon River, whitefish move from the Yukon into the lower Innoko during late May and early June (Alt 1983). Humpback whitefish were observed feeding in the slow-moving water of the main Innoko River in mid June (ibid.). After summer feeding, whitefish continue up the Innoko to spawning grounds and are abundant in the upper river and tributaries in September. Movement downstream to overwintering areas occurs in October and November (ibid.).

Migration patterns of humpback whitefish in the lower and middle Yukon River are not fully known, but both river resident and anadromous populations probably exist (Alt 1980). The anadromous populations overwinter in the lower Yukon River. After breakup there is an upstream migration in the main Yukon and tributary rivers. By late June, most whitefish have moved upstream in the tributaries to summer feeding areas in lakes and sloughs (ibid.).

Humpback whitefish overwinter in Hotham Inlet and the lower Kobuk River and feed upstream in lakes and sloughs. The prespawning fish continue moving slowly upstream in the Kobuk River during the summer. Whitefish spawn in the upper Kobuk river in October and then migrate rapidly back to the lower Kobuk River (Alt 1979a).

In the Colville River, whitefish migrate upstream past Umiat in late July and early August, possibly spawning in the upper Colville River in the fall (Alt and Kogl 1973). Adult humpback whitefish were sampled along beaches between the Sagavanirktok and Colville rivers from July through August (Bendock 1977), possibly before migrating upstream in these rivers.

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

Egg, larval, and juvenile stages of humpback whitefish are dependent on physical factors such as water temperature and dissolved oxygen for growth and development. Laboratory feeding experiments of European whitefish species have shown that there are two main reasons for the high natural mortality rate of whitefish larvae: high sensitivity to even a short-term lack of food and specific food requirements (Fluchter 1980). Whitefish larvae can feed only on juvenile stages of certain zooplanktonic crustaceans (ibid.).

Predation in all the life history stages of humpback whitefish probably influences population numbers. A prespawning female humpback whitefish was found in a pike stomach in the Pilgrim River on the Seward Peninsula (Alt 1980). Unidentifiable whitefish have been found in pike stomachs from the Minto flats

area (northwest of Fairbanks) and the Andreafsky and Innoko rivers (lower Yukon drainage) (Alt 1968, 1981, 1983; Cheney 1971, 1972). Whitefish have also been found in burbot stomachs from the Glennallen area (Williams 1970).

Competition for food with other fish species, especially other whitefish, may also regulate populations of humpback whitefish. In a lake in northern Sweden, the growth rate and prey species consumed by humpback whitefish changed in areas where populations of other whitefish species occurred (Nilsson 1958).

B. Human-related

Water quality is important to the egg and larval stages of humpback whitefish. Whitefish are dependent on physical factors such as dissolved oxygen and temperature for growth and development (Fluchter 1980, Protopopov 1982). Any disturbances that degrade whitefish spawning, rearing, or feeding habitats or that degrade water quality may adversely affect population levels. A summary of possible impacts from human-related activities includes the following:

- Change in water temperature
- Addition of physical barriers to migration
- Change in levels of dissolved oxygen
- Removal or addition of substrate materials in spawning or feeding areas
- Change in levels of biocides or toxic chemicals

(The Impacts of Land and Water Use volume of this series contains additional information regarding impacts.)

VIII. LEGAL STATUS

The Alaska Board of Fisheries develops regulations governing the harvest of humpback whitefish throughout its freshwater and coastal marine range. Because only localized harvesting by commercial, subsistence, and sport fishermen occurs, no statewide management plan has been formulated.

IX. LIMITATIONS OF INFORMATION

Little information is available on pH, turbidity, or dissolved oxygen tolerances of the different life history stages of humpback whitefish. Their spawning behavior and the physical features they require in their spawning grounds have not been studied. The fecundity of humpback whitefish in Alaska is unknown. Little is known also about the incubation period and emergence of Alaskan humpback whitefish. The seaward extent of whitefish migrations is unknown, and the extent of upstream migrations in Alaska has not been extensively studied. The degree to which factors such as competition and predation regulate whitefish populations is also unknown.

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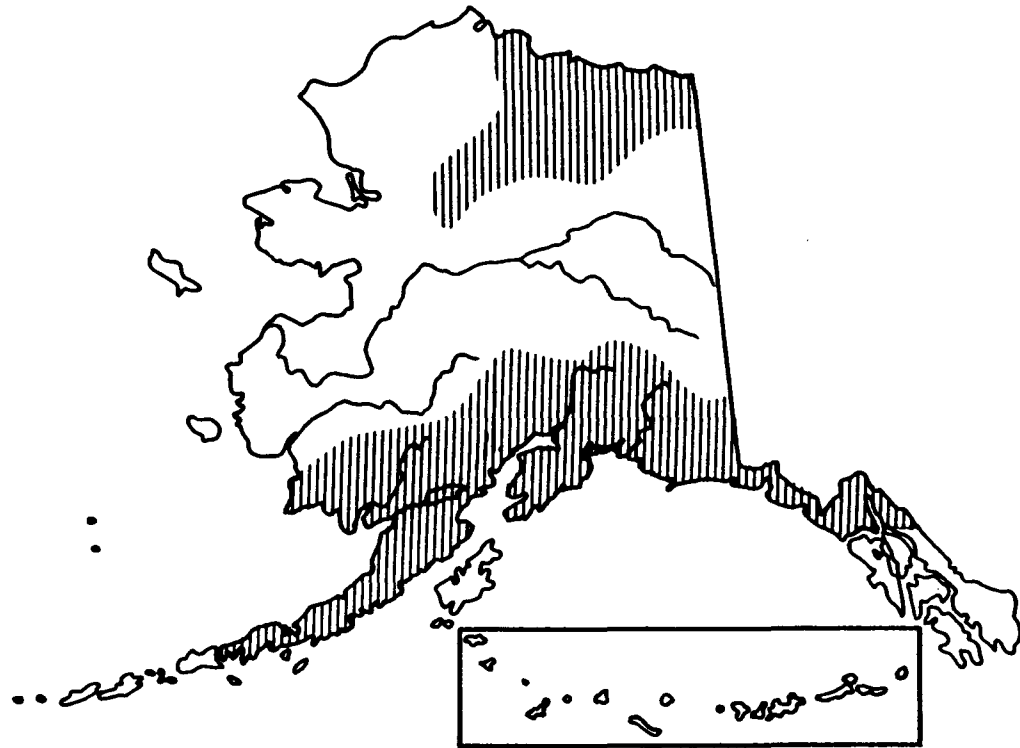
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Lake Trout Life History and Habitat Requirements
Southcentral, Arctic, Western, and Interior Regions



Map 1. Range of lake trout (Morrow 1980, ADF&G 1978b, Bendock and Burr 1985, Pearse 1978)

I. NAME

- A. Common Name: Lake trout
- B. Scientific Name: Salvelinus namaycush
- C. Native Names: See appendix A.

II. RANGE

A. Statewide

Lake trout are distributed throughout highland lakes of the Brooks Range, the arctic coastal plain, Bristol Bay, and the Kenai, upper Susitna, and Copper river drainages (ADF&G 1978b). They are generally absent from lakes of the North Slope lowlands and the lower Yukon-Kuskokwim river basins (Morrow 1980, McPhail and Lindsey 1970) and are not found in the Wood River system, streams

on the south side of the Alaska Peninsula, or in northern Alaska Peninsula systems south of Mother Goose Lake (ADF&G 1978b).

B. Regional Distribution Maps

To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for each region. In this series, lake trout distribution information is included on the series of 1:250,000-scale maps titled Distribution of Selected Freshwater Fish. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of selected fish and wildlife species has been prepared and may be found in the Atlas that accompanies each regional guide.

C. Regional Distribution Summary

1. Southcentral. Lake trout are most abundant in the upper Susitna and Copper river drainages, occurring in most large area lakes and some smaller ones (e.g., Lake Louise, Paxson, Crosswind, Fielding, and Susitna lakes and Klutina Lake and River). They are found in several lakes on the Kenai Peninsula (e.g., Tusteumena, Skilak, Hidden, Swan, Juneau, and Kenai lakes and Trail Lake and River). They also occur in a few lakes on the west side of Cook Inlet (e.g., Chelatna, Chakachamna, and Beluga lakes) and in the Matanuska Valley (e.g., Byers and Lucy lakes). In the Cordova area, Little Tokun Lake, near Bering Glacier, contains the only known population (ADF&G 1976, 1978a, 1978b; Redick 1967). (For more detailed narrative information on lake trout distribution in the Southcentral Region, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)
2. Arctic. Lake trout are widely distributed across the North Slope, primarily inhabiting lakes, but also occurring in streams within the Colville, Sagavanirktok, and Canning river drainages (Bendock 1982). They have been found in most of the glacial lakes that lie within the Brooks Range and in the southern foothills adjacent to the mountain front (McCart et al. 1972). Waters within the foothills region and the western margin of the coastal plain have few lake trout, but the species is well represented in the central coastal plain, which marks the northernmost distribution of this species in Alaska (Bendock 1982). Lake trout are present in the Kobuk drainage as far west as Selby and Narvak lakes (ADF&G 1978b). (For a more detailed narrative on lake trout distribution in the Arctic Region, see volume 2 of the Alaska Habitat Management Guide for the Arctic Region.)
3. Western and Interior. Lake trout are distributed throughout many lakes and a number of rivers in the Yukon and Kuskokwim drainages (ibid.). They are commonly associated with deep, oligotrophic lakes located in the Brooks, Kuskokwim, and Alaska mountain ranges (ibid.). Lake trout are generally not found at lower elevations of the Yukon or Kuskokwim basins

(Redick 1967, Morrow 1980). (For more detailed narrative information on lake trout distribution in the Western and Interior regions, see volume 2 of the Alaska Habitat Management Guide for the Western and Interior regions.)

III. PHYSICAL HABITAT REQUIREMENTS

A. Water Quality

1. Temperature. Temperature is probably the most important single factor determining the movements of lake trout (Martin and Olver 1980). In most cases, lake trout inhabit waters with a temperature range of about 6 to 13°C (ibid.) in the shallows during winter and in deeper waters below the thermocline during summer. The species has been found in temperatures as low as -0.8°C in marine situations in arctic Canada (Boulva and Simard 1968) and up to 18°C in Ontario lakes and Cayuga Lake in New York State (Martin 1952, Straight 1969, Galligan 1962). Reported upper lethal temperatures have ranged from 17.8°C (Seguin 1957) to 23.5°C (Gibson and Fry 1954).
2. The pH factor. Little information was found in the available literature on the influence of pH levels on the survival and development of lake trout in Alaska. Waters of the western North Slope inhabited by lake trout, among many other species of fish, are characteristically soft, having low values for alkalinity and hardness and a neutral pH (Bendock 1979). Experimental studies conducted in Whitepine Lake near Sudbury, Canada, indicate that under natural conditions most lake trout sac fry could tolerate short periods of substantial pH depression (five days at pH less than 5.0), though they show obvious signs of stress under these conditions (Gunn and Keller 1984).
3. Dissolved oxygen (D.O.). Lake trout eggs and fry have a low tolerance for reduced oxygen concentrations. From the results of laboratory experiments, Carlson and Siefert (1974) concluded that, for good larval survival and development, the oxygen concentrations for eggs and fry should be no less than 50% saturation at 7°C. At 10°C the effect of lowered oxygen concentrations was more pronounced. Martin and Olver (1976) concluded that 4 mg/l is about the minimal acceptable level of oxygen for adult lake trout. Studies examining the eutrophication (organic enrichment) of the Great Lakes concluded that, especially during periods of thermal stratification, oxidation of organic matter can cause widespread hypolimnetic oxygen depletion, which is probably detrimental to this species (Leach and Nepsky 1976).
4. Turbidity. Turbidity and resultant sedimentation from either runoff material or eutrophication could degrade inshore spawning areas used by lake trout (ibid.). Rayner (1941) suggested that mud brought down to Cayuga Lake in New York by a flood may have had a deleterious effect on lake trout eggs.

Webster et al. (1959) noted that a mantle of silt over the deeper spawning areas in Cayuga Lake has resulted in the complete absence of natural reproduction in that lake.

5. Salinity. Boulva and Simard (1968) found lake trout to be the least tolerant of salt water of all the chars and reported that the upper limit of salinity tolerance appears to be around 11 to 13 parts per thousand (ppt), though they are common in water with salinity values between 6 and 9 ppt. Rounsefell (1958) noted that lake trout have been caught at the head of tidewater in the Naknek River.

B. Water Quantity

Lake trout in temperate areas require lakes deep enough to thermally stratify during periods of hot, calm weather. They prefer the cooler water below the thermocline. Rawson (1961) found that lake trout required depths of at least 15 and usually 20 m in Lac La Ronge, Saskatchewan (55 north latitude), during the months of July and August. Lake trout are found in Teshekpuk Lake on the North Slope west of Harrison Bay, which has a maximum depth of 15 m (Bendock 1979).

C. Substrate

Spawning typically occurs over a clean, rocky, or rubble bottom (Morrow 1980, ADF&G 1978b, Rawson 1961). More details of spawning substrate requirements are given in the reproductive habitat section of this narrative.

D. Cover Requirements

Protective cover is provided for adults by deep pools and swift riffles in rivers and sometimes by undercut banks (Alt 1977). Rocky bottom areas in lakes provide cover from predation for juveniles. In far northern waters, juveniles may spend several years hiding in the rubble of a lake bottom (Machniak 1975, Miller and Kennedy 1948).

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

Preferred foods vary with the age and size of the fish and in response to availability. Juvenile lake trout feed on small crustaceans, particularly Mysis relicta, when present, plankton, detritus, Diptera (true fly) larvae, and some small fish (Morrow 1980, ADF&G 1978b). As lake trout mature, they generally begin to eat more fish and fewer invertebrates; however, some feed on plankton throughout their lives (Martin 1966). Lake trout populations in systems where forage fish are not available do not grow as large as those that feed on fish (Martin 1966, Sautner and Stratton 1984). Furniss (1974) examined the stomach contents of lake trout from four mountain lakes on the north side of the Brooks Range in July. Mosquito larvae (Diptera: Culicidae), caddisfly (Trichoptera) pupae, detritus, and snails were frequently consumed food items. The lake trout stomachs also contained remains of sculpin (Cottidae), round whitefish (Prosopium cylindraceum), lake trout, and arctic char (Salvelinus

alpinus). Bendock (1982) found that lake trout from eight coastal plain lakes consumed ninespine stickleback (Pungitius pungitius), other fish, including least cisco (Coregonus sardinella), slimy sculpin (Cottus cognatus), and lake trout, and snails and clams. Lake trout from Old John Lake near Arctic Village consumed snails, slimy sculpin, juvenile lake trout, pike (Esox lucius), and burbot (Lota lota). Surface insects and benthic invertebrates other than snails were also found in the stomachs, although these organisms were not commonly eaten (Craig and Wells 1975). Snails (Lymnaea sp.) were the major food item in lake trout over 400 mm in length from Itkillik Lake in the Colville River drainage (McCart et al. 1972). Hablett (1979) reported that lake trout captured during summer in the western arctic had consumed least cisco, snails, aerial insects, round whitefish, slimy sculpin, and voles.

B. Types of Feeding Areas Used

Juvenile lake trout in northern waters may spend several years near the bottom, seeking protection from predators and feeding. In the spring, older lake trout feed inshore and near the surface. As the water temperatures in the lakes rise, lake trout move deeper and finally reside beneath the thermocline (Martin and Olver 1980). Lake trout were generally more abundant near inlet and outlet streams of lakes studied in the lower Kuskokwim River and Kuskokwim Bay area in July 1978, because of cooler water temperatures and greater food abundance (Alt 1977).

C. Factors Limiting Availability of Food

Nutrient loading, or eutrophication, of a system leads to changes in the quality and species types of phytoplankton, zooplankton, and benthic organisms available to lake trout (Leach and Nepsky 1976). Excessive sedimentation may inhibit production of aquatic invertebrate fauna (Hall and McKay 1983).

During periods of thermal stratification, lake trout are restricted to food items available below the thermal barrier (Scott and Crossman 1973, Eck and Wells 1983).

As lake trout are top predators in most situations and also found in deeper waters, food competition is generally not too extensive (Martin and Olver 1980). Instances have been recorded, however, of competition between lake trout and burbot, northern pike, and longnose suckers (Catostomus catostomus) (ibid.). Alevins or juveniles may have to compete with the young or adults of other species, particularly for invertebrate foods (ibid.). Competition may also be more significant in northern lakes where lake trout may not enter deep water away from other species during the summer.

D. Feeding Behavior

Lake trout are opportunistic feeders able to take advantage of an abundance of almost any food. They are particularly voracious in the spring (Scott and Crossman 1973). Studies of lake trout food habits from northern lakes have shown, however, that at any given time a large percentage of lake trout in these lakes may have empty stomachs. Fifty-one percent of lake trout sampled during

the summer from the western North Slope by Bendock (1979) had empty stomachs. Among lake trout sampled from arctic coastal plain lakes during the summer, 38% had empty stomachs, and Craig and Wells (1975) found that 35% of lake trout taken from Old John Lake near Arctic Village had empty stomachs. Furniss (1974), however, found that lake trout taken from Chandler, Itkillik, Elusive, and Shainin lakes on the north side of the Brooks Range in July had only 4.0 to 7.1% empty stomachs. The feeding rate of adult lake trout decreases immediately preceding and during spawning; however, lake trout do continue to feed to some extent during the spawning season (Machniak 1975).

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Most lake trout are lake spawners, but river-spawning populations are known to exist. Spawning typically occurs on reefs or shoal areas at depths of less than 12 m (40 ft) but sometimes in depths of less than a meter to as deep as 61 m (200 ft) (Morrow 1980, ADF&G 1978b). Redick (1967) reported that all spawning in Susitna Lake appeared to occur between depths of from 2 to 5 m. Lake trout spawning grounds are generally restricted to areas with clean gravel or rubble substrate free of sand and mud (Machniak 1975). Eggs are broadcast over the bottom and settle into cracks and crevices between rocks. Areas that tend to accumulate heavy bottom sediments are thus rendered useless for lake trout spawning (Redick 1967). The presence of rubble of such a size as to permit the eggs to drop between and receive protection from predators and light is essential to egg and fry survival (Paterson 1968). It is also essential that water percolate among the rubble to provide adequate aeration for the eggs and freedom from silt (ibid.). Though lake trout have been known to spawn over areas with smooth and soft substrate, egg and fry survival in these cases is not good (Hacker 1957, Dorr et al. 1981). The location of suitable areas of bottom in a lake is primarily determined by currents or winds that keep spawning areas clear of mud and debris (Redick 1967, Machniak 1975). Spawning reefs and shoals frequently face the prevailing winds and are close to deep water (Martin and Olver 1980).

B. Reproductive Seasonality

Generally, lake trout spawn in late summer and early autumn, with many factors, such as cyclic weather changes, physiological characteristics of certain populations or races, and physical and biological peculiarities of individual lakes playing roles resulting in variations in spawning times in different areas (Machniak 1975). Spawning occurs as early as late August and early September in northern Alaska (McCart et al. 1972) to as late as November in southern Canada (Scott and Crossman 1973). Temperature plays an important part in the initiation and length of the spawning period (Martin and Olver 1980). Spawning begins with falling water temperatures, and in many of the more temperate

lakes, at about 10°C (Martin and Olver 1980, Royce 1951). Wind is also important in triggering spawning activity (Martin and Olver 1980). Heavy onshore winds of several days duration may induce spawning (ibid.). Lake trout from Paxson and Summit lakes probably spawn from mid to late September (VanWhye and Peck 1968). Lake trout in Itkillik Lake spawn in early September (McCart et al. 1972).

C. Reproductive Behavior

Evidence indicates that in many populations lake trout, having once spawned at a particular ground, will return to the same spot to spawn in subsequent years (Machniak 1975, Martin and Olver 1980).

Several authors have reported that male lake trout clean the spawning area of mud and silt by brushing it with their body or tail fin or by digging with their jaws (Martin 1957, Royce 1951, DeRoche and Bond 1957). Martin and Olver (1980), however, concluded that in most situations wave action and currents effectively keep the spawning area clean.

Lake trout do not dig a redd. One or two males may spawn with one female or a group of males and females may spawn in mass, broadcasting eggs and sperm over the bottom to settle into crevices between rocks. The spawning act may be repeated many times before a female has voided her eggs (Morrow 1980, Scott and Crossman 1973). Lake trout reproductive studies conducted in New York and Ontario found that spawning activity occurred only at night. During the day, the fish were dispersed but returned to the spawning beds in great numbers, with peak activity occurring between dusk and 9 or 10 P.M. (Royce 1951, Martin 1957). No information on circadian spawning activity in Alaskan waters was found in the available literature.

D. Age at Sexual Maturity

Lake trout are slow-growing and late-maturing. Sexual maturity is more closely correlated with size than with age; however, it is usually attained by ages 5 to 7 but may not be achieved until as late as age 13 (Morrow 1980, ADF&G 1978b, Scott and Crossman 1973). In the lower Kuskokwim River and Kuskokwim Bay area, age at first maturity is generally 9 to 10, and most fish are mature by age 12 (Alt 1977). Males usually mature a year earlier than females (Morrow 1980). In Paxson Lake in Interior Alaska, lake trout mature at ages 7 to 8. In Summit Lake, a less productive lake close to Paxson Lake, lake trout mature at ages 8 to 10 (VanWhye and Peck 1968). Lake trout in the arctic area mature at an older age than those from more southern populations. Lake trout in Old John Lake near Arctic Village reach sexual maturity between 10 and 15 years of age (Craig and Wells 1975). Male lake trout in Itkillik and Campsite lakes on the Alaskan North Slope may mature as early as age 11 (McCart et al. 1972). The youngest female with maturing eggs was age 13 in Campsite Lakes and age 14 in Itkillik Lake (ibid.). Lake trout from North Slope coastal plain lakes, including Teshekpuk Lake, mature at age 11 (Bendock

1982), and all lake trout over age 10 from an unnamed lake at the headwaters of the Kuparuk River were mature (Alt 1976). Longevity of lake trout is variable, with the oldest on record estimated to be 42+ from Chandler Lake, Alaska (Furniss 1974). Most individuals caught in the lower Kuskokwim River/Kuskokwim Bay area are 9 to 11 years old (Alt 1977). Alt (1977) also reports that the growth of lake trout from the Kuskokwim study area is generally slower than that reported from other waters in Interior Alaska and Great Slave Lake in Canada but more rapid than growth of lake trout in lakes of the Brooks Range, Alaska, and Great Bear Lake, Northwest Territories. Lake trout from the Kuskokwim area of Alaska generally do not live as long as slower-growing populations in northern Alaska and Great Bear Lake (Alt 1977).

E. Frequency of Breeding

Spawning frequency may vary from annually to about once in three years (Morrow 1980, ADF&G 1978b, Rawson 1961). Lakes in which lake trout spawn less than once in every year are typically northern, oligotrophic lakes (Machniak 1975). Lake trout in Great Bear Lake spawn about once in every three years (Miller and Kennedy 1948). Kogl (1971) found three nonspawners in a sample of 11 lake trout from the Colville River, indicating nonconsecutive spawning in this population. Furniss (1974) also found nonconsecutive spawners in lake trout from Chandler, Shainin, and Itkillik lakes.

F. Fecundity

Fecundity varies with the size and condition of the female and may range from a few hundred up to 18,000 eggs (Morrow 1980, ADF&G 1978b, Scott and Crossman 1973). Fecundity of eight lake trout from Chandler Lake ranged from 1,088 eggs for a 420-mm-long female to 6,371 for a 748-mm female (Furniss 1974).

G. Incubation Period and Time of Emergence

Incubation period and time of hatching varies considerably throughout the lake trout range (Machniak 1975, Martin and Olver 1980). Paterson (1968) suggested that the critical period determining time of emergence is that between egg disposition and the time that stream temperatures drop to their minimum. During this time, higher temperatures may accelerate incubation, causing the hatching period to be significantly shortened (ibid.). In most populations, hatching occurs in March or April (Machniak 1975), but in Great Bear Lake, Northwest Territories, it is delayed until June (Miller and Kennedy 1948). The alevins may remain near the spawning area in shallow water for one to two months after emergence if the water temperature does not exceed 15°C for an extended period (Peck 1982). In far northern waters, young lake trout may remain among the boulders near shore for several years. Miller and Kennedy (1948) noted that fry and one-to-three-year-old lake trout were found in shallow water of Great Bear Lake. This tendency of fry to inhabit warm shallow areas may be a local adaptation to stimulate growth and aid juvenile survival in this rigorous environment (Redick 1967).

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

Whole populations of lake trout do not undertake movements in definite directions; they are solitary wanderers that move freely throughout lakes between seasonal feeding areas and spawning grounds, limited in movement chiefly by the size of the body of water (Morrow 1980, Scott and Crossman 1973). Larger fish tend to travel greater distances (Morrow 1980).

Depth distribution and seasonal movements of lake trout are primarily related to changing water temperatures. Lake trout typically move into shallow water in the spring during ice breakup and remain there until the surface water warms to above 10°C. As surface waters approach 10°C, lake trout tend to move to cooler (deeper) waters, eventually congregating below the thermocline during the summer months, preferring temperatures between 4.4 and 10°C (Martin 1952, ADF&G 1978b, Rawson 1961, Scott and Crossman 1973).

In the fall, when cooling surface waters destroy the thermal stratification, lake trout return to the rocky shallows to spawn. There is evidence of homing to prior spawning grounds (Martin 1960, Rawson 1961). After spawning, lake trout disperse throughout the lake at various depths and remain dispersed throughout the winter months (Rawson 1961, Scott and Crossman 1973).

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

A low water table and cold winter temperatures could cause eggs deposited at lake margins to desiccate or to freeze. Lake trout eggs may be dislocated from spawning beds by winter storms and washed onto shore or to areas unsuitable for development (Dorr et al. 1981). Extensive bottom scouring by winter storms may also injure developing eggs (ibid.). High water temperatures (above 10°C) and resultant deep heating during the summer could be detrimental to lake trout.

Occasionally, lake trout become cannibalistic, eating their own eggs and young (Furniss 1974, Bendock 1982). Martin and Olver (1980) stated that cannibalism may be most common in arctic lakes where there is not a diversity of forage species. Small lake trout are also preyed upon by burbot and northern pike (Redick 1967). Round whitefish have been reported consuming eggs of river-spawning lake trout (Loftus 1958); burbot are reported to eat lake trout eggs (Anon. 1960); and suckers (Catostomidae) have been found to prey on lake trout eggs in many areas (Martin and Olver 1980).

B. Human-related

Disturbances that degrade lake trout spawning, rearing, or feeding habits or degrade water quality may adversely affect the population levels of lake trout that use the disturbed system (ADF&G and USFWS 1984). Martin and Olver (1980) stated that lake trout are extremely sensitive to exogenous, man-induced perturbations, and that it is essential that pristine conditions be maintained for the well-being of this species. Domestic and

industrial pollution, mining, agricultural and forestry practices, power development schemes, and shoreline development all may have a deleterious effect on lake trout and other salmonids found in North American oligotrophic lakes (Ryder and Johnson 1972). Lake trout are slow-growing and late-maturing fish and so are also very susceptible to overfishing (Martin and Oliver 1980).

In arctic areas, where many of the lakes and streams freeze to the bottom in winter months, overwintering habitat is limited, and lake trout populations become concentrated into small open-water areas. These overwintering areas are critical, and any disturbance in or near them would be very detrimental to arctic lake trout populations.

A summary of possible impacts from human-related activities includes the following:

- Alteration of preferred water temperatures, pH, dissolved oxygen, and chemical composition
- Alteration of preferred water velocity and depth
- Alteration of preferred lake and stream morphology
- Increase in suspended organic or mineral material
- Increase in sedimentation and reduction in permeability of substrate
- Reduction in food supply
- Reduction in protective cover
- Shock waves in aquatic environment
- Human harvest

(See the Impacts of Land and Water Use volume in this series for additional information on impacts.)

VIII. LEGAL STATUS

The Alaska Board of Fisheries develops regulations governing the sport harvest of fish in Alaska. Research and monitoring of lake trout populations is conducted by the Alaska Department of Fish and Game, Division of Sport Fish.

IX. LIMITATIONS OF INFORMATION

Most of the information available on lake trout has been collected in Canada and the Great Lakes region; very little life history information specific to Alaska has been collected. There are major gaps in our knowledge critical to the future management of lake trout and their habitat. Little information was found on the effects of environmental changes. A better understanding of early life history, population dynamics, and river-spawning populations is necessary.

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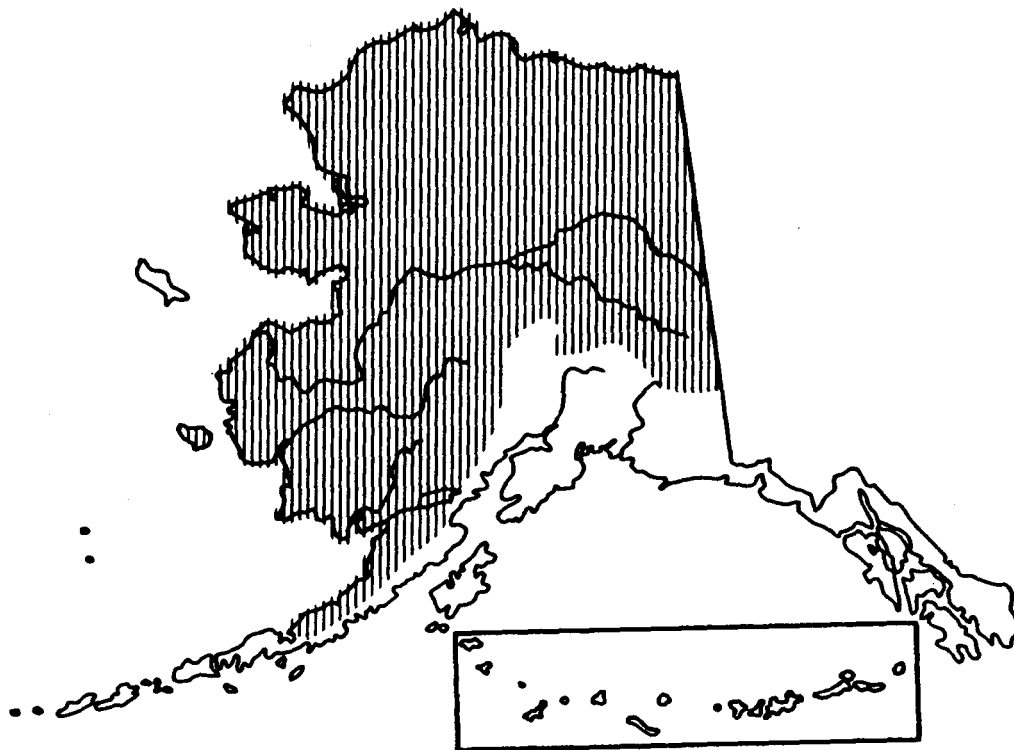
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Least Cisco Life History and Habitat Requirements
Arctic, Western, and Interior Regions



Map 1. Range of least cisco

I. NAME

- A. Common Names: Least cisco, lake herring
- B. Scientific Name: Coregonus sardinella Valenciennes
- C. Native Names: See appendix A.
- D. The least cisco is a member of the family Salmonidae, subfamily Coregoninae, the whitefishes. Whitefishes are common throughout the north, inhabiting both lakes and rivers, and some species exhibit anadromous characteristics. There are many species of whitefish and cisco recognized, but because of extensive intra-specific variation and interspecific similarities the taxonomic structure of this group of fishes has changed often. The least cisco Coregonus sardinella is known to occur in several forms with uncertain relationships and has been referred to as a "species complex" (McPhail and Lindsey 1970). Various distribution and

local population characteristics have contributed to changes in classification of least cisco in past years.

II. RANGE

A. Worldwide

Least cisco are found in northern Europe, Siberia, and western North America. The species occurs in coastal regions from Bristol Bay throughout Alaska and eastward along the arctic coast into Canada, at least to Bathurst Inlet. Least cisco are present on St. Lawrence Island in the Bering Sea and north to Victoria and Banks islands in the Arctic Ocean (McPhail and Lindsey 1970, Scott and Crossman 1973).

B. Statewide

The least cisco is a resident of many inland waters throughout Interior Alaska and is anadromous in streams and rivers draining into the Bering, Chukchi, and Beaufort seas (Bendock 1979). The species spawn and overwinter in the Colville and MacKenzie river deltas and migrate in the nearshore coastal waters of the Beaufort Sea during the open-water period. Apparently, the general limits to which they can migrate are east to Prudhoe Bay (for the Colville River population) and west to Herschel Island (for the MacKenzie River population) (Bendock 1979, Craig and Haldorson 1981, Mann 1974). Thus, the species are rarely found in the region between Prudhoe Bay and Herschel Island, and these two major populations are geographically isolated (Bendock 1979).

C. Regional Distribution Maps

To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for each region. Least cisco distribution information is included on the 1:250,000-scale maps titled Distribution of Selected Freshwater Fish. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of selected fish and wildlife species has been prepared and may be found in the Atlas that accompanies each regional guide.

D. Regional Distribution Summary

In the Arctic, Western, and Interior regions, least cisco are present in most streams and lakes north of the Alaska Range and in the nearshore zone of the marine coastal environment. Least cisco are present and abundant throughout the Colville, Kuskokwim, and Yukon river drainages (Morrow 1980). They ascend the Yukon River upstream at least as far as Circle (McPhail and Lindsey 1970). In the arctic, least cisco apparently do not penetrate very far inland (ibid.). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for either the Arctic or the Western and Interior regions.)

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

1. Water quality:

- a. Dissolved oxygen (DO) and pH. No information exists on the DO and pH requirements of least cisco. Craig and Haldorson (1981) reported an average DO level of 9.8 ml/l during the open-water period in 1977 in Simpson Lagoon, Beaufort Sea (range = 7.0 to 12.0 ml/l, n = 40). Least cisco were widely distributed and abundant in this area.
- b. Turbidity. Little information is available on the turbidity requirements of least cisco. Craig and Haldorson (1981) defined a narrow band of water immediately adjacent to the shoreline in the Beaufort Sea where wind-generated turbidity fluctuated widely from day to day (1-146 NTU, recorded 80 m from shore). This band of coastal water was inhabited throughout the summer by anadromous fishes, of which least cisco was one of the most abundant species.
- c. Salinity. Anadromous least cisco inhabit brackish waters throughout the summer, at which time they make extensive migrations along the coast (at least 100 mi distance). Craig and Haldorson (1981) measured salinities in Simpson Lagoon, Beaufort Sea, during the open-water period, in which anadromous least cisco are present. Salinities ranged from nearly fresh to saline. In late June and early July, melting ice and river-flooding caused low salinities (1-10 ppt) in the lagoon. Between mid July and September, brackish conditions existed (18-25 ppt). In fall, least cisco migrate back into freshwater rivers and lakes to spawn and over-winter. Presumably, their coastal environment becomes uninhabitable in winter because of thick nearshore ice and hypersaline conditions, which are common in winter. Alt (1971) reported a high abundance of least cisco in the Imuruk Basin-Grantly Harbor-Port Clarence (Norton Sound) area. Salinity values there ranged from 23 ppt in Grantly Harbor and 29 ppt in Port Clarence to 3.8 ppt in the upper Imuruk Basin (ibid.).

2. Water velocity and depth. Least cisco inhabit a wide variety of habitats: shallow, slow-moving lakes and sloughs; large, deep, fast-moving rivers; and shallow tributary streams. Migratory forms of least cisco spend the winter in freshwater rivers and river deltas and the summer and early fall in coastal regions immediately adjacent to the shoreline. On the Beaufort Sea coast, Craig (1984) found least cisco abundant in the nearshore brackish-water zone. The depth of this zone fluctuated widely with freshwater input, nearshore currents, prevailing winds, and topographic features (ibid.).

In the Chatanika River, near Fairbanks, least cisco spawning sites have been defined. Water depths range between 1.3 and 2.6 m at these sites, and the average velocity is about .5 m/s (Kepler 1973). Water depth and stream velocity appeared to be important for spawning, because males and females move toward the surface, perpendicular to the current, while the eggs are released and fertilized (ibid.). In connection with building roads and culverts along the gas pipeline route, Jones et al. (1974) studied the critical velocities of 17 species of fish in the Mackenzie River. They determined that flow rates in culverts (100 m long) should be kept below .3 to .4 m/s to allow successful passage of the majority of mature individuals of migratory species.

3. Water temperature. Least cisco are apparently tolerant of a wide range of temperatures. Alt (1971) reported July temperatures of 12 to 13°C in shallow, slow-moving waters of the Imuruk Basin area. Kepler (1973) reported surface temperatures of 0 to 3°C during the spawning period (late September) in the Chatanika River. Craig and Haldorson (1981) reported temperatures of 0 to 6°C during the spring and fall and 7 to 10°C during the summer in Simpson Lagoon on the arctic coast. Craig and Griffiths (1981) attributed the nearshore distribution of anadromous fishes to an association with the band of relatively warm and brackish water that flows along the Beaufort Sea coast. Walters (1955) suggested that the habits of feeding during summer in the sea and moving up rivers and into lakes for the winter might be an arctic adaptation to escape the low winter temperatures (below 0°C) in sea water yet also take advantage of higher food abundance in coastal waters during the short arctic summer.
4. Substrate. Little is known about substrate requirements for least cisco. Adults are known to spawn over sand and gravel bottoms in shallow areas of lakes and streams. The eggs are simply scattered over the bottom (McPhail and Lindsey 1970). Alt (pers. comm.) found them spawning over a gravel bottom in the upper Innoko River in 4 to 8 ft of water.

IV. NUTRITIONAL REQUIREMENTS

A. Foods Species Used

Least cisco are generalists in their food habits. They consume a wide variety of the secondary producers (invertebrates) in both marine and freshwater environments. Composition of food items is largely dependent upon the specific location at which least cisco species are sampled. Primary food items recorded are various species of copepods, cladocerans, mysids, amphipods, and isopods; some fish (fourhorn sculpin and nine-spine stickleback); and some surface-dwelling insects (Plecoptera nymphs and adults, hemiptera adults) (Mann and McCart 1980, Bendock 1979, Griffiths et al. 1975, Scott and Crossman 1973, Morrow 1980, Mann 1974, Russell 1980).

- B. Types of Feeding Areas Used
Least cisco are primarily planktonic feeders, utilizing the mid-water column in lakes, sloughs, and coastal marine waters. Populations of least cisco that inhabit rivers apparently feed also on aquatic and terrestrial insects (Scott and Crossman 1973).
- C. Factors Limiting Availability of Food
Availability of food is undoubtedly related to seasonal abundance in marine coastal regions in the arctic and in coldwater rivers and lakes throughout the Arctic, Western, and Interior regions in Alaska. In arctic habitats, there is no productivity throughout most of the year, and an outburst of exceedingly high productivity occurs in the short summer season (Russell-Hunter 1970). Similarly, productivity in winter in the inland freshwater environments is much reduced because of cold temperatures, ice-cover, and reduced light availability. However, least cisco captured in winter have been known to be feeding (Mann 1975).

V. REPRODUCTIVE CHARACTERISTICS

- A. Reproductive Habitat
Least cisco spawn in freshwater rivers, river deltas, tributary streams, and lakes. Adults spawn over sand and gravel bottoms in shallow areas (McPhail and Lindsey 1970).
- B. Reproductive Seasonality
Least cisco spawn in the fall, as is characteristic of many coregonids. Some variation in spawning time occurs between geographically isolated populations, but spawning typically takes place in late September and October (Scott and Crossman 1973, McPhail and Lindsey 1970, Morrow 1980, Kepler 1973, Mann and McCart 1980). In the Chatanika River near Fairbanks, the peak spawning period was the last week of September (Kepler 1973).
- C. Reproductive Behavior
During the upstream spawning migration, least cisco generally move at night and rest in quiet pools during daylight hours. Kepler (1973) caught only small groups of least cisco in gill nets during overnight sampling, indicating that they migrate in small groups. Observations of least cisco in the Chatanika River revealed that least cisco spawn at night, with most spawning activity occurring from 10 P.M. to midnight (Kepler 1973). Alt (1983), however, observed least cisco actively spawning at 1 P.M. in the Innoko River, a tributary of the Yukon River.
During spawning, a female swims almost vertically toward the surface, with her ventral side upstream. As many as five males may join her (but usually only one or two) and swim vertically and close to her (Morrow 1980). As they approach the surface, eggs and milt are released. The fish break the surface, fall over backward, and swim to the bottom of the pool. It is not known whether a female deposits all her eggs in one night or whether more nights are required (ibid.).

D. Age at Sexual Maturity

Age at sexual maturity apparently varies among different geographically isolated populations of least cisco, as well as among different life history types of least cisco that occur sympatically. In the Minto flats area, Interior Alaska, Kepler (1973) determined that some least cisco males mature at two years and that most mature by three years of age; some females mature at three years, but most mature at four years. On the Colville River, in the Arctic Region, Alt and Kogl (1973) found that individual least cisco mature at four years, whereas the majority were mature at five years. In the Yukon Territory, North Slope, and eastern MacKenzie River delta drainages, Mann (1974) found differences in age at sexual maturity between sympatric "dwarf" and "normal" populations of least cisco. Dwarf individuals matured at three to four years, and 100% of the normal individuals were mature at seven years (freshwater population) and eight years (anadromous population).

E. Frequency of Breeding

Information regarding frequency of breeding in least cisco populations is inconsistent. Isolated geographic populations vary in behavior and life functions because of the different environmental conditions present. Kepler (1973) examined least cisco ovaries from specimens captured during July and August in the Minto flats area. The presence of retained eggs plus those that could develop fully by mid September indicated that all individuals sampled were consecutive spawners. In Trout Lake, Yukon Territory, Mann and McCart (1981) determined that least cisco spawn consecutively after reaching maturity. In contrast, several other authors have reported alternate-year spawning of least cisco in localized populations: Mann (1974) for least cisco captured in the Mackenzie River delta, Furniss (1975) for least cisco captured in Prudhoe Bay, and Alt and Kogl (1973) for least cisco captured in the Colville River delta. Mann (1974), however, points out that a great deal of subjectivity may be inherent in the methods used to determine mature spawners (i.e., eggs have the potential to ripen for the upcoming spawning season) and mature nonspawners (eggs are in resting stage).

F. Fecundity

Kepler (1973) found that fecundity in least cisco was more closely correlated with age than with length. In samples (from the Chatanika River) of individual least cisco ranging from 2+ to 7+ years, fecundity ranged from 27,825 to 93,500 eggs. Mann (1974) found that fecundity varied greatly between local populations of least cisco in the Yukon Territory's north slope and the eastern Mackenzie River delta drainages. In sympatric "normal" and "dwarf" populations, fecundity of normal least cisco exceeded that of dwarf least cisco by nearly 30 times (Mann and McCart 1981). Fecundity of normal, nonmigratory populations in Trout Lake, Yukon Territory, ranged from 7,886 to 19,261 eggs (mean = 12,059, s.d. = 3,330, n = 13). The dwarf populations from the same lake

had a lower fecundity, ranging from 223 to 1,080 eggs (mean = 412, s.d. = 105, n = 33) (Mann 1974). Egg diameter at time of spawning for normal individuals was consistently 1.5 mm. Egg diameter for dwarf individuals at time of spawning exceeded that for normal individuals by an average of 0.3 mm diameter (Mann and McCart 1981).

G. Incubation Period/Emergence

Eggs are demersal and lodge in crevices between gravel where they incubate and overwinter (late September to late May or early June) (McPhail and Lindsey 1970). In Siberia, larvae of the migratory forms move downstream toward the sea soon after hatching (Scott and Crossman 1973). Alt (1983) also reported that young-of-the-year least cisco undertake a slow downstream migration to rearing areas in slower, deeper waters of the lower Yukon River.

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

Least cisco are characterized by several life history types. Mann (1974) defined three types: anadromous, freshwater migratory, and freshwater nonmigratory. Anadromous forms of least cisco generally spend the summer months feeding in the nearshore coastal marine zone and migrate into the lower reaches of coastal rivers and river deltas in the fall. In the Beaufort Sea, this movement is associated with the ice-free period; in Prudhoe Bay, e.g., ice-out generally occurs in the first two weeks of June, and least cisco first appear during the first week of July (1975 and 1976) (Bendock 1979). Moulton et al. (1985) reported high catches of large (greater than 250 mm) least cisco in Gwydyr Bay in early July in 1984; a major movement occurred about 20 July through Gwydyr Bay and Prudhoe Bay. Craig and Haldorson (1981) reported least cisco movements through Simpson Lagoon in the last week of June. Tagging studies indicate that the Colville River is the primary freshwater source of these fish. Tagged individuals showed an eastward movement through Simpson Lagoon, followed by a build-up in Prudhoe Bay from breakup through mid August, and then a westward movement until freeze-up (Bendock 1979, Craig and Haldorson 1981, Moulton et al. 1985). Mann (1975) reported similar findings in the Mackenzie River delta population of least cisco. In September, the nearshore brackish water zone freezes over, and least cisco move into the freshwater deltas to spawn and overwinter. The presence of shore-fast ice and hypersaline conditions prevent least cisco from utilizing the marine environment until breakup occurs again in the spring (Bendock 1979, Craig and Haldorson 1981). Utilization of the more productive marine environment for feeding generally fosters greater growth rates and greater maximum age in these migratory least cisco than in the nonmigratory forms (Scott and Crossman 1973).

Mann (1974) defined a second migratory form of least cisco that remains in fresh water rather than migrating to sea. He concluded from seasonal sampling results that least cisco migrated into Peter Lake, Yukon Territory, in September to spawn. This population had direct access to the Mackenzie River delta and the Beaufort Sea, but growth

rates (similar to other lake resident populations) indicated they resided in fresh water throughout the year (Mann 1974). Alt (1983) reports that in the Innoko River, a tributary of the lower Yukon River, least cisco begin an upstream migration in late spring, or soon after ice-out. They move into lakes and sloughs to feed along the migration route. This feeding migration is composed mainly of mature fish, although immature individuals of ages 1 and 2 are present (ibid.). In late summer (August), the mature fish continue the upstream movement towards spawning areas. After spawning occurs, they apparently move downstream again to the Yukon River. It is not known whether this population is anadromous or not (Alt 1983). Similar movements were recorded in the Chatanika River near Fairbanks (Kepler 1973).

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

It is apparent that natural environmental factors influence nearly all local populations of least cisco. Lindsey (1981) documented the fact that a significant amount of plasticity occurs in morphological characteristics of whitefish genera because of coinhabitation of certain species. In least cisco, this may be related to the sympatric "dwarf" and "normal" populations documented by Mann and McCart (1980). Lindsey and Kratt (1982) reported a jumbo spotted form of least cisco in lakes of the southern Yukon Territory. They identified a variety of natural factors that could cause such distinct differentiation from other least cisco: glacial isolation, high levels of dissolved solids in the lakes, high lacustrine productivity and summer temperatures, lack of significant competition, and the migratory nature of the population.

Predation presumably has some influence on least cisco populations. Craig and Haldorson (1981) suggest that anadromous fish species use the nearshore coastal marine zone because there is a low predator density in that environment. Freshwater predators of least cisco include pike, burbot, lake trout, and sheefish. Eggs and young least cisco are very important in the diets of these predators (Alt 1977).

B. Human-related

Anadromous least cisco would potentially be vulnerable to disturbances from construction and/or oil development in the nearshore marine zone during the summer feeding migrations. The presence of a solid-fill causeway in the nearshore coastal zone of the Beaufort Sea (Prudhoe Bay) has been shown to cause temperature and salinity gradients that affect least cisco movements (Moulton et al. 1985). In freshwater streams, construction of roads, culverts, dams, etc., would create unnatural barriers (either physical or due to water velocity) and possibly cause a loss of spawning habitat.

A summary of possible impacts from human-related activities includes the following:

- Alteration of preferred water temperatures, pH, dissolved oxygen, and chemical composition
- Introduction of water-soluble substrates
- Increase in suspended organic or mineral material
- Increase in sedimentation
- Reduction in food supply
- Human harvest
- Seismic shock waves

(See the Impacts of Land and Water Use volume of this series under the category Freshwater Fish for additional impacts information.)

VIII. LEGAL STATUS

The Board of Fisheries develops regulations governing the harvest of least cisco throughout its freshwater and coastal marine range. Because only localized harvesting by commercial, subsistence, and sport fishermen occurs, no statewide management plan has been formulated.

IX. LIMITATIONS OF INFORMATION

Least cisco inhabit much of Interior Alaska in the Yukon and Kuskokwim river drainages and coastal Alaska from Bristol Bay through the Bering, Chukchi, and Beaufort seas. Because of the variations in local populations, apparently caused by geographic isolation and numerous natural environmental factors, it is difficult to generalize about the life history characteristics of the species. Information on least cisco is available primarily in areas where studies actually targetted on other species. Thus, there is a general data gap for least cisco distribution and abundance in many portions of its range, particularly uninhabited areas and/or areas not yet proposed for development.

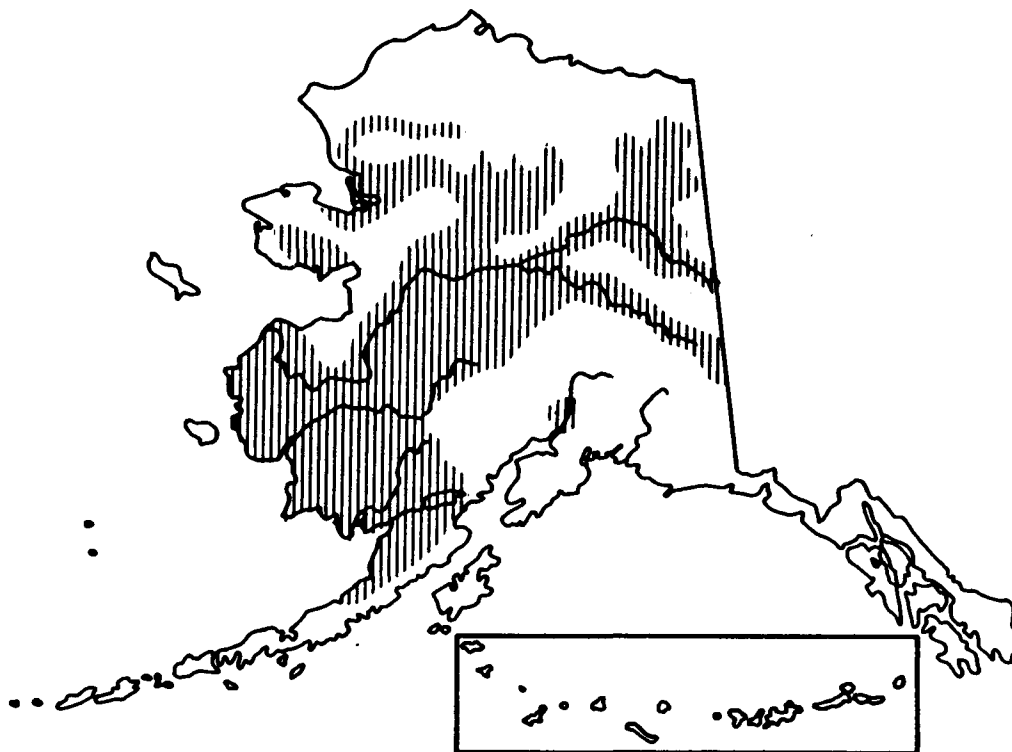
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Northern Pike Life History and Habitat Requirements
Western and Interior Regions



Map 1. Range of northern pike (ADF&G 1978)

I. NAME

- A. Common name: Northern pike
- B. Scientific name: Esox lucius Linnaeus
- C. Native Names: See appendix A.
- D. Species Group Representation
Five species of pike in the genus Esox are distributed in the northern hemisphere. One species is found in Siberia; three are native to eastern North America; and the fifth, the northern pike, has a circumpolar distribution (Morrow 1980).

II. RANGE

- A. Worldwide
The northern pike has a circumpolar distribution in the northern hemisphere. It inhabits fresh water and may be found in slightly

brackish water in the Baltic Sea. Pike are found throughout Asia and Europe as far south as Spain and northern Italy and from the British Isles east to the Pacific coast of Siberia. In North America, pike ranges from western Alaska to eastern Canada and from the arctic coast south to Nebraska, Missouri, and southern New England. Only scattered populations of pike are known to exist from areas of northern and arctic coastal plains in the USSR, Scandinavia, Canada, and Alaska, and pike are not found on arctic islands (Morrow 1980, Scott and Crossman 1973, McPhail and Lindsey 1970).

B. Statewide

The range of northern pike extends from Alaska Peninsula streams that flow into Bristol Bay through lowland areas of the Yukon River, Kuskokwim River, Norton Sound, and Kotzebue Sound drainages (map 1) (ADF&G 1978). Populations of pike occur on the north slope of the Brooks Range around the Colville River. Other areas of the arctic coastal plain have not been well surveyed. Few pike occur south or east of the Alaska Range, although populations exist in the Ahrnklin River southeast of Yakutat, the lower Susitna drainage, and in the Mackays Lakes on the Kenai Peninsula (ibid.). Pike are absent from Kodiak Island and the Aleutian Islands (Morrow 1980). Pike were introduced into Bulchitna Lake of the Susitna River drainage and first reported there in 1972 (Trent 1972). Since then, pike have expanded their range to other lakes of the lower Susitna drainage, such as Fish Lakes, 8-Mile Lake, and Hewitt-Whiskey Lakes (ADF&G 1978, 1984). The Kenai Peninsula pike were introduced into Mackays Lakes in the 1970's and now inhabit this chain of lakes, which drains into the Kenai River (ADF&G 1978, Hammarstrom 1977).

C. Regional Distribution Maps

To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for each region. In this series, northern pike distribution information is included on the series of 1:250,000-scale maps titled Distribution of Selected Freshwater Fish. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of selected fish and wildlife species has been prepared and may be found in the Atlas that accompanies each regional guide.

D. Regional Distribution Summary

1. Western and Interior. Northern pike distribution includes the entire lowland areas of the Yukon, Kuskokwim, and Tanana rivers. Pike prefer the slow-moving waters of sloughs, interconnected lakes, and the lower reaches of large rivers. The largest populations are found in meandering river-slough areas such as the Minto flats area and Yukon Flats (ibid.). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Western and Interior regions.)

III. PHYSICAL HABITAT REQUIREMENTS

A. Water Quality

1. The pH factor. Pike occur in alkaline lakes and have been found in Nebraska lakes with average pH values of 9.5. Pike have lived at a pH range of 9.5 to 9.8 for up to four months, and prior acclimatization appears to increase tolerance levels (McCarraher 1962). Pike occur in lakes with total alkalinities as high as 1,000 ppm, but growth appears to be less than in less alkaline waters. Fry are more sensitive to extremes of pH, bicarbonate, and monocarbonate than adults (ibid.). Pike fry and eggs are adversely affected by pH values of 5.2 or less (Johansson and Kihlstrom 1975). Pike sac fry suffered 97% mortality when reared in a water solution of pH 4.2, 26% mortality at pH 5.2, and 17% mortality at pH 6.8 (ibid.).
2. Dissolved oxygen. Northern pike are tolerant of low oxygen and in shallow lakes can survive minimum winter oxygen concentrations of 0.3 mg/l (Casselman 1978). Northern pike were captured in Ontario lakes with oxygen concentrations of 0.04 mg/l, but activity in oxygen concentrations below 0.7 mg/l was extremely low (ibid.). During winter, the fish congregate in areas where the oxygen concentration is higher. Pike in the Tanana River were found overwintering in a deep hole with swift-flowing water, where the dissolved oxygen level was 8 mg/l, and in the Tolovana River, where the dissolved oxygen was 4 mg/l (Hallberg 1984). Laboratory experiments have been conducted to determine the effects of reduced oxygen concentrations on northern pike embryos and larvae. At 15 and 19°C and at velocities of 3.3 and 1.6 cm/min, 50% oxygen saturation (approximately 5 mg/l) was sufficient for survival and development of pike from fertilization until all surviving larvae fed (Siefert et al. 1973). Oxygen concentrations of about 33% saturation (approximately 3 mg/l) were inadequate for survival.
3. Turbidity. Little information is available on turbidity tolerances of northern pike. Pike are visual predators, and turbidity may decrease their effectiveness. Pike generally show a preference for shallow, nearshore areas, but they select habitats further from shore on windy days (Chapman and Mackay 1984). The waves generated by wind create turbidity in shallow areas, and this may decrease the desirability of nearshore areas.
4. Salinity. Northern pike are a freshwater fish, and salinities as high as 18 parts per thousand (ppt) are lethal (Scott and Crossman 1973). They are known to occur in waters with salinities as high as 10 ppt in the Baltic Sea and to be able to reproduce in salinities as high as 7 ppt. Pike are common in coastal areas of the Baltic Sea with salinities of 5-6 ppt (Johnson and Muller 1978).

B. Water Velocity and Depth

Pike inhabit areas of quiet water that are shallow and near shore. Both adults and juvenile pike are usually found in water less than 4 m deep (Diana et al. 1977, Scott and Crossman 1973). Pike have been taken in Lake Nipigon, Ontario, from depths of over 30 m (Scott and Crossman 1973). Spawning usually occurs in shallow water less than .6 m deep (Cheney 1972, Morrow 1980, Alldridge and White 1980). In New York, northern pike spawning preferences were correlated with depth, not vegetation type. Spawning occurred in open water, over any available vegetation in depths ranging from .1 to .6 m (Alldridge and White 1980).

C. Water Temperature

Northern pike are spring spawners, spawning soon after ice breakup in water temperatures ranging from 4 to 13°C. In the Aniak River, a tributary of the lower Kuskokwim River, pike spawn in temperatures of 4 to 6°C (Alt 1977). Pike in the Innoko River drainage, north of the Aniak River, spawn at 8.5 to 13°C in sloughs and shallow lakes that have higher temperatures than the main river (Alt 1983). Pike in the Minto Lakes area, northeast of Fairbanks in the Interior Region, began spawning in the ice-free shallows while ice was still in the main rivers. Pike have been recorded spawning in the Minto Lakes area in water temperatures of 5.6 to 11.7°C (Cheney 1971). Pike in the Vilyuy River of Yakut, USSR (63°N lat) begin spawning at water temperatures of 3.8 to 4.5°C, and the most intense spawning occurs when temperatures reach 5 to 8°C (Sukhanova 1979).

Pike eggs were incubated in the laboratory, and the range of hatching temperatures was 3.1 to 20.9°C (Hassler 1982). The optimum hatching range was 6.2 to 20.9°C; maximum hatch occurred at 9 to 15°C; and lethal temperatures were 3 and 24°C.

Northern pike showed the best growth in the laboratory at 19°C for weight and 21°C for length (Casselman 1978). Growth rate was low at temperatures below 4°C but increased rapidly at temperatures above 10°C. Growth was stimulated slightly by long periods of daylight (16 hours) but was reduced in continuous light (ibid.). However, northern populations of pike adapted to more severe climatic conditions can grow nearly as much during the winter as the summer (Diana 1983a).

D. Substrate and Cover Requirements

Pike preferred summer habitat in Lake Ste. Anne, Alberta, in areas a short distance from shore with shallow depth, vegetation, and mud bottom (Diana et al. 1977). These characteristics were closely linked in their occurrence. Pike in the Wood River Lakes system in the Southwest Region select areas with warm, shallow, dark waters and abundant vegetation growing from a muddy bottom (Chihuly 1979). Chapman and Mackay (1983) found that meteorological factors influenced the selection of habitat by pike. On sunny days, pike chose areas that were close to shore and relatively shallow. On windy days, pike moved further from shore but not necessarily into deeper water.

Spawning often occurs in flooded emergent vegetation, but a wide variety of vegetation types have been used (Threinen et al. 1966). Vegetation is also important to juvenile pike. Holland and Huston (1984) found juveniles more commonly in areas with beds of submersed plants than in areas of emergent vegetation.

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

Young pike feed on zooplankton and small aquatic insects for 7 to 10 days after the yolk sac is absorbed. Pike then begin to feed on small fish, and by the time they reach a length of 50 mm, fish become more important in the diet (Scott and Crossman 1973). Adult pike are omnivorous and are limited in prey selection only by the size of their mouth. The optimum food size has been calculated at between one-third to one-half the size of the pike, but adult pike feed on small invertebrates when fish are not available (ibid.). Most food-habit studies have been conducted in summer, but pike also feed and grow during the winter (Diana 1983b).

Small pike (less than 200 mm in length) in the Minto flats area fed mainly on invertebrates, whereas pike from 200 to 400 mm added vertebrates to the diet, and pike over 400 mm fed mainly on fish with invertebrates rarely eaten (Cheney 1972). Chihuly (1979) found that the Lake Aleknagik pike less than 200 mm fed on invertebrates, with mayfly nymphs the most common item. Pike longer than 200 mm fed most often on blackfish, with stickleback, sockeye salmon fry, and pike also included as prey.

Food habits of adult pike have been sampled throughout Alaska (table 1). Many species of fish are eaten, with smaller vertebrates and invertebrates occasionally included. Pike prey on whatever species of fish are locally available, and the prey species in Alaska include coho salmon, sockeye salmon, cisco, whitefish, burbot, pike, sculpin, blackfish, lamprey, suckers, and sticklebacks. Ducklings, shrews, voles, and invertebrates such as snails, amphipods, and mayfly nymphs are also eaten.

B. Types of Feeding Areas Used

Pike summer and feed mainly in shallow, vegetated areas near shore (Threinen et al. 1966, Chihuly 1979). Pike may select these areas because of an increased availability of prey. Pike have also been shown to move extensively in water farther from shore (Chihuly 1979, Chapman and Mackay 1984). This versatility in selecting habitats may be an important feature in the behavior of top predators.

C. Factors Limiting Availability of Food

Adult northern pike are opportunistic predators, able to switch from one food source to another. Changes in abundance and vulnerability of prey through the seasons are reflected in the diet of pike (Mann 1982). Young pike prey on zooplankton, insects, and very small fish and therefore do not have the range of prey species or size from which older pike can select.

Table 1. Food Species Used by Adult Northern Pike in Alaska

Location	Species	Source
Killik River drainage - North Slope	Burbot, least cisco, broad whitefish, slimy sculpin	Bendock 1979
Lakes on south slope of Brooks Range	Burbot, sculpin, grayling, round whitefish, amphipods, snails	Roguski and Spetz 1968
Pilgrim River - Seward Peninsula	Whitefish	Alt 1980
Minto flats - northwest of Fairbanks	Pike, whitefish, blackfish, least cisco, burbot, ducklings, shrews, invertebrates	Alt 1968, Cheney 1971 and 1972
Harding Lake - southeast of Fairbanks	Coho salmon, cisco, slimy sculpin, burbot, pike, insects	Hallberg 1979
Andreafsky River - lower Yukon drainage	Blackfish, sculpins, lampreys, whitefish, salmon fry	Alt 1981
Innoko River - lower Yukon drainage	Salmon fry, whitefish, pike, suckers, least cisco, shrews, voles, water beetles	Alt 1983
Eek Lake - Kuskokwim delta	Snails, insects, leeches, small pike	Alt 1977
Lake Aleknagik - Wook River Lakes	Blackfish, threespine stickleback, ninespine stickleback, sockeye salmon fry, pike, mayfly nymphs	Chihuly 1979

Abundance of zooplankton can be affected by temperature, light, and availability of nutrients.

D. Feeding Behavior

Adult northern pike are visual feeders and are most active during the daytime (Threinen et al. 1966). However, light is not critical to young-of-the-year pike feeding on invertebrates (Holland and Huston 1984). In adult pike, the feeding time was short relative to time between meals, and including large items in the diet had a positive effect on growth rate (Diana 1979, Hart and Connellan 1984). Feeding on large prey items allows pike to feed less often and on fewer items per day.

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Pike return to the same spawning area every year, preferring marshy areas with shallow water, emergent vegetation, and mud bottoms with vegetation mats. Suitable vegetation and quiet water seem to be the most important factors in the choice of spawning areas (Morrow 1980). Pike spawning grounds in the Minto flats area, northwest of Fairbanks, have emergent vegetation, depths from .1 to .6 m, little or no current, mud bottom, and are ice-free before the main rivers (Cheney 1971). These areas have rapidly fluctuating temperatures. Pike have also been observed spawning in sloughs and lakes of the Innoko River, which is part of the lower Yukon drainage (Alt 1983). Water in the sloughs warms more quickly than in the main river, and pike can spawn earlier in these habitats.

Pike in Manitoba spawn in areas of flooded terrestrial vegetation (Bodaly and Lesack 1984). These areas, however, may be used for spawning in only the first year of flooding. Loss of leaves from flooded shrubs after the first year of high water levels may make the vegetation less attractive to spawning pike or may offer less protection from predators of incubating eggs.

Pike may spawn on many different substrates, and spawning preferences have been correlated with depth, not vegetation type; and as depth changes in the spawning area, substrates may shift (Alldridge and White 1980). Heavy or thick vegetation may be avoided, however, and areas with heavy silt deposition may have higher egg mortality (Alldridge and White 1980, Bodaly and Lesack 1984).

B. Reproductive Seasonality

Northern pike are spring spawners, and spawning occurs soon after the ice melts in shallow areas. In the Minto flats area, northwest of Fairbanks, most spawning was observed in mid May, with some pike spawning as late as mid June (Cheney 1971). Spawning occurred in late May in sloughs and lakes of the Innoko River of the lower Yukon drainage and in the Aniak River of the lower Kuskokwim drainage (Alt 1977 and 1983). In the Lena River drainage of the northeastern USSR (63°N) spawning began as soon as

ice melted from areas of the inlets in the end of May and continued through early June (Sukhanova 1979).

C. Reproductive Behavior

Northern pike spawn during daylight, forming pairs or with larger females attended by several smaller males. No nest is built, and from 5 to 60 eggs are released at a time over the vegetation. Eggs are released every few minutes for up to several hours. The spawned-out adults may stay on the spawning ground for as long as 14 weeks, but most leave within 6 weeks (Morrow 1980, Scott and Crossman 1973, Sukhanova 1979).

D. Age at Sexual Maturity

The growth rate of northern pike decreases northward, with a corresponding increase in longevity (Scott and Crossman 1973). In the Niagara River watershed and in Lake Ontario, male pike mature at age 2 and females at ages 3 and 4 (Harrison and Hadley 1983, Wolfert and Miller 1978). In the Wood River Lakes, most pike mature at age 5, but the age of maturity may range from 2 to 7 (Chihuly 1979). In the lower Yukon drainage, most pike mature by ages 4 or 5, although some are mature at age 3 (Alt 1981 and 1983). In the lower Kuskokwim, males mature at ages 5 and 6 and females at age 4, but all fish are mature by age 6 (Cheney 1971 and 1972). In the Killik River drainage of the North Slope, pike show a slower growth rate, and the age of first maturity is age 10 (Bendock 1979).

E. Frequency of Breeding

Northern pike spawn in the spring and appear to spawn every year after they reach sexual maturity (Alt 1977 and 1983).

F. Fecundity

The eggs of northern pike are 2.5 to 3.0 mm in diameter, demersal, adhesive, and remain attached to the vegetation of the spawning area (Scott and Crossman 1973). Pike fecundity increases with the size of the female and decreases if poor foraging conditions existed in the previous year or resorption of eggs occurred because of unfavorable spawning conditions (Spanovskaya and Soloninova 1983). Egg numbers range from 2,000 to nearly 600,000, with 32,000 eggs the average number for mature females (Morrow 1980, Scott and Crossman 1973).

G. Incubation Period/Emergence

Development time to hatching varies inversely with temperature. Eggs hatch in 23 to 29 days at 6°C and require 4 to 5 days at 18°C. Mortality rates of the eggs increase with increasing temperatures (Swift 1965). The young remain inactive, often attached to the vegetation, and feed on the stored yolk for 6 to 10 days. Active feeding begins at about 10 days, when the mouth develops and the young fish have reached 11 to 13 mm in length (Morrow 1980, Scott and Crossman 1973).

Young-of-the-year pike in the Innoko River of the lower Yukon drainage were 39 mm long in mid June of 1982 and had probably hatched in early June. Spawning occurred in May. The pike were

abundant in lakes and sloughs and grew from 45 mm on June 25 to 155 mm on September 1 (Alt 1983).

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

Pike spend the summer in shallow, nearshore areas moving very little (Chihuly 1979). As the waters approach freezing, pike move to deeper water in lakes and rivers. As the water warms in the spring, pike move inshore or upstream to the spawning grounds, usually moving at night (Morrow 1980, Cheney 1972, Chihuly 1979).

In the Minto flats area of Alaska, pike spawn, then disperse and remain in the area over summer (Cheney 1972). Minto flats pike move in the fall before the waters freeze, and most mature pike winter in the lower Tolovana or Tanana rivers. However, some pike overwinter in areas of the flats such as Grassy Slough or the Chatanika River that maintain good water flows throughout the winter (Hallberg 1984). Immature pike remain longer in the main rivers of the flats before moving downstream (Cheney 1972). Pike overwinter in the lower Kuskokwim and in the Innoko River of the lower Yukon drainage, moving out of the marshes and tributary rivers in the fall (Alt 1977, 1983).

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

Egg mortality, competition for food, predation, cannibalism, and environmental factors have all been identified as causing changes in numbers, biomass, and growth of pike populations. Pike spawn in shallow, flooded areas, and pike eggs are subject to fluctuating water levels. Large year classes of pike have been associated with high and stable water levels during the incubation and fry stages (Threinen et al. 1966). Mortality from the egg to fry stage from predation or changing water levels has been estimated to be as high as 99% (Scott and Crossman 1973, Morrow 1980). Temperature in the first summer after hatching and food supply for both young-of-the-year and older pike have had significant impacts on year-class strength (Kipling 1983).

When insufficient food is available to adult pike, cannibalism on the young can reduce the year-class size. Young northern pike are prey to a wide variety of fish, birds, and mammals (Scott and Crossman 1973). In the Minto flats area, northern pike fingerlings were the most important food of sheefish (Alt 1968). Adult pike have few natural predators; however, during spawning in shallow water, pike are vulnerable to such predators as bears, dogs, eagles, and ospreys (Scott and Crossman 1973).

B. Human-related

Water quality is especially important to northern pike fry and eggs, and they are sensitive to extremes of pH and to concentrations of carbonate and bicarbonate (McCarraher 1962, Johansson and Kihlstrom 1975). Pike eggs are especially vulnerable to fluctuating water levels in flooded areas and may be adversely affected by water-control structures. Any disturbances that degrade pike spawning, rearing, or feeding habitats or

degrade water quality may adversely affect population levels of pike. A summary of possible impacts from human-related activities includes the following:

- Changes in water temperature, depth, or velocity
- Change in turbidity or suspended sediments
- Alteration of aquatic vegetation for cover or spawning
- Addition of physical barriers to migration
- Changes in levels of dissolved oxygen, pH, alkalinity, or hardness

(The Impacts of Land and Water Use volume of this series contains additional information regarding impacts.)

VIII. LEGAL STATUS

The Alaska Board of Fisheries develops regulations governing the harvest of fish in Alaska. Research and monitoring of northern pike populations is conducted mainly by the Alaska Department of Fish and Game, Division of Sport Fish.

IX. LIMITATIONS OF INFORMATION

Northern pike have been studied in many areas, but little information is available on northern populations adapted to cold climates. Summer and winter growth rates for populations of pike in areas with cold temperatures need to be studied. Information on turbidity tolerances of pike is scanty, and little knowledge about tolerance of pH, salinity, dissolved oxygen, or temperature for pike in Alaska is available.

More information on the natural factors influencing populations of pike would be useful for management of pike populations. The effects of competition and predation on the egg, juvenile, and adult stages, as well as cannibalism by older pike on eggs and fry, should be better studied.

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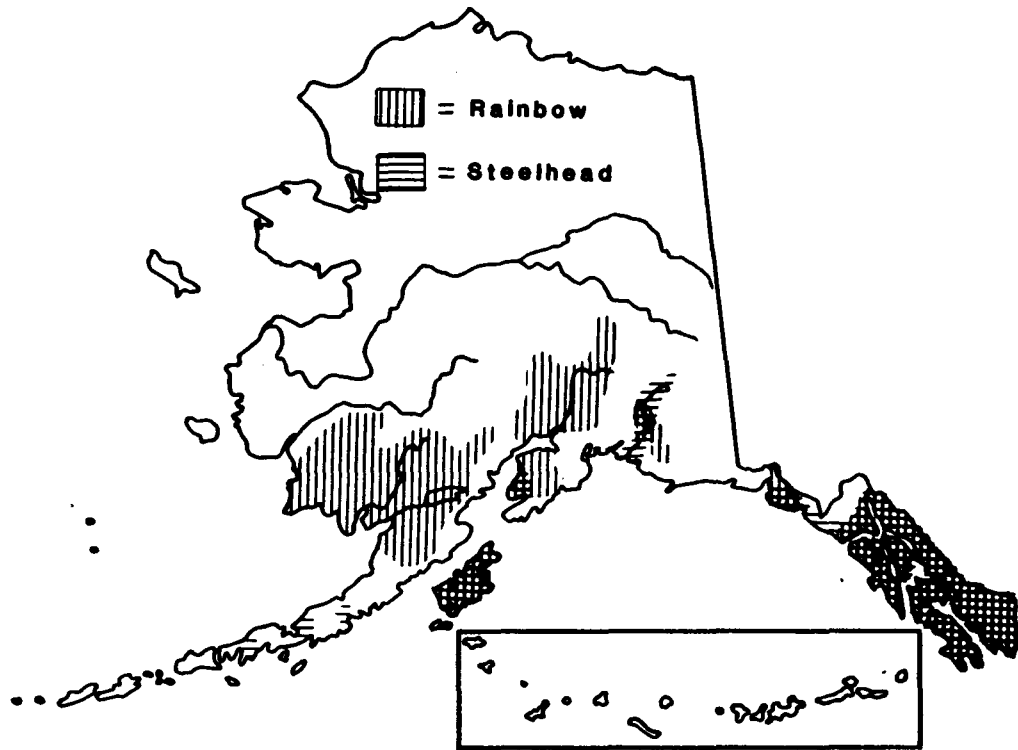
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Rainbow Trout/Steelhead Life History and Habitat Requirements
Southwest, Southcentral, and Western Regions



Map 1. Range of rainbow trout/steelhead trout (ADF&G 1978)

I. NAME

- A. Common Names: Rainbow trout and steelhead trout
- B. Scientific Name: Salmo gairdneri
- C. Native Names: See appendix A.

II. RANGE

- A. Statewide
Rainbow trout are found throughout Southeast Alaska, west to the Alaska Peninsula, and up the Kuskokwim River as far as Sleetmute (ADF&G 1978).
Steelhead are found throughout Southeast Alaska, in the Copper River drainage, on the lower Kenai Peninsula as far up as the Kasilof River, on Kodiak Island, and on the Alaska Peninsula.

B. Regional Distribution Maps

To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for each region. For rainbow trout, the maps in this series are at 1:250,000 scale. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of selected fish and wildlife species has been prepared and may be found in the Atlas that accompanies each regional guide.

C. Regional Distribution Summary

1. Southwest. Native rainbow trout are found on Kodiak Island. Some of the more important Kodiak rivers are Karluk, Ayakulik, Portage, and Afognak. Native rainbow trout are also found in Bristol Bay drainages north of Becharof Lake and the Egegik River to the Kuskokwim River (ibid.). Largest trout are found in most lake-river systems, such as the Naknek, Kvichak, and Alagnak (ibid.). Steelhead trout are also native to Kodiak Island, where they are most abundant in the Karluk and Ayakulik rivers (Murray, pers. comm.). Steelhead are also found in a few streams on the north side of the Alaska Peninsula, including the Sandy River, Bear River, King Salmon River, and Steelhead Creek. On the south side of the peninsula, steelhead have been documented in the Chignik River and a stream that drains into Ivan Bay (ADF&G 1984). (For more detailed narrative information, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)
2. Southcentral. Native rainbow trout are found in most drainages of the northern and western Kenai Peninsula, from Anchor River north to the Chickaloon River (ADF&G 1978). They are found in the lower Susitna River drainage and, to a lesser extent, the Matanuska drainage and some of the larger rivers flowing into northwestern Cook Inlet. Rainbows are also found in some clearwater tributaries of the Copper River, most importantly the Gulkana River (ibid.). In addition to native fish, several lakes in Southcentral Alaska are stocked with rainbow trout on a put-and-take basis. Steelhead trout are found in several Kenai Peninsula streams between Homer and the Kasilof River (ibid.). They are also found in the Copper River drainage, especially the Gulkana River (ibid.). Steelhead trout in the Middle Fork of the Gulkana River may be the northernmost natural steelhead population in Alaska (Williams, pers. comm.). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)
3. Arctic. In the Arctic Region, brightly colored char are frequently called rainbow trout, but this is a misnomer. The Arctic Region contains no known populations of rainbow or steelhead trout.

4. Western and Interior. Natural populations of rainbow trout are found in the southwest portion of the Western Region. They are found in streams flowing into Kuskokwim Bay south of the Kuskokwim River and in the Kuskokwim River drainage as far as 125 mi upstream from Aniak (Alt 1977). Natural populations of rainbow trout are not found in the Interior Region, but they have been stocked in many Interior lakes and support many popular Interior sport fisheries. (For more detailed narrative information on rainbow trout distribution in the Western and Interior regions, see Volume 2 of the Alaska Habitat Management Guide for the Western and Interior regions.)

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

1. Water quality:

- a. Temperature. Preferred temperatures for rainbow trout from hatchery and wild populations in the Great Lakes, Ontario, and New York State have been reported to be between 11.3 and 20°C (McCauley et al. 1977, McCauley and Pond 1971, Cherry et al. 1977). Upper lethal temperatures for Great Lakes and New York rainbow were 25 to 26°C (Bigood and Berst 1969, Hokanson et al. 1977, Cherry et al. 1977). The lower lethal temperature is 0°C (McAfee 1966).

Russell (1977) reported that rainbow spawning in Talarik Creek (tributary to Lake Iliamna in Southwest Alaska) peaked at 5 to 7°C and terminated at 7 to 16°C. Allin and Baxter (1957) observed rainbow spawning in Cottonwood Creek (drainage of Wasilla Lake in Southcentral Alaska) at temperatures of 6.7 to 7.8°C.

McAfee (1966) found increased mortality in rainbow embryos at temperatures less than 7°C and normal development at temperatures between 7 and 12°C.

Jones (1972) reported temperatures for the adult steelhead spawning migration to be 2 to 6°C in Petersburg Creek in Southeast Alaska. In 1973, however, temperatures were 0 to 4°C, and he stated that temperature did not appear to affect in-migration (Jones 1973).

Sutherland (1973) reported that the limits of steelhead distribution in the open ocean conform to the 5°C isotherm in the north and the 15°C isotherm in the south.

- b. The pH factor. Rainbow trout have been found to acclimate to pH from 5.8 to 9.8 (McAfee 1966, Murray and Ziebell 1984); however, acclimation to pH levels above 8.5 must take place gradually (over at least four days) (Murray and Ziebell 1984).

- c. Dissolved oxygen (D.O.). Optimal oxygen levels for rainbow trout are given by Raleigh and Hickman (1982) to be 7 mg/l or greater at temperatures less than 15°C and 9 mg/l or greater at temperatures higher than 15°C. State of Alaska water quality standards for growth and propagation of fish require D.O. levels greater than 7 mg/l (ADEC 1979). Lethal levels of D.O. reported for adults and juveniles range from 2.9 mg/l at 10 to 20°C (Downing and Merckens 1957) to 0.5 to 1.5 mg/l at 15°C (Streltsova 1964). Raleigh and Hickman (1982) state that the lethal level is approximately 3 mg/l. Phillips and Campbell (1962) found that steelhead embryos from Oregon did not survive at D.O. levels of 7.2 mg/l or less. Silver et al. (1963) found that steelhead eggs from an Oregon hatchery survived to hatching at D.O. levels as low as 2.6 mg/l but that the time to hatching increased from a mean of 36 days at 11.2 mg/l to a mean of 44 days at 2.6 mg/l (at a water velocity of 6 cm/hr). Shumway et al. (1964) also found an increase of hatching time and a decrease in weight of newly hatched fry at decreased D.O. levels (from approximately 11 mg/l down to approximately 3 mg/l). Fry that are small and have taken long to develop may not be viable in the natural environment.
- d. Turbidity. High levels of turbidity may abrade and clog fish gills, reduce feeding, and cause fish to avoid some areas (Reiser and Bjornn 1979). Turbidity and sedimentation may smother food organisms and reduce primary productivity (Bell 1973). Turbid water will absorb more solar radiation than clear water and may thus indirectly erect thermal barriers to migration (Reiser and Bjornn 1979). Herbert and Merckens (1961) found that suspended mineral solids in excess of 90 ppm caused increased mortality of rainbow trout. Rainbow trout held in tanks with high concentrations of suspended solids suffered damage to their gills (thickening of epithelial cells and fusion of adjacent lamellae) and increased susceptibility to fin-rot disease. Olson et al. (1973) also found gill damage in rainbow trout held in water with high turbidity levels and decreased feeding of rainbow trout when turbidity exceeded 70 JTU (Jackson Turbidity Units). Kramer and Smith (1965) found that suspended wood fiber at concentrations as low as 60 ppm (the lowest level studied) caused significant sublethal stress to rainbow trout juveniles. Responses to suspended fiber included reduced breathing rate, heart rate, respiration rate, and growth rate. Fiber clogged buccal and gill cavities

and killed a high proportion (up to 100% at 250 ppm) of alevins within 48 hours of hatching (Kramer and Smith 1965). Excess turbidity from organic materials in the process of oxidation may reduce oxygen below acceptable levels (Bell 1973). Studies of rainbow trout habitat in the Susitna River indicate that rainbow trout generally avoid turbid water. However, when no other form of protective cover is available, the trout apparently use the turbid water for cover (Suchanek et al. 1984).

2. Water quantity. In the Susitna River, adult rainbow trout were typically caught by boat electrofishing in areas with water velocities less than 46 cm/sec (Suchanek et al. 1984). Hook and line sampling indicated that rainbow trout preferred pools with velocities less than 15 cm/sec and depths greater than 0.6 m (ibid.). During spawning, stream velocity influences the ease with which bottom materials are moved for redd excavation and affects the energy expenditure required for a spawner to maintain position above the redd site (Russell 1977). Sufficient water velocity and depth are needed to allow proper intragravel water movement so that dissolved oxygen is transported to eggs and alevin and metabolic wastes are removed (Reiser and Bjornn 1979). Smith (1973) gave depth and velocity requirements for spawning steelhead in Oregon as at least 0.24 m deep and 40 to 91 cm/sec. Rainbow trout values were at least 0.18 m deep and 48 to 91 cm/sec. Allin and Baxter (1957) noted that spawning rainbow trout prefer water .1 to .25 m deep with a moderately swift velocity (less than 1.2 m/sec) in Cottonwood Creek, Alaska. Jones (1975) found that spawning steelhead in Petersburg Creek in Southeast Alaska favored water 0.2 to 0.35 m deep but that they were also found spawning on shallow riffles not exceeding 0.16 m in depth. In Lower Talarik Creek (draining into Lake Iliamna, Alaska), rainbow trout redds are located in areas where stream velocities are 30 to 60 cm/sec (Russell 1977).

Withler (1966) noted that temporary high-water flows (freshets) may be necessary to initiate upstream movement of spawning steelhead in British Columbia. Jones (1973) also noted that water level is the most important factor influencing immigrating steelhead in Petersburg Creek, Alaska. Steelhead moved upstream most readily on rising stream levels.

Steelhead and rainbow fry in streams are found in shallower water and slower velocities than at other life stages (Miller 1957, Horner and Bjornn 1976). Everest and Chapman (1972) found underyearling steelhead in an Idaho stream in water less than 0.5 m in depth and of less than 0.3 m/sec velocity. Age 1+ steelhead were in water greater than 0.6 m in depth and of greater than 0.5 m/sec velocity. Jones (1972) stated that the most favored rearing habitat type in Petersburg

Creek, Alaska, is a stream section 0.15 to 0.60 m deep with moderate-to-fast flow (no actual velocity measurements were taken).

3. Substrate. In the Susitna River, adult rainbow trout use rocks with diameters over 8 cm for cover (Suchanek et al. 1984). The substrate composition of salmonid spawning beds influences the development and emergence of fry. Substrates with low permeability result in lower apparent velocities and reduced oxygen delivery to, and metabolite removal from, eggs (Reiser and Bjornn 1979). Successful fry emergence is also hindered by excessive amounts of sand and silt in the gravel (ibid.).

Phillips et al. (1975) found that emergent survival of steelhead alevins from an Oregon stream was only 18% in a substrate mixture of 70% sand (less than 3.3 mm diameter), compared to 94% survival in the control substrate with no sand. McCuddin (1977) reported that survival and emergence of steelhead embryos was reduced when sediments less than 6.4 mm in diameter made up 20 to 25% or more of the substrate.

Jones (1975) found that steelhead in Petersburg Creek, Alaska, generally select redd sites in areas with gravel 5 to 10 cm in diameter; however, some redds were in areas comprised of fine gravel (less than 5 cm) and in areas of large cobble and boulders. Allin and Baxter (1957) observed that rainbow trout in Cottonwood Creek in Southcentral Alaska prefer to spawn on gravel loose enough for digging to a depth of 10 to 13 cm. Gravel taken from one Cottonwood Creek redd consisted of 72% particles greater than .85 cm in diameter.

Large substrate is important as cover for overwintering steelhead fry in streams. Bustard and Narver (1975) found that rubble in the 10 to 25 cm range was used as cover by over 50% of age 0 steelhead fry overwintering in a Vancouver Island stream. In streams where larger substrate is available, overwintering steelhead fry may be associated with rubble 20 to 40 cm or larger (Everest 1969, Hartman 1965). Hiding in rubble in the winter reduces downstream displacement during freshets and probably also is a means of avoiding predation in winter, when swimming ability is reduced (Bustard and Narver 1975).

Substrate size also influences stream invertebrate populations, which are important as the food source of rearing salmonids. Reiser and Bjornn (1979) stated that highest invertebrate production is from areas with gravel and rubble-size materials.

B. Terrestrial

Protective cover is provided by overhanging vegetation and undercut banks (in addition to instream cover provided by such factors as rocks, submerged logs, and turbulent water) (Giger 1973, Suchanek et al. 1984). Nearness of cover may be important to fish waiting to spawn, as spawning often takes place in open segments

of streams where fish are vulnerable to disturbance and predation (Reiser and Bjornn 1979). Jones (1976) noted that adequate cover to escape predation is the most important factor in redd site selection in small tributary streams of Petersburg Creek in Southeast Alaska.

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

Rainbow and steelhead are largely opportunistic feeders, consuming whatever is available in their environment (Morrow 1980). Generally, those in fresh water feed on insects (especially larval and adult dipterans) and crustaceans (such as Gammarus) (ibid.). Large adult rainbows eat other fishes (ibid.). In the open ocean, steelhead feed on squid, amphipods, and greenling (Hexagrammidae) (Sheppard 1972).

Allin and Baxter (1957) found that 75% of the total food intake by rainbow from Cottonwood Creek and Wasilla Lake was fish, predominantly sticklebacks (Gasterosteidae). They also noted that lake fish feed more heavily on sticklebacks than do stream resident fish. Engel (1970) found that sticklebacks comprised more than 75% of the food (by volume) of rainbow trout larger than 254 mm in Gruski Lake on the Kenai Peninsula. Insects (especially Trichoptera larvae) were of secondary importance in the diet of these large fish. Trout less than 254 mm preferred insects (especially Diptera, Trichoptera, and Coleoptera). Engel (1970) noted that the rainbow trout switched to a diet of fish after attaining a size of 204 to 254 mm, regardless of the availability of other food.

Rainbow trout in Lower Talarik Creek in Southwest Alaska consume mainly eggs of sockeye salmon (Oncorhynchus nerka [Walbaum]); aquatic dipterans (midges); and Trichoptera larvae (Russell 1977). Forage fishes, especially pond smelt (Hypomesus olidus), were eaten by trout over 175 mm in length (Russell 1977). In the Susitna River, rainbow trout concentrate near tributary mouths and in sloughs during the summer, presumably to feed on eggs of pink and chum salmon, which spawn in these areas (Sundet and Wenger 1984).

Russell (1980) reported that rainbows from the Chilikadrotna and Mulchatna rivers in southwestern Alaska frequently consumed small rodents. One Chilikadrotna rainbow stomach contained a total of five shrews.

B. Types of Feeding Areas Used

In streams, the highest invertebrate production usually occurs in riffle areas (velocity 0.46 to 1.07 m/s) with a substrate of coarse gravel (3.2 to 7.6 cm diameter) and rubble (7.6 to 30.4 cm diameter) (Reiser and Bjornn 1979). Everest and Chapman (1972) observed that steelhead juveniles rearing in Idaho streams nearly always were found close to (but not in) areas of fast-water invertebrate production. Steelhead juveniles remained near the

bottom in low-velocity areas, except when darting after food items.

Scott and Crossman (1973) state that rainbow trout feed on the bottom most often but also rise to the surface to feed on emerging or egg-laying insects. The presence of large numbers of Trichoptera larvae in rainbow trout from Gruski Lake (Engel 1970) and Talarik Creek (Russell 1977) supports that statement.

Observations of radio-tagged rainbow trout in the Susitna River revealed that their distribution within a microhabitat may be dependent on the food source (Suchanek et al. 1984). In areas where rainbow trout were feeding on salmon eggs, they were closely associated with spawning salmon and used shallow water riffles with cobble substrate for cover (ibid.). In areas where rainbow trout were apparently feeding on aquatic insects, they were found in deep pools and used turbulent water and depth, along with the rubble/cobble substrate and debris, as cover (ibid.).

C. Factors Limiting Availability of Food

Excessive sedimentation may inhibit production of aquatic invertebrate fauna (Hall and McKay 1983).

Small rainbow trout (less than 230 mm) compete with threespine stickleback (Gasterosteus aculeatus [Linnaeus]), for food in some lakes (Engel 1970). Upon reaching a length of 230 mm, however, forage fish such as sticklebacks become important in the diet. In fact, the availability of forage fish may be necessary for rainbows to reach maximum size (Morrow 1980).

The magnitude of sockeye salmon runs in Southwest Alaska streams may affect the general condition of juvenile rainbows in that area (Russell 1977). Rainbow trout have been reported to follow spawning sockeye salmon upstream in Idavik Creek in the Naknek drainage in Southwest Alaska (Gwartney 1983). The availability of large numbers of salmon eggs in the summer may enhance the rainbows' chances of overwinter survival (ibid.). A similar relationship between the size of sockeye salmon runs and the growth of steelhead trout was also noted in Petersburg Creek in Southeast Alaska (Jones 1978).

D. Feeding Behavior

Maciolek and Needham (1952) found that rainbow trout in Convict Creek, California, fed actively all winter, even in frazil ice conditions. The volume of food in rainbow trout stomachs from Paul Lake, British Columbia, was only slightly less in winter than in summer (Larkin et al. 1950). Studies in Gruski Lake on the Kenai Peninsula also indicate that rainbow trout continue to feed in winter under the ice (Engel 1970).

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Spawning takes place in streams, usually in a riffle above a pool (Morrow 1980). Side channels, the tails of pools just above riffles, and areas along the anterior portions of islands are frequently used (Russell 1977). More specific spawning habitat

characteristics are included in the Physical Habitat Requirements portion (section III.) of this account.

B. Reproductive Seasonality

Generally, rainbow trout spawn during May and June (ADF&G 1978). Russell (1977) found that rainbow trout in Lower Talarik Creek in Southwest Alaska spawned from late April through mid June, with the spawning peak occurring between early May and early June, depending upon water temperature. In 1983, Susitna River rainbow trout spawned in late May to early June (Sundet and Wenger 1984). Peak steelhead spawning in the Copper River occurs from late May through mid June (Burger et al. 1983). In a sample of 10 steelhead taken from the Anchor River on May 10, two of six males had loose milt and four did not; none of the four females had loose eggs (Wallis and Balland 1983).

C. Reproductive Behavior

Breeding behavior is typically salmonid (Morrow 1980). The female digs a redd by turning on her side and giving several upward flips of her tail. Displaced sand and gravel is washed downstream, eventually resulting in a pit somewhat longer and deeper than the female's body (ibid.). When the redd is finished, the female drops into the pit and is joined by the male. Both fish gape their mouths, quiver, and extrude eggs and milt for a few seconds. One or more small, subordinate males may dart alongside the female and participate in the spawning act (Morrow 1980, Allin and Baxter 1957). As soon as spawning is completed, the female moves to the upstream edge of the redd and digs again, thus displacing gravel downstream and covering the eggs. This process is repeated either with the same or other males until the female's egg supply is exhausted (Morrow 1980).

D. Age at Sexual Maturity

Generally, the age at which these trout reach sexual maturity is between three and five years, with males usually maturing a year earlier than females (Morrow 1980). Most rainbows in Lower Talarik Creek in Southwest Alaska mature at ages 6 and 7 (Russell 1977). In the Susitna River, rainbow trout of both sexes spawn after age 5 (Sundet and Wenger 1984). Steelhead in Southeast Alaska spend from two to five years in the streams before migrating to sea and then spend at least two years at sea before returning to spawn, so they are normally five or six years old at maturity (Jones 1978).

Wallis and Balland (1983) found that among first-time steelhead spawners in the Anchor River, the majority of the females had spent three years in fresh water and two in the ocean. Among the males, there were about equal numbers of fish that had spent one and two years in the ocean; most had spent three years in fresh water.

E. Frequency of Breeding

Many rainbow and steelhead survive to spawn more than once (Morrow 1980). Spring runs of steelhead in Southeast Alaska contain 20 to 50% repeat spawners (Jones 1978). Fall runs of steelhead in

Southeast contain 15 to 25% repeat spawners (Jones 1978). The percentage of repeat spawners among Anchor River steelhead in different years has ranged from 3.5 (Redick 1968) to 33% (Wallis and Balland 1983).

Rainbow trout from Lower Talarik Creek in Southwest Alaska also may spawn several times (Russell 1977). Generally, large, older females are less likely to survive spawning than younger ones, and males are less likely to survive than females (Morrow 1980).

F. Fecundity

Fecundity varies with the size and condition of the females (Allin and Baxter 1957, Scott 1962). Fecundity of steelhead in Petersburg Creek in Southeast Alaska averaged 5,286 eggs per female from 1973 to 1976 (Jones 1976). Fecundity of steelhead 655 to 770 mm in length from the Anchor River ranged from 4,081 to 7,502 eggs in a sample of 10 females (Wallis and Balland 1983).

Rainbow from Talarik Creek in Southwest Alaska averaged 3,431 eggs per female (Russell 1977). Rainbow from Cottonwood Creek in Southcentral Alaska averaged 489 to 2,042 eggs per female, depending on size (Allin and Baxter 1957). Morrow (1980) gives a general fecundity value of 3,250 eggs for rainbow trout and steelhead.

G. Incubation Period

Eggs usually develop to hatching in a period of four to seven weeks (ibid.), although the time of development varies with the stream temperature and may take up to four months (ADF&G 1978). Young-of-the-year rainbow trout were found on July 17 in Lower Talarik Creek (Southwest Alaska), 68 days after peak rainbow spawning (Russell 1974). Steelhead fry in Southeast Alaska emerge from the gravel in July (Jones 1978). Allin and Baxter (1957) found that approximately 1100 heat units (based on 11 A.M. daily temperatures ([Fahrenheit]) and presumably calculated by summing the difference of these temperatures from 32°F) were required for eggs to develop to fry with absorbed yolk sacs.

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

Rainbow trout and steelhead populations follow several different life history patterns. Some rainbow trout remain in streams for their entire life and do not undertake any long migrations. Juveniles of other rainbow trout populations move into lakes after a year or more (four to five years in Talarik Creek populations). Rainbows, however, do not spawn in lakes. Most lake-dwelling rainbow trout return to streams to spawn in the spring (Morrow 1980). Russell (1977), however, found rainbow in Talarik Creek that return to the stream in the fall (though they still do not spawn until the following spring). Hartman et al. (1962, 1963, and 1964) also noted rainbows moving from Brooks River into Brooks Lake (both in the Naknek drainage) until late July, followed by a smaller migration from the lake to the river through September. Lake-dwelling rainbows usually move back to the lake three to six weeks after leaving it (Morrow 1980).

Steelhead juveniles remain in the stream for generally one to four years (usually two) (ibid.) and then move downstream in the spring and summer to marine waters. Steelhead are found throughout most of the north Pacific ocean, north of 42° north latitude. Seasonal shifts in distribution of ocean steelhead are associated with changes in water temperature. Steelhead in the North Pacific Ocean generally move north and west in late winter and early spring and shift to a southeasterly movement in late summer, fall, and early winter (Sutherland 1973). All steelhead spawn in the spring; their return migration to the streams, however, may take place in spring, summer, or fall (Jones 1978). Spring-run steelhead are nearly ripe when they enter the stream from late February to mid June, and they spawn that same spring, spending about a month in fresh water (Jones 1975). Summer-run steelhead enter the stream in June and July and do not spawn until the following spring (Jones 1978). Fall-run steelhead return from mid September to November and also do not spawn until spring.

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

Rainbow and steelhead juveniles are subject to predation by various species of fish, including other trout, chars, and coho salmon smolts (Scott and Crossman 1973). Cannibalism also occurs (McAfee 1966). Diving birds (e.g., mergansers and kingfishers) and mammals also take a small number (Scott and Crossman 1973, McAfee 1966).

Young rainbow trout potentially compete with several other fish for food, including other salmonids and sticklebacks (Scott and Crossman 1973, Engel 1970). Adult rainbows compete for food with other bottom feeders and with other predaceous fish (Scott and Crossman 1973).

High winter mortalities of rainbow trout may be caused by physical catastrophies such as dewatering, collapsed snow banks, and anchor ice formation (Needham and Jones 1959, Needham and Slater 1945).

The greatest natural mortality of salmonids occurs during early life stages and is greatly influenced by environmental factors (Straty 1981). These factors include flooding, sedimentation, stream temperature, and scouring of stream beds by ice.

Wallis and Balland (1981) reported spawning mortalities of 80 to 85% in steelhead from the Anchor River. Rainbow trout also suffer from high spawning mortalities (Sundet and Wenger 1984). For more information on spawning mortality, see the Frequency of Breeding section of this report.

B. Human-related

A summary of possible impacts from human-related activities includes the following:

- Alteration of preferred water temperatures, pH, dissolved oxygen, and chemical composition
- Alteration of preferred water velocity and depth
- Alteration of preferred stream morphology
- Increase in suspended organic or mineral material

- Increase in sedimentation and reduction in permeability of substrate
- Reduction in food supply
- Reduction in protective cover (e.g., overhanging stream banks, vegetation, or large rocks)
- Shock waves in aquatic environment
- Human harvest

(See the Impacts of Land and Water Use volume of this series for additional information regarding impacts.)

VIII. LEGAL STATUS

The Alaska Board of Fisheries develops regulations governing the sport harvest of fish in Alaska. Research and monitoring of rainbow trout populations is conducted by the Alaska Department of Fish and Game, Division of Sport Fish.

IX. SPECIAL CONSIDERATIONS

Stocks of Salmo gairdneri from different geographic areas have evolved over time to specific habitat conditions. Thus, environmental requirements for one stock may be different from those of a stock in another area. Therefore, caution must be used when applying information gathered from one geographic location to a stock found in a different area.

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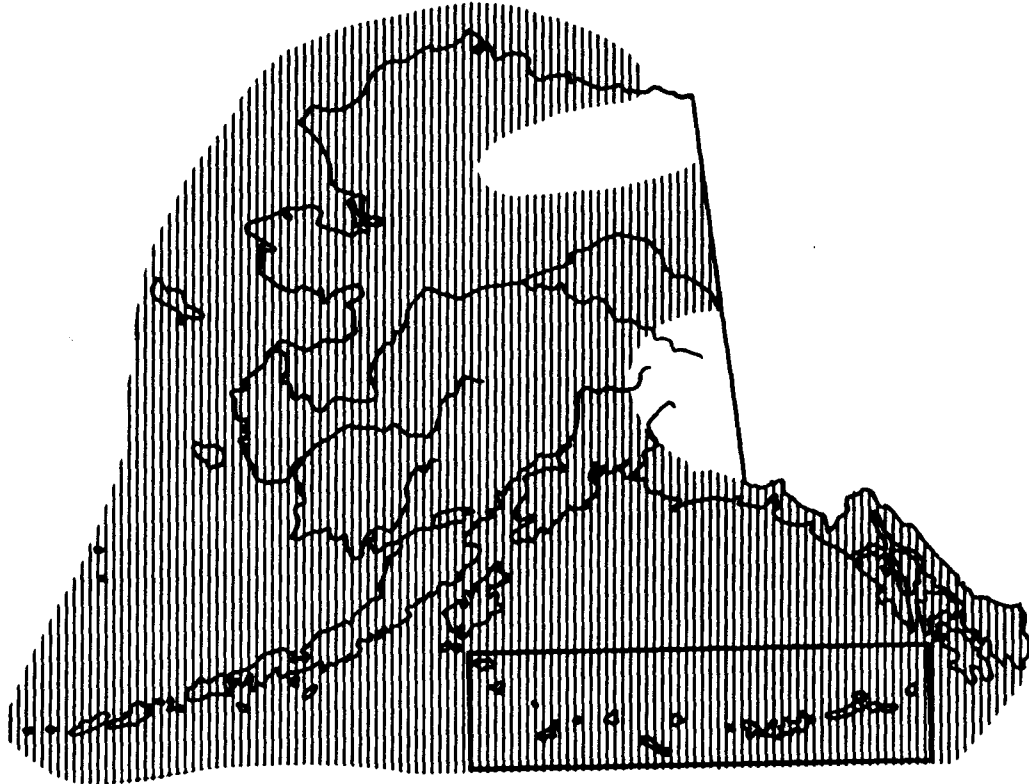
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Chum Salmon Life History and Habitat Requirements
Southwest, Southcentral, Arctic, Western, and Interior Regions



Map 1. Range of chum salmon (ADF&G 1978, Morrow 1980)

I. NAME

- A. Common Names: Chum salmon, dog salmon, keta salmon
- B. Scientific Name: Oncorhynchus keta
- C. Native Names: See appendix A.

II. RANGE

A. Worldwide

Chum salmon have the widest distribution of any of the Pacific salmon. In North America, the chum salmon ranges from the Sacramento River in California (and as far south as Del Mar, about 50 km north of the Mexican border) north to the arctic and east at least as far as the Mackenzie and Anderson rivers in northern Canada. In Asia, they range from the Lena River on the arctic coast of Siberia east and south along the coast to near Pusan,

Korea, and Honshu Island, Japan. They are also found in the Aleutian, Commander, and Kurilei islands (Morrow 1980, McPhail and Lindsey 1970, Hart 1973).

B. Statewide

Chum salmon generally occur throughout Alaska, except for certain streams in the Copper River drainage upstream of Miles Lake (Roberson, pers. comm.) and in the eastern Brooks Range (Hale 1981). Relatively few streams north of the Kotzebue Sound drainage support runs of chum salmon (ibid.).

C. Regional Distribution Maps

To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for each region. In this series, chum salmon distribution information is included on the 1:250,000-scale maps titled Distribution of Anadromous Fish. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of selected fish and wildlife species has been prepared and may be found in the Atlas that accompanies each regional guide.

D. Regional Distribution Summary

1. Southwest. In the Kodiak area, very little escapement information for chum salmon is available. They utilize many of the same streams as pink salmon for spawning (ADF&G 1977b), but the majority of the important chum salmon-producing systems are located on the south shore of the Alaska Peninsula between Cape Douglas and Kaflia Bay and on the east side of Kodiak Island (Pedersen, pers. comm.). In the Bristol Bay area (for waters from Cape Newenham to Cape Menshikof and north-side Alaska Peninsula streams south to Cape Sarichef), the Nushagak, Togiak, and Naknek-Kvichak districts are the major producers of chum salmon (Middleton 1983). Other important runs are also found in the Egegik and Ugashik systems (Russell, pers. comm.) and at Izembek-Moffet lagoons, Bechevin Bay, the Sapsuk River (Nelson Lagoon), Herendeen Bay, Moller Bay, Frank's Lagoon, Port Heiden, and Cinder River (Shaul, pers. comm.). In south-side Alaska Peninsula streams, chum salmon are found at Canoe Bay and in every other major bay east of False Pass (ADF&G 1977a). Unga Island in South Peninsula waters produces moderate numbers of chum salmon compared to other south-side areas (Shaul, pers. comm.). In the Chignik area, the Chignik Lagoon, Amber Bay, Ivanof Bay, Kuikukta Bay, Ivan River, Kujulik Bay, Chiginagak Bay, Agripina Bay, Aniakchak River, Hook Bay, and Nakalilok River support runs averaging several thousand fish each (ibid.). Small runs of chum salmon occur sporadically throughout the Aleutian Islands chain, but few of these would ever be expected to be of commercial importance (Holmes 1984). (For more detailed

narrative information, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)

2. Southcentral. In the Upper Cook Inlet (UCI) area, chum salmon survey and escapement data are limited. Production areas for chum have been identified as Chinitna Bay, west-shore river systems of UCI, and the Susitna River (ADF&G 1982). In Lower Cook Inlet (LCI), chum salmon production areas include Port Graham, Tutka Bay, Dogfish (Koyuktolik) Bay, Island Creek (in Port Dick), Tonsina and Clear creeks in Resurrection Bay, and Port Chatham (ADF&G 1981a). In addition, all streams in the Kamishak Bay District are chum salmon producers. They include the McNeil, Douglas, Big Kamishak, Little Kamishak, Bruin, and Iuiskin rivers and Cottonwood, Sunday, and Ursus Lagoon creeks (Schroeder, pers. comm.).

In the Prince William Sound area, chum salmon stocks exhibit an early, middle, and late run pattern that is linked to geographic distribution and related to stream temperature regimes. Early run (early and mid July) stocks spawn in major, non-lake-fed mainland streams of all districts. Middle-run (late July-mid August) stocks spawn in lake-fed streams of the mainland and most chum salmon streams of the outer island complex. Included in these stocks are the Coghill and Duck river (in Galena Bay) runs, which are the two largest stocks of the middle run. The late-run (mid August-late September) stocks spawn almost exclusively in small spring-fed creeks at the upper ends of Port Fidalgo and Valdez Arm (ADF&G 1978a).

A more detailed narrative regarding chum salmon distribution and abundance in the Southcentral Region is included in volume 2 of the Alaska Habitat Management Guide for the Southcentral Region. (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)

3. Arctic. Major chum salmon-producing systems in the Norton Sound District include the Unalakleet and Fish river drainages and the Shaktoolik, Egavik, Inglutalik, Ungalik, Koyuk, Tubutulik, Kwiniuk, Kachavik, Bonanza, Eldorado, Flambeau, Nome, Snake, and Sinuk rivers (Schwarz, pers. comm.).

Within the Port Clarence District, chum salmon have been documented in the Bluestone, Cobblestone, Agiapuk, and Kuzitrin river systems (ADF&G 1984).

Major chum salmon-producing systems in the Kotzebue District are the Kobuk and Noatak rivers (ADF&G 1977). Important spawning areas in the Kobuk River system are found in the Squirrel, Salmon, and Tutuksuk rivers and the headwaters of the main Kobuk River (ADF&G 1983a). Important spawning areas in the Noatak River system are found in the Eli and Kelly rivers, Eli Lake, and in the main Noatak River (ibid.).

The Northern District of the Arctic Region represents the most northern range of chum salmon in North America. Populations in the area are existing at the outer limits of their environmental tolerances, and their numbers are extremely limited (ADF&G 1977c). First-order streams (those with mouths at salt water) in which chum salmon have been documented include the Pitmegea, Kukpowruk, Kokolik, Utukok, Kuk, Meade, Fish, Colville, Sagavanirktok, and Canning (ADF&G 1984). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Arctic Region.)

4. Western. Both the Kuskokwim and Yukon rivers traverse the Western Region and serve as migration corridors for chum salmon. Important Western Region chum salmon-producing waters of the Kuskokwim River system (i.e., those tributaries located downstream and including the Holitna River drainage) include the Eek, Kwethluk, Kisaralik, Kasigluk, Aniak, Salmon (Aniak River tributary), Kipchuk, Tuluksak, Chukowan, Kogrulkuk, Holitna, Holokuk, George, and Oskawalik river systems (ADF&G 1983b, 1983c). The Yukon River supports a distinct summer and a distinct fall run of chum salmon (ADF&G 1978b). Summer chum salmon spawn primarily in runoff tributaries of the lower 500 mi of the drainage and in the Tanana River system, whereas fall chum salmon migrate farther upstream and spawn in spring-fed tributaries that usually remain ice-free during the winter (ADF&G 1983d). Within that portion of the Yukon River found in the Western Region (i.e., tributaries downstream of the village of Paimuit), chum salmon are found in many of the sloughs, passes, and branches of the river in the delta area and in such tributaries as the Archuelinguk, Andreafsky, and Chuilnak rivers and Kako Creek (ADF&G 1985). Chum salmon are also documented between the Yukon and Kuskokwim rivers on the delta in such systems as the Anerkockik, Azun, Manokinak, Kashunuk, Keoklevik, Ningikfak, Kun, and Kolavinarak rivers (ibid.). South of the Kuskokwim River mouth, chum salmon are known to utilize most of the Kanektok River, the lower portion of the Arolik River, Jacksmith Creek, Cripple Creek, and the Indian and Goodnews rivers for spawning (ADF&G 1977c; Francisco, pers. comm.). On Nunivak Island, the ADF&G (1985) documents 32 streams in which chum salmon have been found. (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Western and Interior regions.)
5. Interior. The Kuskokwim and Yukon rivers serve as pathways for chum salmon bound for spawning areas in the Interior Region. Important chum salmon-producing waters of the Kuskokwim River system in the Interior Region (i.e., those tributaries upstream of the Holitna River drainage) extend to the North, East, and South Forks of the Kuskokwim River and include the Pitka Fork of the Middle Fork Kuskokwim,

Tatlawiksuk, and Cheeneetnuk rivers and Can Creek, a tributary of the Stony River (ADF&G 1983b). The Yukon River supports distinct runs of summer and fall chum salmon. Summer chum salmon spawn primarily in runoff tributaries of the lower 500 mi of the drainage and in the Tanana River system, whereas fall chum salmon migrate farther upstream and spawn in spring-fed tributaries that usually remain ice-free during the winter (ADF&G 1983d). Within the Yukon River drainage of the Interior Region (i.e., those tributaries upstream of the village of Paimuit), important summer chum salmon-producing systems include the Anvik, Nulato, Koyukuk, Melozitna, and Tanana drainages (ibid.). The Porcupine and Tanana river drainages are the two most important systems for fall chum salmon production (Buklis and Barton 1984). Major known spawning areas include the Sheenjek, Chandalar, Toklat, and Delta rivers and the Tanana River near the town of Big Delta (ibid.). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Western and Interior regions.)

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

1. Water quality:

- a. Temperature. Egg hatching and alevin development have occurred in Alaska at temperatures ranging from 0.2 to 6.7°C during the winter months (Hale 1981). Optimal incubation temperatures, however, appear to range between 4.4 and 13.3°C (Bell 1973). Vining et al. (1985), during chum salmon incubation studies in tributary, slough, main stem, and side channel habitats of the middle reach of the Susitna River, Alaska, found that the pattern of accumulation of thermal units for developing salmon embryos varies between spawning habitat types. A general thermal regime describing the incubation period for each type was described as follows (ibid.):

- Tributary habitats typically have intragravel water temperatures that are strongly influenced by surface water temperatures. This results in relatively high intragravel water temperatures during the fall and spring months, with near-freezing water temperatures during the intervening winter months.
- Slough habitats generally have relatively high and more stable intragravel water temperatures during most of the incubation period because of the influence of suitable upwelling sources.
- Main stem habitats are similar to tributary habitats, having winter intragravel water temperature that are strongly influenced by surface water

temperatures. They differ, however, from tributary habitats by having colder water temperatures during fall and spring periods.

- In general, winter intragravel water temperatures in side channel habitats are quite variable and may reflect any of the patterns exhibited by the other habitat types, depending upon the relative influences of and relationships between upwelling and surface water sources.

Emergence from the gravel and downstream migration to the sea have occurred at temperatures between 3.0 and 5.5°C for Delta River fall chum salmon (Raymond 1981); peak movements, however, derived from several stocks, occur at warmer temperatures (i.e., 5.0 to 14°C) (Hale 1981). During laboratory experiments, Brett (1952) found the upper lethal temperature limit of British Columbia chum salmon juveniles to be 23.8°C. Brett and Alderdice (1958), in later experiments, showed the ultimate lower lethal temperatures of juveniles from British Columbia to be 0.1°C.

In Alaska, adult chum salmon have migrated upstream in temperatures ranging from 4.4 to 19.4°C (Hale 1981), with peaks of migration occurring between 8.9 to 14.4°C. Bell (1973) suggests water temperature criteria for successful upstream migration of from 8.3 to 15.6°C, with an optimum of 10°C.

Spawning has occurred in Alaskan waters at temperatures from 6.9 to 12.8°C, with preferred temperature ranges of 7.2 to 12.8°(Hale 1981).

- b. The pH factor. There is no optimum pH value for fish in general; in waters where good fish fauna occur, however, the pH usually ranges between 6.7 and 8.3 (Bell 1973). State of Alaska water quality criteria for freshwater growth and propagation of fish call for pH values of not less than 6.5 or greater than 9.0, with variances of no more than 0.5 pH unit from natural conditions (ADEC 1979).
- c. Dissolved oxygen (D.O.). Laboratory experiments show that the supply of dissolved oxygen to eggs and alevins is of critical importance because a low (less than 1 ppm) supply leads to increased mortality or delay in hatching and/or decreased fitness (Alderdice et al. 1958). These same tests tend to indicate a slow but steady increase in the incipient low oxygen lethal level through development. Early stages exhibit a plasticity in which development may decelerate virtually to zero under extreme hypoxial conditions. In later stages, this plasticity is lost, and oxygen levels that would produce no more than a cessation of development at earlier stages become rapidly lethal. The rate of

supply to the embryos and alevins is influenced primarily by the D.O. concentration of the source water and the rate of flow through the gravel substrate. Dissolved oxygen levels as low as about 2 mg/l can meet the oxygen requirements of eggs and alevins if the rate of flow of intragravel water is sufficient (Kogl 1965, Levanidov 1954). Intragravel D.O. concentrations in the Chena River during incubation of chum salmon eggs ranged from 0.6 to 6.5 mg/l and resulted in low survival rates at the lower concentrations and high survival rates at the higher concentrations (Kogl 1965).

Studies concerning juvenile chum salmon dissolved oxygen requirements summarized by Hale (1981) indicate lower thresholds of 1.5 mg/l at water temperatures of 10°C. Dissolved oxygen levels of 8 to 9 mg/l at 8 to 10°C seem most favorable.

Adult swimming performance can be reduced by levels of D.O. below air saturation (Rieser and Bjornn 1979).

State of Alaska water quality criteria for the growth and propagation of fish state that "D.O. shall be greater than 7 mg/l in waters used by anadromous and resident fish. Further, in no case shall D.O. be less than 5 mg/l to a depth of 20 cm in the interstitial waters of gravel utilized by anadromous or resident fish for spawning. . . . In no case shall D.O. above 17 mg/l be permitted. The concentration of total dissolved gas shall not exceed 110% of saturation at any point of sample collection" (ADEC 1979).

- d. Turbidity. Sedimentation causes high mortality to eggs and alevin by reducing water interchange in the redd. If 15 to 20% of the intragravel spaces become filled with sediment, salmonid eggs have suffered significant (upwards of 85%) mortality (Bell 1973). Prolonged exposure to turbid water causes gill irritation in juveniles that can result in fungal and pathogenic bacterial infection. High suspended sediment loads could be inhibiting to adults attempting an upstream migration (Hale 1981). Exposure can lead to tail rot and reduction of gas exchange across gills by physical damage, coating, or accumulation of mucous (Smith 1978). Turbid water will absorb more solar radiation than clear water and may thus indirectly raise thermal barriers to adult upstream spawning migration (Reiser and Bjornn 1979).

2. Water quantity:

- a. Instream flow. Hale (1981) states, "The flow of water in the stream channel is important to incubating embryos in promoting an adequate intragravel flow and in protecting the substrate from freezing temperatures. Heavy mortality of embryos can occur during periods when

there is a relatively high or a relatively small discharge. Flooding can cause high mortality by eroding eggs from the redds or by depositing fine sediments on the surface of the redds which can reduce permeability or entrap emerging fry. Low discharge periods can lead to dessication of eggs, low oxygen levels, high temperatures, or, during cold weather, freezing."

During laboratory tests in British Columbia, juveniles 25 to 45 mm long when presented with a choice between two 8-cm-wide, 4-cm-deep channels with "laminar" flows preferred 350, 500, 600, and 700 ml/min flows to a flow of 200 ml/min, and the greatest response (i.e., positive rheotaxis) was toward the 500 ml/min flow (Mackinnon and Hoar 1953). In another experiment with "turbulent" water flow, they found that fry seemed to prefer flows of about 5,000 to 12,000 ml/min over either lesser or greater flows. Levanidov (1954) stated that optimum stream velocities to support the feeding of fry in the Amur River, USSR, are less than 20 cm/sec.

There is little information available on the maximum sustained swimming velocity of which adult chum salmon are capable. Chum salmon have less ability than other salmon to surmount obstacles (Scott and Crossman 1973) and in general show less tendency to migrate upstream beyond rapids and waterfalls (Neave 1966). In a study of the migration of adult chum salmon in the middle reach of the Susitna River, Alaska, Blakely et al. (1985) found that the upstream passage criteria were primarily determined by depth of water, were slightly affected by the length of the reach, and were not significantly influenced by channel configuration or substrate size. A brief summary of the water depth thresholds for successful, difficult, and unsuccessful upstream migration is provided in table 1.

During spawning, chum salmon in the Chena River of Alaska make redds in water depths ranging from 5 to 120 cm (Kogl 1965). Those in the side channels and sloughs of the middle reach of the Susitna River seemed to prefer depths of 9.6 to 70.1 cm for spawning, although it was determined that depth alone, if greater than 70.1 cm, would not likely affect chum salmon spawning within the ranges of conditions encountered in the study sites (Vincent-Lang et al. 1984). Water velocity at spawning sites has ranged from 0 to 118.9 cm/sec (Hale 1981). Spawning chum salmon in sloughs and side channels of the middle reach of the Susitna River exhibited a general preference for velocities between 0 and 39.6 cm/sec (Vincent-Lang et al. 1984). The ADF&G (1977) states that optimum stream velocity is 10 to 100 cm/sec (presumably for spawning and incubation).

Table 1. Adult Chum Salmon Passage Criteria Thresholds for Reaches up to 200 ft Long Within Slough and Side Channel Habitats in the Middle Portion of the Susistna River, Alaska

Upstream Movement	Threshold Depths (in Feet)	
	Thalweg ^a	Passage ^b
Successful ^c	0.35 and greater	0.26 and greater
Difficult ^d	0.28 to 0.34	0.20 to 0.25
Unsuccessful ^e	0.12 to 0.26	0.09 to 0.19

Source: Blakely et al. 1985.

a Thalweg depth is the maximum depth in a stream cross-sectional profile.

b Passage depth was defined as an average of the mean depth and the thalweg depth of a passage reach transect and was considered to be a more accurate indicator of the water depth affecting salmon passage. Passage depth values were calculated using the equation, $d_p = 0.75d_t^{1.02}$, where d_p = passage depth, and d_t = thalweg depth.

c Fish passage into and/or within a spawning area was uninhibited.

d Fish passage into and/or within a spawning area was accomplished, but with stress and exposure to predation.

e Fish passage into and/or within a spawning area may be accomplished by a limited number of fish, which, because of excessive exposure, are susceptible to increased stress and predation.

3. Substrate. Egg incubation and alevin development occur in substrates ranging widely in size and composition. Hale (1981) summarizes redd sites by stating that, "in general, chum salmon excavate redds in gravel beds with a particle size of 2 to 4 cm diameter, but they will also construct redds in substrates with particles of a greater size and will even use bedrock covered with small boulders (Morrow 1980, Scott and Crossman 1973). Vincent-Lang et al. (1984) found that spawning chum salmon in sloughs and side channels of the middle reach of the Susitna River seem to prefer substrates of larger gravel and rubble ranging in size from 2.5 cm to 22.8 cm in diameter for spawning. Generally, substrates with a percentage of fine particles (less than 0.833 mm in diameter) greater than 13% are of poor quality because of reduced permeability (Thorsteinson 1965). Chum salmon, however, often spawn in areas of upwelling ground water and may therefore be able to tolerate higher percentages of fines than would seem desirable if some of the fines are kept in suspension by the upwelling water." Studies of slough and side channel habitat within the middle reach of the Susitna River note that spawning chum salmon appear to key on upwelling areas (Vincent-Lang et al. 1984). The ADF&G (1977) observed that spawning usually occurs in riffle areas and that chum salmon generally avoid areas where there is poor circulation of water through the stream bed.
- B. Terrestrial
1. Conditions providing security from predators or other disturbances. Upon emergence from the gravel of short streams, chum salmon juveniles migrate mainly at night and seek cover in the substrate during the daytime if the journey is not completed in one night (Neave 1955). Hoar (1956) found that chum salmon fry, after schooling has occurred during downstream migration, use the protection of schools during daylight and no longer seek protection in the substrate.
 2. Conditions providing protection from natural elements. A gravel substrate was found to prevent yolk sac malformations of alevins reared at 12°C and water velocities of 100cm/hr (Emadi 1973). Alevins reared on a smooth substrate with identical temperature and water velocities were susceptible to yolk sac malformation. Since alevins prefer to maintain an upright position, which is difficult on a flat surface, the swimming activity to right themselves results in continual rubbing on the flat surface, which is thought to injure the yolk and cause malformation (ibid.).

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

Upon hatching, young alevin remain in the gravel for 30 to 50 days until their yolk sacs are absorbed (Bakkala 1970). Bailey et al.

(1975) found that about 63% of the preemergent juveniles excavated from redds in the Traitors River of Southeast Alaska contained items such as sand or detritus in the digestive tract. Of the total sample, however, only 13% contained food organisms that included chironomid larvae and pupae, plecopteran nymphs, ephemeropteran nymphs, and an arachnid. Most chum salmon juveniles begin their downstream migration to the sea soon after emergence. Young chum salmon with only a short distance to travel probably do not feed until they reach the ocean (Morrow 1980). Bailey et al. (1975), however, sampled 40 downstream-migrating chum salmon in the short, coastal Traitors River and found that 22.5% contained substantial numbers of chironomid pupae and plecopteran nymphs. Those that must spend several days to weeks on their journey, however, feed actively on chironomid larvae, cladocerans (water fleas), copepods, nematodes, and a variety of mature and immature insects (Morrow 1980, Scott and Crossman 1973). Stomach contents of chum salmon fry caught in the main stem of the Noatak River, its tributaries, and its backwaters, during the period May through early August 1980 reveal that the fry had fed mainly on the larvae, pupae, and adult forms of insects. Only 4% of the stomach contents were of other types of organisms, and, of these, most were zooplanktors (Merritt and Raymond 1983). The primary insect prey species were of the order Diptera and the order Plecoptera. Other types of insects were represented and included specimens from the orders Ephemeroptera (mayflies), Homoptera, and Hymenoptera. Zooplanktors included specimens from the order Cladocera. Cyclopoid and Harpacticoid forms of the subclass Copepoda were also represented. Some chum salmon fry had also consumed roundworms (Nematoda) (ibid.). During their early sea life they feed on a wide variety of organisms, such as diatoms, many small crustaceans (e.g., ostracods, cirripeds, mysids, cumaceans, isopods, amphipods, decapods), dipterous insects, chaetognaths, and fish larvae (Morrow 1980, Scott and Crossman 1973). Bailey et al. (1975) found that chum salmon fry in Traitors Cove consumed food items that were mostly from 0.3 to 3.0 mm long. They also tended to feed on larger and harder items than did pink salmon, as evidenced by the greater incidence of harpacticoid copepods, collembolans (intertidal spring tails), cumaceans, and chironomids in chum salmon. Benthic and intertidal forms of mysids, cumaceans, isopods, amphipods, and insects were rare in plankton samples, and their presence in some of the stomachs shows that chum salmon did on occasion feed in these ecological niches (ibid.). The food of chum salmon fry caught in the brackish water areas in Kotzebue Sound during June and early July 1980 consisted largely of insects (58%). Zooplankton, which made up most of the remainder, were mostly copepods. During early August of 1981, chum salmon fry caught near Cape Blossom in Kotzebue Sound in more saline water than the 1980 samples were found to be feeding primarily on cladocerans (Chydorinea) and copepods (Merritt and Raymond 1983).

Copepods, tunicates, and euphausiids dominate the diet at sea (Morrow 1980, Scott and Crossman 1973). Other items eaten at sea include other fishes, pteropods, squid, and mollusks.

B. Types of Feeding Areas Used

Because chum salmon spend such a short time in natal water following emergence from the gravel, no data are available on fresh-water feeding locations. At sea, the fish are found from close to the surface down to at least 61 m. There is some indication of vertical movement according to the time of day, with the fish tending to go toward the surface at night and deeper during the day (Manzer 1964). This is probably a response to movements of food organisms (Morrow 1980).

C. Factors Limiting Availability of Food

Chum salmon juveniles that feed while in fresh water eat benthic organisms. Excessive sedimentation may inhibit production of aquatic plants and invertebrate fauna (Hall and McKay 1983) and thereby decrease available food.

D. Feeding Behavior

Juvenile daily food intake while in fresh water increases as water temperatures increase. Levanidov (1955), using aquaria, found that at 4 to 10°C the weight of food eaten daily was 5 to 10% of the body weight; at 12 to 20°C it was 10 to 19% of the body weight.

Bailey et al. (1975), during studies of estuarine feeding habits at Traitors Cove in Southeast Alaska, found that many more food items were contained in the stomachs of juvenile chum salmon collected in daytime than in those collected at night - an average of 124 items versus 4. They also found that the fry fed selectively. Relatively more cladocerans, decapod zoeae, and larvaceans were eaten than appeared in the samples of available planktonic food items. Visual observations of individual chum salmon fry in shore-oriented schools indicate that their feeding varied with the speed of the water current. Bailey et al. (1975) found that "at velocities of 0 to 10.7 cm/s, a fry would typically swim a darting course as much as three times its body length to capture a food item. At higher velocities, 10.8 to 19.8 cm/s, schools of fry sometimes held position relative to the shore or bottom while facing the current, and an individual would typically deviate up, down, or to the sides no more than one-third of its body length to capture oncoming food. At still higher velocities, 19.9 to 24.4 cm/s, fry in schools often held a constant position relative to shore or bottom but did not feed. Fry that appeared to be in visual contact with the shore or bottom avoided currents above 24.4 cm/s unless frightened."

Adult feeding seems to be opportunistic and is based on the availability of, rather than a preference for, certain kinds of food (Le Brasseur 1966). Upon returning to fresh water to spawn, adults cease feeding and obtain energy from body fat and protein (Morrow 1980, Bakkala 1980).

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Chum salmon spawn in waters ranging from short coastal streams, where the adults may spawn within the tidal zone, to large river systems, such as the Yukon River, where they are known to migrate upstream over 2,500 km. Most, however, spawn above the reaches of salt water and within 200 km of the sea (Bakkala 1970). Spawning grounds must provide suitable substrate as well as suitable stream conditions. Many stocks of chum salmon (particularly fall chum) select areas with springwater or groundwater emergence. These areas tend to maintain water flows and temperatures warm enough to keep from freezing during the winter months (Morrow 1980, Hale 1981), as in the lower Delta River southeast of Fairbanks, Alaska, where spawning occurs in several small spring-fed channels whose fall and winter flows are composed entirely of clear upwelling groundwater (Bulkis and Barton 1984). Vining et al. (1985), from studies of artificial chum salmon redds in slough, side channel, tributary, and main stem habitats of the middle reach of the Susitna River, determined that dewatering and freezing of salmon redds were the most important factors contributing to the high levels of embryo mortality found in the habitats used for incubation. In general, they found that these factors were most pronounced in slough habitats that were protected from cold surface water overtopping and where upwelling groundwater was more prevalent. Upwelling is the most significant physical variable affecting the development and survival of chum salmon embryos incubating in the slough and side channel habitats because 1) it eliminates or reduces the likelihood of dewatering or freezing of the substrate environment; 2) it provides a relatively stable intragravel incubation environment, buffering it from variations in local surface water and climatic conditions; and 3) it increases the rate of exchange of intragravel water over the embryos, which enhances the replenishment of dissolved oxygen and the removal of metabolic wastes (ibid.).

B. Reproductive Seasonality

The chum salmon is typically a fall spawner. In Alaska, they ascend the rivers from June to September, the peak spawning for most of the northern populations occurring from July to early September and for southern populations in October or November (Morrow 1980, Hale 1981). Within the Yukon River drainage, summer chum salmon spawn from July through early to mid August, whereas fall chum salmon spawn from September through early November (Barton 1984). On the Alaska Peninsula, spawning occurs from August to early September (Shaul, pers. comm.).

C. Reproductive Behavior

As with other salmon, adult chum salmon return from the sea and move into their natal freshwater streams to spawn. The female selects the spawning site and digs the redd (nest) by turning on her side and thrashing her tail up and down. The current washes loose redd substrate material downstream, and a depression 8 to

43 cm deep is formed in the river bottom (Burner 1951, Bakkala 1970). Eggs and sperm (milt) are released simultaneously and deposited in the redd. After egg deposition, the female moves to the upstream margin of the redd and repeats the digging process. Dislodged substrate is washed over the eggs. In this manner, the eggs are covered and prevented from washing away. The process is repeated, and the redd appears to move upstream (Burner 1951). As a result of the continued digging, the redd may grow to become 1.6 to 3.2 m long and 1.1 to 2.1 m wide (Bakkala 1970). A female may spawn with several males, and a male may mate with more than one female (Morrow 1980).

D. Age at Sexual Maturity

The age at which chum salmon mature sexually ranges from two to seven years, although most mature in their third to fifth year. In general, fish from the southern part of the range return to streams during their third and fourth years, whereas those from the Yukon (and probably other far north rivers) return mostly in their fourth and fifth years (Bakkala 1970, Morrow 1980). In Alaska Peninsula waters, fourth-year chum salmon are normally predominant, followed by significant numbers of third- and fifth-year fish (Shaul, pers. comm.). Fish in their fourth year are usually most common in Southeast Alaska. Fifth-year fish predominate from Prince William Sound northward, with fourth- and sixth-year fish being next in abundance. Seventh- and eighth-year fish are rare (Hale 1981).

E. Fecundity

Fecundity varies by stock and the size of the female and ranges from 1,000 to 8,000 eggs. In Alaska, 2,000 to 3,000 are most common (ibid.). Samples taken from the lower Noatak River north of Kotzebue on September 1, 1981, ranged from 1,860 to 4,190 eggs and averaged 3,120 eggs, which is larger than fecundities reported for other Alaskan chum salmon (Merritt and Raymond 1983).

F. Frequency of Breeding

As with all Pacific salmon, the spawning cycle for chum salmon is terminal. Both male and female die after spawning.

G. Incubation Period/Emergence

The time required for eggs to hatch is dependent upon many interrelated factors, including 1) dissolved oxygen, 2) water temperature, 3) apparent velocity in gravel, 4) biological oxygen demand, 5) substrate size (limited by percentage of small fine material), 6) channel gradient and 7) configuration, 8) water depth, 9) surface water discharge and velocity, 10) permeability, 11) porosity, and 12) light (Reiser and Bjornn 1979, Hale 1981). Generally speaking, factors 4 through 12 influence or regulate the key factors 1, 2, and 3.

The time from fertilization to hatching can range from 1.5 to 4.5 months, depending primarily on water temperature. In Alaska, hatching of eggs occurs from December to February in the southerly parts of the range. The time of hatching in northern Alaska is not definitely known, although studies of spawning grounds in the

Noatak River in northwestern Alaska suggest that egg hatching occurs from late December through January (Merritt and Raymond 1983). Results of three years of study in the Delta River of Interior Alaska reveal that hatching began in early February and was completed by mid March (Buklis and Barton 1984). Vining et al. (1985), during studies of incubation in different habitat types within the middle reach of the Susitna River, found that embryos fertilized on August 26, 1983, and placed in slough, side channel, and main stem habitats reached 100% hatch at approximately late January, late December, and mid April, respectively. Embryos in slough and side channel habitats were influenced by warmer upwelling water, whereas embryos in the main stem were not. The alevins remain in the gravel until the yolk sac is absorbed, 60 to 90 days after hatching, then make their way through the gravel and begin migration to the sea (Morrow 1980). Although rare, chum salmon that have spent at least a year in freshwater lakes and grown to lengths of 160 to 170 mm have been captured at Lake Aleknagik in the Wood River system of Bristol Bay (Roberson, pers. comm.).

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

A. Sizes of Use Areas

From studies of Columbia River tributaries, Burner (1951) suggests that a conservative figure for the number of pairs of salmon that can satisfactorily utilize a given area of spawning gravel may be obtained by dividing the area by four times the average size of the redds. Redd area can be computed by measuring the total length of the redd (upper edge of pit to lower edge of tailspill) and the average of several equidistant widths (Reiser and Bjornn 1979).

The average size of the redd area has been reported to range from 1.0 m² to 4.5 m² (Hale 1981). The ADF&G (1977) states that the optimum size is considered to be 3 m². Schroder (1973) found that the optimum density at which maximum egg deposition occurred ranged from 1.7 to 2.4 m² per female chum salmon. Vining et al. (1985) caution that, because of the effects of dewatering and freezing, the amount of available habitat at the time when adult chum salmon are spawning is a poor indicator of the amount of actual habitat that is available as potential incubation habitat. Estimates of available incubation habitat must take into account the differential effects of dewatering and freezing in various habitat types.

B. Timing of Movements and Use of Areas

Soon after emerging from the gravel, juvenile chum salmon begin moving to the sea. Where known, Alaska specific timing information is contained in the salmon distribution and abundance narratives found in this report series. In studies of Hooknose Creek, British Columbia, Hunter (1959) found that downstream migration in this relatively shallow (13 inches deep), coastal stream is usually at night near the surface of the water and in

the center of the stream, where the currents are strongest. Barton (1978), however, found that out-migrating juvenile chum salmon were captured in similar numbers at all stations sampled across the Yukon River. The sampling location was near the Anuk River, approximately 101 km upstream of Flat Island at the mouth of the Yukon River.

In summarizing several studies conducted in different locations of the Yukon River system, Buklis and Barton (1984) suggest that chum salmon fry out-migrations tend to be correlated with increased or peak water flows following spring breakup.

In their first year at sea, chum salmon migrate to offshore waters of the North Pacific Ocean and Bering Sea.

Adults return to fresh water during the period from June through September. Rates of movement during upstream migration vary greatly. Bakalla (1970) gives the following examples: "Yukon River chum salmon migrated at 80 km per day for the first 1,300 km and 56 km per day for the next 1,100 km. In the Amur River, USSR, the average rate of migration was 115 km per day. In some rivers of Japan where spawning grounds are much closer to the sea, the average rate of travel was 1.9 to 4.2 km per day." Bulkis and Barton (1984), in summarizing several fall chum salmon studies at different locations of the Yukon River system, showed estimates of average upstream migration rates to range from 28 to 39 km per day. They suggested that 37 km per day was the best average migration rate for Yukon River fall chum salmon.

C. Migration Routes

Rivers serve as corridors for smolt out-migration. Adult upstream migration may be hindered or prevented by excess turbidity, high temperatures (20.0°C or more), sustained high water velocities (greater than 2.44m/sec), and blockage of streams (e.g., log jams, beaver dams, and waterfalls) (Reiser and Bjornn 1979).

Once in the sea, the young chum salmon remain close to shore (within 37 to 55 km of the shoreline) during July, August, and September before dispersing into the open ocean (Morrow 1980, Neave et al. 1976). During this time, stocks found along the northern coast of the Gulf of Alaska and south of the Alaska Peninsula probably migrate westward. Stocks found north of the Alaska Peninsula probably move to the southwest (Neave et al. 1976).

From tagging studies, Neave et al. (1976) summarize maturing Alaskan chum salmon movements as follows: "Maturing chums of western Alaskan origin occupy the entire Gulf of Alaska in spring and were found westward along the Aleutians to 179°E. There was no tagging evidence of the presence of Alaskan chums in the Bering Sea before June. The recovery in the Yukon River of a maturing fish tagged in July at 60°N, 174°E, not far from the U.S.S.R. coast, constitutes the westernmost record of a north American chum salmon, as revealed by tagging. Other chums, tagged in the Gulf of Alaska, were found to travel as far north as the Arctic Ocean. The direction of movement in the Gulf of Alaska is westward in

April-June. In the latter month most of the fish pass through the eastern part of the Aleutian Chain and migrate rapidly northward in the Bering Sea. No significant penetration of the Bering Sea by immature fish (from the Gulf of Alaska) was disclosed. Maturing chum salmon originating in central and southeastern Alaska occupy a large part of the Gulf of Alaska in spring but were rarely found west of 155°W. From May to July the fish tend to shift northward into waters from which western Alaska chums have largely withdrawn. Some immature fish move westward along the Aleutians to at least 177°W. No significant penetration of the Bering Sea by immature or maturing fish was indicated."

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

The period the eggs and alevin spend in the gravel is a time of heavy mortality. The survival rate from eggs to fry in natural streams averages less than 10% (Hale 1981).

Scott and Crossman (1973) state that "young chum salmon on the spawning grounds and during downstream migration are preyed upon by cutthroat and rainbow trout, Dolly Varden, coho salmon smolts, and sculpins. . . . kingfisher, merganser, other predaceous birds, and mammals are also responsible for a small loss. Even stonefly larvae and possibly other predaceous insects many prey on eggs and alevins. Water temperature, floods, droughts, other fluctuations in water level, spawning competition, and poor returns of adults, control number of young to a far greater extent." Barton (pers. comm.) states that there is often heavy predation on eggs of spawning fall chum salmon by arctic grayling and mallard ducks in such Yukon River drainage systems as the Delta, Sheenjek, and Toklat rivers.

Murphy (1985) documents the die-off of prespawn adult chum salmon in Porcupine Creek on Etolin Island in Southeast Alaska. The fishes' migration route to spawning areas was blocked at the intertidal stream reach by low stream flow and neap tides. Within four days, about 3,000 pink and chum salmon had collected in a large pool in the intertidal reach of the stream. The crowded fish lowered the dissolved oxygen level to less than 2 mg/l, and some salmon began to die in the center of the pool.

At sea, chum salmon are preyed upon by marine mammals, lampreys, and, in the early sea life, possibly by large fishes. Upon returning to fresh water to spawn, adults fall prey to bears, eagles, osprey, and other mammals (Scott and Crossman 1973).

B. Human-related

A summary of possible impacts from human-related activities includes the following:

- Alteration of preferred water temperatures, pH, dissolved oxygen, and chemical composition
- Alteration of preferred water velocity and depth
- Alteration of preferred stream morphology
- Increase in suspended organic or mineral material

- Increase in sedimentation and reduction in permeability of substrate
- Reduction in food supply
- Reduction in protective cover (e.g., overhanging stream banks or vegetation)
- Shock waves in aquatic environment
- Human harvest

(For additional impacts information see the Impacts of Land and Water Use volume of this series.)

VIII. LEGAL STATUS

A. Managerial Authority

1. The Alaska Board of Fisheries develops regulations governing the commercial, sport, and subsistence harvest of salmon in Alaska. The Alaska Department of Fish and Game manages salmon populations in the fresh waters of the state and in the marine waters to the 3-mi limit.
2. The North Pacific Fishery Management Council is composed of 15 members, 11 voting and 4 nonvoting members. The 11 are divided as follows: 5 from Alaska, 3 from Washington, and 3 from state fishery agencies (Alaska, Washington, Oregon). The four nonvoting members include the director of the Pacific Marine Fisheries Commission, the director of the U.S. Fish and Wildlife Service, the commander of the 17th Coast Guard District, and a representative from the U.S. Department of State.
The council prepares fishery management plans that become federal law and apply to marine areas between the 3-mi limit and the 200-mi limit. With regard to salmon, the only plan prepared to date is the Salmon Power Troll Fishery Management Plan.
3. The International North Pacific Fisheries Commission is a convention comprised of Canada, Japan, and the United States established to provide for scientific studies and for coordinating the collection, exchange, and analysis of scientific data regarding anadromous species.
With regard to salmon, the INPFC has also prepared conservation measures that limit the location, time, and number of fishing days that designated high seas (beyond the 200-mi limit) areas may be fished by Japanese nationals and fishing vessels.

IX. LIMITATIONS OF INFORMATION

Limited life history and habitat information concerning Alaskan chum salmon has been documented. Most of the available information comes from Pacific Northwest and Canadian field and laboratory studies.

X. SPECIAL CONSIDERATIONS

Caution must be used when extending information from one stock of chum salmon to another stock. Environmental conditions from one area must

not be treated as absolute; the stocks (races) have acclimated or evolved over time and space to habitat conditions that can vary greatly.

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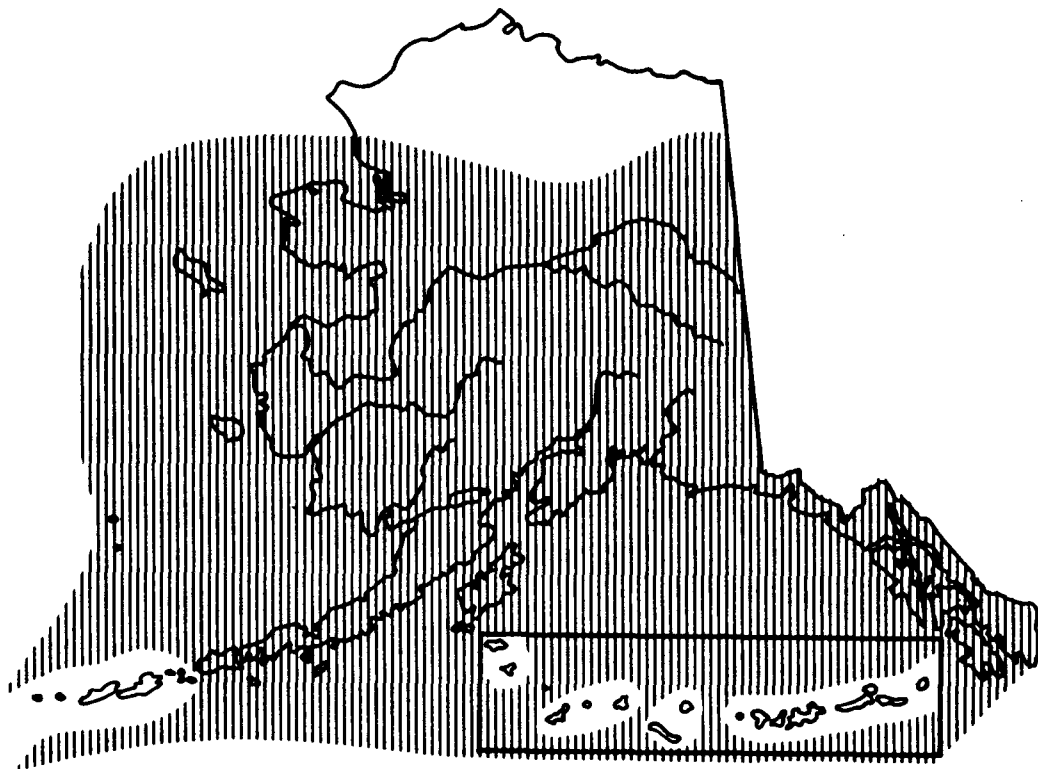
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Chinook Salmon Life History and Habitat Requirements
Southwest, Southcentral, Arctic, Western, and Interior Regions



Map 1. Range of chinook salmon (ADF&G 1978, Holmes 1982)

I. NAME:

- A. Common Names: Chinook salmon, king salmon, spring salmon, tyee, tule, quinnat, blackmouth
- B. Scientific Name: Oncorhynchus tshawytscha
- C. Native Names: See appendix A.

II. RANGE

- A. Worldwide

Chinook salmon are native to the Pacific coasts of Asia and North America, and, except for areas immediately adjacent to the coast, it is possible that they do not occur on the high seas south of about 40°N (Major et al. 1978). In North America, spawning populations range from the Ventura River, California, northward to the Wulik River, Kotzebue Sound, Alaska. Along the Asian coast,

they are found from the Anadyr River, Siberia, south to the Amur River, and they occur in the Komandorskie Islands, USSR, and at Hokkaido Island, Japan (Hart 1973, Major et al. 1978).

B. Statewide

Chinook salmon are found in major river drainages from Southeast Alaska to the Wulik River, Kotzebue Sound, Alaska (Major et al. 1978). During an Aleutian Islands salmon study, Holmes (1982) found that there were no systems in the Aleutian Islands (from Unimak Pass to Attu Island) that would provide for spawning and rearing of chinook salmon.

C. Regional Distribution Maps

To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for each region. In this series, chinook salmon distribution information is included on the 1:250,000-scale maps titled Distribution of Anadromous Fish. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of selected fish and wildlife species has been prepared and may be found in the Atlas that accompanies each regional guide.

D. Regional Distribution Summary

1. Southwest. In the Kodiak area, major chinook salmon spawning and rearing drainages include the Karluk and Red river systems (ADF&G 1977b).

In the Bristol Bay area (for waters from Cape Newenham to Cape Menchikof and north-side Alaska Peninsula streams south to Cape Sarichef), major chinook-producing drainages include the Togiak, Wood, Nushagak, Mulchatna, Alagnak (Branch), and Naknek rivers. Other Bristol Bay drainages supporting lesser runs of chinook salmon include the Egegik, Ugashik, Meshik, Cinder, and Sapsuk rivers (ADF&G 1977a).

Streams on the Alaska Peninsula (south and west of Moffet Bay) and the Aleutian Islands appear to be unsuitable for supporting chinook salmon (ADF&G 1977a, Holmes 1982). Chinook salmon are found in one drainage on the south side of the Alaska Peninsula: the Chignik River system (ADF&G 1977a). (For more detailed narrative information, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)

2. Southcentral. In the Cook Inlet area, major chinook spawning and rearing drainages include the Susitna, Kenai, and Kasilof river drainages. In the Prince Williams Sound area, the Copper River drainage accounts for most of the chinook salmon production (ADF&G 1977b, 1978a). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)

3. Arctic. The presence of chinook salmon has been documented in 13 first-order streams (those with mouths at salt water) within the Norton Sound District (ADF&G 1984). Although other important chinook salmon-producing systems exist in the

area, the Unalakleet River drainage and the Shaktoolik River are considered the major chinook salmon producers in the district (Schwarz, pers. comm.).

Within the Port Clarence District, chinook salmon have been documented in the Kuzitrin River system (ADF&G 1984).

In the Kotzebue District, chinook salmon have been documented in the Buckland, Kobuk, Noatak, Wulik, and Kivalina rivers (ibid.).

Within the Northern District, chinook salmon have been documented in the Kuk and Colville rivers; however, in these systems they are considered strays (Hablett 1979, Bendock and Burr 1984). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Arctic Region.)

4. Western. Both the Kuskokwim and Yukon rivers traverse the Western Region and serve as migration corridors for chinook salmon. Important Western Region chinook salmon-producing waters of the Kuskokwim River system (i.e., those tributaries located downstream of and including the Holitna River drainage) include the Kwethluk, Kisaralik, Aniak, Salmon (Aniak River tributary), Kipchuk, Tuluksak, Chukowan, Kogruluk, Holitna, Hoholitna, Kasigluk, Eek, George, Oskawalik, Holokuk, and Cheeneetnu rivers (ADF&G 1977c, 1978b, 1983). Within the Yukon River system, the Andreafsky River is a major chinook salmon producer of the Western Region (i.e., of those tributaries located downstream of the village of Paimuit) (ADF&G 1977c, Barton 1984). Other known chinook salmon spawning systems of the Western Region include the Kanektok, Arolik, and Goodnews rivers (ADF&G 1977c, 1983). They are located south of the mouth of the Kuskokwim River. (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Western and Interior regions.)
5. Interior. The Kuskokwim and Yukon rivers serve as pathways for chinook salmon bound for spawning areas in the Interior Region. Important chinook-producing waters of the Kuskokwim River system in the Interior Region (i.e., those tributaries upstream of the Holitna River drainage) extend to the North, East, and South Forks of the Kuskokwim River and include the Salmon (tributary of Pitka Fork of Middle Fork Kuskokwim River), Tatlawiksuk, Gagaryah, Big Salmon Fork (tributary of South Fork Kuskokwim River), and Nixon Fork (tributary of Tokotna River) rivers, and Bear Creek (a tributary of the Salmon River that flows into the Pitka Fork of the Middle Fork Kuskokwim River) (ADF&G 1983). Chinook salmon are present in nearly all of the major Yukon River tributaries of the Interior Region (i.e., those upstream of the village of Paimuit) (ADF&G 1977c). A few of these systems include the Anvik, Innoko, Nulato, Rodo, Tozitna, Gisasa, Hogatza, Alatna, Koyukuk, Chandalar, Sheenjek, Porcupine, Black,

Tanana, Kantishna, Toklat, Chatanika, Salcha, Chena, Delta, and Goodpaster rivers (ibid.). Of these, the Anvik, Nulato, Salcha, and Chena rivers are major chinook salmon spawning streams (Barton 1984). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Western and Interior regions.)

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

1. Water quality:

- a. Temperature. Water temperature requirements play an important role in the chinook salmon life cycle and encompass an extremely wide range of temperatures, 0 to 25°C. The ability to survive within this temperature range and specific requirements, however, vary by life stage (i.e., egg, alevin, juvenile, and adult), the temperature to which the fish have been acclimated, and adaptations that specific stocks have made over the course of their evolutionary history. The results of several field and laboratory studies are provided in the following paragraphs.

Egg hatching and alevin development have occurred under a variety of temperature regimes in hatchery and laboratory conditions. Combs and Burrows (1957) found that 100% mortality of eggs from Entiat River and Skagit River Washington stocks occurred when water temperatures in laboratory tests remained constantly at 1.7°C; and they established a temperature range of 5.8 to 14.2°C for normal development if the temperatures remained constant throughout incubation, a situation not likely to occur under natural conditions. In later experiments, Combs (1965) found that Entiat River chinook salmon eggs that had developed to the 128-cell, or early blastula, stage in 5.8°C water could tolerate 1.7°C water for the remainder of the incubation period, with only normal losses. The 128-cell stage was attained after eggs had been incubated for 144 hours in 5.8°C water.

Alderdice and Velson (1978) assembled data from the literature and analyzed the relations between incubation temperature and rate of development from fertilization to 50% hatch of the eggs. They found that early imposition of low (below 6 to 7°C), constant (having a range around a mean not greater than 2°C) temperatures appears to slow egg development below those rates occurring at ambient (average daily temperatures with ranges around a mean greater than 2°C) temperatures having the same mean values. Information in these analyses included constant temperature values ranging from 1.6 to 18.1°C and

ambient temperature values ranging from 2.3 to 16.4°C (ibid.).

The juvenile (including fry, fingerling, and parr stages of development) upper lethal limit was found to be 25.1°C under laboratory conditions (Brett 1952). During the same experiment, he found that young chinook salmon were very sensitive to low temperatures. The lower lethal temperature, however, could not be precisely defined because it appears to be conditioned by the size of the juvenile, the temperature to which the juvenile has been acclimated, the length of time it is exposed to low temperatures, and the osmotic balance. For young chinook salmon from Dungeness, Washington, hatchery stocks acclimated to 23°C, the lower lethal temperature was 7.4°C.

Chinook salmon eggs were hatched at the ADF&G Crooked Creek Hatchery near Soldotna, Alaska, in waters with gradually decreasing, fluctuating mean daily temperatures ranging from 11.1 to 4.4°C (in 1981) and 11.7 to 6.7°C (in 1982). Within five weeks after hatching, the water temperature dropped to 0°C. The alevin were successfully incubated at this temperature and within 4.5 months had absorbed their yolk sacs. The fry were then transferred to rearing ponds that contained 0°C waters, and feeding was begun. During both years, the pond water temperatures remained at 0°C for at least 70 days following the introduction of the fry. During this time, the young fish fed and grew (Och, pers. comm.).

Adult spawning studies in the Columbia River watershed revealed that temperatures at redd sites ranged from 8.3 to 11.7°C, 4.4 to 16.7°C, and 5.6 to 16.1°C for the spring, summer, and fall runs, respectively (Burner 1951). Burrows (1960) indicates that Columbia River female chinook salmon in holding ponds apparently lost all inclination to spawn naturally when the water temperature dropped abruptly below 4.4°C.

- b. The pH factor. There is no optimum pH value for fish in general; however, in waters where good fish fauna occur, the pH usually ranges between 6.7 and 8.3 (Bell 1973). State of Alaska water quality criteria for freshwater growth and propagation of fish specify pH values of not less than 6.5 or greater than 9.0, with variances of no more than 0.5 pH unit from natural conditions (ADEC 1979).
- c. Dissolved oxygen (D.O). Silver et al. (1963), during laboratory studies, found that low (1.6 ppm) dissolved oxygen concentrations caused total mortality of chinook embryos in 11°C waters flowing at rates of 82,570 and 1,310 cm/hr. They also found that oxygen concentrations of 2.5 ppm and more (3.5, 5.6, and 8.0 ppm) resulted in

low prehatching mortalities similar to controls reared at 11.7 ppm. Further, embryos reared to hatching at low and intermediate (2.5 to 8.0 ppm) concentrations produced smaller sacfry than did embryos reared at high (11.7 ppm) concentrations.

Whitmore et al. (1960) noted that juvenile chinook salmon showed marked avoidance of mean oxygen concentrations near 1.5, 3.0, and 4.5 ppm in laboratory experiments when summer water temperatures were high (means of 18.4 to 22.8°C). They also noted that juvenile chinook salmon showed little avoidance of concentrations near 4.5 ppm in the fall when water temperatures were low (means of 8.1 to 13.2°C) and that no avoidance of concentrations near 6.0 ppm occurred regardless of the temperature range.

Adult swimming performance is adversely affected by reduction of D.O. concentrations below air saturation level. Bell (1973) states that it is desirable that D.O. concentrations be at or near saturation and that it is especially important in spawning areas where D.O. levels must not be below 7 ppm at any time. State of Alaska water quality criteria for growth and propagation of fish state that "D.O. shall be greater than 7 mg/l in waters used by anadromous and resident fish. Further, in no case shall D.O. be less than 5 mg/l to a depth of 20 cm in the interstitial waters of gravel utilized by anadromous or resident fish for spawning. In no case shall D.O. above 17 mg/l be permitted. The concentration of total dissolved gas shall not exceed 110% of saturation at any point of sample collection."

- d. Turbidity. Sedimentation causes high mortality in eggs and alevin by reducing water interchange in the redd. If 15 to 20% of the intragravel spaces become filled with sediment, salmonid eggs have suffered significant (upwards of 85%) mortality (Bell 1973). Prolonged exposure to turbid water causes gill irritation in juveniles that can result in fungal and pathogenic bacterial infection. Excess turbidity from organic materials in the process of oxidation may reduce oxygen below safe levels, and sedimentation may smother food organisms and reduce primary productivity (ibid.). Turbid water will absorb more solar radiation than clear water and may thus indirectly raise thermal barriers to migration (Reiser and Bjornn 1979).

2. Water quantity:

- a. Instream flow. Sufficient water velocity and depth are needed to allow proper intragravel water movement (apparent velocity) so that dissolved oxygen is transported to eggs and alevin and, in turn, metabolic wastes are removed (ibid.). Juveniles are closely

associated with low (3.0-60.0 cm/sec, depending on fish size) velocities and are typically found in pools along the margins of riffles or current eddies (Burger et al. 1983: Kenai River). Kissner (1976), during studies on the meandering Nahlin River (in the Taku River drainage of Southeast Alaska), found that the highest densities of juvenile chinook salmon were located on the steep sides of S-curves below riffles. Measured depths of juvenile rearing areas range from 0.15 to 0.30 m in Idaho (Everest and Chapman 1972), with water velocities of less than .5 m/sec. Burger et al. (1983) indicate that juvenile chinook salmon utilize depths up to 3 m when water velocities are not limiting and avoid depths less than 6.0 cm during their free-swimming stage.

Velocity is also important to juveniles because it is the most important parameter in determining the distribution of aquatic invertebrates (food sources) in streams (Reiser and Bjornn 1979).

Excessive velocities and shallow water may impede migrating fish. Thompson (1972) indicates that Pacific Northwest chinook salmon require a minimum depth of .24 m, with velocities less than 2.44 m/sec for migration. No measurement of Alaskan waters for adult migration criteria is available.

Velocity is also important in redd construction because the water carries dislodged substrate materials from the nesting site. Measured flow rates at 0.12 m above the streambed include 0.186 to 0.805 m/sec in Oregon and 0.305 to 1.144 m/sec in the Columbia River tributaries (Smith 1973). Minimum water depths at the spawning sites ranged from 0.183 to 0.305 m in Oregon and 0.381 to 1.983 m in Columbia River tributaries (ibid.). Burger et al. (1983), in a Kenai River tributary stream, found redds at depths from 61.0 to 70.2 cm. Their velocity measurements at 0.6 of total depth had mean values of 39.6 to 94.5 cm/sec pit velocity and 70.2 to 115.9 cm/sec tailspill velocity. Burger et al. (1983) also suggest that mainstream spawning might occur in depths from 1.0 to 2.8 m, with velocities near the bottom (0.2 total depth) ranging from 0.3 to 1.4 m/sec. Vincent-Lang et al. (1983) determined from studies of four Susitna River tributary streams that suitable chinook salmon spawning depths ranged from 0.15 to 1.22 m, with depths of 0.3 to 0.48 being most often used in the study areas. Suitable mean water column velocities as measured at the upstream end of each redd ranged from 0.09 to 1.37 m/sec, with velocities of 0.5 to 0.7 m/sec being most often used. Water velocities in these studies were measured at 0.6 of the total depth

(from the surface of the water) if the total depth was less than 0.76 m. If total depths exceeded 0.76 m, measurements were made at 0.2 and 0.8 of the total depth (from the surface) and then averaged. Mean velocities less than 0.09 m/sec were not utilized for spawning, and those greater than 1.37 m/sec were considered unsuitable for spawning (ibid.).

3. Substrate. Egg incubation and alevin development occur in substrates ranging widely in size and composition. Successful growth and emergence has been recorded in areas with the following bottom materials:

- ° 1.9 to 10.2 cm diameter materials (Bell 1973)
- ° 5% mud/silt/sand, 80% 15.2 cm in diameter to heavy sand, 15% larger than 15.2 cm diameter (averages of Burner 1951: Columbia River tributaries)
- ° 11.3% less than 0.8 cm, 28.7% 0.8 to 1.6 cm, 45% 6.4 to 1.6 cm, 15% 12.7 to 6.4 cm (mean values of Burger et al. 1983: Kenai River tributary)
- ° 15.5% less than 0.8 cm, 17.9% 1.6 to 0.8 cm, 46.4% 6.4 to 1.6 cm, 20.2% 12.7 to 6.4 cm (mean values of Burger et al. 1983: Kenai River mainstream)

Generally, sediments less than .64 cm diameter should comprise less than 20 to 25% of the incubation substrate (Reiser and Bjornn 1979).

Substrate composition regulates production of invertebrates, which are food sources for juveniles. Highest production is from gravel and rubble-size materials associated with riffle areas (ibid.). Substrate is important to juveniles during winter months when temperatures fall and the streambed becomes partially dewatered. During this period, many juvenile chinook salmon burrow into the substrate (Bjornn 1971, Edmundson et al. 1968: in Idaho) and do not begin growing again until the following spring (Everest and Chapman 1972). Studies on the Kenai River from late fall to early spring found juvenile chinook salmon throughout reaches with large cobble substrate and water velocities under 30 cm/sec. In river sections without large substrate materials, chinook salmon were observed to school in pool-riffle interfaces and remained close to cover such as log debris and/or surface ice, if these were present (Burger et al. 1983).

B. Terrestrial

1. Conditions providing security from predators or other disturbances. Overhanging vegetation along shorelines and undercut banks serves as cover for juveniles and adults during spring and summer high-flow conditions. At other times, many (49 to 52%) of the juveniles were found within one swimming burst of cover provided by overhanging banks, tree stumps and branches, and large boulders (ibid.).
2. Protection from natural elements. Bank irregularities provide small pools and current eddies, with little or no

velocities, for rearing juveniles (ibid.). Kissner (1977) found that juvenile chinook salmon were closely associated with log jams and cover in the main channels of the Taku River and in places where the river braided and the water was shallow.

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

Upon hatching, young alevin remain in the gravel for two to three weeks until the yolk sac has been absorbed. Following emergence from the redd and while still in fresh water, juveniles feed on plankton, aquatic insect larvae, terrestrial insects, salmon eggs, and spiders (Scott and Crossman 1973, McLean et al. 1977). They are characterized as opportunistic drift and benthic feeders (Beauchamp et al. 1983). Juvenile chinook salmon food habitat studies during August and September in sloughs and clearwater tributaries of the middle reach of the Susitna River suggest that the range and diversity of invertebrates in their diet indicate an ability to adapt to variable conditions (ADF&G 1982). Specimens collected during the study had consumed both terrestrial and aquatic invertebrates. Midges (Diptera: Chironomidae) were the numerically dominant taxa and were consumed as larvae, pupae, and adults. Chironomid adults and terrestrial invertebrates caught on the water surface, as opposed to immature insects drifting in the water column, were often an important food item for juvenile chinook salmon (ibid.). Upon migration to the sea, young chinook salmon eat crab larvae, amphipods, copepods, euphasiids, cladocerans, barnacles, and a variety of small fish, such as sand lance, eulachon, herring, rockfish, and smooth tongue (Hart 1973). Adults eat fish, squid, euphasiids, shrimps, and crab larvae (Major 1978). Fishes make up the bulk (97%) of the food of marine adults, with herring and sand lance being the most frequently eaten (Scott and Crossman 1973). Crustaceans (composed dominantly of euphasiids but including young crabs, crab megalops, and other miscellaneous forms) are eaten in considerable numbers in the spring months (May and June), as documented by Prakash (1962) in studies off the coast of British Columbia. Merkel (1957) made a similar finding for chinook salmon in the marine waters near San Francisco, California, where euphasiids dominated the diet during April and May. Major (1978) suggests that the diet of adult chinook salmon at sea is related to the types and abundance of food items available.

B. Types of Feeding Areas Used

Juveniles feed in low-velocity areas of streams and rivers, such as riverbank pools formed by bank irregularities (Burger et al. 1983) and in the pools below riffles, where drifting invertebrate material provides a ready food supply. During the first year at sea, the young fish stay near shore. During the second and subsequent years, chinook salmon are far-ranging, undertake extensive migrations, and are found over a wide range of depths,

from surface waters to depths exceeding 100 m. It is not unusual to encounter them at depths ranging from 20 to 110 m (Major 1978).

C. Factors Limiting Availability of Food

Sedimentation is one of the major factors that affects freshwater food availability. Excessive sedimentation may inhibit production of aquatic plants and invertebrate fauna (Hall and McKay 1983). Bell (1973) states that primary food production is lowered above levels of 25 JTU (Jackson Turbidity Unit) and visual references lost above levels of 30 JTU.

D. Feeding Behavior

Chinook salmon are opportunistic feeders. Food consumption is related directly to the types and abundance of items available (Major 1978), although juvenile chinook salmon in fresh water do not seem to utilize fish as food (Scott and Crossman 1973, Morrow 1980). Upon returning to fresh water, adult salmon no longer feed but live off the fat stored up in the ocean (Netboy 1974).

V. REPRODUCTIVE CHARACTERISTICS

A. Breeding Habitat

The general nature of the spawning ground, which may be located from just above tidal limits to great distances upstream (over 3,200 km in the Yukon River), varies considerably (Major 1978). Main channels and tributaries of larger rivers serve as the major chinook spawning areas (Scott and Crossman 1973). Normally, the spawning grounds are characterized by stream underflow (downwelling currents or intragravel flow) created by the depth and velocity of the water, rather than being associated with the emergence of groundwater (Vronskiy 1972, Burner 1951). Vronskiy found that 95% of the redds in the Kamchatka River, USSR, were situated precisely at the transition between a pool and a riffle. Burger (1983) found that many chinook salmon redds were located near the upstream tips of vegetated islands in the Kenai River where loose, clean gravels aggraded and where predominant substrates ranged from 1.6 to 6.4 cm diameter materials. Areas just below log jams, where flow through the gravel is increased as a consequence of reduced surface flow, are also favorite spawning sites (Major 1978).

Exceptions to what may be considered normal breeding habitat and behavior have been documented. During late October and early November 1965, approximately 50 chinook salmon from University of Washington hatchery stocks spawned in groundwater seepage areas of gravel and sand beaches in Lake Washington (Roberson 1967). This behavior is believed to have resulted from crowding and high water temperatures, both unfavorable conditions, at the hatchery homing pond. Although the returns were similar in 1964, 1965, and 1966, the biomass in 1965 was 1.81 and 1.82 times that in 1964 and 1966, respectively. A decline in the rate of entry was noted in 1965, when water temperatures rose to about 14.4°C during peak entry. In 1965 and 1966, the water temperature dropped from about 14.4 to 11.1°C during the entry period. Also, during the 1965 return, the

water temperatures remained .6 to 1.4°C warmer for the remainder of the run than during the same time frames in 1964 and 1966. A sample of several redds, approximately two weeks after spawning had occurred, revealed that, of all eggs recovered, most had been fertilized, but all were dead (ibid.).

B. Breeding Seasonality

In Alaska, mature chinook salmon ascend the rivers from May through July. Generally, fish that appear at the river mouth earliest migrate farthest (Scott and Crossman 1973). Peak spawning occurs from July through September (Morrow 1980).

C. Breeding Behavior

As with other salmon, adult chinook salmon return from the sea and normally move into their natal freshwater streams to spawn. The female selects the spawning site and digs the redd (nest) by turning on her side and thrashing her tail up and down. The current washes loosened substrate material downstream, and a depression 35 to 60 cm deep is formed in the river bottom (Burner 1951, Morrow 1980, Major 1978). Eggs and sperm (milt) are released simultaneously and deposited in the redd. After egg deposition, the female moves to the upstream margin of the redd and repeats the digging process. Dislodged substrate is washed over the eggs. In this manner, the eggs are covered and prevented from washing away. The process is repeated many times, and the redd appears to move upstream (Burner 1951). As a result of the continued digging, the redd may grow to become 1.3 to 5.6 m in length and 1.5 to 3.3 m wide (Morrow 1980, Burger et al. 1983). A female may dig several redds and spawn with more than one male (McPhail and Lindsey 1970). Males may also spawn with several females (ADF&G 1977, Morrow 1980).

D. Age at Sexual Maturity

The age at which chinook salmon reach sexual maturity ranges from two to eight years (generally zero to two years in fresh water and one to seven years at sea), although the vast majority of the fish mature in their third to sixth year. Age at maturity, like freshwater age and ocean age, tends to be greater in the north than in the south because more northern populations spend a longer time at sea (Major 1978, Scott and Crossman 1973). From California northward to Cook Inlet, Alaska, for example, three, four, and five-year-old fish prevail (there are significant numbers of six-year-olds in some areas, but few if any seven- or eight-year-olds). Five- and six-year-olds dominate runs from Bristol Bay northward, but seven- and eight-year-olds are not uncommon (Major 1978).

E. Fecundity

Chinook salmon fecundity varies by stock and the size of the female; however, northern stocks generally produce more eggs. In Alaska, the number of eggs ranges from 4,242 to 17,255 per female (Morrow 1980, Burger et al. 1983).

F. Frequency of Breeding

As with all Pacific salmon, the spawning cycle is terminal. Both male and female die after spawning.

G. Incubation Period/Emergence

The amount of time required for eggs to hatch is dependent upon many interrelated factors, including 1) dissolved oxygen, 2) water temperature, 3) apparent velocity in gravel, 4) biological oxygen demand, 5) substrate size (limited by percentage of small fine material), 6) channel gradient and 7) configuration, 8) water depth, 9) surface water discharge and velocity, 10) permeability, 11) porosity, and 12) light (Reiser and Bjorhn 1979, Hart 1973). Generally speaking, factors 4 through 12 influence/regulate the key factors 1, 2, and 3.

Eggs require about 900 temperature units (TU) to hatch and become alevins and an additional 200 to 800 TUs to absorb their yolk sac (Burger et al. 1983). The TUs for one day = mean 24-hour water temperature in degrees Fahrenheit - 32°F + 1°F if the mean temperature is 32°F. Incubation of the eggs takes place with both ascending and descending water temperatures (Scott and Crossman 1973). Depending on the time of spawning and the water temperature, the eggs usually hatch in late winter or early spring (Gusey 1979). The newly hatched fish, or alevins, remain in the gravel until the attached yolk sac has been absorbed, normally two to three weeks after hatching. The juveniles then work their way up through the gravel to become free-swimming, feeding fry (Morrow 1980).

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

A. Size of Use Areas

From studies of Columbia River tributaries, Burner (1951) suggests that a conservative figure for the number of pairs of salmon that can satisfactorily utilize a given area of spawning gravel may be obtained by dividing the area by four times the average size of the redds. The redd area can be computed by measuring the total length of the redd (upper edge of pit to lower edge of tailspill) and the average of several equidistant widths (Reiser and Bjornn 1979). Burger et al. (1983) list mean measurements for a Kenai River tributary stream, indicating that chinook salmon redds are about 4.37 m² in size. Mean values for mainstream Kenai River chinook salmon redds, however, are 6.38 m². Vining et al. (1985), from chum salmon incubation studies of main stem, tributary, side channel, and slough habitats within the middle reach of the Susitna River, Alaska, caution that because of the effects of dewatering and freezing, the amount of available habitat at the time when adult salmon are spawning is a poor indicator of the amount of actual habitat that is available as potential incubation habitat. Estimates of available incubation habitat must take into account the differential effects of dewatering and freezing in various habitat types.

B. Timing of Movements and Use of Areas

Young-of-the-year juveniles move downstream in the fall to overwinter in areas of the stream with larger substrate (possibly because it provides better cover) (Bjornn 1971, Burger et al. 1983). Out-migrating smolt bound for the sea depart fresh water in the springtime. Major and Mighell (1969), during studies on the Yakima River, Washington, noted that smolt out-migrations tended to be nocturnal. Where known, Alaska specific timing information is contained in the salmon Distribution and Abundance narratives found in this report series.

Adults return to fresh water during the period of May through July. Studies on the Kenai River (Burger et al. 1983) indicate that of all radio-tagged adults returning to the spawning grounds, most moved between 1400 and 2200 hours. Neave (1943), during studies of the Cowichan River, Vancouver Island, British Columbia, found that adult chinook salmon moved upstream mainly in the daytime.

C. Migration Routes

Large rivers serve as corridors for smolt out-migration. Barriers to adult upstream movement include excess turbidity, high temperatures (20.0°C or more), sustained high-water velocities, and blockage of streams (log jams, waterfalls) (Reiser and Bjornn 1979). While in the marine environment, first-year ocean fish are confined primarily to coastal areas and are much less abundant in the open ocean (Major 1978). During the second and subsequent years of ocean life, they are found widely distributed in the North Pacific Ocean and Bering Sea. Morrow (1980) states that chinook salmon from Alaskan streams enter the Gulf of Alaska gyre and move extensively across the North Pacific. In the spring, they seem to be scattered across the northern Pacific and in the Bering Sea, and during the summer their numbers increase in the area of the Aleutian Islands and in the western Gulf of Alaska. Many of the inshore fish of Southeast Alaska, however, appear to be of local origin (Morrow 1980).

Major (1978) suggests that except for areas immediately adjacent to the coast it is possible that chinook salmon do not occur in the high seas south of 40°N. The central Bering Sea is a feeding ground and migration path for immature chinook salmon in Western Alaska (defined as the area from and including Bristol Bay northward to Point Hope). Tag recoveries are known to occur in the Bering Sea as far west as 172°12'E (at 59°03'N), whereas scale-pattern and maturity studies, combined with seasonal distribution and Japanese mothership and research vessels information, push the range further west, to probably at least 160° to 165°E (Major 1978). These same stocks have been found as matures in the North Pacific Ocean just south of Adak at 176°18'W (at 51°36'N). Scale-pattern analysis shows tentatively that they may extend from 160°-170°E to at least 175° W; but their distribution to the south over this range, at least beyond 50° N, is even more uncertain (ibid.).

Other North American chinook salmon (including stocks from central Alaska [Cook Inlet] southward) are known to occur as immatures in the North Pacific Ocean as far west as 176°34'W (at 51°29'W) (ibid.). Recent coded-wire tag recoveries of chinook salmon marked in Oregon, Southeast Alaska (Stikine River and Little Port Walter), and Southcentral Alaska (Crooked Creek, a tributary of the Kasilof River on the Kenai Peninsula) indicate that these stocks occur in the southeastern Bering Sea north of the Alaska Peninsula (Meyers et al. 1984). Tag recoveries occurred during the months of November, February, April, and May in an area from 54°21' to 55°26'N and 165°21' to 167°58'W (ibid.). The tag recovery of the Crooked Creek fish at 55°26'N, 167°58'W was a definite range extension of Southcentral Alaska chinook salmon stocks into the Bering Sea (Wertheimer and Dahlberg 1983).

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

Juvenile chinook salmon are preyed on by other fish (e.g., rainbow, cutthroat, Dolly Varden, coho salmon smolts, and sculpins) and birds (e.g., mergansers, king fishers, terns, osprey, other diving birds). Estuarine and marine predators include fish-eating birds, pelagic fishes, killer whales, seals, sea lions, and possibly the Pacific lamprey (Scott and Crossman 1973, Beuchamp et al. 1983).

The greatest natural mortality occurs in fresh water during the early life stages and is greatly influenced by the environment (Straty 1981); therefore, deleterious changes in freshwater quality, quantity, or substrate are most detrimental.

Flooding can either wash away or bury eggs. Natural sedimentation can smother eggs.

B. Human-related

A summary of possible impacts from human-related activities includes the following:

- Alteration of preferred water temperatures, pH, dissolved oxygen, and chemical composition
- Alteration of preferred water velocity and depth
- Alteration of preferred stream morphology
- Increase in suspended organic or mineral material
- Increase in sedimentation and reduction in permeability of substrate
- Reduction in food supply
- Reduction in protective cover (e.g., overhanging stream banks, vegetation, or large rocks)
- Obstruction of migration routes
- Shock waves in aquatic environment
- Human harvest

(For additional impacts information, see the Impacts of Land and Water Use volume of this series.)

VIII. LEGAL STATUS

A. Managerial Authority

1. The Alaska Board of Fisheries develops regulations governing the commercial, sport, and subsistence harvest of salmon in Alaska. The Alaska Department of Fish and Game manages salmon populations in the fresh waters of the state and the marine waters to the 3-mi limit.
2. The North Pacific Fishery Management Council is composed of 15 members, 11 voting and 4 nonvoting members. The 11 are divided as follows: 5 from Alaska, 3 from Washington, 3 from state fishery agencies (Alaska, Washington, Oregon). The four nonvoting members include the director of the Pacific Marine Fisheries Commission; the director of the U.S. Fish and Wildlife Service; the commander, 17th Coast Guard District; and a representative from the U.S. Department of State.
The council prepares fishery management plans, which become federal law and apply to marine areas between the 3-mi limit and the 200-mi limit. With regard to salmon, the only plan prepared to date is the Salmon Power Troll Fishery Management Plan.
3. The International North Pacific Fisheries Commission (INPFC), a convention comprised of Canada, Japan, and the United States, has been established to provide for scientific studies and for coordinating the collection, exchanges, and analysis of scientific data regarding anadromous species.
With regard to salmon, the INPFC has also prepared conservation measures that limit the location, time, and number of fishing days that designated high seas (beyond the 200-mi limit) areas may be fished by Japanese nationals and fishing vessels.

IX. SPECIAL CONSIDERATIONS

Caution must be used when extending information from one stock of chinook salmon to another stock. Environmental conditions for one area must not be treated as absolute; the stocks (races) have acclimated or evolved over time and space to habitat conditions that can vary greatly.

X. LIMITATIONS OF INFORMATION

Very little life history and habitat information concerning Alaskan chinook salmon has been documented. Most of the available information comes from Pacific Northwest and Canadian field and laboratory studies.

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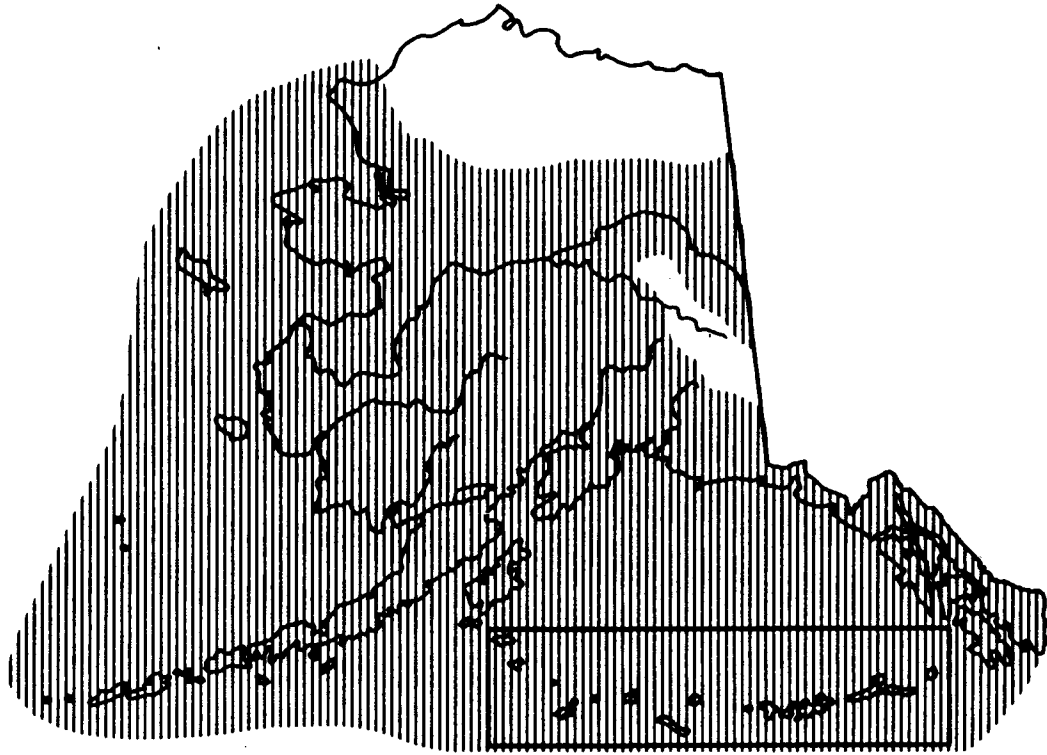
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Coho Salmon Life History and Habitat Requirements
Southwest, Southcentral, Arctic, Western, and Interior Regions



Map 1. Range of coho salmon (ADF&G 1978, Morrow 1980)

I. NAME

- A. Common Names: Coho salmon, coho, silver salmon, sea trout
- B. Scientific Name: Oncorhynchus kisutch
- C. Native Names: See appendix A.

II. RANGE

A. Worldwide

The coho salmon occurs naturally in the Pacific Ocean and its drainages. In North America, it is found from Monterey Bay, California, north to Point Hope, Alaska. In Asia, it occurs from the Anadyr River in northeastern Siberia south to Hokkaido, Japan (Scott and Crossman 1973).

B. Statewide

In Alaska, coho salmon are abundant from Dixon Entrance (Southeast Alaska) north to the Yukon River. Evidence suggests that coho

salmon are rare north of Norton Sound (ADF&G 1977) although ADF&G documents them as far north as Kuchiak Creek, which is located northeast of Cape Lisburne and immediately south of Kasegaluk Lagoon.

C. Regional Distribution Maps

To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for each region. In this series, coho salmon distribution information is included on the 1:250,000-scale maps titled Distribution of Anadromous Fish. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of selected fish and wildlife species has been prepared and may be found in the Atlas that accompanies each regional guide.

D. Regional Distribution Summary

1. Southwest. In the Kodiak area, many streams have runs of coho salmon; however, the runs are late in the season, and escapement figures are incomplete (ibid.).

In the Bristol Bay area (for waters from Cape Newenham to Cape Menshikof and northside Alaska Peninsula streams south to Cape Sarichef), major coho salmon-producing drainages include the Togiak and Nushagak systems, with smaller runs found in the Kulukak, Naknek, Kvichak, Egegik, and Ugashik systems (Middleton 1983). Further south on the Alaska Peninsula, important north-side coho salmon-producing systems are found at Nelson Lagoon, Port Heiden, and Cinder River. Smaller fisheries also exist at Swanson Lagoon and Ilnik (Shaul, pers. comm.).

For south-side Alaska Peninsula streams and the Aleutian Islands, data are scarce concerning coho salmon production. The best known runs on the South Peninsula occur in Russel Creek, Mortensen Lagoon, and Thin Point Cove at Cold Bay (ADF&G 1977a). A few streams on Unalaska Island and several small drainages in the Aleutian Islands contain coho salmon, but the size of the run is unknown (Holmes, pers. comm.). It is known that the Chignik River system produces most of the coho salmon utilized by the commercial fishery in the Chignik area. Other streams in the Chignik area also contain coho salmon, although the size of the runs is not known (ADF&G 1977a). (For more detailed narrative information, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)

2. Southcentral. In the Upper Cook Inlet area, major coho salmon spawning and rearing drainages include the Susitna, Kenai, and Kasilof river systems (McLean et al. 1977a). In the Lower Cook Inlet area, coho salmon are found in the English Bay lakes system, Clearwater Slough, and the Douglas, Big Kamishak, Little Kamishak, and McNeil river systems (ADF&G 1983b). In the Prince William Sound area, coho salmon

are the dominant species in the Bering River (ADF&G 1978a). They are also found in numbers in the Copper and Katalla river drainages (ADF&G 1978a, 1983c). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)

3. Arctic. In the Norton Sound District, coho salmon have been documented in 19 first-order streams (those with mouths at salt water) (ADF&G 1984). Although not the only significant coho salmon-producing systems, the Unalakleet River drainage and the Shaktoolik River are considered to be the most important coho salmon producers in the district (Schwarz, pers. comm.).

Within the Port Clarence District, coho salmon have been documented in the Agiapuk and Kuzitrin first-order river systems (ibid.).

Within the Kotzebue District, first-order systems known to sustain populations of coho salmon include the Buckland, Noatak, Wulik, and Kivalina rivers (ibid.).

Coho salmon are documented in only one stream in the Northern District: Kuchiak Creek, northeast of Cape Lisbourne (ibid.). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Arctic Region.)

4. Western. Both the Kuskokwim and Yukon rivers traverse the Western Region and serve as migration corridors for coho salmon. Known Western Region coho salmon-producing waters of the Kuskowim River system (i.e., those tributaries located downstream of and including the Holitna River drainage) include the Kwethluk, Aniak, Salmon (Aniak River tributary), Kipchuk, Oskawalik, and Kogrukluk rivers (ADF&G 1977c, 1978b). Coho salmon are also found in the Eek, Kisaralik, Tuluksak, Hoholitna, and Cheeneetnuk river systems of the Kuskokwim drainage (ADF&G 1983d). Within that portion of the Yukon River drainage found in the Western Region (i.e., tributaries downstream of the village of the village Paimuit), coho salmon are documented in the Andreafsky and Chuilnak rivers (ADF&G 1985). Other coho salmon-producing systems in the region include the Arolik, Goodnews, and Kanektok rivers (ADF&G 1978b). Sixteen first-order streams (those whose mouths are at salt water) on Nunivak Island are also documented as having coho salmon present (ADF&G 1985a). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Western and Interior Regions.)

5. Interior. The Kuskokwim and Yukon rivers serve as pathways for coho salmon bound for spawning areas in the Interior Region. Known coho salmon-producing waters of the Kuskokwim River system in the Interior Region (i.e., those tributaries upstream of the Holitna River drainage) extend to the North, East, and South Forks of the Kuskokwim River and include the

Salmon (tributary of Pitka Fork of the Middle Fork Kuskokwim River), Tatlawiksuk, Nixon Fork (tributary of the Tokotna River), and Gagaryah rivers (ADG&G 1983d). Within the Yukon River drainage of the Interior Region (i.e., those tributaries upstream of the village of Paimuit), coho salmon are documented in 10 second-order streams (those whose mouths are at the Yukon River). They include the Innoko, Bonanza, Anvik, Tanana, Hodzana, Porcupine, Kandik, and Tatonduk rivers and Birch and Beaver slough/creeks (ADF&G 1985b). Their presence has also been documented in the Tozitna River (Barton, pers. comm.). The major coho salmon spawning areas documented to date occur in the tributaries of the upper Tanana River drainage (ADF&G 1983e). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Western and Interior Regions.)

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

1. Water quality:

- a. Temperature. Egg incubation and alevin development have occurred over a wide range of temperatures. Reiser and Bjornn (1979) list recommended incubation temperatures for coho salmon as 4.4 to 13.3°C.

Under laboratory conditions, Brett (1952) found the upper lethal temperature limit of juvenile coho salmon from British Columbia to be 25.0°C. Reiser and Bjornn (1979) list preferred temperatures for rearing juveniles as 11.8 to 14.6°C. Bustard and Narver (1975), during winter studies on a small stream in Vancouver, British Columbia, found that at 7°C or less the young coho were associated with water velocities of less than 15 cm/sec. They also noted that as water temperature decreased from 9 to 2°C the coho salmon moved closer to cover (e.g., logs, uprooted tree roots, debris accumulations, overhanging banks, and overhanging brush).

While feeding in the ocean, maturing coho salmon have been found in areas where surface temperatures have ranged from 4.0 to 15.2°C, with most being found in the 8 to 12°C range. Various evidence, however, indicates that coho may occur in even colder waters (Godfrey 1965).

Adult entry into fresh water may be triggered in part by a rise in water temperature (Morrow 1980). Spawning occurs over a wide range of water temperatures. Godfrey (1965) cites Gribov, who reported water temperatures during spawning in Kamchatka, USSR, rivers as low as 0.8°C and as high as 7.7°C. Reiser and Bjornn (1979) suggest that 4.4 to 9.4°C is a more preferred temperature range for spawning.

- b. The pH factor. There is no optimum pH value for fish in general; however, in waters where good fish fauna occur, the pH usually ranges between 6.7 and 8.3 (Bell 1973). State of Alaska water quality criteria for freshwater growth and propagation of fish specify pH values of not less than 6.5 or greater than 9.0, with variances of no more than 0.5 pH unit from natural conditions (ADEC 1979).
- c. Dissolved oxygen (D.O.). The groundwater that is typical of coho salmon spawning beds is usually highly oxygenated (Godfrey 1965). Davis et al. (1963), during laboratory tests of sustained swimming speeds of juvenile coho salmon, found that the reduction of oxygen concentration from air saturation levels to 7, 6, 5, 4, and 3 mg/l usually resulted in reduction of the maximum sustained swimming speed by about 5, 8, 13, 20, and 30%, respectively. Adult swimming performance is also adversely affected by reduction of D.O. concentrations below air saturation level. Bell (1973) states that it is desirable that D.O. concentrations be at or near saturation and that it is especially important in spawning areas, where D.O. levels must not be below 7 ppm at any time. State of Alaska water quality criteria for growth and propagation of fish state that "D.O. shall be greater than 7 mg/l in waters used by anadromous and resident fish. Further, in no case shall D.O. be less than 5 mg/l to a depth of 20 cm in the interstitial waters of gravel utilized by anadromous or resident fish for spawning. . . . In no case shall D.O. above 17 mg/l be permitted. The concentration of total dissolved gas shall not exceed 110 percent of saturation at any point of sample collection."
- d. Turbidity. Sedimentation causes high mortality to eggs and alevin by reducing water interchange in the redd. If 15 to 20% of the intragravel spaces become filled with sediment, salmonid eggs have suffered significant (upwards of 85%) mortality (Bell 1973). Prolonged exposure to turbid water causes gill irritation in juveniles, which can result in fungal and pathogenic bacterial infection. Excess turbidity from organic materials in the process of oxidation may reduce oxygen below safe levels, and sedimentation may smother food organisms and reduce primary productivity (ibid.). From investigation of the Susitna River in Southcentral Alaska during 1982, turbid water was found to be a strong factor that influenced juvenile fish distributions. This study indicates that rearing coho salmon apparently avoid turbid water (ADF&G 1983a). Turbid water will absorb more solar radiation than clear water

and may thus indirectly raise thermal barriers to adult upstream spawning migration (Reiser and Bjornn 1979).

2. Water quantity:

- a. Instream flow. Sufficient water velocity and depth are needed to allow proper intragravel water movement (apparent velocity) so that dissolved oxygen is transported to eggs and alevins and in turn metabolic wastes are removed (ibid.).

Juveniles after emerging from the gravel stay almost entirely in pools, avoiding riffle areas (Morrow 1980). Burger et al. (1983), during studies on the Kenai River, Alaska, and its tributaries, found that recently emerged juveniles (less than 50 mm long) in the main stem of the river were close to banks and often in reaches where the river had flooded terrestrial areas. Most of these juveniles were found in zones of zero water velocity, and almost 80% were captured in areas of less than 6.1 cm/sec mean water column velocity. Larger juvenile coho salmon (51 to 71 mm) were typically captured in creek mouth basins, backwater pools, and man-made canals. Ninety percent of these fish were in habitat having no measurable water velocity. In contrast to these findings, the juveniles in Kenai River tributary streams were found in pool-riffle habitat. Burger et al. (1983) suggest that sooner-emerging chinook salmon juveniles may be displacing main stem spawned coho salmon into tributaries, canals, and basins. He also suggests that since the main stem age 0 coho salmon do not appear to be attaining the same growth as similar age fish in the Deshka or Susitna rivers, the areas to which they have been forced is probably not their preferred habitat and may not supply the drift food items that are a major contributor to salmonid diets. Competition with stickleback may also play a role in the lower coho salmon growth rates.

Bovee (1978) suggests that an optimum water velocity for coho salmon fry is from 15.2 to 18.3 cm/sec.

Stream water velocity is important to juveniles because it is the most important parameter in determining the distribution of aquatic invertebrates (food sources) in streams (Reiser and Bjornn 1979).

Excess velocities and shallow water may impede migrating fish. Thompson (1972) indicates that Pacific Northwest coho salmon require a minimum depth of 0.18 m, with velocities less than 2.44 m/sec. for migration. No measurements of Alaska waters for adult migration criteria are available.

Velocity is also important in redd construction because the water carries dislodged substrate materials from the nesting site. Measured flow rates at 0.12 m above the

streambed include 19.2 to 69.2 cm/sec in Oregon and 7.6 to 61.0 cm/sec in the Columbia River and tributaries (Smith 1973). Minimum water depths at these spawning sites ranged from 0.122 to 0.153 m in Oregon and from 0.305 to 0.458 m in the Columbia River and tributaries. Smith (1973) recommended that the spawning velocity (as measured 0.12 m above streambed) and minimum depth criteria for Oregon coho salmon be 21.0 to 70.0 cm/sec and 0.15 m, respectively. Burger et al. (1983) lists measured velocities for the Kenai River and one tributary stream as 21.4 to 30.5 cm/sec pit velocity and 51.8 to 82.8 cm/sec tailspill velocity (measurement taken at 0.6 total depth). The pit depths at these redds were 54.5 to 76.3 cm, and the tailspill depths were 25.0 to 45.0 cm.

3. Substrate. Egg incubation and alevin development occur in substrates ranging widely in size and composition. The ADF&G (1977) states that optimum substrate composition is small-to-medium gravel. Generally, sediments less than .64 cm diameter should comprise less than 20 to 25% of the incubation substrate (Reiser and Bjornn 1979). Substrate composition regulates production of invertebrates, which are food sources for juveniles. Highest invertebrate production is from gravel and rubble-size materials associated with riffle areas (ibid.).

B. Terrestrial

1. Conditions providing security from predators or other disturbances. Emergent terrestrial vegetation was the dominant cover type used by rearing juvenile coho salmon in their backwater pool-rearing areas in the main stem Kenai River (Burger et al. 1983). Undercut banks and deep water pools provide protection for adults.
2. Conditions providing protection from natural elements. Bustard and Narver (1975), working in Vancouver, British Columbia, noted that the juvenile coho salmon were associated with water velocities of less than 15 cm/sec when the water temperature was 7°C or less. They also noted that as the temperature dropped from 9 to 2°C young coho salmon moved closer to cover provided by such things as logs, uprooted trees, debris accumulations, overhanging banks, and overhanging brush.

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

Upon hatching, young alevin remain in the gravel for two or three weeks until the yolk sack has been absorbed. Following emergence from the gravel, the juveniles begin feeding at or near the surface (Morrow 1980). Major food items at this time are terrestrial insects, especially species of flies (Diptera) and wasps and bees (Hymenoptera), and perhaps also aphids and thrips

(ibid.). Burger et al. (1983) found that midges (chironomids) were dominant in stomach samples of juvenile coho salmon in the Kenai River, Alaska. Juvenile coho salmon food habit studies during August and September in sloughs and clearwater tributaries of the middle reach of the Susitna River suggest that the range and diversity of invertebrates in their diet indicate an ability to adapt to variable conditions (ADF&G 1982). Specimens collected during the study had consumed both terrestrial and aquatic invertebrates. Based on numbers consumed, they relied mainly on midge (Diptera: Chironomidae) larvae, pupae, and adults. Although not contributing much in terms of dry weight, the major components of their terrestrial diet were usually small aphids (Homoptera: Aphidae), small Diptera (Phoridae, Simuliidae, and Scaridae), and small (less than 5 mm) Hymenoptera (ibid.). The diet can also include mites, beetles, springtails (Collembola), spiders, and small zooplankton. As the young fish grow they consume larger food items and often consume young sockeye salmon. In Chignik Lake, Alaska, young coho salmon have been found to eat seven times as many juvenile sockeye salmon as do Dolly Varden, and in other localities coho salmon may be equally serious predators (Morrow 1980). Scott and Crossman (1973) state that large numbers of chum and pink salmon are also taken by coho salmon.

Upon entering the sea, young coho salmon feed on various planktonic crustaceans, pink and chum salmon fry, herring, sand lance, other fishes, and squid (ibid.).

The food of marine adults is more pelagic and more varied than that of many Pacific salmon. Fishes make up 70 to 80% of the coho salmon's food, invertebrates 20 to 30%, and include the following: pilchard, herring, anchovy, coho salmon, capelin, lanternfish, Pacific saury, hake, whiting, rockfishes, black cod, sculpins, sand lance, squid, barnacles, isopods, amphipods, euphausiids, crab larvae, and jelly fish (Morrow 1980, Scott and Crossman 1973). Herring and sand lance make up 75% of the volume (Pritchard and Tester 1944). Some populations, however, remain on the crustacean diet, such coho generally not growing as big as those that eat fish (Prakash and Milne 1958).

B. Types of Feeding Areas Used

Young juveniles feed in low-velocity areas along streambanks and in backwater pools and current eddies. Feeding is generally near the surface, with drifting invertebrates the prey; young coho salmon feed infrequently on bottom-dwelling organisms (Morrow 1980). As they grow in size, the juveniles may become serious predators of other small fish, including other salmon species.

When the young coho salmon migrate to the sea, they tend to stay fairly close to shore at first. The oceanic movements of coho salmon in the southern part of the range (i.e., Washington, Oregon, British Columbia) seem to be chiefly along the coast, with some fish apparently never venturing far from the coast. By contrast, northern fish, particularly those from Alaskan streams, spread out all across the North Pacific and into the Bering Sea

(ibid.). Available evidence from commercial fisheries and research vessels indicates that while at sea coho salmon occur most frequently near the surface. Individuals have been taken at greater depths, but most coho salmon have been caught in the upper 10 m (Godfrey 1965).

C. Factors Limiting Availability of Food

Sedimentation is one of the major factors affecting freshwater food availability. Excessive sedimentation may inhibit production of aquatic plants and invertebrate fauna (Hall and McKay 1983). Bell (1973) states that primary food production is lowered above levels of 25 JTU (Jackson Turbidity Unit) and visual references lost above levels of 30 JTU.

D. Feeding Behavior

Food varies from place to place and with time (Scott and Crossman 1973). While on the high seas, schools may become involved in a feeding frenzy and have been found to be eating blue lanternfish and sauries (Hart 1973). Upon entering fresh water, adult salmon no longer feed but live off the fat they stored up while in the ocean (Netboy 1974).

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Short coastal streams are usually preferred, but coho salmon are known to spawn in spring-fed tributaries of the Yukon River drainage from the Bonasila River at least as far upstream as the Fishing Branch River in the headwaters of the Porcupine River system (Barton, pers. comm.). Although spawning may occur in main channels of large rivers, locations at the head of riffles in shallow tributaries or narrow side channels are preferred (ADF&G 1977). Vining et al. (1985), from chum salmon incubation studies of main stem, tributary, side channel, and slough habitats within the middle reach of the Susitna River, Alaska, caution that, because of the effects of dewatering and freezing, the amount of available habitat at the time when adult salmon are spawning is a poor indicator of the amount of actual habitat that is available as potential incubation habitat. Estimates of available incubation habitat must take into account the differential effects of dewatering and freezing in various habitat types.

B. Reproductive Seasonality

In Alaska, coho salmon enter freshwater streams from mid July through November (Russell, pers. comm.). Actual spawning generally occurs between September and January (ADF&G 1977). In the Norton Sound area, coho salmon spawn during late August (Lean, pers. comm.). As a rule, fish in the northern part of the range enter fresh water earlier in the season, with runs occurring progressively later to the south (Morrow 1980).

C. Reproductive Behavior

As with other salmon, adult coho salmon return from the sea and move into their natal freshwater streams to spawn. The female selects the spawning site and digs the redd (nest) by turning on

her side and thrashing her tail up and down. The current washes loosened substrate material downstream, and a depression 8 to 51 cm (average about 20 to 25 cm) deep is formed in the river bottom (Burner 1951, Morrow 1980). Eggs and sperm (milt) are released simultaneously and deposited in the redd. After egg deposition, the female moves to the upstream margin of the redd and repeats the digging process. Dislodged substrate is washed over the eggs. In this manner, the eggs are covered and prevented from washing away. The process is repeated many times, and the redd appears to move upstream (Burner 1951). As a result of the continued digging, the redd may grow to become 1.2 m² to 6.6 m², with a general average of about 2.8 m² for Columbia River basin redds (ibid.). A female may dig several redds and spawn with more than one male (McPhail and Lindsey 1970).

D. Age at Sexual Maturity

The age at which coho salmon reach sexual maturity ranges from two to six years, although most usually return from marine waters to spawn at ages 3 or 4. The number of four- and five-year-old fish usually increases northward (Scott and Crossman 1973).

E. Fecundity

The number of eggs varies with the size of the fish, the stock, and sometimes the year. Numbers have been reported from 1,440 to 5,770; the average probably lies between 2,500 and 3,000 (Morrow 1980). Godfrey (1965) cites studies of Kamchatkan (Russian) salmon, where the average number of eggs was 4,883.

F. Frequency of Breeding

As with all Pacific salmon, the spawning cycle is terminal. Both male and female die after spawning.

G. Incubation Period/Emergence

The amount of time required for eggs to hatch is dependent upon many interrelated factors, including 1) dissolved oxygen, 2) water temperature, 3) apparent velocity in gravel, 4) biological oxygen demand, 5) substrate size (limited by percentage of small fine material), 6) channel gradient and 7) configuration, 8) water depth, 9) surface water discharge and velocity, 10) permeability, 11) porosity, and 12) light (Reiser 1979, Hart 1973). Generally speaking, factors 4 through 12 influence or regulate the key factors 1, 2, and 3.

In Alaska, hatching usually takes place from mid winter to early spring, the amount of time varying with the water temperature. Scott and Crossman (1973) indicate that hatching times have ranged from 38 days at 10.7°C to 48 days at 8.9° in California, and they postulate that it might take 42 to 56 days farther north. Morrow (1980) states that incubation takes six to nine weeks and may require as long as five months. After hatching, the alevin remain in the gravel for 2 to 3 weeks (some may take up to 10 weeks) and emerge from the gravel sometime from April to June (ADF&G 1978 Morrow 1980, Godfrey 1965).

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

A. Size of Use Areas

Juvenile coho salmon after emerging from the gravel take up residence not far from redds, especially near the banks, where they tend to congregate in schools. As they grow they disperse and become aggressive and territorial. Laboratory experiments by Chapman (1962) show that juveniles are aggressive and territorial or hierarchical in behavior. Hierarchies and territories were organized on the basis of fish size, and smaller fish tended to move downstream because of the continuous harassment by the larger fish. Stein et al. (1972) support these findings and from their laboratory experiments with Sixes River, Oregon, stocks found that rearing coho salmon were more aggressive than chinook salmon, tolerated fewer individuals of their own species than did chinook salmon, and defended positions at the upstream end of a riffle where drifting food organisms were first available to fish.

From studies of Columbia River tributaries, Burner (1951) suggests that a conservative figure for the number of pairs of salmon that can satisfactorily utilize a given area of spawning gravel may be obtained by dividing the area by four times the average size of the redds. Redd area can be computed by measuring the total length of the redd (upper edge of pit to lower edge of tailspill) and the average of several equidistant widths (Reiser and Bjornn 1979). Burner (1951) states that Columbia River basin coho salmon redds averaged 2.8 m². Burger et al. (1983) measured three redds (two in the Kenai River main stem, one in a tributary stream) and listed their sizes. Main stem redds were 1.5 and 0.9 m long x 1.2 and 0.6 m wide, respectively. The tributary redd was 1.8 m long x 1.0 m wide.

B. Timing of Movements and Use of Areas

The young coho salmon normally spend a year in fresh water before going to sea, although some may go to sea at the end of their first summer. Others, as in the Karluk River on Kodiak Island, Alaska, may stay two, three, or even four years in fresh water (Morrow 1980). Middleton (1983) states that in Bristol Bay streams coho juveniles stay in fresh water mainly two or more years. The same is said for the Chignik and Nelson Lagoon systems by Shaul (pers. comm.), who postulates that most coho salmon on the Alaska Peninsula probably spend two winters in fresh water. In the Taku River of Southeast Alaska, downstream movement of juveniles bound for the sea is usually at night (Meehan and Siniff 1962), and the trip is completed during the period mid April through mid June. Studies of smolt out-migration in the Bear Lake system, near Seward, indicate that very few smolts migrate prior to stream temperatures attaining 3.9°C (Logan 1967), and for this system the seaward movement of natural stocks commences during mid May and continues through late September, with 50% of the migration passing the sampling weir by mid June (Logan 1967, 1968, 1969). Burger et al. (1983) suggest that the Kenai River seaward migration occurs probably from July to November. More detailed run timing information for different stocks is presented in the

salmon distribution and abundance narratives found in this report series.

Having spent two or three years in the ocean, mature coho salmon first arrive in appreciable numbers in coastal waters of central and southeastern Alaska early in July, and the runs extend into August or September (Morrow 1980, Godfrey 1965). Alaska Peninsula coho salmon spend only one year in salt water (Shaul, pers. comm.). Returns of western Alaskan stocks begin in late July in the Kuskokwim and Yukon rivers and extend through August (ADF&G 1977c). Returning adult coho salmon are found in the bays and estuaries of Norton Sound from early to mid August (ibid.).

Adult upstream migration and intensive entry into a river is associated with the beginning of a rising tide, whereas schooling off the mouth of a river, in brackish waters, occurs during the period of the falling tide (Gribanov 1948). They ascend the rivers during both rising and falling water levels but cease movement during peak floods (ibid.). When in the river, they move upstream mainly during daylight hours (Neave 1943).

C. Migration Routes

Rivers and streams serve as corridors for smolt out-migration. Barriers to adult upstream movement include excess turbidity, high temperatures (20.0°C or more), sustained high-water velocities (greater than 2.44 m/sec), and blockage of streams (log jams, waterfalls) (Reiser and Bjornn 1979).

Results of seining and tagging operations have demonstrated that juvenile North American coho salmon make extensive migrations. Alaskan coho salmon enter the Alaskan gyre (a generally counter-clockwise flow of water moving westerly near the south side of the Alaska Peninsula and Aleutian Islands) and travel "downstream," making one complete circuit per year (Morrow 1980). They disperse widely in both coastal waters and in the Gulf of Alaska and eastern North Pacific Ocean (including the Bering Sea) to as far south as 40°N at least (Godfrey et al. 1975). Tag recoveries have shown that juvenile coho salmon that originate in streams tributary to the Bering Sea penetrate into waters south of Adak Island in the North Pacific Ocean at least as far west as 176°51'W (ibid.) and at least as far south as 45°24'N (Harris and Myers 1983). Coho salmon of Western Alaska origin (e.g., Yukon River and Kuskokwim River drainages) are also known to enter the central Gulf of Alaska to at least as far east as 145°W and well to the south of 50°N (Godfrey et al. 1975).

During early spring and summer, as surface water temperatures warm, North American coho salmon begin a generally northly movement. There is not yet sufficient information that would indicate clearly from what locations or at what times the continued migrations of particular stocks become more positively directed toward home streams. Tagging data do suggest, however, that this does happen - that is, that a general northward movement over a broad east-west front of many mixed stocks changes to migrations by individual stocks or particular groups of stocks

that vary in relation to the locations (and probably distances also) of their ultimate destinations (ibid.).

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

Scott and Crossman (1973) state that "coho juveniles especially when aggregated and abundant, are preyed on by a variety of fishes (e.g., coho salmon smolts, cutthroat and rainbow trout, Dolly Varden, and sculpins), mergansers, loons, kingfishers, other birds, and some small mammals. The adults during their spawning run are taken by bears, other mammals, and large birds. In the ocean, lampreys, and aquatic mammals (e.g., seals and killer whales) are the chief predators."

The greatest natural mortality occurs in fresh water during the early life stages and is greatly influenced by environment (Straty 1981); therefore, deleterious changes in the freshwater quality, quantity, or substrate are most detrimental.

B. Human-related

A summary of possible impacts from human-related activities includes the following:

- Alteration of preferred water temperature, pH, dissolved oxygen, and chemical composition
- Alteration of preferred water velocity and depth
- Alteration of preferred stream morphology
- Increase in suspended organic or mineral material
- Increase in sedimentation and reduction in permeability of substrate
- Reduction in food supply
- Reduction in protective cover (e.g., overhanging stream banks or vegetation)
- Shock waves in aquatic environment
- Human harvest

(For additional impacts information, see the Impacts of Land and Water Use volume of this series.)

VIII. LEGAL STATUS

A. Managerial Authority

1. The Alaska Board of Fisheries develops regulations governing the commercial, sport, and subsistence harvest of salmon in Alaska. The Alaska Department of Fish and Game manages salmon populations in the fresh waters of the state and in the marine waters to the 3-mi limit.
2. The North Pacific Fishery Management Council is composed of 15 members, 11 voting and 4 nonvoting members. The 11 are divided as follows: 5 from Alaska, 3 from Washington, and 3 from state fishery agencies (Alaska, Washington, Oregon). The four nonvoting members include the director of the Pacific Marine Fisheries Commission, the director of the U.S. Fish and Wildlife Service, the commander of the 17th Coast

Guard District, and a representative from the U.S. Department of State.

The council prepares fishery management plans, which become law and apply to marine areas between the 3-mi limit and the 200-mi limit. With regard to salmon, the only plan prepared to date is the Salmon Power Troll Fishery Management Plan.

3. The International North Pacific Fisheries Commission (INPFC), a convention comprised of Canada, Japan, and the United States, has been established to provide for scientific studies and for coordinating the collection, exchange, and analysis of scientific data regarding anadromous species. With regard to salmon, the INPFC has also prepared conservation measures that limit the location, time, and number of fishing days that designated high seas (beyond the 200-mi limit) areas may be fished by Japanese nationals and fishing vessels.

IX. LIMITATIONS OF INFORMATION

Very little life history and habitat information concerning Alaskan coho salmon has been documented. Most of the available information comes from Pacific Northwest and Canadian field and laboratory studies.

X. SPECIAL CONSIDERATIONS

Caution must be used when extending information from one stock of coho salmon to another stock. Environmental conditions for one area must not be treated as absolute; the stocks (races) have acclimated or evolved over time and space to habitat conditions that can vary greatly.

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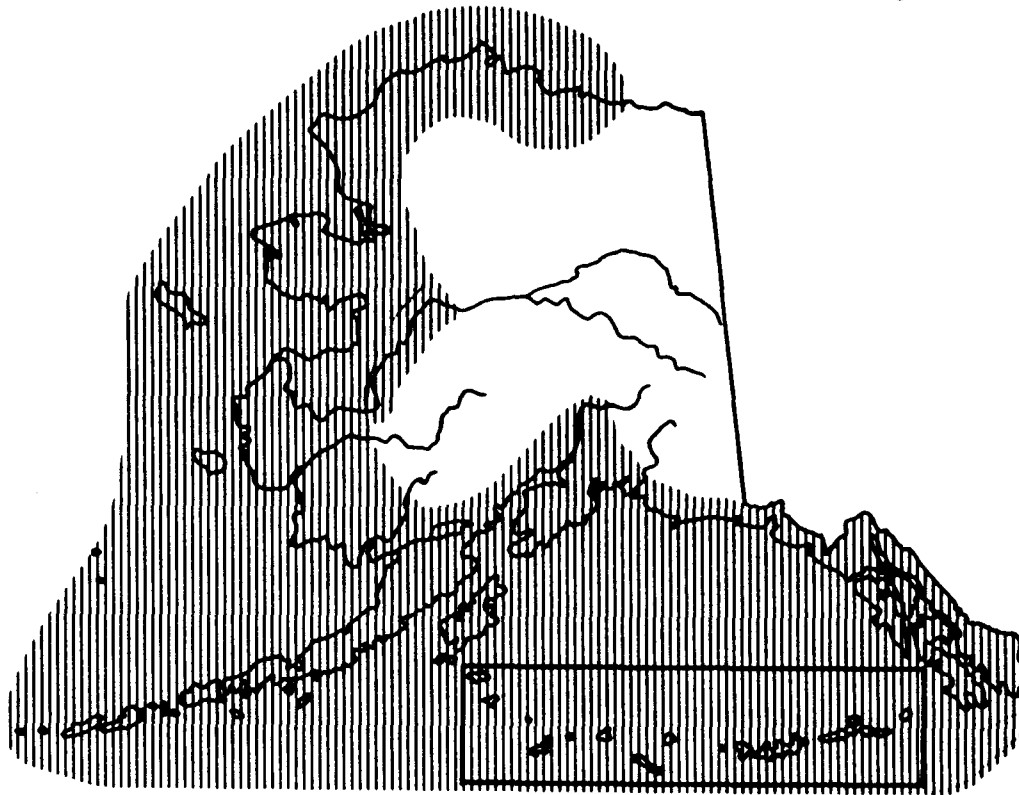
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Pink Salmon Life History and Habitat Requirements
Southwest, Southcentral, Arctic, Western, and Interior Regions



Map 1. Range of pink salmon (ADF&G 1978, Morrow 1980)

I. NAME

A. Common Names: Pink salmon, pinks, humpback salmon, humpy

B. Scientific Name: Oncorhynchus gorbuscha

C. Native Names: See appendix A.

II. RANGE

A. Worldwide

Pink salmon are the most abundant of the Pacific salmon (Krueger 1981). In North America, pink salmon range from the Russian River, California, north through the Bering Strait, and east to the Mackenzie River in the Northwest Territories, Canada. In Asia, pink salmon occur from the Tumen and North Nantai rivers of North Korea and the island of Hokkaido, Japan, north to the Lena River, Siberia. They also occur in the Kurile, Commander, and Aleutian islands (Neave 1967).

B. Statewide

Pink salmon are widely distributed along coastal Alaska, with only a few in the Copper River delta and none in the upper Copper River drainage (ADF&G 1978; Roberson, pers. comm.). They typically ascend streams only short distances (65 km or less), and some spawn in the intertidal areas of short coastal streams (Bailey 1969, Scott and Crossman 1973). In large river systems, however, such as the Nushagak drainage in Southwestern Alaska, the Susitna drainage in Southcentral Alaska, and the Yukon and Kuskokwim drainages of Western and Interior Alaska, pink salmon are known to travel much greater distances. Measuring from Picnic Point at the Wood River confluence with the Nushagak River, pink salmon have been documented about 230 km upstream in the Nuyakuk River and approximately 410 km upstream in the Mulchatna River (ADF&G 1984a). Studies on the Susitna River in Southcentral Alaska have found spawning pink salmon at least 223 km upstream (ADF&G 1981a). Pink salmon have been caught in the main stem of the Yukon River upstream as far as river km 967 in the vicinity of the village of Ruby (ADF&G 1983a). They are also found at the mouth of the South Fork Hoholitna River approximately 620 river km upstream of the village of Popokamiat, which is located at the mouth of the Kuskokwim River (ADF&G 1985).

C. Regional Distribution Maps

To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for each region. In this series pink salmon distribution information is included on the 1:250,000-scale maps titled Distribution of Anadromous Fish. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of selected fish and wildlife species has been prepared and may be found in the Atlas that accompanies each regional guide.

D. Regional Distribution Summary

1. Southwest. In the Kodiak area, there are approximately 300 streams that produce pink salmon, although 60 to 85% of the total escapement is usually contained in 35 major river systems during odd-numbered years and in 47 of the major river systems during even-numbered years (Prokopowich, pers. comm.). These systems comprise the Kodiak area's index streams.

In the Bristol Bay area (for waters from Cape Newenham to Cape Menashikof and north-side Alaska Peninsula streams south to Cape Sarichef), the Nushagak District is the major pink salmon producer. Within the district, pink salmon spawn almost entirely in the Nuyakuk River, with smaller populations also found in the Wood, Igushik, Nushagak, and Mulchatna rivers. Occasionally, strong runs occur in the Kvichak, Alagnak (Branch), and Naknek rivers (Middleton

1983). Bechevin Bay streams occasionally produce strong pink salmon runs during even-numbered years (Shaul, pers. comm.). In south-side Alaska Peninsula streams and the Aleutian Islands, pink salmon are abundant and are found in many drainages. In the Chignik area, there are approximately 75 salmon streams. In the south peninsula area, Mino Creek, Settlement Point, and Southern Creek on Deer Island occasionally produce one-half the total pink salmon run to the area. Two other streams (Apollo Creek and Middle Creek) have the combined potential of producing another 500,000 to 62 million pink salmon in a good year, if waterfalls on these streams could be bypassed with fish-passage structures (ibid.). (For more detailed narrative information, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)

2. Southcentral. In the Northern and Central districts of the upper Cook Inlet area, the majority of the pink salmon are produced in the Lake Creek, Deshka, Talachulitna, Kenai, and Kasilof river drainages (ADF&G 1977b). In the Southern, Outer, and Kamishak districts of the lower Cook Inlet area, the majority of the pink salmon are produced in the following locations: Humpy Creek, Tutka Lagoon, Seldovia Creek, Port Graham River, Windy Left River, Windy Right River, Rocky River, Port Dick Creek, Bruin Bay River, Big Kamishak River, Little Kamishak River, Amekedori Creek, Sunday Creek, and Brown's Peak Creek (ADF&G 1981b).

In Prince William Sound (PWS), the genetically unrelated odd-year and even-year pink salmon stocks have adapted differently to the use of the same spawning streams. The odd-year stocks use primarily upstream spawning sites, with 43 to 65% (average of 25.6%) selecting spawning sites above the high tide line, while even-year stocks are more oriented toward intertidal spawning areas, with only 23 to 28% (average of 25.6%) selecting spawning sites above high tide. With regard to spawning areas, PWS pink salmon may be generally categorized as early, middle, and late spawning stocks, which are distributed by geographic zones associated with different temperature regimes. Early runs (about July 20 to August 5) are found in relatively few streams, primarily in the major fiords of the northern main land, Port Wells, Valdez Arm, Port Fidalgo, Port Gravina, and Sheep Bay. Middle runs (about August 6 to August 20) utilize most of the larger, cold, clear streams of the mainland districts and a few cold mountain streams of Knight and LaTouche islands. Late runs (about August 21 to September 10) occupy the majority of the streams used and include nearly all the island streams, mainland lake-fed streams, and mainland streams in which only intertidal zones are accessible to migrants (ADF&G 1978a). (For more detailed narrative

information, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)

3. Arctic. In the Norton Sound area, pink salmon did not historically exhibit strong even-odd year fluctuations in abundance as do pink salmon in more southerly latitudes (ADF&G 1977c). Recently, however, a strong even-year, weak odd-year cycle has developed (Lean, pers. comm.). Major pink salmon-producing systems in the Norton Sound District include the Unalakleet and Fish river drainages and the Shaktoolik, Egavik, Inglutalik, Ungalik, Koyuk, Tubutulik, Kwiniuk, Kachavik, Bonanza, Eldorado, Flambeau, Nome, Snake, Sinuk, Solomon, Golsovia rivers (Schwarz, pers. comm.; Lean, pers. comm.).

Within the Port Clarence District, pink salmon have been documented in the Bluestone, Agiapuk, and Kuzitrin river systems (ADF&G 1984b).

Within the Kotzebue District, pink salmon have been documented in the Pinguk, Inmachuk, Kugruk, Buckland, Kobuk, Noatak, Tasaychek, Wulik, and Kivalina rivers and Fish Creek (ibid.).

The Northern District of the Arctic Region represents the most northern range of pink salmon in North America. Populations in the area are existing at the outer limits of their environmental tolerances, and their numbers are extremely limited (ADF&G 1977c). First-order streams (those whose mouths are at salt water) in which pink salmon have been documented include the Kukpuk, Pitmegea, Kukpowruk, Kokolik, Utukok, Chipp, Ikpikpuk, Fish, Colville, Sagavanirktok, Staines, and Canning (ADF&G 1984b). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Arctic Region.)

4. Western. Both the Kuskokwim and Yukon rivers traverse the Western Region and serve as migration corridors for pink salmon. Pink salmon spawn in Western Region waters of the Kuskowim River system (i.e., those tributaries located downstream of and including the Holitna River drainage) and include the upper portions of the Kwethluk and Holitna rivers, the lower portion of the Kogrukluk River, and the Eek, Aniak, Tuluksak, Holokuk, and Oskawalik rivers (ADF&G 1977c, 1983a). South of the mouth of the Kuskokwim River large runs occur in the Kanektok, Arolik, and upper Goodnews rivers (ADF&G 1978b). Pink salmon have been documented in nine streams on Nunivak Island (ADF&G 1985a). Within that portion of the Yukon River found in the Western Region (i.e., tributaries downstream of the village of Paimuit), pink salmon are found in many of the sloughs, branches, and passes of the delta area and in the Archuelinguk and Andreaafsky rivers (ADF&G 1985a). The Andreaafsky River supports the highest recorded escapement in the Yukon River system (Barton 1984). Between the mouths of the Yukon and Kuskokwim rivers,

the Kokechik, Keoklevik, Kashunuk, Aphrewn, Manokinak, Aknerkochik, Azun, and Kolavinarak rivers are used by pink salmon, as are Nelson Island streams, including the Tanunak, Alakuchak, and Toksook rivers and Chukchak Creek (ADF&G 1985a). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Western and Interior regions.)

5. Interior. Pink salmon have not yet been documented in that portion of the Kuskokwim River system in the Interior Region (i.e., main stem or tributaries upstream of the Holitna River drainage) (ADF&G 1985). Within that portion of the Yukon River system found in the Interior Region (i.e., upstream of the village of Paimuit), pink salmon have been caught in the main stem as far upstream as Ruby (river km 967) (ADF&G 1983b). Most known spawning, however, occurs downstream of the village of Grayling (river km 541) (ibid.). ADF&G (1985b) documents pink salmon in two second-order tributary streams (those whose mouths are at the Yukon River) in this section of the river, the Anvik River and Grayling Creek. (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Western and Interior regions.)

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

1. Water quality:

- a. Temperature. Pink salmon in Southeast Alaska have been observed to spawn in water temperatures ranging from 7.4 to 18.3°C (Sheridan 1962). The preferred range appears to be 7.2 to 12.8°C (Krueger 1981). Egg hatching rates are influenced by water temperature; abnormally warm or cold water can accelerate or depress developmental rates and cause premature or delayed fry emergence. Laboratory tests have shown that eggs require at least 4.5°C water temperatures from the time the egg is deposited in the redd through the gastrula stage of development (Bailey and Evans 1971). Thereafter, the embryos can tolerate water temperatures to 0°C if the water does not freeze. The upper lethal temperature limit for pink salmon juveniles from Washington was experimentally determined to be 23.9°C (Brett 1952), but lower lethal limits were not determined. Brett found, however, that juveniles preferred 12 to 14°C temperatures.
- b. The pH factor. There is no optimum pH value for fish in general; however, in waters where good fish fauna occur, the pH usually ranges between 6.7 and 8.3 (Bell 1973). State of Alaska water quality criteria for freshwater growth and propagation of fish call for pH values of not less than 6.5 or greater than 9.0, with variances of no

more than 0.5 pH unit from natural conditions (ADEC 1979).

- c. Dissolved oxygen (D.O.). From laboratory experiments, Bailey et al. (1980) recommend that for successful development of pink salmon eggs and alevins the D.O. level should exceed 6.0 mg/l. Dissolved oxygen levels below 6.0 mg/l apparently cause premature emergence, decreased size, and low survival (ibid.). State of Alaska water quality criteria for growth and propagation of fish state that "D.O. shall be greater than 7 mg/l in waters used by anadromous and resident fish. Further, in no case shall D.O. be less than 5 mg/l to a depth of 20 cm in the interstitial waters of gravel utilized by anadromous or resident fish for spawning In no case shall D.O. above 17 mg/l be permitted. The concentration of total dissolved gas shall not exceed 110% of saturation at any point of sample collection" (ibid.).

- d. Turbidity. Sedimentation causes high mortality to eggs and alevin by reducing water interchange in the redd. If 15 to 20% of the intragravel spaces become filled with sediment, salmonoid eggs have suffered significant (upwards of 85%) mortality (Bell 1973). Prolonged exposure to turbid water causes gill irritation in juveniles, which can result in fungal and pathogenic bacterial infection. Excess turbidity from organic materials in the process of oxidation may reduce oxygen below safe levels, and sedimentation may smother food organisms and reduce primary productivity (ibid.). Turbid water will absorb more solar radiation than clear water and may thus indirectly raise thermal barriers to the adult's upstream spawning migration (Reiser and Bjornn 1979).

2. Water quantity:

- a. Instream flow. Sufficient water velocity and depth are needed to allow proper intragravel water movement (apparent velocity) so that dissolved oxygen is transported to eggs and alevin and in turn metabolic wastes are removed (ibid.).

Adults returning to spawning grounds may be blocked if current velocities exceed 2.1 m/sec (Krueger 1981). Low flows and shallow water depths can also block upstream migration. Thompson (1972) suggests that adult pink salmon need a minimum of about 0.18 m water depth for upstream passage. These values will vary with the size and condition of adult pink salmon and the length of stream reach with shallow water (Krueger 1981). Pink salmon have been observed passing over shallow riffles less than 0.09 m deep in the Kizhuyak and Terror rivers

on Kodiak Island (Baldrige, pers. comm. cited in Krueger 1981).

Water velocity at spawning locations as measured at 0.16 m above the substrate has ranged from 0.1 to 1.32 m/sec, and the preferred range appears to be about 0.35 to 0.75 m/sec as measured by mean column velocity (Krueger 1981). Depth at redds has ranged from 0.1 to 1.32 m, with preferred depths ranging from 0.39 to 0.70 m (ibid.). Use of waters outside the preferred ranges may in large part be due to crowding on the spawning grounds.

3. Substrate. Pink salmon spawn over a variety of substrates ranging widely in size and composition. Adults generally select areas with a relatively low gradient combined with beds of small-to-medium-size gravel (1.3 to 10 cm diameter) (Neave 1966, Scott and Crossman 1973, Krueger 1981). Egg and alevin development is influenced by substrate composition because increased amounts of small material (fines) can reduce intragravel water flow. McNeil and Ahnell (1964), from studies in Southeast Alaska, concluded that productive pink salmon streams generally contained fines (0.833 mm diameter) contributing less than 5% of the volume of the substrate. They also found that less productive streams were characterized by 15% or more fines in the substrate.

B. Terrestrial

1. Conditions providing security from other predators or disturbances. The gravel over fertilized eggs reduces the disturbance caused by ice and floods. It also protects the eggs from sunlight and predation by other fish and aquatic insects.
2. Conditions providing protection from natural elements. Because pink salmon remain in fresh water for a very short time after emergence from the substrate, no data are available concerning protection from natural elements for free-swimming juveniles.

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

Upon hatching, young alevin remain in the gravel for several weeks until the yolk sac has been absorbed. Immediately upon emerging from the gravel, juveniles begin migrating downstream (Scott and Crossman 1973). Migrating juveniles generally do not feed; if the distance to the sea is great, however, they may feed on nymphal and larval insects (ibid.). Studies in Lake Aleknagik and Tikchik Lake in the Bristol Bay area, however, indicate differences in the early life history of pink salmon that spawn in a lake system from those that spawn in coastal rivers. Rogers and Burgner (1967) state that "in coastal rivers, the fry migrate to salt water upon emergence from the gravel. They are then about 30 mm long. The

young fry obtain little food from the freshwater environment and subsist largely on the yolk. In the Wood River lakes and Tikchik Lake, the fry must travel some distance to reach the outlet rivers (96 km in the case of Agulukpak River fry); and it is quite apparent that they feed actively during the course of their travel." In addition, it was found that some of the juvenile pink salmon remained in Lake Aleknagik long after emergence, were caught in tow net samples as late as September 10, and had grown to mean lengths of 89 mm (ibid.). An examination of stomach contents taken from Lake Aleknagik fry during July 1-8, 1967, revealed that zooplankton (i.e., Bosmina, Daphnia, Holopedium, Cyclopoida, and Calanoida) made up the bulk of the food (ibid.). In nearshore salt water, the juveniles consume small crustaceans (e.g., copepods, euphausiids, amphipods, ostracods), larvae of decapods, cirripeds and tunicates, and dipterous insects (Neave 1966). Bailey et al. (1975) found that pink salmon fry in Traitors Cove of Southeast Alaska consumed estuarine food items that were mostly between 0.3 and 3.0 mm long, with copepods (calanoids and cyclopoids) constituting the bulk of the diet (77% of the total volume). Also found in the diet were barnacle nauplii (cirripedes), cladocerans (Podon sp. and Evadne sp.), and various other planktonic forms and occasional epibenthic organisms (ibid.). As they grow, the diet consists of larger items until, during their final summer in the high seas, the diet consists of many organisms, the most important being euphausiids, amphipods, fish, squid, copepods, and pteropods (Neave 1966).

B. Types of Feeding Areas Used

Because pink salmon spend such a short time in natal waters following emergence from the gravel, little data are available on freshwater feeding locations. Samples of pink salmon fry in Lake Aleknagik indicate that although they were caught in the lake littoral zone (inshore), their stomach contents indicated they had foraged mainly in the pelagic zone of the lake (Rogers and Burgner 1967). Juvenile pink salmon school in estuarine waters and frequent the water's edge along mainland and inland shores (Neave 1966). They remain in nearshore areas for about a month, and when they have attained a length of 6 to 8 cm they begin a gradual, irregular movement to offshore waters. On the high seas, pink salmon vertical distribution has been found to range from 10 to 23 m (Takagi et al. 1981), although a few have been caught at depths from 24 to 36 m (Neave 1966).

C. Factors Limiting Availability of Food

Because pink salmon feed very little if at all in fresh water, the major factors limiting food availability would be those found in the estuarine environment. Variations in weather patterns and ocean currents, which affect dispersal of planktonic organisms, could influence food sources for juvenile pink salmon.

D. Feeding Behavior

Pink salmon select their food by sight and swallow it whole (Bailey 1969). Bailey et al. (1975), during studies of estuarine

feeding habits at Traitors Cove in Southeast Alaska, found that many more food items were contained in the stomachs of juvenile pink salmon collected in daytime than in those collected at night - an average of 136 items versus 16. They also found that the fry fed selectively. Relatively more cladocerans, decapod zoeae, and larvaceans were eaten than appeared in the samples of available planktonic food items.

Visual observations of individual pink salmon fry in shore-oriented schools at Traitors Cove indicate that their feeding varied with the speed of the water current. Bailey et al. (ibid.) found that "at velocities of 0 to 10.7 cm/s, a fry would typically swim a darting course as much as three times its body length to capture a food item. At higher velocities, 10.8 to 19.8 cm/s, schools of fry sometimes held position relative to the shore or bottom while facing the current, and an individual would typically deviate up, down, or to the sides no more than one-third of its body length to capture oncoming food. At still higher velocities, 19.9 to 24.4 cm/s, fry in schools often held a constant position relative to shore or bottom but did not feed. Fry that appeared to be in visual contact with the shore or bottom avoided currents above 24.4 cm/s unless frightened."

In offshore marine waters, pink salmon appear to have a vertical feeding pattern, with light intensity the major factor. Studies by Shimazaki and Mishima (1969) show that feeding indices of pink salmon near surface waters began to increase before sunset, attained a maximum two to three hours after sunset, and thereafter decreased to a minimum before sunrise. The feeding indices again became large in daytime. Whereas the dominant organisms of the stomach contents before sunset were large prey animals such as squids and fish larvae, the percentage of amphipods (whose numbers increased in surface waters with darkness), as well as feeding indices, increased after sunset, when amphipods became the main item of diet. Shimazaki and Mishima (ibid.) concluded that darkness prevented pink salmon from seeing and feeding on amphipods.

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Pink salmon spawning takes place in a variety of locations. Neave (1966) states: "In some instances spawning takes place in stream mouth areas where water levels change with the tides and where varying degrees of salinity are experienced. In small coastal streams the upstream limit is usually defined by a waterfall situated within a few miles of the sea. In larger rivers without major obstructions, the end-point may be less definite. The grounds that are intensively occupied by pink salmon tend to have a relatively low gradient." Vining et al. (1985), from chum salmon incubation studies of main stem, tributary, side channel, and slough habitats within the middle reach of the Susitna River, Alaska, caution that because of the effects of dewatering and

freezing, the amount of available habitat at the time when adult salmon are spawning is a poor indicator of the amount of actual habitat that is available as potential incubation habitat. Estimates of available incubation habitat must take into account the differential effects of dewatering and freezing in various habitat types.

B. Reproductive Seasonality

In Alaska, pink salmon ascend freshwater streams from June to late September, depending largely on location. Spawning takes place in mid July in the lower Yukon but generally not until late August to October in areas to the south (Morrow 1980).

C. Reproductive Behavior

As with other salmon, adult pink salmon return from the sea and move into their natal freshwater streams to spawn. There is, however, a degree of wandering. Adults have been taken in spawning streams as much as 643 km from their original stream. The female selects the spawning site and digs the redd (nest) by turning on her side and thrashing her tail up and down. The current washes loosened substrate material downstream, and a depression up to 45.7 cm deep is formed in the river bottom (ibid.). Eggs and sperm (milt) are released simultaneously and deposited in the redd. After egg deposition, the female moves to the upstream margin of the redd and repeats the digging process. Dislodged substrate is washed over the eggs. In this manner the eggs are covered and prevented from washing away. The process is repeated many times, and the redd appears to move upstream (Burner 1951). As a result of the continued digging, the redd may grow to become 0.9 m in length (Morrow 1980). A female may dig several redds and spawn with more than one male (McPhail and Lindsey 1970). Males may also spawn with several females (Neave 1966).

D. Age at Sexual Maturity

Unlike the other Pacific salmon, the pink salmon matures in two years. Though rare three-year-old fish have been found, it is probable that they are sterile (Morrow 1980).

E. Fecundity

The number of eggs carried by pink salmon entering the spawning area varies with the size of the female, the area, and the year (Scott and Crossman 1973). Each female may produce as few as 800 or as many as 2,000 eggs (Morrow 1980), with the average estimated at 1,500 to 1,900 (Scott and Crossman 1973). In general, larger fish have more eggs, but fish from small runs are said to be more fecund than those of the same size from large populations (Nikolskii 1952).

F. Frequency of Breeding

As with all Pacific salmon, the spawning cycle is terminal. Both male and female die after spawning.

G. Incubation Period/Emergence

The amount of time required for eggs to hatch is dependent upon many interrelated factors, including 1) dissolved oxygen, 2) water temperature, 3) apparent velocity in gravel, 4) biological oxygen

demand, 5) substrate size (limited by percentage of small fine material), 6) channel gradient, 7) channel configuration, 8) water depth, 9) surface water discharge and velocity, 10) permeability, 11) porosity, and 12) light (Reiser and Bjornn 1979, Hart 1973). Generally speaking, factors 4 through 12 influence or regulate the key factors 1, 2, and 3.

Egg development requires from 61 to about 130 days, depending largely on temperature (Morrow 1980). The young hatch from late December through February and remain in the gravel until April or May.

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

A. Size of Use Areas

From studies of Columbia River tributaries, Burner (1951) suggests that a conservative figure for the number of pairs of salmon that can satisfactorily utilize a given area of spawning gravel may be obtained by dividing the area by four times the average size of the redds. The redd area can be computed by measuring the total length of the redd (upper edge of pit to lower edge of tailspill) and the average of several equidistant widths (Reiser and Bjornn 1979). No documented information on the average size of pink salmon redds in Alaska was found in the preparation of this report.

B. Timing of Movements and Use of Areas

Pink salmon fry emerge from the gravel at night and begin their downstream migration to the sea (Bailey 1969). Where known, Alaska specific timing information is contained in the salmon distribution and abundance narratives found in this report series. During July of 1967, small schools of pink salmon fry were observed migrating upstream along shore through the narrows between Tikchik Lake and Nuyakuk Lake in company with larger sockeye fry and yearlings. This behavior is unusual for pink salmon (Rogers and Burgner 1967). When the distance to the sea is short, they reach the estuary of the stream before dawn (Bailey 1969). On longer journeys that cannot be made in one night, the fry hide in the gravel during the day and resume their downstream movement the next night (Neave 1955). Fry that must migrate for several days sometimes become daylight-adapted, in which case they school and no longer hide during the day (Hoar 1956).

After entering the estuary, the juveniles begin feeding and move with surface currents (Bailey 1969). After about a month, the young fish attain a length of 4 cm, then follow the salinity gradient within the estuary, generally staying fairly close to the shore. When they reach a length of 6 to 8 cm they move to offshore waters (Morrow 1980). After about 18 months at sea, the adult pink salmon return to fresh water to spawn (Scott and Crossman 1973).

C. Migration Routes

Freshwater streams and rivers serve as downstream migration corridors for ocean-bound juveniles and as upstream migration pathways for spawning adults.

Following is a summary of ocean migration patterns taken from Takagi et al. (1981). From marine distribution data, it is evident that pink salmon are present across the entire North Pacific Ocean from Asia to North America, north of about 42°N. Tagging studies have shown that each stock has a characteristic distribution that is similar in odd-and even-year cycles. When combined, these studies have shown that the mass of maturing pink salmon in the North Pacific is composed of a number of stocks, each of which has a rather well-defined distribution that may overlap with one or more distributions of adjacent stocks.

1. Southeastern, Southcentral, and Southwestern (south-side of Alaska Peninsula) stocks. The oceanic migrations of stocks of pink salmon originating in Southeast, Southcentral, and Southwest Alaska (south-side Alaska Peninsula) are similar enough to be treated as one. Generally speaking, these stocks are found in the North Pacific and Gulf of Alaska in an area bounded on the west by about longitude 165°W, on the south by latitude 42°N, and on the east and north by the North American continent. Juveniles from Southeast Alaska in their first marine summer and fall move generally northwestward but likely do not move far offshore. Juveniles from Southcentral and Southwest Alaska (south of the Alaska Peninsula) in their first marine summer and fall move southwestward along the Alaska Peninsula. Some juveniles from Southeast Alaska may move west and join the Southcentral and Southwestern stocks in this area.

Juvenile pink salmon are distributed farther offshore in the north Gulf of Alaska than they are off Southeast Alaska, which may indicate that offshore dispersion begins in the northcentral Gulf of Alaska. No adequate measurements of offshore dispersion have been made south of the Alaska Peninsula.

Assumed migrations during the late fall and winter of their first year at sea indicate that the young pink salmon are further offshore and have begun a general southeastward movement that probably occurs on a broad front within the spring-summer distribution. During their second spring and summer, the maturing fish begin a generally northward movement from the high seas enroute to their natal streams.

2. Southwestern (north-side Alaska Peninsula). Very little information is available concerning pink salmon marine migrations from stocks in Western and Southwest Alaska (north of the Alaska Peninsula). No data are available on seaward migrations of the juveniles during their first summer. From small numbers of tag returns of maturing adults it is supposed that these stocks are found in an area bounded on the west by 180° in the Bering Sea. They may also be found

south of the eastern and central Aleutian Islands south to about latitude 50°N and thence southeasterly to about longitude 140°W at latitude 48°N. They probably do not extend beyond 54°N in the North Pacific.

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

The greatest natural mortality of pink salmon occurs during the early life stages. Bailey (1969) states that, in streams, less than 25% of the eggs survive from the time of spawning to the time of emergence from the gravel; he lists the principle causes of death of the eggs as 1) digging in the redds by other females, 2) low oxygen supply because of low stream flows or impairment of water circulation within the streambed, 3) dislodgement of eggs by floods, 4) freezing of eggs during periods of severe and prolonged cold, and 5) predation by other fish.

Juveniles are preyed upon by a variety of fishes (e.g., cutthroat and rainbow trout, Dolly Varden, coho salmon smolts, and sculpins), kingfisher, mergansers, and other predaceous birds and mammals. Morrow (1980) states that mortality during early sea life (first 40 days) is fairly high at 2 to 4% per day, where predation by birds, fishes, and various invertebrates may be an important factor in mortality at this time.

Adults at sea are preyed upon by marine mammals, Pacific and arctic lamprey, and to a lesser extent by large fish (Scott and Crossman 1973). Sea survival rates are highly variable and have been computed at about 2 to 22% and probably average 5% (Morrow 1980). Murphy (1985) documents the die-off of prespawn adult pink salmon in Porcupine Creek on Etolin Island in Southeast Alaska. The fishes' migration route to spawning areas was blocked at the intertidal stream reach by low stream flow and neap tides. Within four days, about 3,000 pink and chum salmon had collected in a large pool in the intertidal reach of the stream. The crowded fish lowered the dissolved oxygen level to less than 2 mg/l, and some salmon began to die in the center of the pool.

B. Human-related

A summary of possible impacts from human-related activities includes the following:

- Alteration of preferred water temperature, pH, dissolved oxygen, and chemical composition
- Alteration of preferred water velocity and depth
- Alteration of preferred stream morphology
- Increase in suspended organic or mineral material
- Increase in sedimentation and reduction in permeability of substrate
- Reduction in food supply
- Reduction in protective cover (e.g., overhanging stream banks or vegetation)
- Shock waves in aquatic environment
- Human harvest

(For additional impacts information, see the Impacts of Land and Water Use volume of this series.)

VIII. LEGAL STATUS

A. Managerial Authority

1. The Alaska Board of Fisheries develops regulations governing the commercial, sport, and subsistence harvest of salmon in Alaska. The Alaska Department of Fish and Game manages salmon populations in the fresh waters of the state and in the marine waters to the 3-mi limit.
2. The North Pacific Fishery Management Council is composed of 15 members, 11 voting and 4 nonvoting members. The 11 are divided as follows: 5 from Alaska, 3 from Washington, and 3 from state fishery agencies (Alaska, Washington, Oregon). The four nonvoting members include the director of the Pacific Marine Fisheries Commission, the director of the U.S. Fish and Wildlife Service, the commander of the 17th Coast Guard District, and a representative from the U.S. Department of State.
The council prepares fishery management plans, which become federal law and apply to marine areas between the 3-mi limit and the 200-mi limit. With regard to salmon, the only plan prepared to date is the Salmon Power Troll Fishery Management Plan.
3. The International North Pacific Fisheries Commission (INPFC) a convention comprised of Canada, Japan, and the United States, has been established to provide for scientific studies and for coordinating the collection, exchange, and analysis of scientific data regarding anadromous species.
With regard to salmon, the INPFC has also prepared conservation measures that limit the location, time, and number of fishing days that designated high seas areas (beyond the 200-mi limit) may be fished by Japanese nationals and fishing vessels.

IX. LIMITATIONS OF INFORMATION

Limited life history and habitat information concerning Alaskan pink salmon has been documented. Most of the available information is from Pacific Northwest and Canadian field and laboratory studies.

X. SPECIAL CONSIDERATIONS

Neave (1966) states: "Schools of adult pink salmon often frequent bays and estuaries for days and even weeks before entering the streams. Fish tagged at this stage still show movements away from, as well as towards, the nearest spawning grounds. It appears, therefore, that spawning populations are not necessarily well segregated until actual entrance into the spawning streams."

Because of the two-year life cycle, returns of spawning adults are predictable by highly segregated even-numbered year and odd-numbered year runs. Both types of runs, or races, may use the same stream, or

one or the other may predominate in a particular river (Scott and Crossman 1973). Some streams with a dominant run of one type have a very much smaller off-year run of the other race; they often utilize different tributaries as spawning grounds. There may be a significant difference in the date of return and in the length and weight of individuals of the two races or of the same race in different spawning rivers (ibid.).

In addition, caution must be used when extending information from one stock of pink salmon to another stock. Environmental conditions for one area must not be treated as absolute; the stocks (races) have acclimated or evolved over time and space to habitat conditions that can vary greatly.

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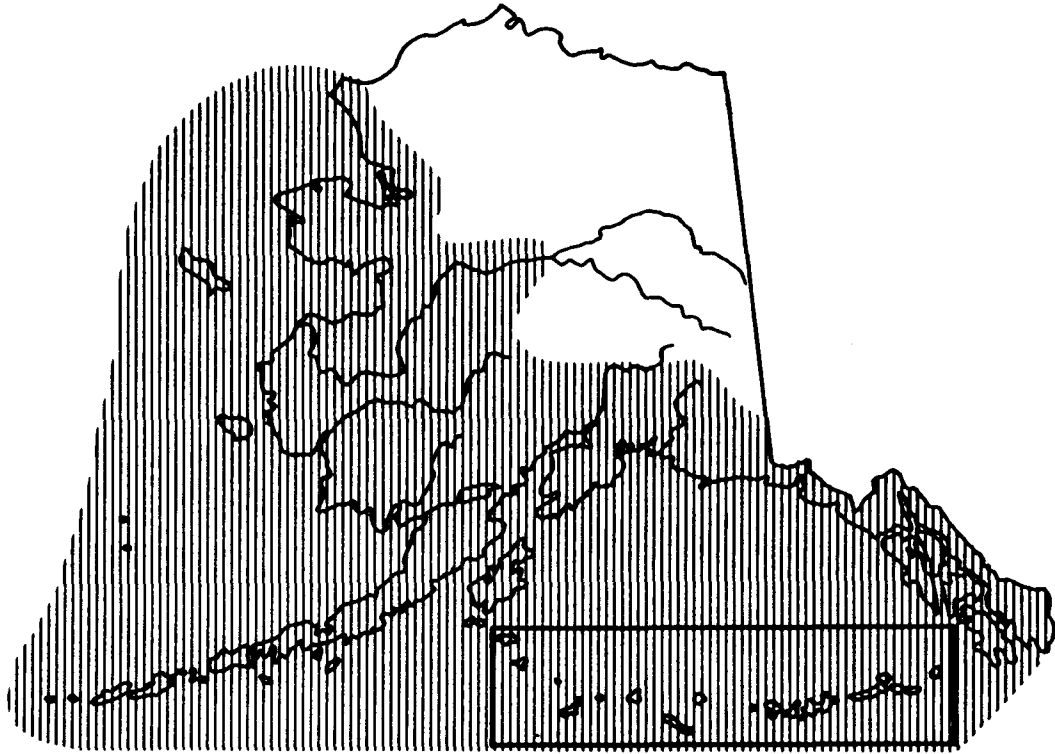
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Sockeye Salmon Life History and Habitat Requirements
Southwest, Southcentral, Arctic, Western, and Interior Regions



Map 1. Range of sockeye salmon (Morrow 1980)

I. NAME

- A. Common Names: Sockeye salmon, red salmon, blueback salmon
- B. Scientific Name: Oncorhynchus nerka
- C. Native Names: See appendix A.

II. RANGE

- A. Worldwide
In North America, the sockeye salmon ranges from the Klamath River, California, north to Point Hope, Alaska. In Asia, sockeye salmon are found from northern Hokkaido, Japan, to the Anadyr River in northeastern Siberia (Scott and Crossman 1973).

B. Statewide

The sockeye salmon is found in stream and river drainages from Southeast Alaska to Point Hope, Alaska. Spawning rivers are usually those with lakes in their systems (Hart 1973).

C. Regional Distribution Maps

To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for each region. In this series, sockeye salmon distribution information is included on the 1:250,000-scale maps titled Distribution of Anadromous Fish. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of selected fish and wildlife species has been prepared and may be found in the Atlas that accompanies each regional guide.

D. Regional Distribution Summary

1. Southwest. In the Kodiak area, major sockeye salmon spawning and rearing waters include the Karluk, Red (or Ayakulik) River, and Upper Station systems (ADF&G 1977c). The introduced sockeye salmon run in the Fraser Lake system is growing in productivity (Pedersen, pers. comm.).
In the Bristol Bay area (for waters from Cape Newenham to Cape Menshikof and north-side Alaska Peninsula systems south to Cape Sharichef), major sockeye salmon-producing waters include the Togiak, Igushik, Snake, Wood, Nushagak, Kvichak, Alagnak (or Branch), Naknek, Egegik, Ugashik, and Bear river systems. Other important runs are located at Nelson Lagoon, Sandy River, Ilnik, and Urilla Bay (ADF&G 1977b).
In the waters draining the south side of the Alaska Peninsula and the Aleutian Islands are found numerous small runs of sockeye salmon. On the south peninsula, Thin Point and Orzinski lakes are important producers of sockeye salmon (Shaul, pers. comm.). The most significant Aleutian Island run is at Kashega on Unalaska Island. In the Chignik area, almost all are found in the Chignik River system (ADF&G 1977b), although there are several other minor systems in the area (Shaul, pers. comm.). (For more detailed narrative information, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)
2. Southcentral. In the Northern and Central districts of Cook Inlet, the majority of the sockeye salmon are produced in the Kasilof, Kenai, Susitna, and Crescent rivers and Fish Creek (Big Lake) systems (ADF&G 1982a). In lower Cook Inlet, systems producing smaller runs of sockeye salmon are the English Bay Lakes, Leisure Lake, Amakdedori, and Mikfik creeks, and Aialik, Delight, and Desire lakes (ADF&G 1981; Shroeder, pers. comm.). In the Prince William Sound area, the Copper River drainage is the major producer of sockeye salmon, with runs also found in the Bering, Eshamy, and Coghill systems (ADF&G 1978a). (For more detailed narrative

information, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)

3. Arctic. Sockeye salmon are rare in the Norton Sound District and have been documented in only one first-order system (first-order systems are those with mouths at salt water). This is the Sinuk (Sinrock) River system (Lean, pers. comm.). In the Port Clarence District, sockeye salmon are found in the Pilgrim River-Salmon Lake-Grand Central River complex of the Kuzitrin River system (ADF&G 1977d, 1984). Within the Kotzebue District, sockeye salmon have been found in the Noatak and Kivalina rivers, Rabbit Creek, and Kelly Lake (ADF&G 1984). The presence of sockeye salmon has not been documented in Northern District waters. (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Arctic Region.)
4. Western. Both the Kuskokwim and Yukon rivers traverse the Western Region and serve as migration corridors for sockeye salmon. Sockeye salmon in the Yukon River, however, are extremely rare (Barton 1984), and no spawning or rearing areas have yet been documented for that portion of the drainage that lies within the Western Region (i.e., downstream of the village of Paimuit) (ADF&G 1985a). Important Western Region sockeye salmon-producing waters of the Kuskowim River system (i.e., those tributaries located downstream of and including the Holitna River drainage) include the Eek, Holokuk, Oskawalik, Holitna, Hoholitna, Kogrukuk, and Chukowan river systems (ADF&G 1977d, 1978b). South of the mouth of the Kuskokwim River, sockeye salmon are produced in the Kanektok River system, with most spawning occurring in Lake Kagati at the headwaters. The Arolik Lake and River system provides spawning grounds for sockeye salmon, as does the Goodnews River system. There are nine known sockeye spawning lakes in the Goodnews River system. One of the more important spawning areas is Goodnews Lake; others include Canyon and Kukaktlim lakes (ibid.). The Dooksook Creek system on Nunivak Island is known to be populated by sockeye salmon (ADF&G 1985a). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Western and Interior regions.)
5. Interior. The Kuskokwim and Yukon rivers serve as pathways for sockeye salmon bound for spawning areas in the Interior Region. Sockeye salmon are extremely rare in the Yukon River (Barton 1984). For that portion of the river found in the Interior Region (i.e., main stem and tributaries upstream of the village of Paimuit), sockeye salmon have been reported taken in the main Yukon River upstream of Rampart (river km 1,227) (ADF&G 1983b), and spawning has been reported in the Innoko River drainage by local residents (Barton 1984).

Exact spawning areas, however, have not yet been documented by the ADF&G (Barton 1984, ADF&G 1985b). Within that portion of the Kuskokwim River drainage in the Interior Region (i.e., that portion upstream of the Holitna River drainage), sockeye salmon are found in the Stony River drainage and in the Big Salmon Fork of the Little Tonoza River in the South Fork Kuskokwim River drainage (ADF&G 1985b). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Western and Interior regions.)

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

1. Water quality:

- a. Temperature. Egg hatching under experimental conditions has occurred across a wide range of temperatures, including 4°C, 15°C, and at descending habitat temperatures of 13.0 to 5.1°C. The amount of time to 100% hatching in these tests was 140 days, 48 days, and 70 to 82 days, respectively (Scott and Crossman 1973). For juvenile sockeye salmon from Washington, the upper lethal temperature limit is 24.4°C (Brett 1952), and preferred temperatures range from 12 to 14°C (ibid.). Smolt out-migration from freshwater nursery lakes takes place when surface water temperatures approach 4 to 7°C (Hart 1973). Adult spawning has occurred in temperatures ranging from 3 to 10°C (McLean et al. 1977, Scott and Crossman 1973.) Water temperatures of 20°C and more have caused death in upstream-migrating adult sockeye (Foerster 1968).
- b. The pH factor. There is no optimum pH value for fish in general; however, in waters where good fish fauna occur, the pH usually ranges between 6.7 and 8.3 (Bell 1973). State of Alaska water quality criteria for freshwater growth and propagation of fish call for pH values of not less than 6.5 or greater than 9.0, with variances of no more than 0.5 pH unit from natural conditions (ADEC 1979).
- c. Dissolved oxygen (D.O.). Foerster (1968) cites studies from the USSR indicating that adult spawning has occurred in lakeshore areas, streams, and spring areas where the mean D.O. level was 11.47 mg/l at 3.82°C and 86.13% saturation (range of 10.22 to 12.50 mg/l, 3.05 to 4.44°C, and 77.05 to 92.14%, respectively). State of Alaska water quality criteria for growth and propagation of fish state that "D.O. shall be greater than 7 mg/l in waters used by anadromous and resident fish. Further, in no case shall D.O. be less than 5 mg/l to a depth of 20 cm in the interstitial waters of gravel utilized by anadromous or resident fish for spawning. . . . In no case shall D.O. above 17 mg/l be

permitted. The concentration of total dissolved gas shall not exceed 110 percent of saturation at any point of sample collection."

- d. Turbidity. Sedimentation causes high mortality to eggs and alevin by reducing water interchange in the redd. If 15 to 20% of the intragravel spaces become filled with sediment, salmonoid eggs have suffered significant (upwards of 85%) mortality (Bell 1973). Prolonged exposure to turbid water causes gill irritation in juveniles, which can result in fungal and pathogenic bacterial infection. Excess turbidity from organic materials in the process of oxidation may reduce oxygen below safe levels, and sedimentation may smother food organisms and reduce primary productivity (ibid.). Turbid water will absorb more solar radiation than clear water and may thus indirectly raise thermal barriers to migration (Reiser and Bjornn 1979).

2. Water quantity:

- a. Instream flow. Sufficient water velocity ("flow," in the case of rivers and streams; and "springs" or seepage, in the case of lake spawning) and depth are needed to allow proper intragravel water movement. This flow is required to provide oxygen to the developing eggs and alevins and to carry away metabolic waste products (Reiser and Bjornn 1979, Foerster 1968). Upon emergence from the gravel, the juveniles must have sufficient water available to be able to move to their nursery lake.

Excessive velocities may impede upstream migrating adults. Experiments in Canada discussed by Foerster (1968) concluded that none of the 406 mature sockeye salmon tested could withstand a current of 2.86 m/s for two minutes, and 50% could not maintain position for 65 seconds. Reiser and Bjornn (1979) suggest that 2.13 m/sec is the maximum velocity that sockeye salmon can successfully negotiate during their spawning runs. They also suggest that optimal velocity at spawning sites ranges from .21 to 1.01 m/sec and that depth of water is usually .15 m or less. No information for adult sockeye salmon migration or spawning criteria in Alaska were found during the literature review.

3. Substrate. Egg incubation and development occur in substrates ranging widely in size and composition. Morrow (1980) states that spawning nests are usually constructed where the bottom is fine gravel but that they may be over large pebbles of 5 to 10 cm in diameter or even over large rocks. Preferred sites have less than 10% of the gravel larger than 7.5 cm in diameter, about 50% of the gravel between 2.5 and 7.5 cm in diameter, and the remaining gravel smaller than 2.5 cm in diameter (ibid.).

B. Terrestrial

1. Conditions providing security from predators or other disturbances. No information was found in the literature.
2. Conditions providing protection from natural elements. Gravel over fertilized eggs provides protection from surface ice and sunlight.

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

Upon hatching, young alevin remain in the gravel for several weeks until the yolk sac is absorbed. After emerging from the gravel, they usually swim to a lake to begin feeding. Juveniles, during their first few weeks in the nursery lake, feed largely on ostracods, cladocerans (water fleas), insects, and insect larvae (Morrow 1980, Hart 1973, Foerster 1968). After moving to deeper water, the young sockeye salmon become pelagic and feed on plankton in the upper 20 m or so. The major summer food items are copepods (Morrow 1980). Juvenile sockeye salmon were found to be feeding on a broad range of invertebrates in slough habitats of the middle reach of the Susitna River during August and September. Midges (Diptera: Chironomidae) were the numerically dominant taxa and were consumed as larvae, pupae, and adults (ADF&G 1982b). In some samples, zooplankton (copepods and cladocerans) became numerically important, but because they are very small their volumetric contribution to the diet was not great. On other occasions, however, the juveniles appeared to have taken advantage of a transient zooplankton bloom, as evidenced by the majority of the stomach contents being comprised of copepods and cladocerans (ibid.).

While in salt water, young sockeye salmon near shore eat insects, small crustaceans or zooplanktons (e.g., copepods, amphipods, decapods, barnacle larvae, ostracods, and euphausiids), and such young fishes and larvae as sand lance, bigeye whiting, rockfishes, eulachon, starry flounder, herring, prickly backs, and hake (Hart 1973).

On the high seas, the growing fish consume ever larger prey, which includes such crustaceans as euphausiids, amphipods, and copepods and also includes squids and young fishes (ibid.).

B. Types of Feeding Areas Used

When they first enter the nursery lake, sockeye salmon juveniles feed along the shore for a few weeks but soon move out over the deeper water in the body of the lake, where they are concentrated in the top 10 or 20 m but may be found as deep as 40 m or more (ibid.). In the Wood River system, Bristol Bay area, Alaska, Burgner (1958) reports that "while the fry do leave the rivers between lakes soon after emergence, downstream migration of fry in most of the tributary creeks is not completed for some time after breakup of the lake ice. In many creeks a portion of the fry population remains to feed and sometimes the fry acquire considerable growth before entering the lake. Sockeye fry in the

Wood River lakes are observed in abundance along the lake shores for at least a month after breakup of the lake ice. When the lake level is high early in the season they are to be found in droves in flooded grass along protected areas of the lake shore."

After migrating to salt water, the young sockeye salmon at first stay fairly close to shore (within 50 km) (Morrow 1980, Hart 1973, French et al. 1976), although they are not seen regularly near shore for several weeks during the summer as young pink salmon and chum salmon are (Ricker 1966).

As the young sockeye salmon get bigger and stronger, they head out to sea. Vertical distribution studies discussed by French et al. (1976) show that sockeye salmon in the ocean occupy depths to at least 61 m and may go deeper; most catches (90%), however, were within 15 m of the surface. These studies also suggest that the thermocline may limit the depth to which sockeye salmon descend.

Morrow (1980) states that the area bounded on the north by the Aleutians, on the south by 50° north latitude, on the west by 165 to 170° east longitude, and on the east by 160° west longitude is an important late spring, summer, and autumn feeding area. By late winter, the sockeye salmon have left this area and are found in a broad band across the North Pacific south of 50°N.

C. Factors Limiting Availability of Food

The well-being and growth of young sockeye salmon depend primarily on 1) the abundance of the food organisms on which they subsist, 2) the numbers of young sockeye salmon present, and 3) the numbers of other species of fish in the lake that compete with sockeye salmon for food (Foerster 1968). Further, temperature conditions, water transparency, and chemical conditions (particularly the amounts of nitrates, nitrites, phosphates, and silicates) all have a direct influence on the production of plankton populations, which are the main food of the young fish (ibid.).

D. Feeding Behavior

Juveniles in nursery lakes feed in schools (Hartman 1971).

Maturing sockeye salmon stop feeding as they near fresh water, and the spawning fish derive nourishment from oils and proteins of their flesh, skeletal structures, and scales (ibid.).

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Spawning occurs primarily in streams that connect with lakes (Morrow 1980), although some populations spawn along lake shore beaches and island beaches in lakes (Morrow 1960, McPhail 1966), and other populations spawn in streams with slow-moving reaches but no lakes in the system (Morrow 1980; Roberson, pers. comm.). Factors determining the selection of spawning sites are variable and include stream gradient, water depth and velocity, and the size of the streambed materials (substrate). Spawning sites are usually selected where there is a good waterflow through the gravel (ADF&G 1977a). These areas may be 1) in the streams flowing into the lake, 2) in the upper sections of the outlet

river, or 3) along the shores of the lake where "springs" or seepage outflows occur (Foerster 1968).

In summarizing Alaskan spawning waters, Foerster (1968) states: ". . . a review of available evidence indicates that in general, while stream spawning is still the most important, lake-beach spawning increases in extent and significance (when compared to Canadian waters). At Karluk Lake on Kodiak Island, it is reported that about 75 percent of the spawning occurs in the streams, the remaining 25 percent on the lake beaches. For Bristol Bay and its highly productive sockeye salmon areas there appears to be a transition in importance of specific types of spawning ground. In the eastern part, stream spawning ranks as the most important. The Naknek and Kvichak River systems each have a number of smaller lakes auxiliary to the main lake. Salmon spawn in streams tributary to these lakes as well as in streams connecting them to the main lake. . . the spawning in both systems is confined to stream bed areas rather than beaches. Further west, however, in the Nushagak River system which comprises 10 major lakes, the sockeye salmon spawn principally in the rivers between lakes and along lake shore beaches, although there are also a few important tributary streams."

During 1965, a study of Iliamna Lake revealed that island beaches used for spawning showed no evidence of upwelling water; apparently the eggs are washed by means of wind-caused lake currents (McPhail 1966).

Vining et al. (1985), from chum salmon incubation studies of main stem, tributary, side channel, and slough habitats within the middle reach of the Susitna River, Alaska, caution that because of the effects of dewatering and freezing, the amount of available habitat at the time when adult salmon are spawning is a poor indicator of the amount of actual habitat that is available as potential incubation habitat. Estimates of available incubation habitat must take into account the differential effects of dewatering and freezing in various habitat types.

B. Reproductive Seasonality

In Alaska, adult sockeye salmon ascend their natal streams from early May to October, depending on the geographic location (Morrow 1980; ADF&G 1977a; Roberson, pers. comm.). Region-specific run timing and spawning time information is presented in the salmon Distribution and Abundance narratives prepared for each of the regions addressed in this series of publications.

In general, fish breeding in lakes and their outlet streams spawn later than those spawning in streams (ADF&G 1977a). This breeding characteristic, however, is by no means universal (Morrow 1980). Roberson (pers. comm.) notes that several factors affect the periods that have evolved to become the spawning times of different populations of sockeye salmon. Among these factors are the average water temperatures during egg incubation and alevin development, the feeding potential upon emergence from the gravel, and water temperature and velocity during adult migration.

A few exceptions to the general spawning time characteristics mentioned above are found in Upper Mendeltna Creek (outlet stream of Old Man Lake), where spawning occurs early and spawners are dead by June 30; in Dickey Lake (at the headwaters of the Middle Fork of the Gulkana River), where spawning occurs early and spawners are dead by July 30; and in the Gulkana River Springs, where spawning occurs late and spawners are dead by late November (ibid.). Likewise, the general timing characteristics do not hold true for Bear Lake on the north side of the Alaska Peninsula or for Chignik Lake on the south side of the Alaska Peninsula (Shaul, pers. comm.).

C. Reproductive Behavior

As with other salmon, adult sockeye return from the sea and move into their natal freshwater streams or lakes to spawn. The female selects the spawning site and digs the redd (nest) by turning on her side and thrashing her tail up and down. The current washes loosened substrate material downstream, and a depression 35 to 41 cm deep is formed in the river bottom (Hartman 1971, Morrow 1980). Eggs and sperm (milt) are released simultaneously and deposited in the redd. After egg deposition, the female moves to the upstream margin of the redd and repeats the digging process. Dislodged substrate is washed over the eggs. In this manner, the eggs are covered and prevented from washing away. The process is repeated several times, and the redd appears to move upstream (Burner 1951, Morrow 1980). As a result of the continued digging, the redd may grow to become 1.0 to 7.0 m², depending on the concentration of fish in the area, although under "normal" conditions a size of 1.6 m² to 2.9 m² is more likely (Foerster 1968). The ADF&G (1977a) states that the redds of lake spawners are usually larger than 1.75 m² and are more irregular in shape than redds of stream spawners. A female may dig several redds and spawn with more than one male. Males may also spawn with several females (Morrow 1980).

D. Age at Sexual Maturity

Morrow (1980) states: "Most sockeye salmon from British Columbia, Canada, spend one year in fresh water and two in the sea, returning to spawn in their fourth year. Farther north, however, two years in fresh water and two or three in the sea are common. Therefore many Alaskan sockeye salmon return in their fifth or sixth years."

E. Fecundity

The number of eggs produced by individual females varies with the stock, positively with the size of the fish and with the earlier migration history of the individual fish, shorter saltwater life being associated with higher egg counts (Hart 1973). The female usually produces 2,500 to 4,300 eggs (Morrow 1980).

F. Frequency of Breeding

As with all salmon, the spawning cycle is terminal. Both male and female die after spawning.

G. Incubation Period/Emergence

The amount of time required for eggs to hatch is dependent upon many interrelated factors, including 1) dissolved oxygen, 2) water temperature, 3) apparent velocity in gravel, 4) biological oxygen demand, 5) substrate size (limited by percentage of small fine material), 6) channel gradient and 7) configuration, 8) water depth, 9) surface water discharge and velocity, 10) permeability, 11) porosity, and 12) light (Reiser and Bjornn 1979, Foerster 1968). Generally speaking, factors 4 through 12 influence or regulate the key factors 1, 2, and 3.

Development of eggs takes six to nine weeks in most areas but may require as long as five months, the time depending largely on water temperature (Hart 1973). Hatching usually occurs from mid winter to early spring, and the alevins emerge from the gravel from April to June (Morrow 1980).

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

A. Size of Use Areas

From studies of Columbia River tributaries, Burner (1951) suggests that a conservative figure for the number of pairs of salmon that can satisfactorily utilize a given area of spawning gravel may be obtained by dividing the area by four times the average size of the redds. Redd area can be computed by measuring the total length of the redd (upper edge of pit to lower edge of tailspill) and the average of several equidistant widths (Reiser and Bjornn 1979). Information obtained by Mathisen (cited in Foerster 1968) from observations in Pick Creek, Wood River system, Bristol Bay area, Alaska, shows that under competitive conditions for space each female usually manages to average 3.7 m² as spawning territory. When competition for space is eliminated each female occupies an average area of 6.97 m². The ADF&G (1977a) states that a redd (presumably in Alaska) generally averages 1.75 m² in stream spawning areas. No specific data on redd size in Alaskan lake-spawning areas were found during literature review.

B. Timing of Movements and Use of Areas

In Alaska, alevins emerge from the gravel during the period April to June (Morrow 1980) and are light-sensitive, tending to hide in the stones and gravel of the stream bottom by day and coming out at night. In a few populations, the fry go to sea during their first summer, but the vast majority spend one or two years (in rare cases three or four years) in a lake (ibid.). After the juveniles emerge from the gravel in lake tributaries, those in inlet streams go downstream to the lake, and those in outlet streams swim upstream to the lake. They migrate singly at night and thus minimize the dangers of predation (Hartman 1971). Once in the lake, the juveniles move about in schools and stay close to shore for the first few weeks before moving to deeper water. In over 30 streams of the Copper River drainage, young sockeye salmon stay in the stream and move to slow-moving sections of the river because no lake is available in the system (Roberson, pers. comm.)

After a year in the lake, often two years and sometimes three years in many Bristol Bay areas (Bucher, pers. comm.), smoltification occurs (the young fish lose their parr marks and turn silvery), and they migrate downstream. Most of the migrants move at night (Morrow 1980), the migration apparently being triggered when the nursery lake's temperature approaches 4°C. The peak of the Bristol Bay out-migration occurs during June. Where known, other Alaska specific timing information is contained in the salmon Distribution and Abundance narratives found in this report series.

Following is a summary of ocean chronological distribution, as given by French et al. (1976):

After entering the open ocean in the late spring or early summer the young fish (age .0) generally are found along the coastlines within about 50 km of shore, but tagging has shown that many of them migrate hundreds of kilometers within this coastal belt. Age .0, as used here, refers to immature sockeye salmon during the period of their initial ocean residence. The period ends during December, at which time the young fish have been in the marine environment about six months. The timing and locations of their offshore migrations are unknown. In the winter as age .1 fish (7th through 18th month of ocean residence), they appear to be distributed broadly across the North Pacific Ocean and Bering Sea. The greatest abundance occurred between 50°N and 45°N. By spring, the young age .1 fish have reached their southernmost limit of migration, which in May is about 44°N in western and central North Pacific waters and somewhat north of this latitude in the northeastern Pacific. June finds the age .1 fish moving northward, a migration that continues until August. During the summer, the sockeye salmon extend in a continuous band across the North Pacific Ocean from near 140°W to 160°E and generally between 50°N and 53°N; their movement is pronouncedly westward as they approach the Aleutian Islands from the south and east. The fish are also found in abundance in the central and western Bering Sea, from 175°W to 165°E from the Aleutian Islands to near 61°N.

Little is known of the distribution of the age .1 sockeye salmon in fall other than that migration must be southward for the fish to attain their winter distribution. The winter distribution of the now age .2 fish (19th through 30th month of ocean residence) is generally similar to that which they had as age .1 immatures, although they stay 2 or 3° north of their former range. In winter, the center of concentration is generally north of 49°N in the northeastern Pacific Ocean, east of 165°W, and may extend somewhat farther south in the central and western North Pacific. The fish in winter extend across the North Pacific from near 140°W to about 165°E. In spring, they commence their inshore spawning migrations and have essentially left the high seas by the end of July.

Sockeye salmon that remain in salt water for an additional season (age .3 fish or those in their 31st through 36th month of ocean residence) winter in areas somewhat north of their age .2 range. Both age .2 and age .3 groups occur in the Bering Sea in winter (the age .3 fish apparently in greater abundance than the age .2 fish). The distribution and migration of these stocks until they leave for the spawning grounds is not known. It is known, however, that they are not found in abundance over the continental shelf areas of the eastern Bering Sea except during migration to and from spawning streams but remain in deep water parts of the ocean in the central and western Bering Sea (French et al. 1976).

C. Migration Routes

Freshwater lakes, streams, and rivers serve as corridors for downstream migration of ocean-bound juvenile sockeye salmon and upstream migration of spawning adults. The following ocean migration routes are taken from French et al. (1976).

While in the ocean, juvenile (age .0) sockeye salmon from western Alaska (primarily from streams that are tributary to Bristol Bay) move southwest along the north side of the Alaska Peninsula, then southwestward along the Aleutian Islands, and then south through various passes (most likely east of 175°E) into the North Pacific Ocean. By January 1 of their first year at sea, the now age .1 sockeye salmon have moved south of the Alaskan Stream and Ridge Area to areas primarily south of 50°N in Western Subarctic Intrusion or Transition Area waters. By April, the fish have reached their southern limit from 45°N to 50°N. In June, the sockeye begin a northward movement and by July are found north of 50°N in the Alaska Stream and Ridge Areas, with a broad east to west distribution from about 170°E to about 150°W. There is a pronounced westerly migration during the summer, particularly close to the south side of the Aleutian Islands. Some elements of the population move northwestward into the central and western Bering Sea in summer and are found to at least 60°N and to 166°E. The circuit is generally repeated again with a few minor variations as the stocks separate into mature and immature stages. Suffice it to say that maturing fish tend to stay a bit (2-3°) north of their first year's southern limit. In June, the spawning migration toward Bristol Bay occurs over a broad front from about 166°E to near 140°W.

Sockeye salmon stocks from the Alaska Peninsula (south-side streams), Southcentral, and Southeast Alaska generally mix during their residence in the northeastern Pacific Ocean. Depending on origin, they move northward, westward, or southward in a general counter-clockwise pattern along the coast as age .0 juveniles. By January, the age .1 fish have moved generally west and south into feeding grounds well offshore. In the spring (June), a northerly movement begins, and by July they are widely spread throughout the northeastern Pacific Ocean. By late summer, migration is westward and southwestward until their distribution lies probably west of 145°W and north of 49°N (some may go as far west as 177°E during

their second summer at sea). In the fall, the fish turn southward and eastward and by mid winter occupy an area from near 140°W to 165°W. There is some separation of age groups of fish at this time: the maturing fish age .2, the ones that will spawn the next season, tend to be in more northern areas of the winter range in the northeastern Pacific Ocean. In the spring, the maturing fish migrate northerly, easterly, and westerly from an area generally east of 160°W and north of 46°N towards their respective spawning streams. The circuit is repeated for those sockeye salmon that remain in the marine environment for three and, rarely, four years.

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

Deposition of silt in the redd, reducing water flow, may result in heavy mortality of eggs and alevins (Morrow 1980). Juveniles in their nursery lakes must compete for food with other species and are preyed upon by Dolly Varden, char, rainbow trout, coho salmon, and prickly sculpin (Hart 1973). Adults may be preyed on by Pacific harbor seals (Phoca vitulina richardsi), bears, and sea gulls (Foerster 1968). An increase in the abundance of predatory marine fishes may also be a very big factor (Shaul, pers. comm.).

B. Human-related

A summary of possible impacts from human-related activities includes the following:

- Alteration of preferred water temperatures, pH, dissolved oxygen, and chemical composition
- Alteration of preferred water velocity and depth
- Alteration of preferred stream morphology
- Increase in suspended organic or mineral material
- Increase in sedimentation and reduction in permeability of substrate
- Reduction in food supply
- Reduction in protective cover (e.g., overhanging stream banks or vegetation)
- Shock waves in aquatic environment
- Human harvest

(For additional impacts information see the Impacts of Land and Water Use volume of this series.)

VIII. LEGAL STATUS

A. Managerial Authority

1. The Alaska Board of Fisheries develops regulations governing the commercial, sport, and subsistence harvest of salmon in Alaska. The Alaska Department of Fish and Game manages salmon populations in the fresh waters of the state and in the marine waters to the 3-mi limit.
2. The North Pacific Fishery Management Council is composed of 15 members, 11 voting and 4 nonvoting members. The 11 are divided as follows: 5 from Alaska, 3 from Washington, 3 from

state fishery agencies (Alaska, Washington, Oregon). The four nonvoting members include the director of the Pacific Marine Fisheries Commission, the director of the U.S. Fish and Wildlife Service, the commander of the 17th Coast Guard District, and a representative from the U.S. Department of State.

The council prepares fishery management plans, which become federal law and apply to marine areas between the 3-mi limit and the 200-mi limit. With regard to salmon, the only plan prepared to date is the Salmon Power Troll Fishery Management Plan.

3. The International North Pacific Fisheries Commission (INPFC), a convention comprised of Canada, Japan, and the United States, has been established to provide for scientific studies and for coordinating the collection, exchange, and analysis of scientific data regarding anadromous species. With regard to salmon, the INPFC has also prepared conservation measures that limit the location, time, and number of fishing days that designated high seas (beyond the 200-mi limit) areas may be fished by Japanese nationals and fishing vessels.

IX. LIMITATIONS OF INFORMATION

The physical habitat requirements for sockeye salmon are less well documented than other aspects (timing and movement patterns, e.g.) of this species' freshwater residency in Alaska.

X. SPECIAL CONSIDERATIONS

A freshwater form of this species exists and is known as the kokanee. The kokanee is generally very similar to the anadromous sockeye salmon except that it is smaller in ultimate length and weight and spends its entire life in fresh water. It, too, dies after spawning.

Caution must be used when extending information from one stock of sockeye salmon to another stock. Environmental conditions for one area must not be treated as absolute; the stocks (races) have acclimated or evolved over time and space to habitat conditions that can vary greatly.

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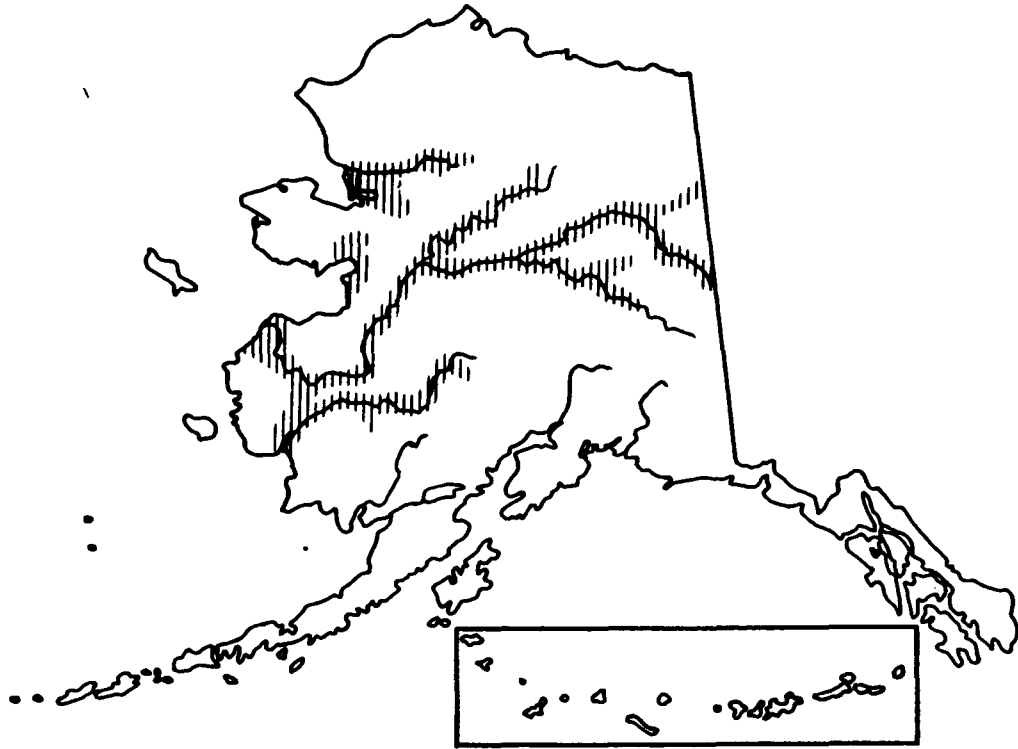
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Sheefish Life History and Habitat Requirements
Arctic, Western, and Interior Regions



Map 1. Range of sheefish (ADF&G 1978)

I. NAME

A. Common Name

Inconnu is the accepted common name for this species (Robins et al. 1980); however, in Alaska sheefish is the most frequently used common name.

B. Scientific Name: Stenodus leucichthys

C. Native Names: See appendix A.

II. RANGE

A. Statewide

Sheefish in Alaska have been separated into five major groups (Alt 1969a, 1977). The Minto flats and upper Yukon River populations are year-round residents in the eastern part of Interior Alaska (ADF&G 1978). The lower Yukon and Kuskokwim

populations overwinter in the delta areas of these two rivers. Lower Yukon River sheefish move upstream to spawn as far as the middle Yukon River above Rampart and the upper Koyukuk River (Alt 1975, 1981, and pers. comm.). Kuskokwim River sheefish travel upstream as far as Highpower Creek to spawn (Alt 1981). The Selawik-Kobuk population overwinters in Hotham Inlet and Selawik Lake and travels to spawning grounds approximately 200 km up the Selawik River and in the Kobuk River 38-100 km above Kobuk Village (Alt 1967 and pers. comm.).

B. Regional Distribution Maps

To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for each region. Sheefish distribution information is included on the 1:250,000-scale maps titled Distribution of Selected Freshwater Fish. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of selected fish and wildlife species has been prepared and may be found in the Atlas that accompanies each regional guide.

C. Regional Distribution Summary

1. Arctic. Sheefish are found in the Selawik and Kobuk rivers but are absent north of Kotzebue Sound across the arctic slope until they are again encountered in rivers east of Demarcation Point (Alt 1969b). The Kobuk-Selawik population overwinters in Selawik Lake, Hotham Inlet, and Kotzebue Sound and travels upstream to spawning grounds approximately 200 km up the Selawik River and in the Kobuk River 40-50 km above Kobuk Village (ibid.). Rearing immature sheefish of ages 4 to 10 are found in Hotham Inlet, Selawik Lake, and in estuarine areas around Kotzebue and Sheshalik (Alt 1980 and pers. comm.). Rearing sheefish are also found in the lower Kobuk, lower Selawik, and Tuklomarak rivers (Alt 1980). A small population of sheefish is also found in the Koyuk River, which drains into Norton Bay (ADF&G 1978). These fish are found 10 mi up the Koyuk River (Alt, pers. comm.). (For more detailed narrative information on sheefish distribution in the Arctic Region, see volume 2 of the Alaska Habitat Management Guide for the Arctic Region.)

2. Western and Interior. In the Western and Interior regions, sheefish are found in the Kuskokwim and Yukon river drainages.

Kuskokwim River sheefish overwinter in brackish water and lakes and sloughs in the lower reaches of the river. During the summer, these sheefish move upstream to feed at tributary stream mouths and in the Holitna River (Alt 1981). Spawning areas for Kuskokwim River sheefish are documented at Big River and Highpower Creek (ibid.).

The lower Yukon River anadromous sheefish population overwinters in the lower Yukon River and nearby brackish

water. Yukon River sheefish feed at the mouths of tributary streams and in the Innoko River (Alt 1983). These sheefish spawn in the Koyukuk River at Hughes and in the Alatna River in the Koyukuk drainage. Another segment of the Yukon River anadromous population spawns in the Yukon River drainage somewhere above the Dalton Highway bridge across the Yukon River (Alt 1975).

Nonanadromous sheefish populations are also found in the middle and upper Yukon areas. Nonanadromous sheefish are found in the Nowitna River, the Minto flats area, the lower Tanana River, the Porcupine River drainage, and at the mouths of nearly all middle and upper Yukon tributaries. (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Western Interior regions.)

III. PHYSICAL HABITAT REQUIREMENTS

A. Water Quality

1. Temperature. Surface water temperatures in areas where sheefish feed range from 22°C in July to 0°C during the winter (Alt 1973). Water temperatures at time of spawning in the Kobuk River ranged from 1.4 to 4.6°C in 1965 and 1966 (Alt 1967). In 1967 in the Koyukuk River, water temperatures at the time of spawning ranged from 4.8 to 4.3°C (Alt 1968), and in 1971 in Highpower Creek (Kuskokwim drainage) spawning began at 3°C and peaked at 1°C (Alt 1972). Spawning temperatures vary from watershed to watershed, and the time of spawning is apparently more related to gonad development than to water temperature (Alt 1969a). Bogdanova (1977) found that the development of sheefish larvae held at a temperature of 3.8°C was slower than development of larvae held at 11.4°C, although the rate of survival at the lower temperature was high.
2. The pH factor. PH readings from areas in Alaska where sheefish are found range from 6.7 to 7.9; however, a comprehensive study relating chemical values and sheefish distribution has not been conducted (Alt 1973).
3. Dissolved oxygen (D.O.). Little information is available on the D.O. requirement of sheefish. Alt (1981) noted that in 1980 sheefish stocked in Island Lake had good overwinter survival although surface D.O. readings from the lake were quite low (2 to 2.5 ppm) during both February and March. No fish were recovered in the lake in 1981 and 1982, however, indicating that they may have perished from low D.O. conditions in late winter (Alt, pers. comm.).
4. Turbidity. Little information is available on the effects of turbidity on sheefish populations in Alaska. Alt (1969b) notes that eggs carried to areas with slow-moving water may be covered with silt and thus have reduced chances of survival.

5. Salinity. Sheefish are generally not found in salt water, and saltwater barriers may limit their range expansion into the Seward Peninsula area and from Kotzebue Sound into northwestern Alaska and northern Alaska (Alt 1973). Sheefish rear and overwinter in brackish water in Hotham Inlet and in Norton Sound. Local fishermen in the Kotzebue area, however, have said that extremely high tides tend to bring about mass movements of sheefish into river mouths or into Selawik Lake (Arthur D. Little, Inc. 1963). Kirilov (1962) stated that sheefish inhabited areas of the Lena River delta in Siberia with a salinity not exceeding 6 to 7 parts per thousand (ppt).

B. Water Velocity and Depth

Sheefish are not strong swimmers, and both Russian and Alaskan studies indicate that they will not ascend streams with rapid current or even small falls (Alt 1973).

Water velocity is a very important factor in successful sheefish spawning. Spawning in the Kobuk River occurs in the relatively swift main current, both where it moves along the cut bank and also in the center of the channel as the current swings to the opposite shore (Alt 1969b). No spawning was observed on gravel bars on the inside curve of the river where the current is slower. Water velocity in spawning areas of Highpower Creek was measured at less than 100 cm/sec (Alt, pers. comm.). The Big River spawning area in the Kuskokwim drainage, which Alt (1981) considered to be far superior to the Highpower Creek spawning area, had a water velocity of 100 to 130 cm/sec.

The depth of water in spawning areas is also important. In the Yukon River above Rampart, sheefish must spawn in water deeper than 5 m to prevent the eggs from freezing when the Yukon water level drops over the winter (Alt 1975). In other areas, sheefish may successfully spawn in shallower water. Spawning in the Kobuk River in 1965 and 1966 occurred at depths of 1.2 to 2.7 m, with the major spawning in waters 1.5 to 1.8 m deep (Alt 1967). Spawning in Highpower Creek in 1971 took place at depths of 1.3 to 2.7 m and in Big River in 1980 at depths of 0.6 to 1.5 m (Alt 1981). In Great Slave Lake, sheefish are seldom found in depths greater than 30 m (Fuller 1955).

C. Substrate

Alt (1969b) noted that in optimum sheefish spawning habitat the substrate is composed of differentially sized coarse gravel, with no silt and some sand present. Apparently, the presence of differentially sized gravel is necessary to ensure lodging of the eggs. With a bottom of uniformly sized gravel, Alt (1969b) speculated that the eggs might fail to lodge because of the swift current and be carried out into the slow-moving water where there is more silt, thus reducing chances for survival. In a study on the lower Volga River in Russia, it was found that sheefish eggs laid over a substrate where suitable shelter was available had better survival than those laid over an open sandy substrate.

(Letichevskiy 1981). Other fishes intensely prey on the sheefish eggs on the open sandy spawning grounds, and practically none survive to the completion of embryogenesis (ibid.). Alt (1981) described the sheefish spawning ground substrate in Big River as generally composed of 5% sand, 15% gravel less than 0.5 inches (1.3 cm), 30% gravel 0.5 to 1 inches (1.3 to 2.5 cm), and 50% coarse gravel and rocks.

Sheefish stocked in Four Mile Lake near Tok, Alaska, successfully spawn in the lake over a mud and silt bottom (Alt 1980, 1984). This is the only record of sheefish spawning in a lake or over such substrate (Alt 1980).

D. Cover Requirements

In Big River, sheefish use small eddies created by downed timber and log jams as holding or resting areas during their upstream spawning migration (Alt 1981).

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

Adult sheefish are piscivorous (Fuller 1955, Alt 1965). Sheefish fry feed on plankton but are feeding actively on crustaceans and insects by the summer of their first year of life (Alt 1973). By July and August, they also begin feeding on fry of other fish and by the second year of life are almost entirely piscivorous (ibid.). Sheefish introduced into lakes barren of fish show excellent growth during the first four years of life on a diet of insects and freshwater shrimp, but sheefish must switch to feeding on fish after three or four years to maintain a good growth rate (Alt 1973, 1980). Sheefish mouth configuration prevents them from consuming prey larger than about 30 cm in length (Alt 1973). In the middle Yukon River, sheefish seldom eat prey over 15 cm in length (Alt 1975).

Sheefish are opportunistic feeders, and their diet varies from place to place, depending on food availability. In the Selawik area, sheefish feed on least cisco (Coregonus sardinella), Mysis relicta (a small pelagic crustacean), Mesidotea entomon (an isopod), ninespine stickleback (Pungitius pungitius), humpback whitefish (Coregonus pidschian), broad whitefish (C. nasus), burbot (Lota lota), and blackfish (Dallia pectoralis), herring, smelt, and lamprey (Alt 1969b, 1979). In estuarine areas around Kotzebue, sheefish captured in June and September had consumed ninespine stickleback, shrimp, smelt, and fish remains (Alt 1979). Sheefish feed on tomcod (probably Eleginus gracilius) in brackish water at the mouth of the Kuskokwim River (Alt 1970).

In the Holitna River (upper Kuskokwim drainage), summer foods include fingerlings of chum, coho, and chinook salmon and Pacific lamprey (Entosphenus tridentatus) (Alt 1972). Sheefish in this area show a preference for salmon fingerlings (ibid.). Nonspawning and immature sheefish that spend the summer and fall in the lakes and streams of the lower Kuskokwim drainage feed very little on salmon fingerlings but rather use ninespine stickleback,

northern pike (Esox lucius), and whitefish (*ibid.*). In the winter on the lower Kuskokwim River, least cisco are the main food item (*ibid.*).

In the middle Yukon River from May to September, sheefish feed on arctic lamprey (Lampetra japonica), humpback whitefish, least cisco, and suckers (Catostomus catostomus) (Alt 1975). In the upper Yukon River, chinook salmon fingerlings and broad whitefish are the major food items, with sheefish near mouths of tributary rivers feeding mainly on salmon and those in adjacent quiet water of the Yukon feeding mainly on whitefish (Alt 1965). Finally, in the Minto flats area sheefish feed heavily on northern pike during the summer (Alt 1968).

Fuller (1955) reported that adult sheefish in the Big Buffalo River taken before their downstream run into Great Slave Lake were gorged with young sheefish; however, Alt has reported only one case of cannibalism in Alaska. The stomach of one sheefish taken from the middle Yukon River contained 14 other sheefish up to 14 cm in length (Alt 1975).

B. Types of Feeding Areas Used

Sheefish from the Selawik and Kobuk drainages overwinter and feed in Hotham Inlet, Selawik Lake, Inland Lake, and the lower reaches of the Selawik and Kobuk rivers (Alt 1977). In early June, sheefish in these areas feed close to the surface, jumping almost completely out of the water as they pursue least cisco (Alt 1969b). In late June, as air and water temperatures increase, most sheefish are found at depths of 2 to 3 m (*ibid.*).

The lower Yukon River sheefish population feeds in the lower reaches of tributaries of the lower and middle Yukon, such as Hess Creek and Ray River, and in slack-water areas of the main Yukon (Alt 1975, 1981). The two main feeding areas of upper Yukon River sheefish are the mouths of tributary rivers and the adjacent quiet-water areas (Alt 1965). In the Kuskokwim River, feeding sheefish are widely distributed in lakes and sloughs of the lower Kuskokwim River and the Holitna River, with smaller concentrations along the Kuskokwim River and its tributaries (Alt 1981). The Holitna River is a major feeding area, and sheefish arrive there in early June, with smaller sheefish arriving first (*ibid.*).

The Minto flats area is the main summer feeding and rearing area for the Minto flats sheefish population. Sheefish move into the Minto flats in May (Alt 1977).

C. Factors Limiting Availability of Food

Little information could be found in the available literature on factors limiting availability of food. Sheefish stocked in Four Mile Lake near Tok apparently competed with land-locked coho salmon and rainbow trout, which were also stocked in the lake (Alt 1978, 1979). Fuller (1955) noted that in Great Slave Lake sheefish probably do not compete with lake trout for food because the lake trout are found in deeper areas than the sheefish.

D. Feeding Behavior

Sheefish generally cease feeding some time prior to spawning. In the Kuskokwim drainage, sheefish that will spawn in October cease feeding in July (Alt 1981). In the middle Yukon, fish that would spawn in the fall were feeding in June, but nearly all spawning fish examined in August and September had empty stomachs (Alt 1975). Thirteen sheefish taken approximately 100 mi up the Chatanika River in late September had empty stomachs, but four had digested food in the intestine (Alt 1965). In 1973, Alt found one prespawning sheefish in the upper Porcupine River to have been actively feeding on fingerlings of humpback whitefish (Coregonus pidschian) (Alt, pers. comm.), suggesting that at least some feeding takes place during the spawning migration. In Russia, sheefish that leave the Caspian Sea to spawn in the lower reaches of the Volga River do not feed after they enter the river, and their body weight decreases by 15 to 20% during the spawning period (Letichvskiy 1981). Petrova (1976) noted that sheefish from the Irtysh River in Siberia feed most intensively during the winter, but males continue to feed at a lesser level during the spawning migration.

Sheefish fry held in darkened aquaria during a rearing experiment ceased feeding and appeared to enter a state of sleep (LaPerriere 1973). When light was allowed to enter the aquaria the fish slowly revived (ibid.).

Bogdanova (1977) found in laboratory experiments that recently hatched sheefish larvae are able to withstand long periods of starvation (up to 44 days at a temperature of 3.8°C). Bogdanova (1977) speculated that this may be an adaptation to conditions of poor food supply where sheefish are hatched in the spring.

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Sheefish spawn in the relatively swift main current of rivers in areas with substrate composed of differentially sized coarse gravel.

B. Reproductive Seasonality

Alaskan sheefish spawn in late September and early October. Kobuk River sheefish spawn during the last week of September (Alt 1969b); Koyukuk River sheefish spawn from the last days of September to the first days of October (Alt 1968); Kuskokwim sheefish spawn during the first days of October (Alt 1972); and middle Yukon River sheefish spawn sometime in early October (Alt 1975).

C. Reproductive Behavior

Morrow (1980) summarized reproductive behavior as follows:

Spawning takes place in the evening, usually beginning about dusk and continuing well into the night. In the spawning act a female accompanied by a male (in rare cases by two or more males) rises to the surface near the upstream end of spawning grounds. She moves rapidly across the current . . .

extruding eggs as she goes. This activity lasts for 1 to 3 seconds. The male, meanwhile, stays below the female. The eggs sink to the bottom through the cloud of sperm released by the male and are fertilized as they sink

After completing a spawning pass, the female drifts downstream. She may repeat the spawning act over the downstream portion of the spawning area or may move upstream to the head of the grounds before releasing more eggs.

Several spawning passes are needed for a female to release all of her eggs (Morrow 1980).

D. Age at Sexual Maturity

Sheefish from the fast-growing Minto flats and Kuskokwim populations become sexually mature at an earlier age than the longer-living, slower-growing Kobuk-Selawik fish (Alt 1973). Males reach maturity at an earlier age and smaller size than do females (ibid.). Males in the Minto flats population mature at ages 5 to 7, in the Holitna River spawning group of the Kuskokwim population at ages 6 to 8, and in the upper Yukon population at ages 6 to 7 (ibid.). Females in these populations mature at ages 6 to 9 (Alt 1973, 1981). Males in the lower Yukon population mature at ages 6 to 9, females at ages 8 to 10 (ibid.). Males in the Kobuk-Selawik population mature at ages 7 to 11, females at ages 9 to 14 (Alt 1973, 1978). Kuskokwim population sheefish at the Big River spawning grounds in 1980 matured at 4 to 13 years for males and 6 to 9 years for females (Alt 1981).

E. Frequency of Breeding

Sheefish are generally nonconsecutive spawners. The majority of females spawn once every two years and possibly once every three years for older fish (ibid.). A male sheefish used during the 1967 egg take at Hughes was recaptured in ripe condition at the spawning grounds in 1968, indicating that at least some males are capable of reproducing every year (Alt 1969a).

F. Fecundity

Fecundities recorded for Alaskan sheefish range from 27,000 eggs for a 1.6 kg female from the Salmon Fork River in the middle Yukon drainage (Alt 1978) to 286,840 eggs for a 11.9 kg female from Big River in the Kuskokwim drainage (Alt 1981). In a sample of 13 Kobuk River females, ovary weight averaged 20% of body weight, and there were 20,300 eggs per kg of body weight (Lebida 1970). Ovaries from the 11.9 kg Big River female contributed 27% of her body weight (Alt 1981).

Petrova (1976) estimated that the average fecundity of sheefish from the Irtysh River in Siberia was 137,000 eggs per female, or 22 to 33 thousand eggs per kg of body weight.

G. Incubation Period and Time of Emergence

Eggs collected from sheefish in the Koyukuk and Kobuk rivers and Highpower Creek in the Kuskokwim drainage from September 29 to October 3 hatched at the Fire Lake Hatchery from late January through March 15 (Alt 1968, 1970, 1972). Vork (1948) mentioned

that sheefish from the Ob River in Russia had an average incubation period of 182 days.

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

Sheefish in the Kobuk-Selawik, lower Yukon, and Kuskokwim populations overwinter and feed in the brackish inlets, deltas, and lower reaches of these rivers. In the summer months, they move far upstream to reach spawning areas in the fall. After spawning in September and October, sheefish move back downstream to overwintering areas. Immature and nonspawning sheefish do not migrate as far upstream as spawning adults. Sheefish fry are swept downstream from spawning areas by spring floods and remain in the lower reaches of large rivers and brackish inlets to feed year-round.

In the middle Yukon, there are local sheefish populations that may mix with fish from the anadromous lower Yukon population during the summer but that are not themselves anadromous (Alt 1981).

The Minto flats sheefish population spawns in the Chatanika River, migrates downstream to overwinter in the lower Tolovana and Tanana rivers, and enters the Minto flats area to feed in late May after breakup (Alt 1977).

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

In the Kobuk River, grayling and whitefish were observed to prey on sheefish eggs released at the water surface during spawning (Geiger et al. 1968). Fuller (1955) reports that adult sheefish from Great Slave Lake feed heavily on immature sheefish; Alt (1975), however, has recorded only one Alaskan example of cannibalism.

Sheefish are not strong swimmers (Alt 1973), and their migrations may be affected by velocity barriers created by periods of high water (Alt 1983).

B. Human-related

Any disturbances within a system that degrade sheefish spawning, rearing, or feeding habitats, degrade water quality, or block migration routes may affect population levels of sheefish occupying that system. Sheefish have stringent spawning requirements, and whole populations spawn in relatively few areas. Any disturbances of spawning areas would have the potential to strongly affect the entire population.

Sheefish are not as strong swimmers as salmon. Because of this, developments that increase water velocity along migration routes may be especially detrimental to sheefish stocks.

The sheefish spawning and overwintering migration behavior makes them available for harvest by commercial, subsistence, and sport fisheries throughout their life cycle and increases their vulnerability to overharvest (ADF&G 1983). In addition, the sheefish's slow maturation rate increases the time required to restore depleted populations (ibid.).

A summary of possible impacts from human-related activities includes the following:

- ° Changes in biological oxygen demand, nutrient loading
- ° Changes in chemical composition of water
- ° Changes in dissolved oxygen, temperature, pH, salinity
- ° Changes in flow or water level, entrapment
- ° Changes in riparian or aquatic vegetation
- ° Changes in sedimentation rates, turbidity, suspended solids
- ° Changes in substrate composition and location
- ° Competition with introduced species
- ° Increased susceptibility to harvest or predation
- ° Inducement of impingement or entrainment
- ° Physical barriers to movement
- ° Shock waves, blasting

(For additional impacts information, see the Impacts of Land and Water Use volume of this series.)

VIII. LEGAL STATUS

The Alaska Board of Fisheries develops regulations governing the sport harvest of fish in Alaska. Research and monitoring of sheefish populations is conducted mainly by the Alaska Department of Fish and Game, Division of Sport Fish.

IX. LIMITATIONS OF INFORMATION

Kenneth Alt has contributed over 20 years of research on sheefish stocks in Alaska. As a result of his efforts, a great deal of information is available on Alaskan sheefish, especially with respect to distribution and movements. Information on habitat requirements, however, remains incomplete. More extensive information is needed on velocity, depth, temperature, and salinity requirements, for example. Russian scientists have conducted a great deal of sheefish research, including many studies on hatchery production, which have been published in Russian language journals for which translations are not readily available. (Several examples of these are cited in Petrova 1976.)

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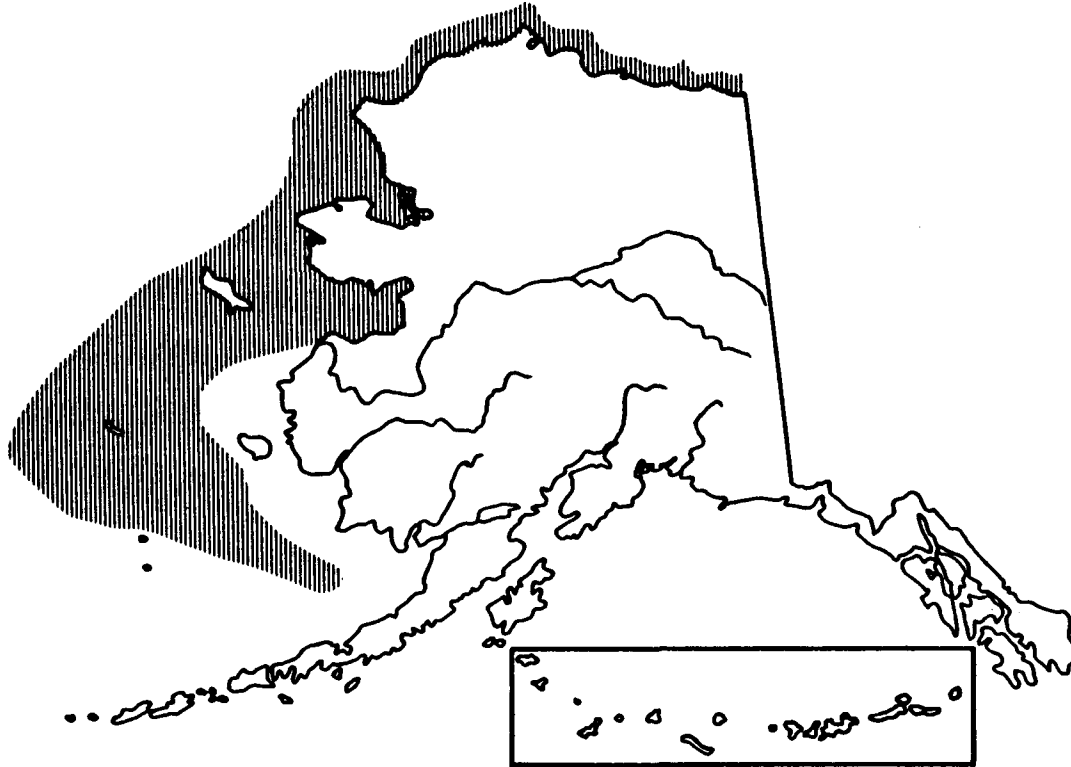
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Marine Fish

Arctic Cod Life History and Habitat Requirements
Arctic Region



Map 1. Range of arctic cod (Morrow 1980, NWAFC 1985)

I. NAME

- A. Common Name: Arctic cod
- B. Scientific Name: Boreogadus saida
- C. Native Names: See appendix A.
- D. Cods (family Gadidae) reach their greatest diversity and abundance in north temperate seas. The arctic cod is the only species of the family that is common throughout its circumpolar range (Sekerak 1982a).

II. RANGE

- A. Worldwide
The arctic cod has a circumpolar distribution in most of the Arctic Ocean, being absent only from the region just north of Scandinavia. On the Atlantic side of North America it has been found as far south as the Saint Lawrence River in Newfoundland.

It ranges throughout the Arctic Ocean across the arctic coast of Canada and Alaska and south in the Bering Sea to Norton Sound (Morrow 1980). The existence of three or more separate stocks of arctic cod is responsible for the circumpolar distribution in arctic seas. These stocks have different feeding and spawning areas and migration routes and mix in the boundary areas (Ponomarenko 1968).

B. Statewide

The general distribution of arctic cod off Alaska is from Norton Sound to the Beaufort Sea (map 1)(Sekerak 1982a, Morrow 1980).

C. Regional Distribution Maps

To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for each region. In this series, arctic cod distribution information is included on 1:000,000-scale maps. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of selected fish and wildlife species has been prepared and may be found in the Atlas that accompanies each regional guide.

D. Regional Distribution Summary

1. Arctic. The range of arctic cod extends from northern Norton Sound throughout the Arctic Region (Morrow 1980). Lowry and Frost (1981) found that arctic cod were most widespread and abundant in the northeastern Chukchi and western Beaufort seas and least abundant in the northern Bering and central Beaufort seas. Arctic cod is probably the most abundant fish in the Alaskan Beaufort and northeastern Chukchi seas (Sekerak 1982a). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Arctic Region.)

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

1. Water quality. No information is available on the pH and dissolved oxygen requirements of arctic cod. Arctic cod occurs in areas between the limits of pack ice and drift ice in waters that are less saline, with salinities from 15 to 30 ppt (parts per thousand) (Andriyashev 1954, Morrow 1980). Arctic cod in Simpson Lagoon, on the Beaufort Sea, were tolerant of widely ranging salinities and turbidities during the open-water season. For at least short periods of time, fish were able to cope with conditions ranging from nearly fresh to salt water (3-28 ppt) and from clear to very turbid water (1-146 Nephelometric Turbidity Units)(Craig et al. 1982).
2. Water depth:
 - a. Juvenile. Quast (1974) found young-of-the-year (yoy) arctic cod in the eastern Chukchi Sea to be much more numerous at depths from 20 to 40 m than they are above

those depths. Quast speculated that this depth preference may be in order to avoid predation by sea birds. Sekerak (1982b) found that the densities of yoy arctic cod were related to season, depth, year, and location. From June to mid August, arctic cod near Greenland in Sekerak's samples were most abundant at 10 to 20 m depths and rare at the surface. Densities decreased below 20 m, and no yoy were caught at depths greater than 250 m. Thus, it appears that yoy are concentrated in the upper 40 to 50 m of water.

- b. Adult. The maximum depths to which adult or subadult arctic cod can be found are unknown, as is their preferred depth range. The bottom of shallow seas, such as the northern Bering, Chukchi, and southern Beaufort seas are within the depth range of arctic cod. They have been collected at depths of 300 m in the Canadian high arctic, 930 m in Baffin Bay, and 400 m in the northern Chukchi and Beaufort seas (Sekerak 1982a). Lowry and Frost (1981) sampled depths from 40 to 100 m in the northeastern Chukchi and Beaufort seas and to 50 m in the Bering Sea and found no relationship between depth of water and catches of arctic cod. In Norton Sound and the southeastern Chukchi Sea, arctic cod were found in high abundance at depths greater than 20 m (Wolotira et al. 1977).

- 3. Water temperature. Adult arctic cod usually inhabit waters with temperatures of 0 to -1.8°C (Andriyashev 1954, Morrow 1980, Hognestad 1968). Adults have been found in waters with temperatures up to 3 or 4°C (Hognestad 1968). In Simpson Lagoon, in the Beaufort Sea, arctic cod were found in waters ranging from 0 to 13.5°C during the open-water season (Craig et al. 1982). Egg development occurs when the water temperature is less than 0 to 2°C ; larval development and growth occur at 2 to 5°C ; and fry development and growth occur from 5 to 7°C and possibly higher (Rass 1968).

B. Substrate and Cover Requirements

Arctic cod are widely assumed to associate with the ice under-surface (Andriyashev 1954, Sekerak 1982a, Ponomarenko 1968); however, they can also occur near the bottom (Hognestad 1968, Morrow 1890) and in open water (Craig et al. 1982, Lowry and Frost 1981). Near the ice edge, the mass development of phytoplankton and zooplankton occurs, and arctic cod are plankton feeders (Ponomarenko 1968). In a study near Greenland, arctic cod were more abundant in areas where the under-ice surface was rough than in areas where it was smooth; this difference may be related to the better protection from predators offered by the rough under-ice areas (Bradstreet 1982). Bradstreet (1982) found that cod captured offshore tended to be smaller and younger than those taken inshore. At the end of their first summer, larval cod leave

the water column and become associated with a substrate, usually the ice undersurface (ibid.).

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

The diet of yoy arctic cod consists of phytoplankton and very small or early stages of zooplankton. After the first summer, phytoplankton are of minor importance as food, and the older cod prey on zooplankton, substrate and ice-associated crustaceans, and young fish (Sekerak 1982a).

Several studies have indicated that the diet of adult arctic cod may be influenced by the food availability or the habitat. Arctic cod in offshore waters and near offshore ice edges eat primarily copepods and some pelagic amphipods (Lowry et al. 1978, Bradstreet and Cross 1982, Lowry and Frost 1981, Craig et al. 1982, Hognestad 1968). Arctic cod in nearshore, shallower water habitats feed on benthic or epibenthic mysids, amphipods, shrimps, and some copepods (Craig and Haldorson 1981, Lowry and Frost 1981, Craig et al. 1982). Mysids, which are the primary food in nearshore areas, are nearly absent from the diet of arctic cod in offshore waters. Craig et al. (1982) indicated that arctic cod prefer to eat mysids rather than amphipods when both are available. Some amphipod species burrow into the substrate, thus becoming less accessible to arctic cod.

B. Types of Feeding Areas Used

Arctic cod are often found near the ice edge where the mass development of phytoplankton and zooplankton occurs. Arctic cod is the main plankton feeder in this habitat, which has resulted in its great abundance (Ponomarenko 1968). The diet of cod in both inshore and offshore waters is apparently influenced by the presence of ice. Certain copepod, mysid, and amphipod species are closely associated with the ice undersurface and cod collected near ice had these species in their stomachs (Bradstreet and Cross 1982).

C. Factors Limiting Availability of Food

The diet of arctic cod, especially in offshore areas, is dominated by copepods and amphipods, which in turn feed on diatoms (Bradstreet 1982). Thus the food available to arctic cod is closely dependent upon primary production. In polar waters, there is no productivity throughout most of the year, and an outburst of exceedingly high productivity occurs in the short summer season. Primary production in arctic waters is usually limited by available sunlight and, less often, by the availability of nutrients for phytoplankton (Russell-Hunter 1970).

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Arctic cod move inshore to warmer coastal waters and mouths of rivers for spawning, often forming large concentrations (Andriyashev 1954, Morrow 1980). Spawning usually occurs under

ice cover (Andriyashev 1954, Rass 1968). On the basis of their widespread distribution, arctic cod are assumed to spawn in many areas of the arctic. The only identified spawning area in the North American arctic is in Stefansson Sound in the Alaskan Beaufort Sea (Craig et al. 1982).

B. Reproductive Seasonality

In Soviet waters, arctic cod spawn from December through March, mainly in January and February (Andriyashev 1954, Rass 1968). In coastal waters of the Beaufort Sea, arctic cod spawn between late November and early February (Craig et al. 1982).

C. Reproductive Behavior

Arctic cod spawn under the ice, and little information on spawning areas exists. Spawning behavior has not been observed.

D. Age at Sexual Maturity

Andriyashev (1954) reported that arctic cod attain sexual maturity at four years of age. Hognestad (1968) reported maturity at age 2 in the Barents Sea. Craig et al. (1982) found that in nearshore waters of the Beaufort Sea most mature males were ages 2 and 3 and females age 3.

E. Frequency of Breeding

The arctic cod is a relatively small fish that rarely attains a length of over 300 mm or an age of five years (Sekerak 1982a). With a reported age at maturity of from two to four years, arctic cod would not be expected to spawn more than several times in their lifetime.

F. Fecundity

Arctic cod produce the largest and fewest eggs of all species in the cod family. Fecundity varies from 9,000 to 21,000, with an average of 12,000 eggs (Andriyashev 1954). The egg diameter ranges from 1.5 to 1.9 mm, and the membrane is very thin and easily damaged (Rass 1968). Rass notes that fish species in low water temperatures usually produce large eggs and that a thin membrane is an adaptation to a calm spawning habitat such as one under ice cover without waves.

G. Incubation Period

Rass (1968) reports that the egg stage of arctic cod lasts from 1.5 to 3 months and that larvae appear in the sea from May through July. The larval stage lasts about two months in the Barents and Siberian seas, from June through July. Transition to the juvenile state occurs at 3 to 5 cm in August.

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

Arctic cod make onshore-offshore migrations, which are associated both with spawning and the movements of ice (Morrow 1980). Arctic cod are usually found near the ice edge and descend to greater depths when the ice melts or breaks and the sea surface temperatures rise. The migration paths and areas of concentration depend mainly on the distribution of ice (Ponomarenko 1968).

The circumpolar distribution of arctic cod consists of separate stocks, which have different feeding and spawning areas and migration routes

(ibid.). The stock in the Barents Sea, north of Norway, moves inshore in mass concentrations from June through August. When the water temperature rises in August and September, the cod move to deeper water.

Prespawning and spawning concentrations form in open northeastern areas of the Barents Sea from September-October to the end of February (ibid.). A local stock of arctic cod in the Laptev Sea, north of Siberia, feeds in the open sea and spends the winter, probably spawning, in the coastal zone (ibid.). In the southern Chukchi and northern Bering seas, the abundance of cod increases in winter and decreases in summer (ibid.).

In the Beaufort Sea, arctic cod were abundant in the nearshore waters of Simpson Lagoon in August and September (Craig and Haldorson 1981). Some cod remained in Simpson Lagoon in early winter, but all apparently vacated the shallow waters by February. The nearby deeper coastal areas of Stefansson Sound, however, were inhabited by arctic cod throughout the winter (ibid.).

The distribution and abundance of yoy arctic cod varies annually and geographically. In spring and most of the summer, yoy are planktonic and are found primarily in surface waters (Sekerak 1982b). The planktonic yoy become highly dispersed and can probably be transported considerable distances from the spawning areas. In surveys done in Norton Sound and the southeastern Chukchi Sea, either cold, deep waters or regions north of the Bering Strait provided the areas of highest density of young fish (Wolotira et al. 1977).

VII. FACTORS INFLUENCING POPULATIONS

A. Arctic cod are key species in the arctic marine ecosystem, which channels the energy flow from plankton to high-level consumers through a few key links. Arctic cod may influence the distribution and movements of marine mammals and seabirds in arctic waters (Craig et al. 1982). Lowry et al. (1978) found arctic cod to be an important summer food source of spotted seals in the Chukchi Sea and a fall and winter food of ringed seals in the Beaufort Sea. Arctic char in the Canning River area of the Beaufort Sea eat juvenile arctic cod (Craig and McCart 1976), and arctic char in the Prudhoe Bay area were found with arctic cod in their stomachs (Furniss 1975). Fulmars, kittiwakes, murre, guillemots, ringed seals, and narwhals feed on arctic cod along the ice edges in Baffin Bay near Greenland (Bradstreet 1982, Bradstreet and Cross 1982). Arctic and saffron cod are probably the most important prey of belukha whales during autumn and winter in Norton Sound and the Chukchi Sea (Seaman et al. 1982). Nevertheless, populations of a small, early maturing, highly fecund species such as arctic cod may be influenced more strongly by physical factors in the environment than by predation (Craig et al. 1982). In the autumn or winter, when the fish have moved close to shore along the USSR, they are often washed ashore in great quantities by gales (Ponomarenko 1968). On islands and on the coast of the Kara Sea, heaps of dead arctic cod from 5 to 10 m

wide and 3 to 5 m high, extending over tens of kilometers, accumulate after storms (ibid.). Polar bears, arctic foxes, and the local human population rely on beached arctic cod as a winter food source (Craig et al. 1982). Little evidence of the effects of competition on populations of arctic cod exists. However, in Newfoundland the distribution and diets of arctic cod and capelin overlap (Vesin et al. 1981). The recent dramatic increase of arctic cod in that area could be a response to a large reduction in zooplankton consumption by capelin in the region that has occurred since 1976 (ibid.).

B. Human-related

Arctic cod eggs are buoyant, and yoy are planktonic. These characteristics make them vulnerable to potential toxicants, such as hydrocarbons, formation waters, disinfectants, algicides, heavy metals, heated waters, drilling muds, and other chemicals that may be released during drilling and production. Arctic cod inhabit and feed at the ice edge where mass plankton blooms occur, and any perturbation of the ice edge environment could have negative effects on the population. The habit of arctic cod of using small cracks in the ice could make them prone to being entrapped where they would be unable to avoid lethal substances. Some arctic cod spawn in nearshore waters, and the same spawning areas are used by the cod every year (Sekerak 1982a). These regions coincide with areas delineated for hydrocarbon development, and the potential exists for disruption of spawning activities through acoustical disturbances, exposure to contaminants, unnatural ice movements, thicknesses or clearances, and shock waves due to explosives (ibid.).

A summary of the possible impacts from human-related activities includes the following:

- Changes in biological oxygen demand or nutrient loading
- Changes in chemical composition of water
- Changes in dissolved oxygen, temperature, pH, salinity
- Entrapment
- Changes in sedimentation rates, turbidity, suspended solids
- Physical barriers to movement
- Shock waves, blasting
- Increased susceptibility to harvest or predation

(See the Impacts of Land and Water Use volume of this series under the category Marine Fish for additional impacts information.)

VIII. LEGAL STATUS

The Alaska Department of Fish and Game has managerial authority over arctic cod extending to 3 mi offshore. However, because harvesting of arctic cod is minimal, no management plan has been formulated.

IX. LIMITATIONS OF INFORMATION

Little information has been collected on populations of arctic cod in Alaska; most studies have concentrated on populations near Greenland, Siberia, and Norway. Information is needed on migrations of Bering and

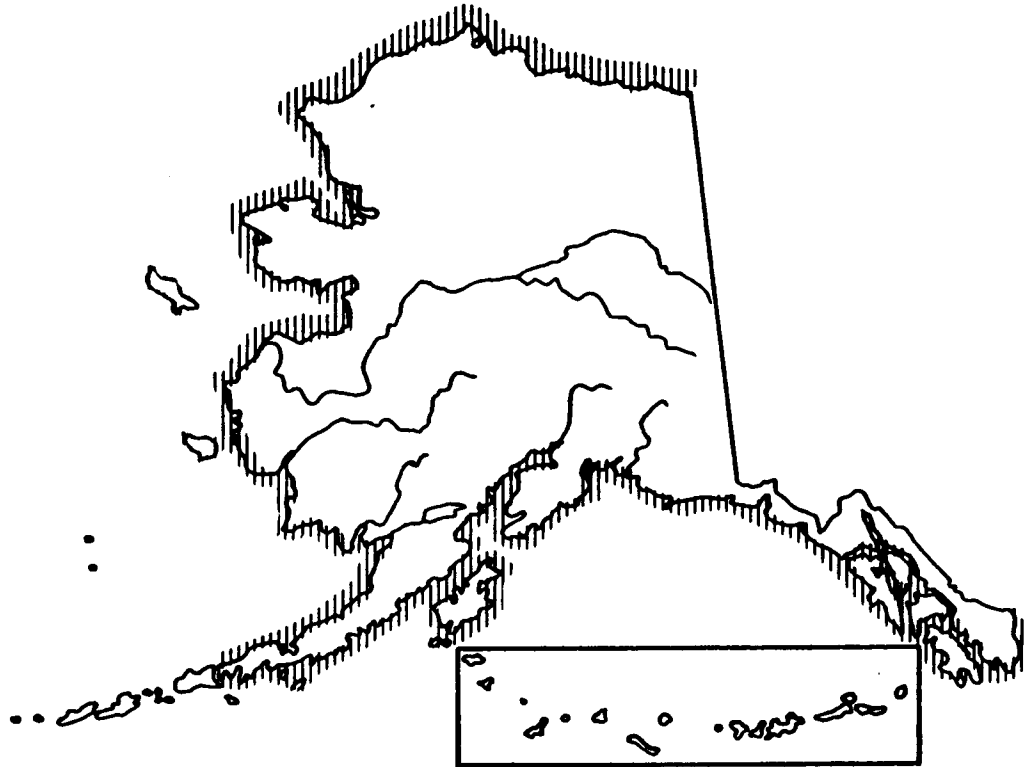
Beaufort sea populations, distribution of yoy, preferred depth range, spawning areas, egg and larval requirements, and the influence of physical factors and competition on population size.

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Capelin Life History and Habitat Requirements
Arctic Region



Map 1. Range of capelin (Hart 1973)

I. NAME

- A. Common Name: Capelin
- B. Scientific Name: Mallotus villosus
- C. Native Names: See appendix A.
- D. Species Group Representation

Capelin belong to the smelt family, Osmeridae. The Pacific capelin and the Atlantic capelin were formerly considered to be two separate species; however, they are now regarded as the same species.

II. RANGE

- A. Worldwide
Capelin has a circumpolar distribution and can be found in the northern regions of the Atlantic, Pacific, and Arctic oceans, but

they are not reported from eastern Siberia. They are found along the Atlantic coast of North America from Labrador northwards and near Greenland, Ireland, and Norway. They are found throughout the Canadian mainland arctic and along the Pacific coasts of British Columbia, Alaska, the Bering Strait, Kamchatka Peninsula, Sea of Japan, and the Sea of Okhotsk as far south as Korea (Hart 1973, Jangaard 1974, Pahlke 1981a).

B. Statewide

Capelin are distributed along the entire coastline of Alaska and extending south along British Columbia to the Strait of Juan de Fuca (map 1)(Hart 1973).

C. Regional Distribution Maps

To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for the Arctic Region. Most of the maps in this series are at 1:250,000 scale, but some are at 1:1,000,000 scale. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction.

D. Regional Distribution Summary

1. Arctic. Capelin are found along the coast of the entire Arctic Region (ibid.). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Arctic Region.)

III. PHYSICAL HABITAT REQUIREMENTS

A. Water Quality

No information is available on the pH, dissolved oxygen, or turbidity tolerances of capelin. Capelin in the Canadian arctic have been reported spawning in warm, brackish water (Ellis 1962). Frank and Leggett (1982a) hypothesize that onshore winds initiate capelin spawning in Newfoundland, because the winds cause the nearshore waters to be warmer and less saline. Capelin larvae have been found over a wide range of salinities from 4.8 to 32.6 parts per thousand, generally moving to cooler, less saline water below the thermocline in the fall (Jacquaz et al. 1977).

B. Water Depth

Andriyashev (1954) reports that Pacific capelin were collected at depths of 65-75 m in the fall and that Atlantic capelin inhabit depths to 200 m. Studies in eastern Canada and Norway have shown that capelin move from deeper water during the day to shallower water at night. Bailey et al. (1977) found that capelin in Canada disperse in the upper 20 m of water during the night and school mostly above 50 m but sometimes as deep as 100 m during the day. There was no difference in the vertical distribution of adult and juvenile capelin. In Norway, capelin moved from 150 m depth during the day to between 50 and 100 m at night (Pearcy et al. 1979). Offshore spawning has been reported to depths of 280 m but usually occurs in the upper 75 m of the water column.

Capelin larvae are mainly concentrated in the upper 50 m during the summer in eastern Canada and move to slightly deeper water in September as the surface waters cool (Jacquaz et al. 1977). Yolk-sac larvae were most abundant in the upper 25 m of the water column. No evidence of vertical migration of the capelin larvae was seen during the summer months (ibid.).

C. Water Temperature

Beach-spawning capelin found along the Newfoundland and Labrador coasts in June and July generally spawned in water temperatures of 5.5 to 8.5°C, although spawning has been reported in temperatures as high as 10°C (Jangaard 1974). In the Canadian arctic near Baffin Island, the surface water temperatures during the spawning period varied from about 13 to 15°C (Ellis 1962), while temperatures in southern British Columbia are about 10 to 12.5°C (Hart 1973). Water temperatures at the time of spawning of Bering Sea capelin are between 5.3 and 10.5°C (Whitmore, pers. comm.). Temperatures for offshore spawning range from 2 to 4.2°C (Bakke and Bjorke 1971, Pitt 1958, Andriyashev 1954). Adult capelin have been trawled at depths of 70 m at a temperature of -1.7 to 1.3°C in the fall (Andriyashev 1954). Capelin larvae in northeastern Canada were collected at temperatures ranging from 0.2 to 14.4°C (Jacquaz et al. 1977).

D. Substrate

Adult and larval capelin are pelagic fish. Capelin spawn either offshore in deep water or on sand and gravel beaches (Anadriyashev 1954, Pahlke 1981a).

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

Capelin are filter feeders, consuming euphausiids, copepods, amphipods, and a variety of planktonic invertebrates (Jangaard 1974). Adult capelin north of Norway feed mainly on copepods and euphausiids (Pearcy et al. 1979), whereas both juveniles and adults in eastern Canada feed primarily on copepods, euphausiids, and appendicularians (Vesin et al. 1981). Bjorke (1976) found that the diet of first-feeding capelin larvae consisted mainly of copepod eggs and nauplii. Vesin et al. (1981) also noted that a shift in diet occurred during growth, with early larval capelin consuming invertebrate eggs, copepods, and diatoms. The diets of juvenile and adult capelin overlapped, with a shift from small copepods to adult euphausiids as the capelin reached a total length of 140 mm.

B. Factors Limiting Availability of Food

The diet of capelin is dominated by zooplankton, which, in turn, feed on phytoplankton. In polar waters, there is no productivity throughout most of the year, and an outburst of exceedingly high productivity occurs in the short summer season. Primary production in arctic waters is usually limited by available sunlight and, less often, by the availability of nutrients for phytoplankton (Russell-Hunter 1970).

- C. Feeding Behavior
Winters (1969) found that capelin's feeding is highly seasonal. Feeding intensity increases before spawning in late winter and early spring and declines with the spawning migration. Feeding ceases during spawning and proceeds again at high intensity until early winter, when zooplankton becomes less abundant. Daily feeding peaks occur in mornings and evenings between May and August in eastern Canada, and a single midday feeding occurs in October and November (Vesin et al. 1981).

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

1. Offshore spawning. Offshore spawning has been reported to depths of 280 m but usually occurs in water less than 75 m deep (Saetre and Gjosaetre 1975, Templeman 1948). Pitt (1958) stated that when waters became too warm on the beach, spawning continues in deeper coastal waters.
2. Beach spawning. Spawning occurs on sand, gravel, or pebble beaches (Andriyashev 1954, Jangaard 1964, Hart 1983, Barton et al. 1977, Pahlke 1981a). Spawning occurs at high tide (Hart 1973) and generally during periods of onshore winds for Atlantic capelin (Frank and Leggett 1981a). However, capelin have been reported to spawn in offshore winds in the Kodiak area (Warner 1981). Spawning usually occurs at night or during dull, cloudy weather (Jangaard 1974); however, Ellis (1962) reports that capelin spawn during daylight in the Canadian arctic when there are 24 hours of light.

B. Reproductive Seasonality

Capelin spawn in May and June in the Kodiak area (Warner 1981) and in late spring in Bristol Bay (Rogers et al. 1980). In the Bering Sea, they spawn in summer, slightly later near Pt. Barrow, and in the Beaufort Sea in August and September (Rogers et al. 1980, Craig and Haldorson 1980).

C. Reproductive Behavior

At the spawning grounds, capelin segregate into schools by sex. Males school near the beaches, while the females remain in slightly deeper water. As the females ripen, individuals proceed to the beaches to spawn, followed by small groups of males. Generally, two males squeeze the female between them on the beach, extruding milt over eggs deposited in a slight hollow. The eggs are covered with sand or gravel by tidal action (ADF&G 1969). Spawning occurred for over four weeks in Norton Sound (Pahlke 1981b).

D. Age at Sexual Maturity

During the first year, males and females are the same size, but during the second year, males grow at a faster rate. A few capelin mature and spawn at age 2, but most maturation occurs at age 3 (Jangaard 1974). Spawning capelin in Norton Sound and Togiak consist mainly of ages 2 and 3 fish (Pahlke 1981b); on Kodiak most were age 2 (ADF&G 1969).

E. Frequency of Breeding

During and following the spawning season, large numbers of dead capelin can be observed floating on the surface or stranded on the beach. The mortality rate of spawning capelin is high, and most investigators believe that postspawning survival is negligible (Jangaard 1974).

F. Fecundity

Fecundity in capelin varies widely with geographic location. Nikolsky (1963) reports that fecundity in Pacific capelin ranges from 15,300 to 39,300 eggs. Capelin in southern British Columbia, however, produce 4,600 to 6,700 eggs (Hart 1973), and in the Sea of Japan fecundity ranges from 15,000 to 57,000 eggs (Andriyashev 1954). The eggs are approximately 1 mm in diameter and stick to the substrate (Andriyashev 1954, Hart 1973).

G. Incubation Period/Emergence

Frank and Leggett (1981b) found that the incubation period in capelin was influenced by the average temperature, which varied between years and between positions on the beach. Incubation temperatures were determined by water temperature, air temperature, and hours of sunlight. Hatching occurs in 55 days at 0°C, 30 days at 5°C, and 15 days at 10°C (Jeffers 1931). Emergence of larvae from the beach is a clearly defined, abrupt transition to a pelagic existence. Atlantic capelin larvae accumulate on the beach as they hatch and are released synchronously by onshore winds (Frank and Leggett 1981a). Because no food is available to the larvae while in the sediments, rapid physical deterioration occurs if larvae are unable to leave the beach before yolk sac reserves are depleted (ibid.). Environmental conditions during the early larval period can influence growth efficiency, size at first feeding, and the prey-capture ability of larvae, independently of the yolk reserves at hatching or the food available (Frank and Leggett 1982b).

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

Capelin in Newfoundland overwinter in large, inactive schools in cold water near the bottom at depths from 140 to 200 m (Winters 1970). In the spring, these fish move into warming surface waters and disperse into smaller feeding schools. About a month before spawning, capelin migrate to shallow water and segregate into schools by sex, with the males closest to shore (Jangaard 1974). During the summer and early fall, juvenile and adult Atlantic capelin were widely distributed in small schools (Bailey et al. 1977). In November, the capelin concentrated into dense schools and moved to deeper water (ibid.).

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

Physical and biological factors such as the availability of food, water temperatures, and winds can contribute to the survival of emergent and larval capelin. Onshore winds replace cold, food-poor, predator-laden upwelling waters, which occupy the

nearshore areas during offshore winds, with warmer, food-rich, predator-deficient surface waters (Frank and Leggett 1983). Haddock and winter flounder consume large quantities of Atlantic capelin eggs during the spawning period (Jangaard 1974, Frank and Leggett 1984). Egg mortality from predation may be significantly greater at deep-water demersal spawning sites and may have a significant impact on recruitment of demersal spawners (Frank and Leggett 1984).

Many fish are predators of adult and juvenile capelin, including cod and salmon in the Atlantic (Jangaard 1974) and arctic char, saffron cod, and starry flounder in the Canadian arctic (Ellis 1962). Marine mammals also consume capelin as a primary part of their diet. In the Gulf of Alaska, harbor seals and Steller sea lions are predators, especially in nearshore waters in the spring and summer (Pitcher and Calkins 1978, Pitcher 1981). Other capelin predators include ribbon seals in the Pribilof Islands area (Lowry et al. 1978), spotted seals in the southeastern Bering Sea in the spring (ibid.), and belukha whales in the coastal northern Bering and Chukchi seas in summer (Seaman et al. 1982). Competition between capelin and other zooplankton-feeding species may occur. In the Newfoundland area, the diets of capelin, arctic cod, and squid overlap. In years when capelin have reduced their zooplankton consumption, the abundance of arctic cod and squid has increased (Vesin et al. 1981).

B. Human-related

Capelin have adhesive, demersal eggs, and any contamination of the beach or offshore substrate where capelin spawn could result in heavy mortality. Juvenile and adult capelin are pelagic, relying on planktonic food sources, and thus are vulnerable to contamination of surface waters. A summary of possible impacts from human-related activities includes the following:

- Changes in biological oxygen demand or nutrient loading
- Changes in the chemical composition of water
- Changes in dissolved oxygen, temperature, pH, or salinity
- Changes in sedimentation rates, turbidity, or suspended solids
- Changes in substrate composition and location
- Increased susceptibility to harvest or predation
- Shock waves, blasting

(For additional impacts information, see the Impacts of Land and Water Use volume of this series.)

VIII. LEGAL STATUS

The ADF&G has managerial authority over capelin, extending to 3 mi offshore. Because harvesting of capelin is minimal, no management plan has been formulated. A policy statement, however, has been established that defines the relationship between herring and capelin fisheries that could occur simultaneously.

IX. LIMITATIONS OF INFORMATION

Generally, most work on capelin has been done on Atlantic rather than Pacific populations, and very little work has been done on capelin in Alaskan waters. No information is available on the pH, dissolved, oxygen, or turbidity tolerances of capelin. It is not known if offshore spawning populations of capelin exist. Seasonal movements of Pacific capelin have not been studied.

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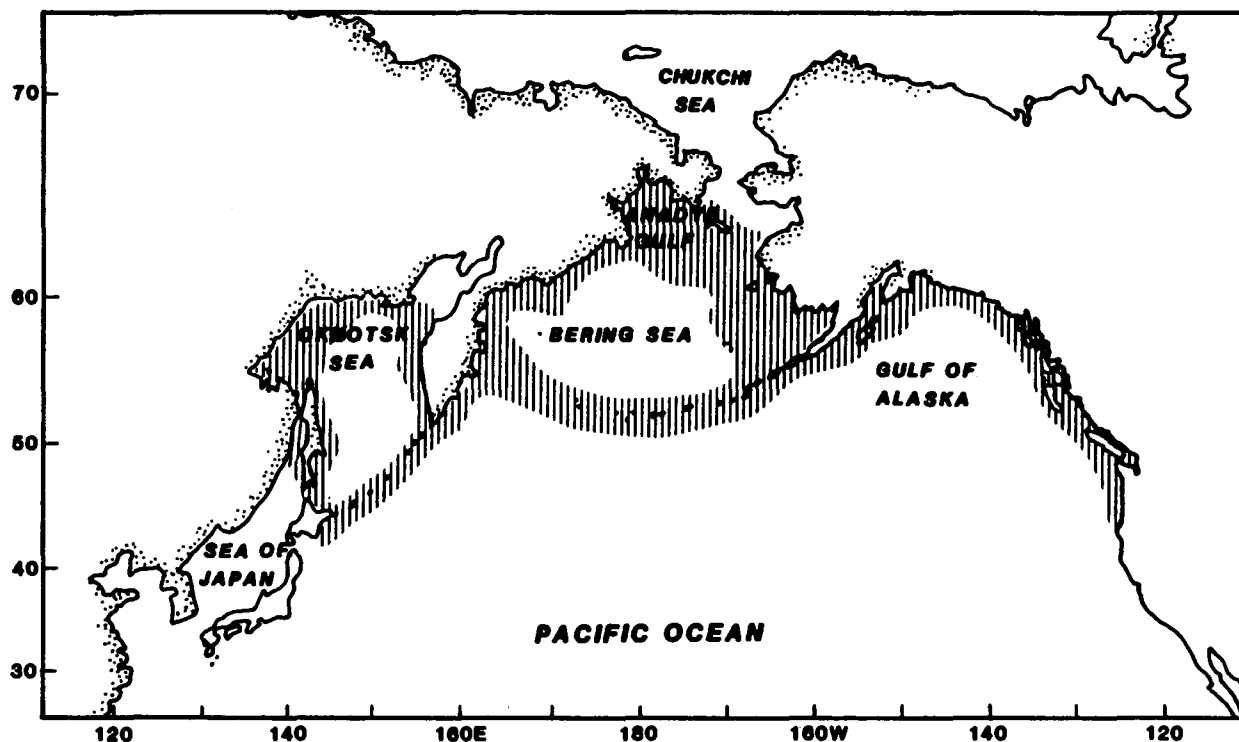
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Pacific Cod Life History and Habitat Requirements
Southwest and Southcentral Regions



Map 1. Range of Pacific cod (Salveson and Dunn 1976)

I. NAME

- A. Common Name: Pacific cod
- B. Scientific Name: Gadus macrocephalus (Tilesius)
- C. Native Names: See appendix A.

II. RANGE

- A. Worldwide
Pacific cod are found from Santa Monica Bay, California, around the North Pacific rim to the northern part of the Yellow Sea. They are also found in the Bering Sea (Salveson and Dunn 1976).
- B. Regional Distribution Maps
To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for each region. Pacific cod distribution maps in this series are at 1:1,000,000 scale. These maps are available for review in ADF&G

offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of selected fish and wildlife species has been prepared and may be found in the Atlas that accompanies each regional guide.

C. Regional Distribution Summary

1. Southwest. In the Gulf of Alaska, cod are most abundant in the western (Kodiak and Alaska Peninsula) regions (Reeves 1972, Hughes 1974, Ronholt et al. 1977). Trawl surveys conducted in the Gulf of Alaska from 1973 through 1976 found highest cod catch-per-unit-effort (CPUE) in the Kodiak and Sanak regions (Ronholt et al. 1977). In the Bering Sea the most productive fishing areas for cod are in the outer shelf, northwest of Unimak Island (Jewett 1977, Low 1974). (For more detailed narrative information, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)
2. Southcentral. Cod are distributed throughout the Southcentral Region. Trawl surveys conducted in the Gulf of Alaska from 1973 through 1976 found the highest cod CPUE in Southcentral to be in the Kenai (south of the Kenai Peninsula) area (37.7 kg/hr) (Ronholt et al. 1977). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)

III. PHYSICAL HABITAT REQUIREMENTS

A. Water Depth

Pacific cod are mostly benthic and are found at depths ranging from 15 to 550 m (Moiseev 1953). Research vessel surveys carried out in the Gulf of Alaska from summer 1980 to late winter 1982 found that the highest Pacific cod density was in the 51 to 100 m depth interval (Zenger and Cummings 1982). Their depth distribution varies, however, with the location of the stock and the time of year.

B. Water Temperature

Water temperature is very important to the hatching success and survival of cod eggs and may in that way determine the limits of Pacific cod distribution (Alderdice and Forrester 1971). In laboratory experiments, Alderdice and Forrester (1971) found that temperatures of 3.5 through 4.0°C were optimal for egg development and that 50% or greater survival could be expected in a temperature range from 2.5 to 8.5°C. Survival drops off more rapidly in temperatures below optimum than in temperatures above optimum. Yamamoto and Nishioka (1952) found that optimal larval survival was at 7 to 8°C.

C. Water Chemistry

Eggs are tolerant of a wide range of oxygen and salinity levels. If temperatures are within the optimum range, eggs tolerate dissolved oxygen levels from saturation down to 2-3 ppm and salinities from at least 12.71 to 23‰ (Alderdice and Forrester 1971).

- IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

Studies from the southeastern and Kodiak areas of the Gulf of Alaska found that fish, crabs, and shrimp were the major foods of adult cod in those areas (Jewett 1978, Clausen 1981). In the Kodiak area, the fish most frequently found in cod stomachs was walleye pollock (Theragra chalcogramma). Flatfishes (Pleuronectidae) and Pacific sand lance (Ammodytes hexapterus) were also commonly found (Jewett 1978). In the southeastern gulf, Pacific herring (Clupea harengus pallasii) and walleye pollock were eaten most often. In both areas, Tanner crab (Chionoecetes bairdi) was the most commonly consumed crab. Clausen (1981) noted that cod in outside waters ate a larger volume of crabs than those in inside waters and, conversely, that cod in inside waters ate a higher volume of shrimp (especially pandalid shrimp) and more fish (especially Pacific herring) than cod in outside waters.

A 1980 Northwest and Alaska Fisheries Center (NWAFC) study reported that in the Bering Sea pollock, shrimp, other invertebrates, and Tanner crab were most frequently found in cod stomachs (Bakkala 1981). Some variation in food habitat by region was also noted. In Bristol Bay, the principal food item was Tanner crab; in the central Bering Sea, pollock, Tanner crab, and other invertebrates; and in the northern Bering Sea, shrimp and pollock (ibid.).

Young cod feed on copepods and similar organisms (Morrow 1980).

B. Types of Feeding Areas Used

Moiseev (1953) reported that in the western Bering Sea and the Sea of Okhotsk cod migrate to shallow waters in search of food in early spring. Cod in other areas also follow short seasonal migratory patterns, spawning in relatively deep water and moving to more shallow water while feeding in the spring (Jewett 1978, Forrester 1969, Ketchen 1961).

C. Factors Limiting Availability of Food

No information is available concerning limitations of cod food supply.

D. Feeding Behavior

Pacific cod do not feed during spawning (Moiseev 1953). They are apparently somewhat opportunistic feeders; the abundance of preferred prey items in their stomachs varies with the abundance of those prey items in the environment (Clausen 1981).

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Cod generally migrate to relatively deep water (80 to 290 m) to spawn (Ketchen 1961, Moiseev 1953). An exception to this is in the southern part of their Asian range, where the cod move inshore to spawn in waters 15 to 50 m deep (ibid.). Location of spawning is probably more closely correlated to water temperature than to depth (see the discussion of egg survival under section III.) (Alderdice and Forrester 1971).

Spawning is probably inhibited at temperatures above 9°C or below 0°C (ibid.).

Spawning usually occurs in the western Bering Sea at depths of 100 to 250 m and at temperatures of 0 to 3°C (Musienko 1970).

B. Reproductive Seasonality

Spawning takes place during the winter months. In Canadian coastal waters, spawning takes place from January to March (Ketchen 1961). In the eastern Bering Sea, spawning probably takes place from January to April (Bakkala 1981).

C. Reproductive Behavior

No information is available on Pacific cod breeding behavior.

D. Age at Sexual Maturity

In British Columbia waters, male cod mature at age 2 (49 cm in length). At age 3 (55 cm), 50% of female cod are mature (Forrester 1969). Teshima (1983) stated that female Pacific cod in the eastern Bering Sea apparently reach maturity at a length greater than 65 cm.

E. Frequency of Breeding

Cod breed annually.

F. Fecundity

Fecundity increases with the size of the fish. A 55-cm female off British Columbia will produce about 860,000 eggs, whereas an 80-cm female will produce about 3,350,000 eggs (Thompson 1962, Forrester 1969).

Thompson (1962) found that the length-fecundity relationship for cod in Asian waters (Sakhalin and West Kamchatka) was the same as that for cod in British Columbia waters.

G. Incubation Period

Pacific cod eggs are demersal (develop on the ocean floor). The rate of development is affected by temperature (Forrester and Alderdice 1966). Hatching takes place in 11.5 days at 8°C, but about 28 days are needed for hatching at 2°C (Forrester 1969). Larvae are found in coastal areas at depths of 25 to 150 m, with the majority occurring between 75 to 100 m (Mukhacheva and Zvyagina 1960). Larvae (8.8 to 11.6 mm in length) have been found in Bering Sea plankton in June and July (Musienko 1963) and in Cook Inlet (5.3 to 9.0 mm in length) in May and July. Larvae of unspecified lengths were found in Kodiak bays in April and May (Rogers et al. 1979) and in March-April and June-July on the Kodiak shelf (Kendall et al. 1980).

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

In the Bering Sea, age 0 (less than one year) cod are found in coastal waters. As the fish grow they move to progressively deeper, less coastal water, with age 1 fish found in inner continental shelf waters, age 2 and 3 on the central shelf, and age 4 and older on the outer shelf (Bakkala 1981).

Pacific cod follow short (300 to 500 km) seasonal migrations. Generally they move into deeper (110 to 128 m) waters to spawn in late winter (January to April). After spawning, the movement is generally

into more shallow (37 to 55 m) areas. The extent and direction of these migrations are probably controlled more by temperature and location of food than by depth (Alderdice and Forrester 1971, Ketchen 1961).

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

Little information is available on predators of Pacific cod; however, halibut (Hippoglossus stenolepis), fur seals (Callorhinus ursinus), belukha whales (Delphinapterus leucas), and sperm whales (Physeter macrocephalus) have all been reported to feed on gadoids (cods) (Salveson and Dunn 1976).

Ocean currents and weather patterns that carry larvae into productive areas and that result in a concentration of plankton are probably important for survival of cod larvae (Cooney et al. 1979).

B. Human-related

A summary of possible impacts from human-related activities includes the following:

- Alteration of preferred water temperatures, pH, dissolved oxygen, and chemical composition
- Introduction of water-soluble substances
- Increase in suspended organic or mineral material
- Reduction in food supply
- Human harvest
- Seismic shock waves

(See the Impacts of Land and Water Use volume of this series for additional information regarding impacts.)

VIII. LEGAL STATUS

Pacific cod within the 200-mi limit are managed by the North Pacific Fishery Management Council (NPFMC) through their groundfish fishery management plans. More details of management status can be found in the pollock Human Use section of this document.

IX. LIMITATIONS OF INFORMATION

Population dynamics of the Pacific cod are not thoroughly understood because of the few years for which good biological assessment data are available (Bakkala 1981). Such information is important for improved management and protection of the resource.

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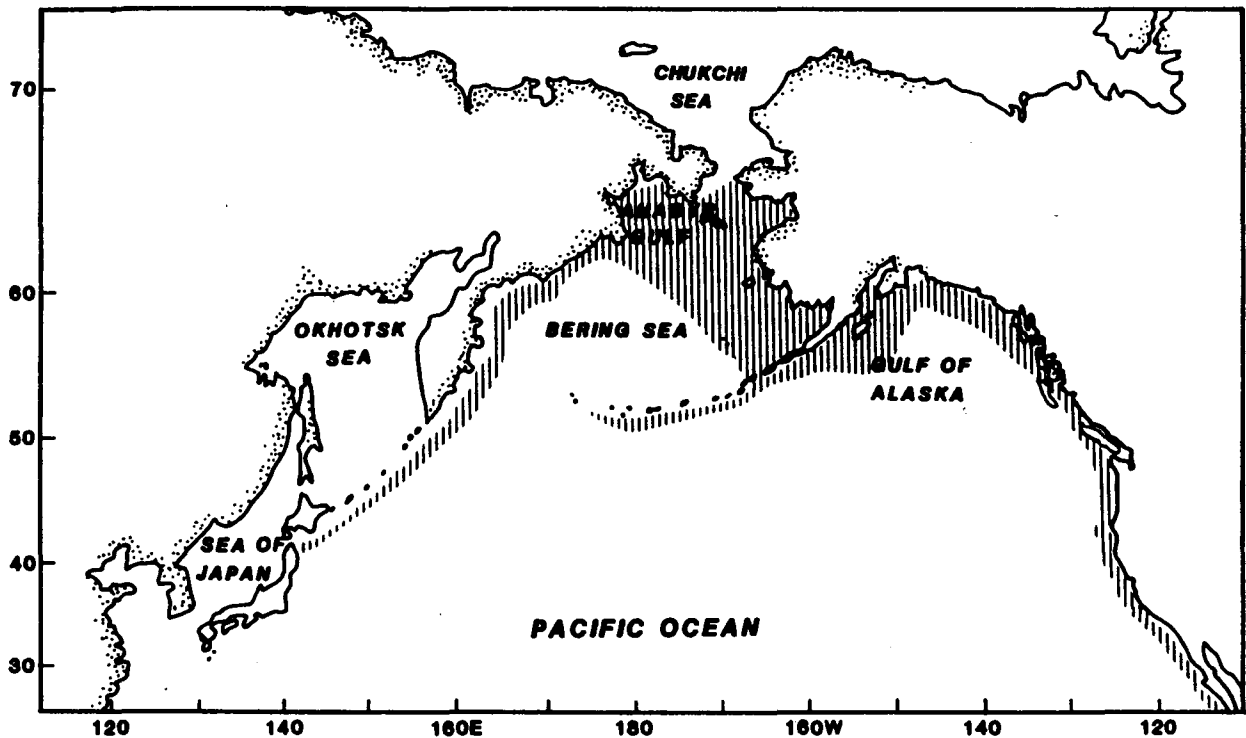
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Pacific Halibut Life History and Habitat Requirements
Southwest, Southcentral, and Western Regions



Map 1. Range of Pacific halibut (IPHC 1978, Best 1981, Bell and St. Pierre 1970)

I. NAME

- A. Common Name: Pacific halibut
- B. Scientific Name: Hippoglossus stenolepis
- C. Native Names: See appendix A.

II. RANGE

- A. Worldwide
Pacific halibut are distributed on the continental shelf of the North Pacific Ocean from Santa Barbara, California, to Nome, Alaska. They are also found along the Asiatic Coast from the Gulf of Anadyr to Hokkaido, Japan (IPHC 1978).
- B. Regional Distribution Maps
To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for each

region. The halibut distribution maps in this series are at 1:1,000,000 scale. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of selected fish and wildlife species has been prepared and may be found in the Atlas that accompanies each regional guide.

C. Regional Distribution Summary

1. Southwest. The largest concentrations of halibut are in the Gulf of Alaska, with a smaller population in the Bering Sea (Best 1981). In the Gulf of Alaska, halibut abundance is highest in the Kodiak Island area (Ronholt et al. 1977, Webber and Alton 1976). More detailed information is presented in the halibut Distribution and Abundance narrative in volume 1 of the Alaska Habitat Management Guide for the Southwest Region.
2. Southcentral. Pacific halibut stocks are located throughout the Southcentral Region. More detailed information is presented in the halibut Distribution and Abundance narrative found in volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.
3. Western. Pacific halibut are found throughout the marine waters of the Western Region. The seasonal distribution of halibut is directly affected by bottom temperature (St. Pierre 1984). During winter the bottom temperature in the shallow, shelf area of the Bering Sea drops to 0°C and halibut concentrate in warmer, deeper waters along the edge of the shelf (ibid.). By June, the halibut migrate into water from 50 to 150 m deep and halibut are distributed over a broad region of the shelf as far north as St. Lawrence Island during summer and fall (Gusey 1979). More detailed information is presented in the halibut Distribution and Abundance narrative found in volume 2 of the Alaska Habitat Management Guide for the Western and Interior regions.

III. PHYSICAL HABITAT REQUIREMENTS

Halibut are concentrated in areas with bottom water temperatures ranging from 3 to 8°C (IPHC 1978). Best and Hardman (1982) note that catches in juvenile halibut surveys were usually larger when bottom water temperatures were near 4°C. The bathymetric range for adult halibut is between 27 and 1,100 m (Rogers et al. 1980, IPHC 1978).

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

Halibut are opportunistic feeders, using whatever food is available (Best and Hardman 1982). Halibut less than 10 cm in length feed primarily on small crustaceans, mainly shrimp and small crabs (Smith et al. 1978). As the size of the halibut increases, the frequency and size of fish in the diet also increases. Best and Hardman (1982) found, in a survey of stomach

contents of young halibut mainly between 10 and 80 cm in length, that species important in the diet were Tanner crab (Chionoecetes bairdi), hermit crab (Paguridae), sandfish (Trichodon trichodon), sand lance (Ammodytes hexapterus), and walleye pollock (Theragra chalcogramma). Larger halibut feed on shrimps, crabs, and fish (especially sand lances) (Smith et al. 1978). In the Gulf of Alaska, halibut feed largely on Tanner crab (Chionoecetes spp.) octopus, Pacific cod (Gadus macrocephalus), and arrowtooth flounder (Atheresthes stomias) (Best, pers. comm.).

B. Type of Feeding Areas Used

Adult halibut feed both on benthic and pelagic organisms as they move on and off the continental shelf (Gusey 1978).

C. Factors Limiting Availability of Food

Growth rate information indicates that food may be a limiting factor when halibut abundance is high (Schmitt and Skud 1978). Apparently, large numbers of halibut can cause a significant reduction of their food supply.

D. Feeding Behavior

Halibut feed year-round, but large halibut feed less in winter than in summer (Webber and Alton 1976).

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Halibut spawning occurs all along the coast in the northeast Pacific but is concentrated near the edge of the continental shelf, generally in depths from 180 to 550 m (St. Pierre 1984). In the area from Cape St. Elias to Kodiak Island and in the Bering Sea spawning takes place along the shelf edge at depths greater than 180 m in concentrations of varying size (ibid.). Spawning grounds include Portlock Edge, Albatross Gully, Manhattan Ground, Seward Gully, Cape Cleare Gully and Spit, all situated east of Kodiak Island. Spawning grounds are also located east and west along the shelf edge off Middleton Island, Barnabas Gully, and the edges of Albatross Bank located south of Kodiak Island (ibid.).

B. Reproductive Seasonality

In the Gulf of Alaska, breeding takes place from November to March (IPHC 1978). In the Bering Sea, spawning occurs from October to March (Novikov 1964) with most of the spawning during December, January, and February (St. Pierre 1984). Environmental conditions could be a factor in determining the time when halibut begin to spawn in a given year; thus the peak spawning period could vary from year to year and from ground to ground (ibid.).

C. Age at Sexual Maturity

In the Gulf of Alaska, most males are mature by age 8; average maturity for females is age 12 (IPHC 1978). Best (1981) reported age at 50% maturity for females in the Bering Sea to be 13.8 years at a length of 122 cm. Males in the Bering Sea averaged 7.5 years and 72 cm at 50% maturity.

D. Frequency of Breeding

The long (approximately 12 years) immaturity of female halibut has apparently caused some confusion over the frequency of spawning. Vernidub (1936), and Novikov (1964) both reported that females spawned at most once every two years. Bell (1981), however, stated that spawning occurs annually. Bell speculated that Vernidub and Novikov's reports were based on immature females with developing ova that were caught in trawl surveys after the spawning period and mistaken for nonspawning adults.

E. Fecundity

The number of eggs produced per female is related to size. A 23-kg female produces about 500,000 eggs, whereas a 113-kg female may produce 4 million eggs (IPHC 1978).

F. Incubation Period

Eggs hatch after about 15 days (Thompson and VanCleve 1936, VanCleve and Seymour 1953); however, this rate of development is related to temperature. In laboratory experiments, Forrester and Alderdice (1973) found that at 5°C 50% of eggs hatch in 20 days, but at 8°C 50% hatch in 12.5 days. At 2, 4, 10, and 12°C the eggs did not survive to hatching.

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

- A. Eggs and larvae of halibut are heavier than surface sea water and drift passively in deep ocean currents, generally at depths of 90 to 180 m but down to 686 m. In the Gulf of Alaska, eggs and larvae are transported great distances by westward ocean currents (IPHC 1978, Gusey 1978). As the larvae grow, their specific gravity decreases. Thompson and Van Cleave (1936) reported that by the age of three to five months all larvae were in the upper 100 m. Larvae are moved by prevailing winds to the shallow (about 12 m) sections of the shelf (Gusey 1978, Thompson and Van Cleave 1936). Juveniles settle to the bottom at about six months old and remain in nearshore waters for one to three years (IPHC 1978, Best and Hardman 1982).

Halibut move from deep water (up to 1,097 m) along the edge of the continental shelf to shallower (27 to 274 m) banks and coastal waters to feed during the summer (IPHC 1978). The halibut return to deep water in the winter to spawn. These movements and coastwide migrations, which may encompass hundreds of miles, have been documented by extensive IPHC tagging studies. A high proportion of adults tagged in the Bering Sea were recovered in the Gulf of Alaska, but no recoveries of adults released in the Gulf of Alaska have been made in the Bering Sea (Bell 1981).

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

Little is known about predation on halibut. Sea lions often prey upon halibut hooked on longline gear, but it is unlikely that they are any threat to free-swimming halibut (Bell 1981).

Eggs, larvae, and juvenile halibut probably fall prey to many fish species, but older halibut, because of their size, must be safe from predation by most animals, except possibly large marine mammals (Webber and Alton 1976).

B. Human-related

A summary of possible impacts from human-related activities includes the following:

- Alteration of preferred water temperatures, pH, dissolved oxygen, and chemical composition
- Introduction of water soluble substances
- Increase in suspended organic or mineral material
- Alteration of preferred substrate
- Reduction in food supply
- Human harvest
- Seismic shock waves

(See the Impacts of Land and Water Use volume of this series for additional impacts information.)

VIII. LEGAL STATUS

The International Pacific Halibut Commission (IPHC) manages the Pacific halibut fishery. The commission monitors catch and effort, restricts gear and size of fish landed, and defines fishing areas. The North Pacific Fishery Management Council includes Pacific halibut in their list of unallocated species that must be avoided by groundfish fleets and includes in their Gulf of Alaska and Bering Sea Groundfish Management Plans time-area closures designed to minimize incidental catch of halibut. Further details of management status are included in the halibut Human Use section of this document.

IX. LIMITATIONS OF INFORMATION

Best (1981) suggested that more information is needed concerning juvenile halibut movements and the similarities and differences between the Bering Sea and Gulf of Alaska stocks.

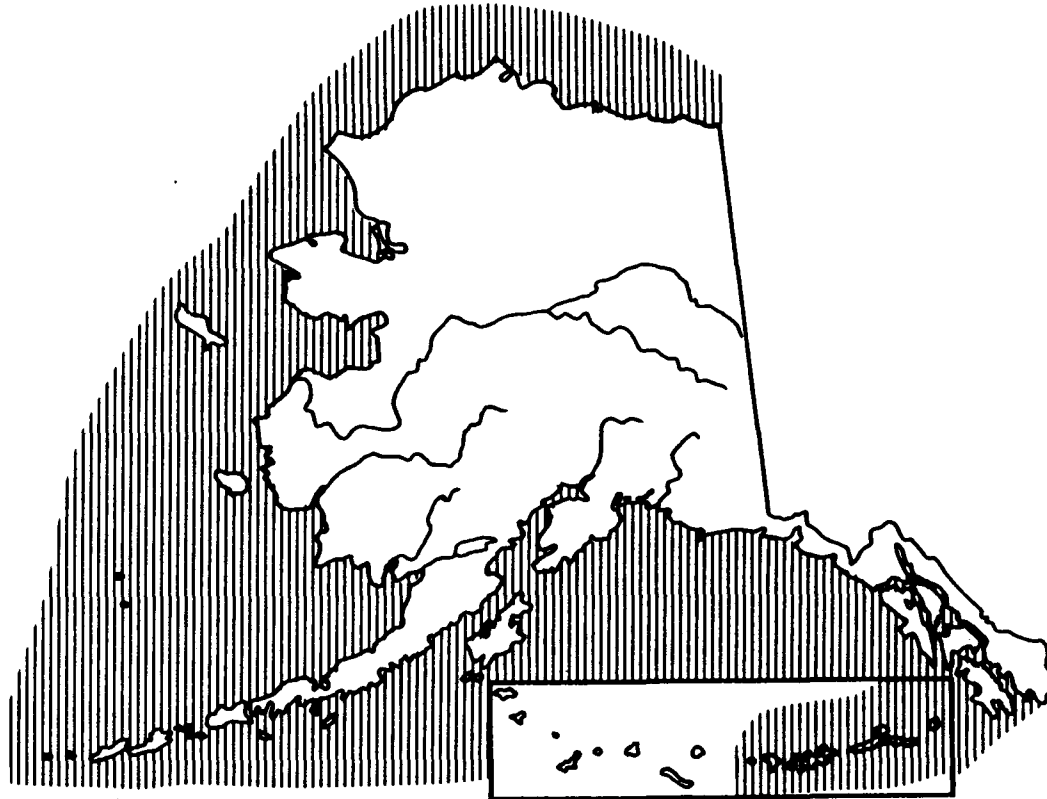
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Pacific Herring Life History and Habitat Requirements
Southwest, Southcentral, Arctic, Western, and Southeast Regions



Map 1. Range of Pacific herring (Hart 1973)

I. NAME

- A. Common Name: Pacific herring
- B. Scientific Name: Clupea harengus pallasii
- C. Native Names: See appendix A.

II. RANGE

- A. Worldwide

The genus Clupea is worldwide; Clupea harengus is of circumpolar distribution in the north temperate hemisphere. Clupea harengus pallasii, Pacific herring, is found in the eastern Pacific (California to Alaska) and western Pacific (China to the Bering Sea).

Along the Pacific coast of North America, Pacific herring are found from San Diego Bay, California, to Cape Bathurst in the

Beaufort Sea (Hart 1973). Along the Pacific coast of Asia, they range from Taksi Bay to the Yellow Sea (Andriyashev 1954).

B. Statewide

In Alaska, herring are distributed from Dixon Entrance in Southeast Alaska to Point Barrow among several major and minor spanning groups (ADF&G 1978).

C. Regional Distribution Maps

To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for each region. In this series, Pacific herring distribution information is included on both 1:250,000 and 1:1,000,000-scale maps. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of selected fish and wildlife species has been prepared and may be found in the Atlas that accompanies each regional guide.

D. Regional Distribution Summary

Major spawning concentrations are summarized below:

- Southwest Region: Kodiak area, along the Alaska Peninsula and Aleutian Islands, and in Bristol Bay
- Southcentral Region: Prince William Sound, lower Cook Inlet, and upper Cook Inlet
- Arctic Region: Kotzebue Sound and Norton Sound
- Western Region: Kuskokwim Bay, Nelson and Nunivak islands, Scammon Bay, and Kokechik Bay
- Southeast Region: from Yakutat Bay south to Dixon Entrance

III. PHYSICAL HABITAT REQUIREMENTS

A. Water Quality

In the Bering Sea, temperature may have the greatest influence on the seasonal distribution of herring (Wespestad and Barton 1981). Dense schools of overwintering adult herring have been found at temperatures of from 2 to 3.5°C in the Bering Sea (Dudnik and Usoltsev 1964). Herring moving from the overwintering grounds in the Bering Sea to spawning grounds have passed through water at subzero (centigrade) temperatures (Wespestad and Barton 1981). Immature herring may typically occupy shallower, less saline waters than adults (Taylor 1964). Juveniles, however, are found in a wide range of salinities in British Columbia, with concentrations documented at 25 parts per thousand (o/oo) (Hourston 1959). Herring eggs and fry were found in Imuruk Basin near Port Clarence, Alaska, in water of 4 o/oo salinity (Barton 1978). Immature fish in the Bering Sea exhibit greater tolerance for colder, less saline areas in their overwintering grounds on the continental shelf than do adult fish (Wespestad and Barton 1981). The timing of spawning in the western Bering Sea is related to winter and spring water temperatures, with early maturation occurring in warm years and delayed development in colder years (Prokhorov 1968). In Bristol Bay, herring appear on

the spawning grounds when water temperatures reach 4°C, and spawning has been observed to occur at 5°C. A water temperature of 10°C has been documented in Bristol Bay during the spawning season (Warner and Shafford 1977). Water temperatures occurring on Bering Sea spawning grounds between Norton Sound and Bristol Bay have ranged between 5.6 and 11.7°C (Barton 1979). In the Kotzebue Sound-Chukchi Sea area, adult herring were captured in areas where water temperatures ranged from 2 to 14°C. Juvenile herring were caught in Krusenstern Lagoon in mid August of 1980 in water temperatures measured to 18.3°C (Whitmore and Bergstrom 1983). Alderdice and Velsen (1971) found the optimum temperature for egg development in the laboratory in southern British Columbia to range from 5 to 9°C. At continuous exposures below 5°C, the eggs die (ibid.).

B. Water Quantity

Adults were found to overwinter at depths from 107 to 137 m in the Bering Sea (Dudnik and Usoltsev 1964). Alaskan herring move inshore to spawn in both subtidal and intertidal areas in the spring. Herring appear to remain in shallower coastal waters after spring spawning in the Bering Sea, as few are taken in offshore trawl surveys (Pereyra et al. 1976, Bakkala and Smith 1978). In Southeast Alaska, herring overwinter in protected bays that are usually close to respective spawning areas. Overwintering herring have been reported at depths of 90 fathoms but are more commonly found at depths of 23 m or less (Blankenbeckler, pers. comm.). Spawning in Southeast Alaska has been documented from the intertidal area to depths of 11.5 m. Major spawning activity occurs in the subtidal area in Southeast Alaska (ibid.).

C. Substrate

See section V. A. this report.

IV. NUTRITIONAL REQUIREMENTS

A. Preferred Foods

1. Larvae and postlarvae. Herring larvae and postlarvae feed on ostracods, small copepods and nauplii, small fish larvae, and diatoms (Hart 1973). Studies of food habits of herring captured in southern British Columbia noted that the food was present in stomachs of herring larvae less than 9 mm in length. Larvae, however, were found to feed before the yolk sac was absorbed (Wailes 1935). At the earliest feeding stages, eggs, diatoms, and small copepod nauplii were eaten. Postlarvae and fry ingested a large variety of organisms, with copepod and cirripid larvae being the most important items (ibid.). The first food eaten by larval herring may be limited to microscopic plankton organisms the larvae practically need to run into to notice and capture. Early food items may be comprised of more than 50% microscopic eggs (Wespestad and Barton 1980).

2. Juveniles. Juveniles consume mostly crustaceans such as copepods, amphipods, cladocerans, decapods, barnacle larvae, and euphausiids. Consumption of some small fish, marine worms, and larval clams has also been documented (Hart 1973). In the western Bering Sea and Kamchatka area in November and December, the diet of juveniles consists of medium-sized forms of zooplankton (Chaetognaths, mysids, copepods, and tunicates) (Kachina and Akinova 1972).
 3. Adults. Adult herring captured in British Columbia fed primarily upon euphausiids, copepods, and occasionally herring eggs (Wailes 1935). In the eastern Bering Sea, August diets of adults were comprised of 84% euphausiids, 8% fish fry, 6% calanoid copepods, 2% gammarid amphipods; fish fry, in order of importance, were walleye pollock, sandlance, capelin, and smelt. During spring months, food items were mainly Themisto (amphipoda) and Sagitta (chaetognath). After spawning (eastern Bering Sea), adults ingested euphausiids, copepods (Calanus spp.), and arrow worms (Sagitta spp.) (Dudnik and Usoltsev 1964). Stomach contents of herring found in demersal areas included polychaete worms, bivalve molluscs, amphipods, copepods, juvenile fish, and detritus (Kachina and Akinova 1972). Barton (1978) found cladocerans, flatworms (Platyhelminthes), copepods, and cirripeds in herring captured during spring months. In Southeast Alaska, adult herring feeding during spring months have preyed upon both pink salmon larvae, pink salmon fry, and herring eggs (Blankenbeckler, pers. comm.; Thorsteinson 1962). Rather than exhibiting a preference for certain food items, adult herring feed opportunistically on any large organisms prevalent among the zooplankton in a given area (Kaganovskii 1955).
- B. Feeding Locations
- Feeding occurs primarily in coastal waters of the inner continental shelf. In British Columbia, large aggregations of herring may be scattered along 100 mi of coastline off the mouth of Juan de Fuca Strait. These aggregations may move many miles north or south during the summer, presumably following their food supply (Hourston and Haegele 1980). Herring remain in coastal waters during the summer because of the concentration of zooplankton food items and feeding conditions (Carlson, pers. comm.). Herring may remain in coastal waters during the summer because heavy phytoplankton blooms and because poor feeding conditions exist on the outer shelf (Rumyantsev and Darda 1970). Herring may avoid areas of heavy phytoplankton bloom because of its low nutritional value. Gills may become clogged by certain species of phytoplankton, and respiration of the fish may be affected (Henderson 1936).
- C. Factors Limiting Availability of Food
- Climatic conditions and ocean currents may affect the availability of food. On the rearing grounds, for instance, in larval-rearing

areas, unfavorable weather conditions, such as lack of sunshine, may delay the spring bloom of phytoplankton and therefore the subsequent development of zooplankton on which herring larvae feed. The result could be an insufficient food supply available to meet the energy needs of the larvae. Currents may carry herring larvae to places where the food supply is inadequate. In British Columbia in years where freshwater runoff is greater than normal or wind-driven water transport offshore has a net southward direction, larvae will be carried offshore away from the more abundant food supplies and be exposed to additional sources of predation (Hourston and Haegele 1980, Outram and Humphreys 1974).

D. Feeding Behavior

A day or so after yolk sac absorption, Atlantic herring larvae instinctively snap at and try to capture bite-size particles and if unsuccessful will give up the attempt (Blaxter and Hempel 1963). Adult herring generally feed heavily in summer and very little during winter months (McBride et al. 1960). Feeding in the Bering Sea declines during early winter, ceasing completely in late winter (Dudnik and Usoltev 1964). Juvenile herring were found to feed during November and December in the Kamchatka waters of the western Bering Sea (Rumyantsev and Darda 1970). Examination of herring captured during spring months from Bristol Bay to Norton Sound revealed that about 95% of the stomachs were empty or contained traces of food items (Barton 1978).

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

In the Bering Sea, spawning occurs on rocky headlands or in shallow lagoons and bays (ibid.). Eggs are deposited both subtidally and intertidally on aquatic vegetation, rock, and sand. Predominant vegetation types along the Bering Sea coastline are eelgrass (Zostera spp.), rockweed (Fucus spp.), and ribbon kelp (Laminaria spp.) (ibid.). In Prince William Sound, broad leaf kelp, Agarum, and Laminaria are the primary vegetation types (Rosenthal 1978). Substrate on which herring spawn in Southeast Alaska includes Fucus, Agarum, Zostera, Alaria, Laminaria, and rock surfaces. The vegetative type used most frequently, however, is Desmarestia (Blankenbeckler, pers. comm.). Spawning activity is related to water temperatures and occurs soon after water has become ice-free. Recorded water temperatures in which spawning activity has been documented are approximately 3 to 5.5°C (Scattergood et al. 1959); 5 to 9.4°C in Southeast Alaska (Blankenbeckler, pers. comm.); 6 to 10°C in Bristol Bay (Warner and Shafford 1977); and 5.6 to 11.7°C on the spawning grounds between Norton Sound and Bristol Bay (Barton 1979). Herring north of Norton Sound may spawn in brackish bays and estuaries (Barton 1978).

B. Reproductive Seasonality

Alaskan herring are classed as spring spawners, although spawning activity within the state may occur from March to August,

depending upon geographic location and environmental conditions. Peak spawning activity is usually earliest in Southeast Alaska and becomes progressively later for more northern areas. Herring in Southeast Alaska spawn from March through May (Carlson, pers. comm.), with most activity occurring during the months of April and May (Blackenbeckler, pers. comm.). In Prince William Sound, spawning activity usually occurs from early April through May, in Cook Inlet from May through mid June, and in the Kodiak area from mid April to early August (ADF&G 1978; Malloy, pers. comm.). In the Kodiak area, timing of spawning usually ranges from early April in the Fox Bay, Paramanof Bay areas, to late July in the Olga Narrows area, and early August in the Deadman Bay area (Malloy, pers. comm.).

On the Bering Sea coast, spawning activity extends from late April through July in Bristol Bay and along the Alaska Peninsula, becoming progressively later to the north and occurring from ice breakup through mid August in Kotzebue Sound (Wespestad and Barton 1981). Because spawning areas in the Chukchi Sea retain their ice cover into July, spawning activity could be delayed until August after ice cover is gone (Whitmore and Bergstrom 1983).

C. Reproductive Behavior

Herring in Lynn Canal in Southeast Alaska overwinter in inshore waters, where maturation continues. About one to four weeks before spawning, herring seem to move closer to the spawning grounds (Carlson 1980). In British Columbia, herring travelled 160 km in 6 days from Barkley Sound to Espenanza Inlet to spawn, and from Lambert Channel they travelled 350 km to Juan de Fuca Canyon in 16 days. Both instances indicate a speed of one body length per second (Lasker 1985). Some herring remain nearshore close to their spawning grounds throughout the year (ibid.). In the eastern Bering Sea, older herring may move inshore first (Barton 1979). In Southeast Alaska, however, adult herring do not exhibit any correlation between the timing of spawning and the age of the fish, although males have been reported arriving on the spawning grounds prior to females (Blankenbeckler, pers. comm.). The herring's shore-spawning behavior may be due to the low temperatures prevailing in deeper water (Svetovidov 1952). Spawning may last from a few days to several weeks (Barton 1979). Environmental or physical stimuli such as storms and crowding may cause a few males to extrude milt, triggering a spawning reaction by the entire herring school (Hourston and Haegele 1980). Laboratory studies have shown that exposing herring to filtrates of ripe herring testes stimulated behavioral and physiological responses leading to spawning. It is unclear whether males or females initiate spawning (Lasker 1985), although there is some evidence to indicate that males start spawning activity before females (Hay 1985) and that females respond only to the presence of milt (Stacey and Hourston 1982). The texture and surface properties of the vegetation are tested by the fish prior to spawning, and the sediment on the substrate may inhibit spawning.

In the presence of suitable substrate, the fish rise to the surface and mill about, extending their genital papillae. The herring then arch their backs and swim with short rapid body movements against the substrate, making contact with their pectoral fins and chins. Eggs or milt are extruded from the papillae, which also contact the substrate (Hourston and Haegele 1980). The extrusion of eggs appears to be impeded unless the vent is in contact with the substrate (eelgrass, kelp, rockweed, or other seaweed) (Hart 1973), but Stacey and Hourston (1982) did find eggs deposited in the water column. Females usually lay few eggs in a single spawning act, but repetition of the act results in multiple layers of eggs on the substrate (Hourston and Haegele 1980). Eggs are fertilized by milt broadcast or dissipated in the water by males (ibid.).

D. Age at Sexual Maturity

Sexual maturity of Alaskan herring varies by geographic area, with some stocks entering the spawning population at age 2. In the Gulf of Alaska and Bering Sea, most herring do not spawn until ages 3 and 4. By age 5, 95% of the population has matured (Rumyantsev and Darda 1970). Herring may live up to 15 years in the Bering Sea (Barton 1978). Though 15-year-old herring have been documented in Southeast Alaska, herring appear to experience a heavy mortality after age 7 (Blankenbeckler, pers. comm.).

E. Fecundity

The number of eggs carried increases with increases in body length and width (Nagasaki 1958). In some Atlantic herring population, egg size also increases with fish size. Egg weights of recruit spawners were significantly less than those of older, large, repeat spawners (Hemple and Blaxter 1967). In comparisons of fecundity from different North American populations, a decrease in fecundity at a particular body size was apparent with increasing latitude (Paulson and Smith 1977). Herring of ages 4 to 8 in the Bering Sea produce 26.6 to 77.8 thousand eggs (ibid.). Warner and Shafford (1977) found that the fecundity of herring from Bristol Bay ranged from 13.1 to 71.9 thousand eggs for herring ranging in size from 171 to 320 mm. Fecundity for herring in Southeast Alaska ranged from 14,000 to 36,000 eggs for fish of standard lengths from 180 to 230 mm. More specifically, fecundities of herring with standard lengths of 220 mm to 230 mm averaged 36,000 eggs; for standard lengths of 210 to 215 mm, fecundity averaged 24,000 eggs; for standard lengths of 200 to 205 mm, fecundity averaged 25,000 eggs; for lengths of 185 to 195 mm, fecundity averaged 23,000 eggs; and for fish of about 180 mm in standard length, fecundity averaged 14,000 eggs (Blankenbeckler, pers. comm.).

F. Frequency of Breeding

Pacific herring breed annually upon reaching maturity.

G. Incubation Period/Emergence

Eggs take 10 to 21 days to hatch, depending on the water temperature (Wespestad and Barton 1981, Alderdice and Velsen

1974). In Bristol Bay, at temperatures of 8 to 11°C, 13 to 14 days are required for hatching (Barton 1979). The optimum temperature reported for egg development is from 5 to 9°C. Newly hatched larvae are about 8 mm in size. Larvae grow to 30 mm in 6 to 10 weeks and begin to metamorphose into free-swimming juveniles.

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS AND DEVELOPMENTAL STAGES

A. Juveniles

Larvae are at the mercy of water currents until they develop the ability to swim (Hourston and Haegele 1980). Larvae migrate downwards during the day and to the surface at night, following their planktonic food supply (Hart 1973). In British Columbia, juveniles form schools that move out of bays as summer progresses (Taylor 1964) and they move from the spawning grounds to different rearing areas (Hourston 1959). In British Columbia and Southeast Alaska, juveniles feed in coastal waters in summer and move to deeper water in winter (Taylor 1964, Rounsefell 1930). Very little is known about juvenile herring in the Bering Sea and other Alaskan waters.

B. Adults

Migrational patterns are specific to each area and population. Temperature may have the greatest influence on seasonal distribution (Svetovidov 1952). Generally, mature adult herring return to offshore feeding grounds after spawning inshore during spring, and in August or September they move further offshore into deeper water to overwinter (Hourston and Haegele 1980). Tagging studies indicate that adult Pacific herring return, or home, to approximately the same geographic spawning areas each year (Hourston 1982). Some smaller herring populations in British Columbia do not move to offshore feeding grounds and are available throughout the year in the same general location. Similar behavior is documented among some nonmigratory stocks in Southeast Alaska (Carlson 1980). These "nonmigratory" and other migratory groups may coexist in the same waters and later segregate as the spawning season approaches (Hay and Outram 1981). Carlson (1980) found that the migration of herring to wintering areas in Southeast Alaska coincided with the breakdown of the thermocline in October.

In the eastern Bering Sea, populations that spawn in Bristol Bay and possibly in areas in the Kuskokwim delta are believed to engage in a feeding migration south along the Alaska Peninsula to the Unalaska Island area during May through August. These fish may then migrate along the continental shelf to major wintering grounds northwest of the Pribilof Islands. Migration from coastal waters to the winter grounds occurs from mid August through September (Wespestad and Barton 1981). Concentrations in water from 2 to 4°C on the overwintering grounds begins in October (Bering Sea), continuing into winter. Mature fish arrive at wintering areas before immature herring (Rumyantsev and Darda

1970). Concentrations of overwintering herring may shift northwest in the Bering Sea in mild winters and southeast during severe winters. Overwintering herring leave the wintering area for the spawning grounds in late March (Shaboneev 1965). Prior to spawning, these large overwintering groups of herring break apart, and the fish appear to travel closer to the spawning grounds, where they may again hold for short periods of time before moving into shallow areas (Lasker 1985). After spawning, adult herring remain in coastal waters to feed (Pereyra et al. 1976, Bakkala and Smith 1978). Concentrations of herring appear off Nunivak and Unimak islands in the Bering Sea during August (Rumyanstev and Darda 1970). Herring spawnings are restricted by depth, temperature, substrate type, and other factors, such as high sediment loads either in the water column or on the sea bottom (Hay 1985).

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

1. Egg stage. Mortality of eggs of British Columbia herring may reach 70 to 80% during incubation (Outram and Humphreys 1974). Up to 80% mortality has been observed in other areas in Alaska, such as Cape Romanzoff (Geiger, pers. comm.), the major causes being wave action, exposure to air, and bird predation (Taylor 1964). Wave action can destroy both spawn and spawn substrate in intertidal areas (Gilmer 1978). Desiccation of eggs by high tidal fluctuation and low salinity caused by freshwater runoff of melting snow and ice also contribute to mortality. Sea birds have been documented as major predators of herring eggs in the intertidal area. Predation by flatfish upon eggs has also been documented (Wespestad and Barton 1981). In Norton Sound, Bering cisco, saffron cod, sculpins, and snails (*Littorina planaxis*) were found to consume herring eggs (Whitmore 1985, Stekoll 1983). Egg survival decreases as the layers of egg deposition increase and oxygen cannot reach the bottom layers. The number of healthy larvae that will hatch from a deposition nine layers thick will very likely be less than for eggs in the same area four layers thick (Hourston and Haegele 1980). Environmental stress during the egg stage also results in malformed larvae and eventual death (ibid.).
2. Larval stage. Mortality is high for herring in the larval stage and may exceed 99%. It is possible that year-class strength is determined at the larval stage (ibid.). Proper-sized food items of adequate nutritional value must be available during the initial feeding of larvae to prevent starvation at the first stage of development (Lasker 1985). Mortality of larvae may be attributed to environmental stress on the organism during the egg stage, resulting in the hatching of incompletely developed or malformed larvae that

are not strong enough to cope with predators or the environment (Hourston and Haegele 1980). Changes in food supply as a result of environmental conditions specified in section III. C. of this report will also cause larval mortality.

Predation upon larvae is intense. Predators may include comb jellies, jellyfish, arrow worms, small salmon, and amphipods (ibid.). Cannibalism of adult herring upon larval herring has been documented when older herring have been present on the spawning grounds during the egg-hatch period (ibid.).

3. Juvenile and immature stage. The rate of natural mortality decreases in this life stage (Wespestad and Barton 1981). Hourston and Haegele (1980) estimate the mortality rate of herring during the juvenile stage at 20%. Juvenile herring are susceptible to predation by fish (e.g., salmon or dogfish), marine mammals, and seabirds. The greater size of immature herring (herring in their second year of life) would render them less vulnerable to the predation suffered at earlier life stages (ibid.).
4. Adult. The natural mortality rate of adult herring is highly variable but averages about 30% (ibid.). The probability of mortality increases with age, particularly for males. Mortality rates increase at age 5 as a consequence of senility, disease, and spawning mortality (Wespestad and Barton 1981). Increased mortality, selective for male herring with age, is not characteristic for herring in Southeast Alaska (ibid.). Mature herring are most susceptible to predation by marine mammals, dogfish, and seabirds on the spawning grounds and during migration to their offshore feeding grounds (Hourston and Haegele 1980). Herring are a very important staple in food webs, and in the Bering Sea they serve as a dietary staple for marine mammals, birds, salmon, and groundfish (Wespestad and Barton 1981). Predation upon herring by northern pike captured in Hotham Inlet in Kotzebue Sound has been documented. Herring have been found to be a major food item for sheefish in northern Kotzebue Sound during November (Whitmore and Bergstrom 1983). Natural mortality of herring through all life stages in the Bering Sea has been estimated to be 47% (Wespestad and Barton 1981) and in Southeast Alaska, about 40% (Blackenbeckler, pers. comm.).

B. Human-related

A summary of possible impacts on herring abundance and distribution from human-related activities includes the following:

- Alteration of preferred water temperatures, pH, dissolved oxygen, and chemical composition
- Alteration of preferred spawning substrate
- Alteration of intertidal areas
- Increase in suspended organic or mineral material
- Reduction in food supply
- Reduction in spawn substrate (e.g., seaweed beds)

- Obstruction of migration routes
 - Shock waves from explosions in the aquatic environment
 - Human harvest
- (See the Impacts of Land and Water Use volume of this series for additional impacts information.)

VIII. LEGAL STATUS

A. Managerial Authority

Herring are managed within the 3-mi limit by the State of Alaska, Department of Fish and Game, and in the Fisheries Conservation Zone (3 to 200-mi limit) by the U.S. Department of Commerce, National Marine Fisheries Service, as directed by the joint policy of the State of Alaska's Board of Fisheries and the North Pacific Fisheries Management Council.

IX. LIMITATIONS OF INFORMATION

Little is known about the larval and juvenile biology of herring in Alaskan waters. Overwintering areas, feeding areas, migration routes of adult herring and stock definition in most areas have yet to be defined.

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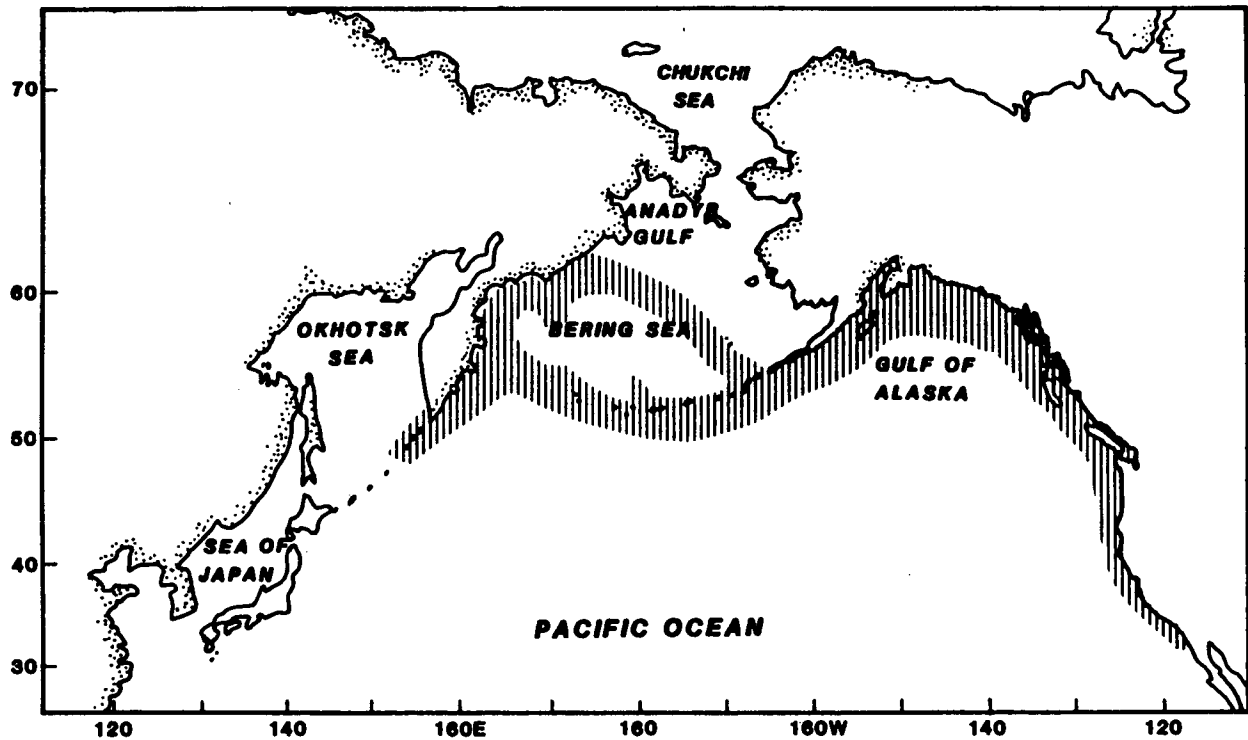
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Pacific Ocean Perch Life History and Habitat Requirements
Southwest and Southcentral Regions



Map 1. Range of Pacific ocean perch (Major and Shippen 1970)

I. NAME

- A. Common Name: Pacific ocean perch
- B. Scientific Name: Sebastes alutus
- C. Native Names: See appendix A.

II. RANGE

- A. Worldwide
Pacific ocean perch are found along the eastern and northern rim of the Pacific Ocean from Southern California to the Gulf of Alaska, along the Aleutian chain to Kamchatka, and in the Bering Sea.
- B. Regional Distribution Maps
To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for each region. Pacific ocean perch distribution maps in this series are

at 1:1,000,000 scale. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of selected fish and wildlife species has been prepared and may be found in the Atlas that accompanies each regional guide.

C. Regional Distribution Summary

1. Southwest. Chikuni (1975) defined two stocks of perch in the Bering Sea: the Aleutian stock, found on both sides of the Aleutian archipelago, and the eastern slope stock. The Aleutian stock is much larger than the eastern slope stock. (For more detailed narrative information, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)
2. Southcentral. In the April-October 1973-1976 NOAA trawl surveys of the Gulf of Alaska, Pacific ocean perch were found in each region where sampling occurred but were generally restricted to outer shelf and upper slope depth zones (Ronholt et al. 1977). The highest mean annual catch rates of Pacific ocean perch by the Japanese trawl fishery from 1964 through 1974 in the gulf were from the area located off Icy Bay and Yakutat Bay (ibid.). In the Gulf of Alaska, feeding schools of perch are found in the Unimak, Shumagin, Kodiak, and Yakutat regions in spring and summer (Lyubimova 1965). (More detailed distribution information is contained in the narratives on the distribution and abundance of Pacific ocean perch found in volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)

III. PHYSICAL HABITAT REQUIREMENTS

Adult Pacific ocean perch are generally found on the continental slope at depths of 200 to 300 m (Chikuni 1975). Reeves (1972) noted large concentrations around submarine canyons. Nearshore, rocky-bottom coastal areas exposed to open sea conditions and adjacent bays and straits are probably nursery areas for Pacific ocean perch (Carlson and Haight 1976, Carlson and Straty 1981). Juveniles inhabit areas where cover and protection are afforded by cracks and crevices in and under rocks and ledges and among sessile invertebrates such as the anemone (Metridium senile) (Carlson and Straty 1981).

Carlson and Haight (1976) reported that both juveniles and adults were found only over areas with a hard or firm substrate, never over muddy substrate. They speculated that these areas of clean substrate may be caused by ocean currents and that current, rather than substrate type, was a controlling factor in Pacific ocean perch habitat (ibid.). Quast (1972) also speculated that distribution of adults may be determined more by food and hydrographic conditions than by substrate.

Water temperature is an important environmental factor controlling distribution of perch (Lisovenko 1964). Adult rockfish live within 4.0 to 6.5°C and the young (14 to 26 cm) at lower temperatures (2.5 to 3.5°C) (Lyubimova 1964).

Lyubimova (1965) related the vertical distribution of perch in the Gulf of Alaska to the depth of the layer of oxygen deficiency (where O_2 content is less than 1 ml/l). Rockfish concentrations throughout the year remain above this layer, which varies from 350 m deep in summer to 420 m in winter.

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

Juvenile perch of all sizes in Southeast Alaska feed on copepods and euphausiids (Carlson and Haight 1976). Chikuni (1975) noted that stocks in the Gulf of Alaska fed almost entirely on euphausiids, whereas those in the Bering Sea consume fishes, euphausiids, and other crustaceans.

B. Types of Feeding Area Used

Schools of feeding perch are found mainly at depths of 150 to 200 m (Lyubimova 1963).

Lyubimova (1964) found dense concentrations of feeding perch in the western Gulf of Alaska southeast of Kodiak Island, southwest of Shumagin Islands, and south of Unimak Island.

C. Factors Limiting Availability of Food

Somerton (1978) speculated that Pacific ocean perch may compete with walleye pollock (Theragra chalcogramma) for food. Rapid growth and survival of larval rockfish, as with other ocean fish (such as pollock and Pacific halibut), is probably dependent on ocean currents and weather conditions that result in a concentration of available food (Cooney et al. 1979).

D. Feeding Behavior

Skalkin (1964) and Lyubimova (1963) state that perch in the Gulf of Alaska feed heavily from May to September and hardly at all through the rest of the year. The feeding rate changes during the day, being most intensive at noon and least intensive in the morning (Skalkin 1964).

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Spawning occurs in the northern Gulf of Alaska, with densities of larvae being highest in the Yakutat area. High larval densities are also found in the Kodiak Island area (Gusey 1978). In the Bering Sea, spawning takes place south and southeast of the Pribilof Islands (Paraketsov 1963).

Lyubimova (1964) related the location of spawning to water temperature, with females spawning in the warmer areas of the gulf. Paraketsov (1963) reported that spawning in the Bering Sea occurs at depths of 360 to 420 m.

B. Reproductive Seasonality

Pacific ocean perch are ovoviviparous, meaning they are internally fertilized and give birth to live young. Copulation takes place October through February, and spawning (release of young) takes place from March through June (Chikuni 1975). Significant

concentrations of larvae have been reported in the Yakutat region during April and May (Lisovenko 1964).

C. Reproductive Behavior

Mating has not been observed (Morin and Dunn 1976); however, Lisovenko (1964) suggested that males may copulate several times with different females. Paraketsov (1963) repeated that mating and fertilization take place simultaneously; Chikuni (1975), however, stated that fertilization may occur two months after mating.

D. Age at Sexual Maturity

Fish from all stocks begin to mature at age 5, and all individuals are mature at age 9 (Chikuni 1975). Fifty percent of the stock is mature at age 7 (ibid.).

E. Frequency of Breeding

Pacific ocean perch breed annually (Morin and Dunn 1976).

F. Fecundity

Fecundity is higher in Bering Sea stocks (75,000 eggs at age 15, 205,000 at age 20) than in the Gulf of Alaska (33,000 at age 15, 48,000 at age 20) (Chikuni 1975). Lyubimova (1965) reported that 10,000 to 270,000 larvae may be released.

G. Incubation Period

Spawning (release of live young) takes place four to five months after copulation (Chikuni 1975).

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

Larval Pacific ocean perch are planktonic, with their distribution largely controlled by ocean currents. Sometime during their first year of life, the juvenile perch become demersal and are found near the ocean bottom in areas 110 to 140 m deep (Carlson and Haight 1976, Buck et al. 1975). When they become sexually mature, the perch move into deeper waters (up to 320-370 m or deeper) (Buck et al. 1975).

Adult Pacific ocean perch do not migrate long distances (Fadeev 1968, Chikuni 1975). Seasonal movements of perch are largely between deep and shallow bottoms within a limited area (Fadeev 1968).

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

Carlson and Haight (1976) noted strong fluctuations in year class strength. Extreme success or failure of year classes is apparently characteristic of the species (Carlson and Haight 1976).

Lisovenko (1964) noted that female perch in the Gulf of Alaska cast their larvae in places where water currents are conducive of high productivity. Cooney et al. (1979) have speculated that weather and current conditions resulting in dispersal of plankton may have a negative effect on larval pollock survival. It seems possible that perch larvae are similarly affected.

Before heavy commercial exploitation began in the early 1960's, Pacific ocean perch were a dominant groundfish in the Gulf of Alaska. But perch stocks now have been severely reduced, and,

possibly as a result of release from competition with perch, pollock have become much more abundant (NPFMC 1979). Pollock and perch feed on largely the same organisms (Somerton 1978), and it is possible that competition with pollock will prevent perch stocks from recovering even if fishing pressure is relieved (NPFMC 1979).

B. Human-related

A summary of possible impacts from human-related activities includes the following:

- Alteration of preferred water temperature, pH, dissolved oxygen, and chemical composition
- Introduction of water-soluble substances
- Increase in suspended organic or mineral material
- Alteration of preferred substrate
- Reduction of food supply
- Seismic shockwaves
- Human harvest

(See the Impacts of Land and Water Use volume of this series for additional information regarding impacts.)

VIII. LEGAL STATUS

Pacific ocean perch within the 200-mi limit are managed by the North Pacific Fishery Management Council in their groundfish fishery management plans. More details of management status can be found in the narrative on the human use of groundfish.

IX. LIMITATIONS OF INFORMATION

Much of the available information on the biology of the Pacific ocean perch was collected by Russian investigators in the early 1960's, before extensive commercial exploitation began. Since then, stocks have been severely reduced, and some aspects of their biology may have changed. The NPFMC recognizes a need to improve and extend groundfish stock assessment surveys and to more accurately model the relationships between organisms (including groundfish) and their environment in Alaskan waters (NPFMC 1979).

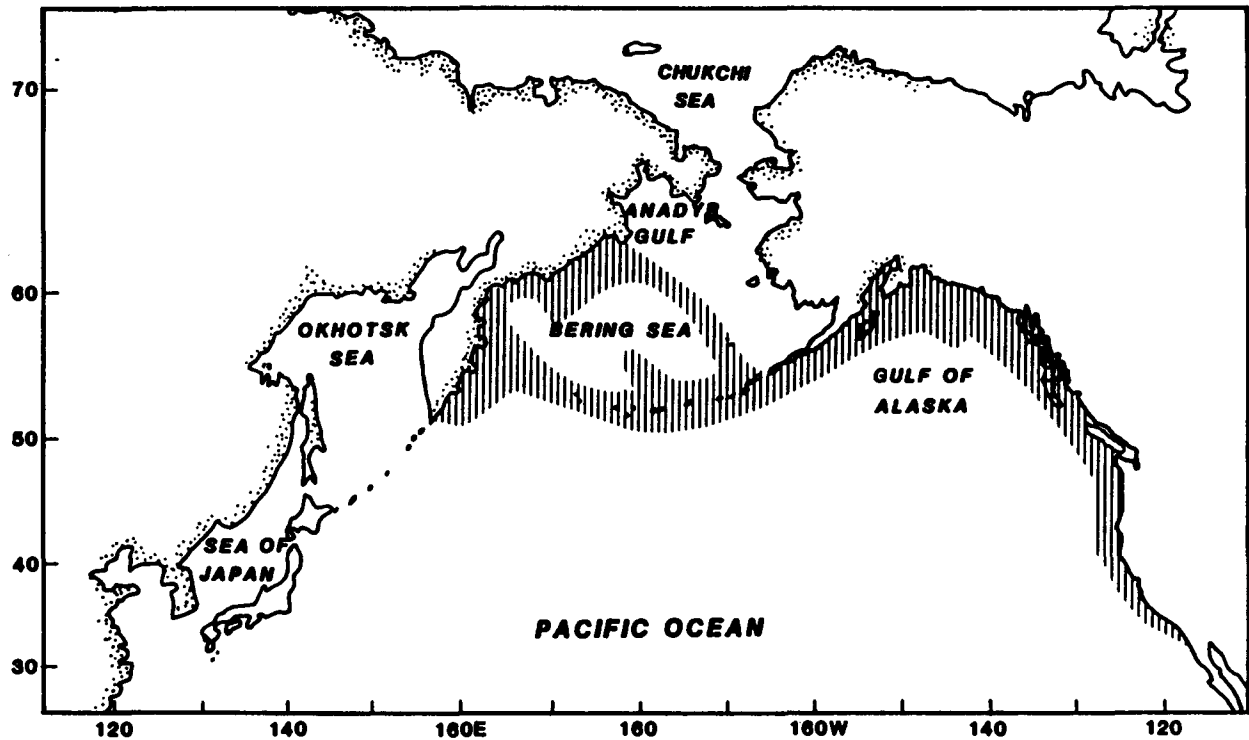
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Sablefish Life History and Habitat Requirements
Southwest and Southcentral Regions



Map 1. Range of sablefish (Low et al. 1976)

I. NAME

- A. Common Name: Sablefish
- B. Scientific Name: Anoplopoma fimbria (Pallas)
- C. Native Names: See appendix A.

II. RANGE

- A. Worldwide
Sablefish are found on the Eastern Pacific coast from Mexico to Alaska, westward along the Aleutian Island chain and the edge of the continental shelf in the Bering Sea, and along the Siberian and Kamchatkan coasts to the northeastern coast of Japan (Low et al. 1976).

B. Regional Distribution Maps

To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for each region. Sablefish distribution maps in this series are at 1:1,000,000 scale. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of selected fish and wildlife species has been prepared and may be found in the Atlas that accompanies each regional guide.

C. Regional Distribution Summary

1. Southwest. Sablefish in the Bering Sea are found along the edge of the continental shelf but are not as abundant as in the Gulf of Alaska. (For more detailed narrative information, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)
2. Southcentral. In the Gulf of Alaska, sablefish abundance is highest from the Shumigan Islands southeastward to northern Queen Charlotte Sound (Low et al. 1976). More details are presented in the sablefish Distribution and Abundance narrative found in volume 2 of this publication. (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)

III. PHYSICAL HABITAT REQUIREMENTS

A. Water Depth

Adult sablefish are found at depths from 150 m down to 1,500 m. Juvenile sablefish occupy shallower, nearshore waters (ibid.). Sablefish larger than 340 mm are not found in nearshore commercial catch and index samples, indicating that young sablefish probably do not remain in the nearshore zone beyond their second summer (Blackburn et al. 1983).

B. Water Temperature

Kulikov (1965) stated that sablefish distribution in the Bering Sea is controlled by temperature, with sablefish found in the relatively warm (3 to 5°C) continental slope zone. Young sablefish occupy a wider range of temperatures (Alton and Webber 1976).

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

Sablefish are opportunistic feeders, consuming a wide variety of organisms. Their diet is dependant upon their life stage, geographic location, the season, and availability of prey (Low et al. 1976). Adult sablefish in the Gulf of Alaska feed on fish, including walleye pollock (Theragra chalcogramma), arrowtooth flounder (Atheresthes stomias), spiny cheek rockfish (Sebastolobus spp.), Pacific herring (Clupea harengus pallasii), Pacific saury (Cololabis saira), and sand lance (Ammodytes hexapterus) (Kennedy

and Pletcher 1968). They also feed on free-swimming and bottom-dwelling invertebrates (Low et al. 1976).

In the Bering Sea, Shubinikov (1963) found that sablefish consume pandalid shrimp (*Pandalus* spp.), sea anenomes (*Actinaria*), brittle stars (*Ophiuroidea*), and small crustaceans (amphipods and euphausiids) in addition to several kinds of fish (Saffron cod, *Eleginus gracilis*; Pacific cod, *Gadus macrocephalus*; walleye pollock; Pacific herring; sculpins, *Cottidae*; and small flounders, *Pleuronectidae*). Kulikov (1965) even noted the occasional presence of bird remnants and seal fur in sablefish stomachs.

Young sablefish in their pelagic stage off the coast of Oregon and Washington have been reported by Grinols and Gill (1968) to feed on blue lanternfish (*Tarletonbeania crenularis*), saury, and euphausiids. Kodolov (1968) also reported that young sablefish feed on Pacific saury.

Carl (1964) noted that small sablefish (36-38 cm) off southern British Columbia gather in estuaries of rivers, where they feed on young salmon.

B. Types of Feeding Areas Used

Sablefish follow a diurnal vertical migration and feed both near the surface and in bottom water layers (down to 1,200 m) (Kulikov 1965).

C. Factors Limiting Availability of Food

Little specific information is available concerning limitations of food availability for sablefish. Sullivan and Smith (1982), however, in laboratory experiments noted that sablefish deprived of food for up to five months did not show any signs of stress due to starvation. They speculated that sablefish under natural conditions may feed very infrequently and that the absence of stress may reflect an evolutionary adaptation to that feeding strategy.

Weather patterns and ocean currents causing dispersal of planktonic organisms may have a negative effect on feeding and, consequently, on the growth of larval sablefish, as is true of the larvae of other marine fishes (Cooney et al. 1979).

D. Feeding Behavior

Shubinikov (1963) noted an annual cycle in the intensity of sablefish feeding. He found the fullest stomachs at the beginning of summer (April-June), with feeding intensity decreasing in autumn (August), and rising again in February-March. Grinols and Gill (1968) observed feeding sablefish and noted that they appeared to be "premeditated" feeders - seeking out selected prey, then leaving and allowing the prey to reconcentrate before feeding again.

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Sablefish breed in deep waters (250 to 750 m) (Thompson 1941, Bell and Gharrett 1945, Kodolov 1968). After spawning, the eggs rise to the surface, where development occurs (Alton and Webber 1976).

Bracken (1982) suggests that a large percentage of sablefish in the Gulf of Alaska may spawn in the southeastern gulf.

Low et al. (1976) report that sablefish in the Bering Sea have been observed to spawn only in the south and southeastern areas, especially in the Bower's Ridge and Aleutian Islands regions.

B. Reproductive Seasonality

Subinikov (1963) reported that spawning in the Bering Sea apparently occurs in February.

Mason et al. (1983) found that sablefish along the entire west coast of Canada spawn from January through April, with peak spawning occurring in February.

C. Reproductive Behavior

No information on reproductive behavior is available.

D. Age at Sexual Maturity

Males mature sooner than females. The average age at 50% maturity is five years for males and seven years for females (Low et al. 1976).

E. Frequency of Breeding

Sablefish breed annually.

F. Fecundity

Fecundity is related to size, with a small (61 cm) female producing about 82,000 eggs and a large (98 cm) female producing 1,277,000 eggs (Alaska Department of Fisheries 1954).

G. Incubation Period

No information on the rate of egg development is available, though small (15.9 to 24.8 mm) larvae have been captured in the eastern Bering Sea in July (Kashkina 1970), approximately five months after spawning. Juveniles are pelagic or semipelagic. The move from a pelagic to more demersal existence may take place at around 30 cm (Alton and Webber 1976).

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

A. Timing of Movements and Use of Areas

Young (45 mm) fish are found in shallow (70 to 200 m), more coastal waters (Kulikov 1965). As the fish get larger (45-50 cm) they migrate to deeper waters (Bracken 1982), with adults found in areas with depths greater than 150 m (Alton and Webber 1976).

Kulikov (1965) reported that sablefish follow a diurnal vertical migration pattern, rising as high as the surface water layer during the day and dropping down to the bottom layers at night.

B. Migration Routes

Years of tagging studies have shown that sablefish conduct extensive migrations (Bracken 1982; Pattie 1970; Phillips 1969; Saskai 1980, cited in Bracken 1982). Until recently it was felt that, though some fish did migrate long distances, most migration was localized (Low et al. 1976). New evidence (Bracken 1982) however, indicates that a significant number of fish (46% of those tagged) do migrate long distances (over 185 km). Bracken (1982) found that large fish (over 60 cm) in the Gulf of Alaska tend to migrate eastward, while small (less than 60 mm) fish tend to move

westward (possibly drifting with prevailing ocean currents). He speculated that the change in direction of movement may be associated with the onset of maturity, with large numbers of adult fish moving to the southeastern gulf to spawn (ibid.).

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

The IPHC (1978) listed sablefish as a frequent food item of Pacific halibut (Hippoglossus stenolepis). Other large predators such as lingcod (Ophiodon elongatus) probably also consume sablefish (Low et al. 1976), and sablefish eggs, larvae, and juveniles are probably consumed by many more species (ibid.). Phillips (1969) noted that sea lions eat sablefish, and Novikov (1968) noted that tagged sablefish were sometimes pursued by seals.

As with many other ocean species, the survival of sablefish eggs and larvae is dependant upon beneficial weather patterns and ocean currents that carry them into areas where temperature regimes and food concentrations are favorable to development (Low et al. 1976).

B. Human-related

A summary of possible impacts from human-related activities includes the following:

- Alteration of preferred water temperatures, pH, dissolved oxygen, and chemical composition
- Introduction of water-soluble substances
- Increase in suspended organic or mineral material
- Reduction in food supply
- Human harvest
- Seismic shock waves

(See the Impacts of Land and Water Use volume of this series for additional impacts information.)

VIII. LEGAL STATUS

Sablefish within the 200-mi limit are managed by the North Pacific Fishery Management Council (NPFMC) in their Gulf of Alaska Groundfish Fishery Management Plan. Sablefish within 3 mi of shore are managed by the Alaska Department of Fish and Game (ADF&G).

IX. LIMITATIONS OF INFORMATION

The extent and prevalence of migration of sablefish between management areas has very strong implications in management of this species. Studies of the direction and extent of movements should be continued, along with analysis of movements by sex (Bracken 1982).

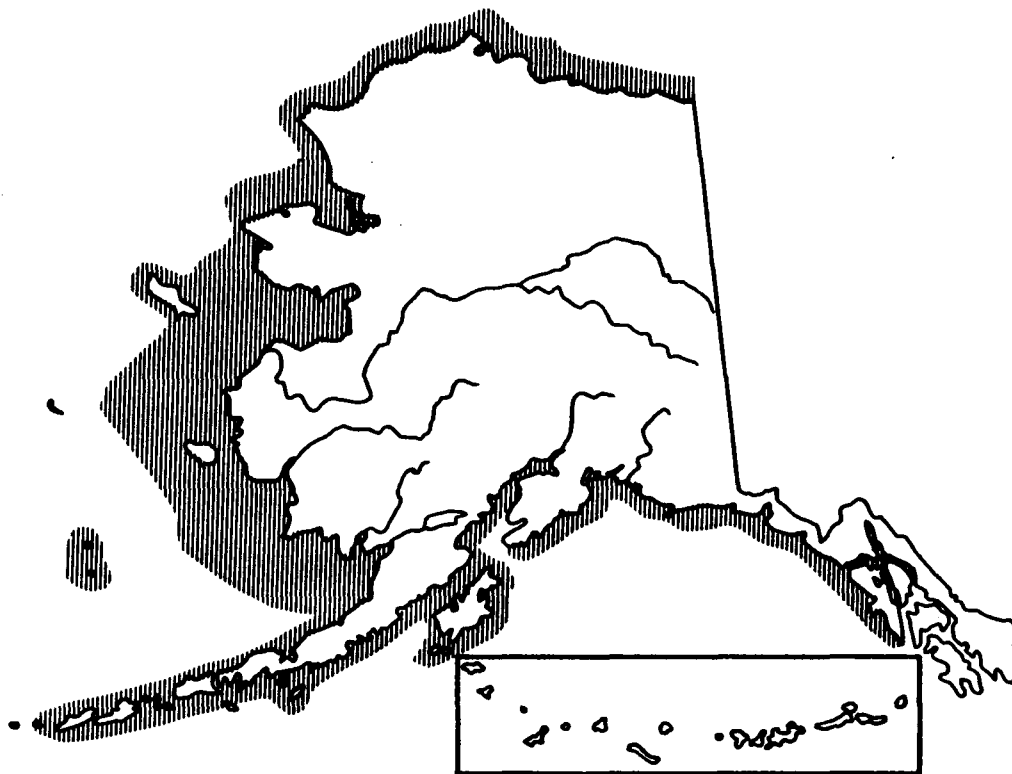
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Saffron Cod Life History and Habitat Requirements
Arctic and Western Regions



Map 1. Range of saffron cod (Morrow 1980, Wolotira 1985)

I. NAME

- A. Common Names: Saffron cod, navaga, far eastern navaga
- B. Scientific Names: Eleginus gracilis (Tilesius), Eleginus navaga (Pallas)
- C. Native Names: See appendix A.
- D. Species Group Representation
Cods (family Gadidae) are primarily northern hemisphere marine fishes. The genus Eleginus is comprised of two species, E. gracilis and E. navaga. Both species are very similar externally and are differentiated by several meristic characteristics, which are given by Svetovidov (1948, cited by Wolotira 1985). The two species are apparently geographically segregated throughout their ranges. E. navaga is found in European, Siberian, and North American arctic waters and is replaced by E. gracilis in North

Pacific waters, including the Bering, Okhotsk, Japan, Yellow, and Chukchi seas (Walters 1955, Wolotira 1985). Meristic differences between the two species are possibly factors of this geographic segregation and associated environmental variability, as well as genetic segregation (Wolotira 1985). For the purposes of this narrative, the two species will not be differentiated, and both will be referred to as saffron cod.

II. RANGE

A. Worldwide

The saffron cod is found in the nearshore coastal zones of the eastern North Pacific from Sitka, Alaska, through the Bering, Chukchi, and Beaufort seas. They range eastward in the Beaufort Sea to Cambridge Bay (approximately 68°N x 105°W) and west to the Sea of Okhotsk and Sea of Japan (Dunn and Vinter 1984, Andriyashev 1954, Morrow 1980). The saffron cod is rare along the southern coast of Korea but is found in the Yellow Sea (Andriyashev 1954).

B. Statewide

The distribution of saffron cod off Alaska is in the nearshore coastal zone, south to Baronof Island and north along the Bering, Chukchi, and Beaufort sea coasts (Andriyashev 1954, Morrow 1980, Craig and Haldorson 1981). The northern Bering Sea is the center of its distribution (see map 1) (Wolotira et al. 1979).

C. Regional Distribution Maps

To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for each region. Saffron cod distribution has been mapped at 1:1,000,000 scale. The maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of selected fish and wildlife species has been prepared and may be found in the Atlas that accompanies each regional guide.

D. Regional Distribution

1. Arctic and Western. Saffron cod occur throughout the Arctic and Western regions of Alaska; however, they are most abundant in Norton and Kotzebue sounds and the adjacent northeastern Bering Sea and southeastern Chukchi Sea (Andriyashev 1954, Frost and Lowry 1981, Morrow 1980). Wolotira et al. (1979) found saffron cod to be much less abundant in the central and southeastern Chukchi Sea and Kotzebue Sound than in the northern Bering Sea and Norton Sound. Greatest densities north of Bering Strait were found in relatively shallow waters near the mouth of Kotzebue Sound, offshore from the northern Seward Peninsula and in waters less than 25 m deep between Cape Lisburne and Point Hope (Wolotira et al. 1979). Craig and Haldorson (1981) report that the Beaufort Sea is the northern limit of distribution for saffron cod. They are widespread along the Beaufort coastline but are not generally abundant. Bendock

(1979) also reported a low relative abundance of saffron cod in Prudhoe Bay from 1 July through 1 September 1976. (For more detailed information, see the saffron cod Distribution and Abundance narrative in volume 2 of the Alaska Habitat Management Guides for the Arctic and Western and Interior regions.)

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

1. Water quality:

- a. Dissolved oxygen (D.O.) and pH. No information is available on the pH and D.O. requirements of saffron cod.
- b. Turbidity. No information is available specifically documenting the levels of turbidity tolerated by saffron cod. Muench et al. (1981) reported that waters of Norton Sound (the major concentration area of saffron cod) were distinctly stratified in terms of temperature and turbidity during the open-water period. Water turbidity was very generally estimated by lateral visibility and tended to be much greater below the 20 ft depth. Visibility in the upper 20 ft of water was 15 to 20 ft; visibility below the 20 ft depth was usually only 2 to 4 ft because of a heavy silt load in the deeper waters (ibid.).
- c. Salinity. Craig (1984) characterizes the nearshore environment of the Alaskan Beaufort Sea as a band of relatively warm (5-10°C), turbid (10-25%), brackish, and shallow water. This band varies in width and depth with freshwater input to coastal waters, nearshore currents, prevailing winds, and topographic features. Barton (1979) found a similar pattern of surface salinities in Norton Sound. The lowest salinities occurred in June and progressively increased into the fall (range = 2.7 to 20.1 ppt; mean = 15.3 ppt). This is probably a function of melting pack ice and freshwater runoff throughout the season from the river systems in Norton Sound, as well as the Yukon River discharge (Barton 1979, Nebert 1974). In the Beaufort Sea, saffron cod were observed to increase in nearshore waters as the open-water season progressed and salinities increased (i.e., after spring floods and ice-melt) (Craig 1984). In winter (February), saffron cod were caught near the Colville River delta, where salinities were measured at 18 to 32 ppt (Craig and Haldorson 1981). It was thought that they moved closer inshore to spawn at this time. Mukhacheva (1959) reported that normal embryonic development of the demersal eggs of saffron cod occurs in salinities of 28 to 30 ppt. Morrow (1980) mentioned that saffron cod often enter rivers and may go

considerable distances upstream, though they usually stay within the region of tidal influence. Thus it is apparent that saffron cod are able to tolerate (at least for short time periods) a wide range of frequently fluctuating salinities.

2. Water depth:

- a. Adult. Saffron cod are thought to reside in the coastal zone, coming close to shore in the fall and winter to spawn and moving into deeper water (30 to 50 m) in summer to feed (Andriyashev 1954, Lowry et al. 1983, Morrow 1980, Svetovidov 1948). Lowry et al. (1983) report that saffron cod are present and abundant in the nearshore shallow waters of the Chukchi Sea in June and July, as is indicated by their importance in the diets of seals and belukha whales at Shishmaref and Eschscholtz Bay at that time. Trawl surveys conducted from August to September 1977 in offshore areas (40 to 400 m) of the northeastern Chukchi and Beaufort seas failed to detect any significant concentrations of saffron cod. They postulate that saffron cod remain in the nearshore environment (0 to 25 m) throughout the year. Wolotira et al. (1979) encountered large concentrations of saffron cod from September through October 1976 in depths of 0 to 25 m in Norton Sound, the northeast Bering Sea, and the southern Chukchi Sea. During this 1976 survey and a subsequent 1979 trawl survey (July-August), nearly all saffron cod were found at depths of less than 50 m.
- b. Juvenile. Juvenile saffron cod were restricted to shallow waters in Norton Sound and the southeastern Chukchi Sea. They were frequently encountered at depths of 0 to 25 m, and their density generally decreased with increased depth (Pereyra et al. 1977).

3. Water temperature:

- a. Summer/fall. Surface water temperatures in Norton Sound were recorded by Zimmerman et al. (1977) and ranged from 13 to 18°C during the summer period. They observed a temperature stratification in the sound at about the 20-ft depth (11-13°C). At depths greater than 40 ft, temperatures were 4 to 6°C. Fleming and Heggarty (1966) recorded temperatures up to 15°C at all depths in the nearshore zone of Norton Sound. This area remains relatively warm in summer because of the general shallowness and the current system. Bottom temperatures are typically 15°C near the shore and drop to 0 to 4°C offshore in the outer Norton and Kotzebue sounds and Bering and Chukchi seas.
- b. Winter. Water temperatures near the sea bottom approach freezing throughout the major distribution range of saffron cod. Vast ice flows often cause ice-scouring of

the littoral zone sea beds from the beach to depths of at least 6 m (Sparks and Pereyra 1966).

Spawning takes place between December and early March (February in Norton Sound) at temperatures of -1.0 to -1.8°C (Lowry et al. 1983; Morrow 1980; Pokrovskaya 1960, cited in Wolotira 1985). Normal embryonic development occurs at temperatures of -3.8 to 8.0°C . Egg development is suspended below -3.8°C ; however, eggs will resume growth even after freezing in ice once temperatures are greater than -3.8°C . Larvae cannot survive in water temperatures greater than 8°C (Mukhacheva 1959).

B. Substrate and Cover Requirements

Saffron cod are a semidemersal species and reportedly spawn over clean sandy or pebbly bottoms (Morrow 1980, Andriyashev 1954). Larvae are pelagic and stay near the surface after hatching. They often associate with the jellyfish Cyanea ferruginea, seeking protection inside the mantle and tentacles from predators (Andriyashev 1954). Upon transformation, juveniles descend to the bottom and assume demersal habits similar to those of adults (Lowry et al. 1983).

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

Barton (1979) characterized the saffron cod as a generalist in terms of feeding habits. It consumes all food groups encountered; larval boreal smelt (Osmerus mordax) and opossum shrimp (Neomysis spp.) were the most important prey species in Norton Sound (Barton 1979, Neimark et al. 1979). Saffron cod diets include isopods, amphipods, pelecypods, mysids, nematodes, plant material, polychaete worms, shrimps, small fishes, and decapods (Andriyashev 1954, Craig 1984, Craig and Haldorson 1981, Lowry et al. 1983, Morrow 1980, Neimark et al. 1979, Percy 1975).

B. Types of Feeding Areas Used

Larval saffron cod are pelagic and feed on plankton near the water surface throughout the spring and summer (April-August) (Andriyashev 1954, Lowry et al. 1983).

Juvenile and adult saffron cod are semidemersal and feed on the numerous epibenthic organisms described above. Adults are thought to migrate into deeper waters (30-50 m) during late spring and summer to feed (Morrow 1980).

C. Factors Limiting Availability of Food

The availability of food probably has some influence on saffron cod populations and their distribution and abundance; however, no studies have been conducted to show such limitations.

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Saffron cod move from water 30 to 60 m deep to shallower ice-covered inshore waters to spawn (Morrow 1980). Spawning

aggregations form in autumn-early winter near river mouths, bays, and inlets in such places as Shishmaref, Kotzebue Sound, and the area near Point Hope (Lowry et al. 1983). In Norton Sound, saffron cod were reported to spawn over pebbly bottoms (Turner 1886). Eggs are demersal and nonadhesive and are typically spawned on clean sandy or pebbly substrates (Dunn and Vinter 1984, Muchacheva 1959). Spawning sites are poorly documented in other portions of the species range. Craig and Haldorson (1981) caught a few saffron cod near the Colville River delta in February and presumed they were spawning there.

B. Reproductive Seasonality

Saffron cod probably spawn between December and early March throughout their range. Timing and duration of the spawning period is related to the region and the severity of winter weather (Pokrovskaya 1960, cited in Wolotira 1985). The only documented spawning to date is during February in Norton Sound (Lowry et al. 1983). Samples collected from subsistence catches jigged through the ice just offshore from Kotzebue, southeast Chukchi Sea, on 15-30 November 1978 were all large saffron cod approaching maturity (Craig and Haldorson 1981).

C. Reproductive Behavior

The spawning behavior of saffron cod has not been documented.

D. Age at Sexual Maturity

Sexual maturity of the saffron cod is reached at 2 to 3 years, and individuals probably live 8 to 9 years in Pacific waters and 12 years in the arctic (Lester et al. 1956, cited in Wolotira 1985; Pokrovskaya 1957). No biological studies with this information are available for saffron cod in the Bering Sea. Craig and Haldorson (1981) caught primarily small, young (ages 1 and 2) saffron cod in August in Simpson Lagoon, Beaufort Sea. The maturity of their specimens was difficult to determine because of the age and limited size range of the fish.

E. Frequency of Breeding

Sexual maturity for saffron cod is reached at two or three years, after which the fish apparently spawn annually (Svetovidov 1948, Andriyashev 1954).

F. Fecundity

Fecundity of saffron cod is between 25,000 and 210,000 eggs per female (Svetovidov 1948). Egg diameter was measured in large mature fish caught in Kotzebue Sound in November; egg diameters of females averaged 0.9 mm ($n = 11$, S.D. = 0.16, range = 0.6 - 1.1 mm) (Craig and Haldorson 1981). They also measured egg diameters of fish caught in late August in Simpson Lagoon, Beaufort Sea. Egg diameters of these fish were as large as 0.4-0.6 mm, but the maturity of the eggs was unknown (ibid.). Results from a number of Soviet studies were summarized by Wolotira (1985). Egg size and fecundity tended to vary considerably in different geographic regions. Egg diameter tends to increase, and the number of eggs tend to decrease from east to west in European arctic waters and from north to south in western Pacific waters (Wolotira 1985).

G. Incubation Period/Emergence

The incubation period for saffron cod eggs is variable. Under normal environmental conditions in Pacific waters, Mukhacheva (1957) determined the development period to be about 2.5 months. In arctic waters, a four-month development period was indicated (Khaldinova 1936, cited in Wolotira 1985). Larvae typically hatch in the spring from April to June and are planktonic for the first few months (Andriyashev 1954, Morrow 1980). Growth is probably very slow until August, when larvae transform into fry and descend to the bottom to assume a demersal life (Svetovidov 1948).

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

Saffron cod are known to make onshore-offshore migrations, which are generally associated with spawning onshore in winter and feeding offshore in summer and fall. Bottom trawl surveys have been conducted in various widely scattered portions of the range of saffron cod and tend to show much variation by area, year of sampling, and season of this movement (Barton 1979, Bendock 1979, Blackburn et al. 1981, Craig 1984, Craig and Halderson 1981, Lowry et al. 1983, and Wolotira et al. 1979). Except for a few studies, information on saffron cod most often has been collected only incidentally to research on other species.

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

Saffron cod are an important food resource for marine birds and mammals where they are locally abundant. They were the primary food of ringed seals in late spring-early summer at Shishmaref in June and July; spotted seals collected near Wainwright in summer had fed primarily on saffron cod; and belukha whales in Kotzebue Sound fed primarily on saffron cod in June (Lowry et al. 1983).

It appears that in the colder, arctic waters of the Chukchi and Beaufort seas, saffron cod are less abundant and are replaced by arctic cod in the diets of marine mammals. This relationship occurs on a seasonal basis in the Bering Sea as well and may be related to seasonal depth distributions and abundances of each species. In either case, the eggs, larvae, juvenile, and adult forms of both species are critical factors in the trophic relationships in northern seas.

Wolotira et al. (1977) reported differences in abundance and in age and growth between saffron cod populations in the Chukchi Sea and in the northern Bering Sea. Between ages zero and four years, Chukchi Sea individuals tend to be smaller in comparison to fish of the same ages in Norton Sound. Beyond about four years of age, however, this growth difference decreases, and Chukchi Sea fish average larger than equal-aged individuals of Norton Sound. Wolotira (1985) suggests that two geographically isolated populations exist on either side of the Bering Strait. Temperature and food availability may also be factors influencing these differences in populations.

The Western Alaskan saffron cod resource has not been previously commercially exploited or otherwise impacted by humans. Wolotira (1985) estimated natural mortality from declining relative abundance of cohorts over time and from single-season age-frequency analysis. The estimate indicated that between 60 and 80% of the Norton Sound population dies annually and that less than 1% of the stock survives beyond age five (ibid.). Environmental factors (i.e., temperature, severity of winter, limited food sources) may cause this high level of natural mortality, but this has not been determined.

Disease does not appear to be a factor in limiting or influencing the population of saffron cod. McCain et al. (1981) conducted a study on the frequency of pathological diseases in marine fish populations in the Bering Sea, Gulf of Alaska, Norton Sound, and Chukchi Sea. They found no tumors in over 10,000 saffron cod they collected and examined from Norton Sound and the Chukchi Sea, whereas Pacific cod (Gadus macrocephalus) collected in the adjacent northwest and southern Bering Sea were affected by skin ulcers and pseudobranchial tumors. They were unsure whether saffron cod were not susceptible to the tumors or simply were not exposed to the tumor-inducing factor (ibid.). Trematode metacercarial cysts were observed in the skin of saffron cod in the Norton Sound/Chukchi Sea area. Of 10,826 saffron cod examined from Norton Sound, 0.8% were affected. No adverse effects on the fish were apparent (ibid.).

B. Human-related

The main concern regarding human-related impacts on saffron cod populations is in relation to oil development in Norton and Kotzebue sounds and the Bering, Chukchi, and Beaufort seas. A primary problem in the event of an oil spill (in winter) is that sinking oil in a saffron cod spawning area could kill or cause abnormal development of eggs and larvae (Lowry et al. 1983). Adult mortality is known to occur within 24 hours when individuals are exposed to the soluble fractions of crude oil at less than 2 ppm at 3°C (DeVries 1976). The benthic food organisms utilized by saffron cod also are known to be very sensitive to dispersed crude oil (ibid.).

In summer, saffron cod larvae are present in the surface waters, where exposure to toxic pollutants is most likely. After metamorphosis, the juveniles descend to the bottom but tend to stay near shore (0-25 m), where effects of development are most likely to be present (Lowry et al. 1983).

A summary of possible impacts from human-related activities includes the following:

- Alternation of preferred water temperatures, pH, dissolved oxygen, and chemical composition
- Introduction of water-soluble substances
- Increase in suspended organic or mineral material
- Increase in sedimentation rates and turbidity
- Reduction in food supply

- Increased susceptibility to harvest or predation
 - Seismic shock waves, blasting
- (See the Impacts of Land and Water Use volume of this series under the category Marine Fish for additional impacts information.)

VIII. LEGAL USE

The Alaska Department of Fish and Game has managerial authority over saffron cod extending through the 3-mi territorial sea. However, since harvesting of saffron cod is limited to minimal subsistence use, no management plan has been formulated.

IX. LIMITATIONS OF INFORMATION

Very little information is available for saffron cod populations throughout the species' range in Alaska. Most data, other than a few demersal studies conducted in the northern Bering Sea and southeastern Chukchi Sea, have been collected incidentally, while research has focused on other species. Information is needed on basic life history functions, limitations due to food availability, seasonal distribution, abundance, and movements, spawning densities, and known spawning areas, depth preferences, egg and larval requirements, and the influence of physical factors and competition on population size.

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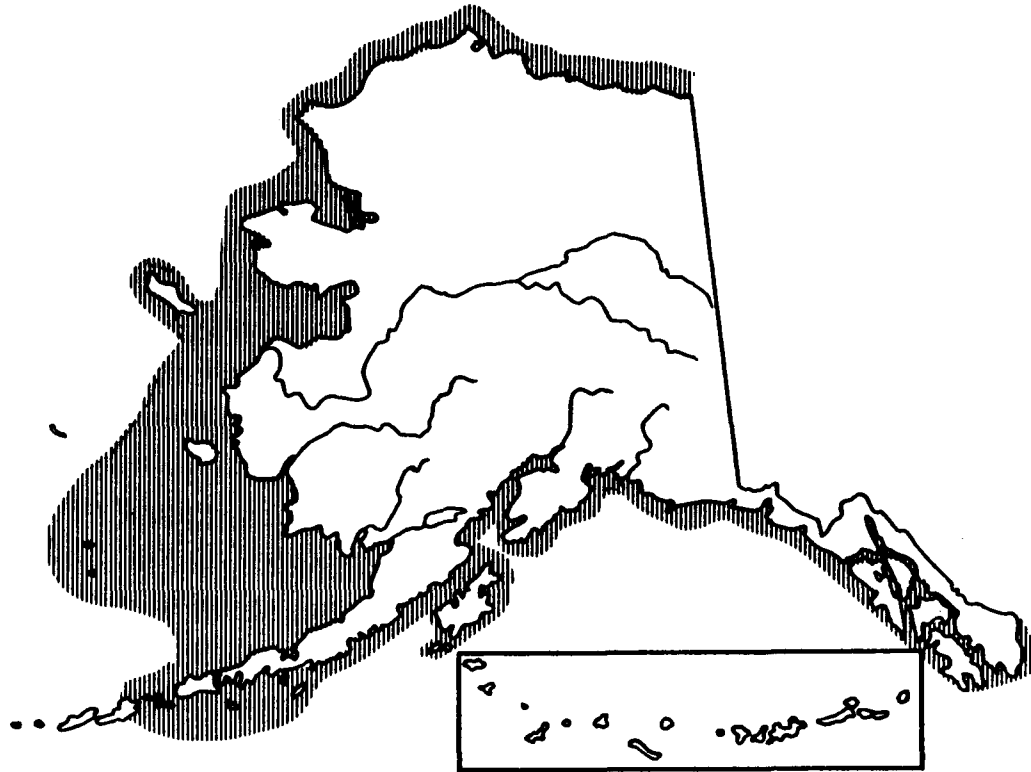
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Starry Flounder Life History and Habitat Requirements
Arctic Region



Map 1. Range of starry flounder (Morrow 1980, NWAFC 1985).

I. NAME

- A. Common Name: Starry flounder
- B. Scientific Name: Platichthys stellatus
- C. Native Names: See appendix A.
- D. Species Group Representation
The starry flounder is a member of the flatfish family, Pleuronectidae. This family is marine, but a few species, including the starry flounder, enter fresh water.

II. RANGE

- A. Worldwide
The starry flounder has a distribution ranging along the coast of North American from southern California, north to the Arctic Ocean, then east along the arctic coast of Canada to Bathurst Inlet. To the west, starry flounders are found along the Chukchi

and Bering coasts of Siberia and southward to Japan and Korea (Hart 1973, Morrow 1980).

B. Statewide

The starry flounder ranges along the entire coastline of Alaska, excluding the Aleutian Islands. From northern California to the Bering Sea it is perhaps the most abundant of the flatfish in nearshore areas (Morrow 1980).

C. Regional Distribution Maps

To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for each region. Starry flounder distribution maps in this series are at 1:1,000,000 scale. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of selected fish and wildlife species has been prepared and may be found in the Atlas that accompanies each regional guide.

D. Regional Distribution Summary

1. Arctic. Starry flounder is distributed along the coast of the Arctic Region in nearshore areas and brackish water. These areas are also inhabited by the arctic flounder, Liopsetta glacialis (ibid.). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Arctic Region.)

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

1. Water quality. No information is available on the pH, dissolved oxygen, or turbidity tolerances of starry flounder. Starry flounder tolerates a wide range of salinities. It is common in brackish water and may ascend rivers even into fresh water (Morrow 1980). Juvenile flatfish in California were found in salinities of 6 to 10 parts per thousand (Hart 1973). Larval starry flounder in the Canadian Northwest Territories were found in colder, more saline waters below the surface waters (Ratynski 1983). Alverson and Wilimovsky (1966) found that salinity was a limiting factor in the distribution of starry flounder in the southeastern Chukchi Sea. Starry flounders are more common in low-salinity water and are replaced by other forms in high-salinity water.
2. Water depth. Starry flounders are normally found in shallow water, but catches have been reported from water deeper than 275 m (Hart 1973). Depth distribution for starry flounder may be seasonal. Morrow (1980) reports that they summer in shallow nearshore water and winter in water up to 300 m.
3. Temperature. Starry flounders are reported to spawn when water temperatures are near 11°C. Temperatures for hatching have not been reported in the field; however, in the lab, eggs hatched in 68 hours at 12.5°C and in 110 hours at 10.5°C (Morrow 1980). Adult starry flounders in Washington stopped

feeding in winter, when the bottom temperatures were lowest (8-9°C) (Miller 1967).

4. Substrate. Starry flounder prefers a soft sand or mud substrate. When disturbed, it may use dorsal, anal, and caudal fins to cover itself with sand or mud (Morrow 1980). Starry flounder is taken commercially on gravel, clear shifting sand, hard stable sand, and mud, appearing to avoid only rock (Orcutt 1950). Starry flounder can alter its colors and color patterns to match the substrate (ibid.).

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

The pelagic larvae of starry flounder feed on plankton (ibid.) After metamorphosis, starry flounders become bottom dwellers. Juvenile starry flounders in Washington consumed polychaete worms, mysids, amphipods, and clams (Thornburgh 1978), whereas adults fed mainly on nemertean and polychaete worms, small clams and crabs, and brittle stars (Miller 1967). Adults from the outer MacKenzie delta in Canada consumed isopods and plant material (Percy 1975). Various investigators have reported that starry flounders ate razor and surf clams in Kodiak, clams and sand shrimp in Cook Inlet, and herring eggs on kelp, clam siphons, brittle stars, and crabs in the northeast Gulf of Alaska (Blackburn et al. 1980). The primary foods in the northeast Bering Sea and Southeast Chukchi Sea were brittle stars and clams (Jewett and Feder 1980). Starry flounders near Kotzebue were found with herring eggs in their stomachs (Alt 1979).

B. Types of Feeding Areas Used

Starry flounders feed on organisms that live on or burrow into silt substrates. Miller (1967) often found mud and, occasionally, bits of bark and pebbles in the stomachs.

C. Factors Limiting Availability of Food

Light and temperature may limit the production of plankton, which is the food of pelagic larvae of starry flounder. Adults are benthic feeders and forage on many species. Any disruption of the bottom sediment, however, could destroy the food source of adults.

D. Feeding Behavior

The food habits of the starry flounder vary with increases in the size of the fish (Orcutt 1950). Observations of food in the stomachs indicated that starry flounders cracked the shells of large clams, swallowed smaller clams, brittle stars, and pea crabs whole, and swallowed whole or severed at any level nemerteans, priapulids, and polychaetes worms (Miller 1967). Starry flounders in Washington apparently began feeding about sunrise and fed through the day until sunset (ibid.).

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

There is evidence that spawning starry flounders use shallow water near river mouths and sloughs. In California, starry flounders in

spawning condition were commonly caught in depths of 30 m or less (Orcutt 1950).

B. Reproductive Seasonality

In California, ripe, spawning, and spent fish occurred in November, became more numerous in the middle part of January, and gradually disappeared in February (ibid.). Spawning occurs from February to April in Puget Sound and British Columbia, and later farther north, with the height of the spawning season corresponding with water temperatures near 11°C (Hart 1973, Morrow 1980).

C. Reproductive Behavior

No information is available on the reproductive behavior of the starry flounder.

D. Age at Sexual Maturity

Sexual maturity for starry flounders in California and Washington is reached at age 2 for males and age 3 for females (Orcutt 1950, Campana 1984). Females grow faster and reach a larger size than males (Campana 1984). The growth of Washington starry flounders slows after sexual maturation, especially in males (ibid.).

E. Frequency of Breeding

Spawning in California occurs no more often than once a year (Orcutt 1950). The arctic flounder (Liopsetta glacialis), which ranges from Bristol Bay northward, apparently spawns only every second year (Morrow 1950).

F. Fecundity

The fecundity of a female of 565 mm standard length was about 11,000,000 eggs (Orcutt 1950). The eggs have diameters ranging from .89 to 1.01 mm, are slightly lighter than seawater, and are nonadhesive (Hart 1973).

G. Incubation Period/Emergency

Orcutt (1950) found the times from fertilization to hatching were 110 hours at 10.5°C and 68 hours at 12.5°C. Metamorphosis from the planktonic to benthic life stage occurs when the fish is about 7 mm long at an age ranging from 27 to 104 days (Policansky 1982, Policansky and Sieswerda 1979). Policansky (1982) noted that although size and age both influence the onset of metamorphosis, the influence of size is stronger. The time to metamorphosis is shorter than that for most flatfish, which would limit the dispersal of starry flounder (Policansky and Sieswerda 1979).

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

The starry flounders make inshore-offshore migrations with the seasons. During summer, the fish are inshore, in shallow water and estuaries. In the winter, they move into deeper water (Morrow 1980). Tagging has shown that starry flounders seldom move more than 8 km (Manzer 1952). Juveniles and adults, however, have been recorded moving up rivers as far as 200 km (Manzer 1952, Morrow 1980).

VII. FACTORS AFFECTING POPULATIONS

A. Natural

Starry flounders are pelagic in their larval stage, and growth and survival are strongly influenced by physical and biological factors, such as water temperature and planktonic food sources. Cold years or years with low food supply could lead to high mortality and low dispersal, which would reduce local recruitment of stocks.

In a study conducted in the southeastern Chukchi Sea, Alverson and Wilimovsky (1966) found an extremely low density of starry flounders, with smaller sizes than reported in more southern waters. They suggested that the physical climate of the Arctic Ocean area may limit the population size of flatfish and depress normal growth patterns.

B. Human-related

Starry flounder eggs are buoyant, and the larvae are planktonic. These characteristics make them vulnerable to any toxicants that may be released into the water. Juveniles and adults are benthic and rely on benthic food sources, so that any contamination or disruption of the sediment could reduce the population. A summary of possible impacts from human-related activities includes the following:

- Changes in biological oxygen demand or nutrient loading
- Changes in the chemical composition of water
- Changes in dissolved oxygen, temperature, pH, or salinity
- Entrapment
- Changes in sedimentation rates, turbidity, or suspended solids
- Changes in substrate composition and location
- Shock waves, blasting

(See the Impacts of Land and Water Use volume of this series under the category Marine Fish for additional impacts information.)

VIII. LEGAL STATUS

The Alaska Department of Fish and Game has managerial authority over starry flounder extending to 3 mi offshore. Because harvesting of starry flounder is minimal, however, no management plan has been formulated.

IX. LIMITATIONS OF INFORMATION

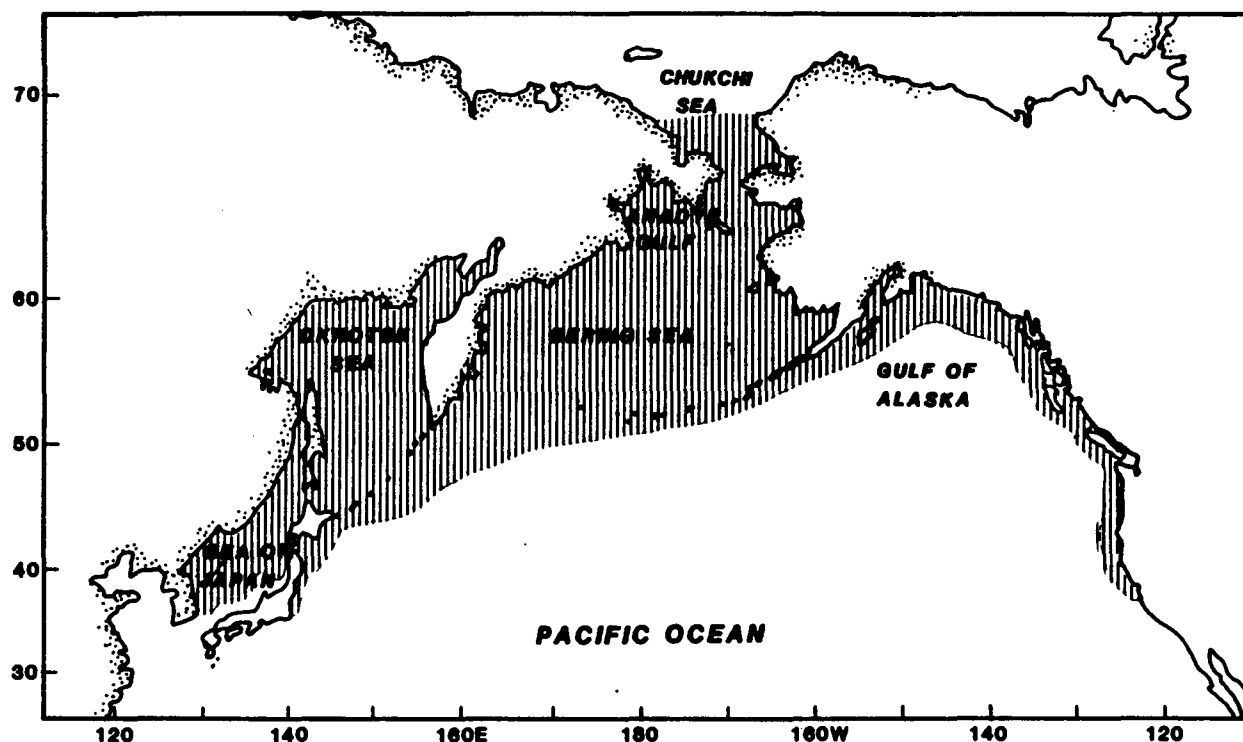
Little information has been collected on populations of starry flounder in Alaska; most studies have been conducted on populations in California, Washington, and British Columbia. Little information exists on tolerances of starry flounder to water quality parameters such as pH, dissolved oxygen, or turbidity. Information on reproductive characteristics, such as seasonality, age at maturity, frequency of breeding, fecundity, and incubation period, is not available for starry flounder in Alaska. Factors affecting Alaskan populations of starry flounder, such as predation and competition, have not been studied.

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Walleye Pollock Life History and Habitat Requirements
Southwest and Southcentral Regions



Map 1. Range of walleye pollock (Bakkala et al. 1983)

I. NAME

- A. Common Name: Walleye pollock
- B. Scientific Name: Theragra chalcogramma
- C. Native Names: See appendix A.

II. RANGE

- A. Worldwide
Pollock are distributed from central California through the Bering Sea to St. Lawrence Island and on the Asian coast to Kamchatka, the Okhotsk Sea, and the Southern Sea of Japan (Hart 1973).
- B. Regional Distribution Maps
To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for each region. Walleye pollock distribution maps in this series are at 1:1,000,000 scale. These maps are available for review in ADF&G

offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of selected fish and wildlife species has been prepared and may be found in the Atlas that accompanies each regional guide.

C. Regional Distribution Summary

1. Southwest. In the western Gulf of Alaska, the Sanak area had the highest mean catch-per-unit-effort, followed by the Chirikof and Kodiak areas, during the National Marine Fisheries Service (NMFS) survey of 1973-1976 (Ronholt et al. 1977). (For more detailed narrative information, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)
2. Southcentral. Walleye pollock had the highest relative apparent abundance of any species in the Gulf of Alaska from Cape Spencer to Unimak Pass during the NMFS survey of 1973-1976 (ibid.). In May-August 1975, a NMFS study team found the highest concentrations of pollock in the northeastern Gulf of Alaska to be near Cape Cleare at the southern end of Montaque Island (ibid.). More detailed information is presented in the pollock Distribution and Abundance narrative found in volume 2 of this publication. (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)

III. PHYSICAL HABITAT REQUIREMENTS

Walleye pollock are schooling fish, found on or near the sea bottom as well as at mid-water and near-surface depths, although most catches are found between 50 and 300 m (Alton and Deriso 1982, Rogers et al. 1980). Juvenile (age 0) pollock in their first months of life are found above the thermocline (depth at which temperature rapidly decreases) in the Bering Sea (Traynor 1983). Traynor (1983) also observed that age 0 pollock avoid depths where water temperature is less than approximately 2.5 to 3.0°C. Age 0 pollock begin to settle to the bottom in the fall months, after which they mainly occupy semidemersal waters (Bakkala 1983).

Concentrations of adult walleye pollock in the Bering Sea are usually found in water temperatures between 2 and 4°C (Serobaba 1970).

IV. NUTRITIONAL REQUIREMENTS

A. Preferred Foods

In the Bering Sea, euphausiids are the most important food for pollock under 400 mm (Smith et al. 1978). Fish make an important contribution to the diet of adult Bering Sea pollock, making up 70% of stomach contents by volume in a study done by Smith et al. (1978). Pollock larvae (4.8 to 17.7 mm standard length) from the Bering Sea consume mainly copepod nauplii and eggs and adult copepods (especially Oithona similis) (Clarke 1978). Copepods are, however, consumed only by small (less than 200 mm) pollock (Smith et al. 1978, Bailey and Dunn 1979).

Studies in the Bering Sea have shown that small (young-of-the-year and one-year-old) pollock comprise at least 44% by weight of the total stomach contents of adult pollock (Dwyer et al. 1983. Takahashi and Yamaguchi 1972).

In the Southeastern Gulf of Alaska, Clausen (1983) found that small (less than 250 mm) walleye pollock ate mostly planktonic crustaceans, particularly euphausiids, mysids, and copepods, while large pollock (larger than 349 mm) generally ate larger prey, such as shrimp and fish. Cannibalism was observed in only 1% of the stomachs; however, few pollock greater than 450 mm were examined.

B. Feeding Locations

Pollock feed mainly in the shallow (90 to 140 m) waters of the outer continental shelf, where tidal mixing occurs in the spring (Serobaba 1970, Salveson and Alton 1976, Chang 1974). Juveniles follow a diel vertical movement, rising to feed on zooplankton near the surface at night (Serobaba 1970, Kobayashi 1963).

C. Feeding Behavior

In the Bering Sea, pollock feeding activity is concentrated in the summer months (June-August). Pollock feed very little or not at all during the spawning period (April-mid May) (Chang 1974).

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Pollock spawn in shallow (90 to 200 m) waters of the outer continental shelf (Smith 1981). There is also evidence that pollock spawn in oceanic areas off the continental shelf. Oceanic spawning has been reported over waters 640 m deep south of Seward, Alaska, and in the Aleutian basin (Blackburn, pers. comm.). Some spawning may also occur under the sea ice (Kanamaru et al. 1979). Spawning in the Bering Sea occurs at temperatures of 1 to 3°C (Serobaba 1968). In Asian waters, variability in time of spawning is believed to be an adaptation to periods when water temperatures are favorable for production of abundant supplies of the initial food of the larvae and for larval growth (Kamaba 1977, Nakatani and Maeda 1983, Hamai et al. 1971). Temperature at time of spawning is, however, apparently not as important for the Shelikof Strait spawning population. Pollock consistently return to Shelikof Strait to spawn, though the temperature varies from 3.5 to 6.5°C (Blackburn, pers. comm.; NMFS 1983).

B. Reproductive Seasonality

In the Bering Sea, spawning begins in late February. Fish in the southeastern Bering Sea spawn first. Most spawning occurs from late March to mid June, with a peak in May (Serobaba 1968). In the western Gulf of Alaska, Hughes and Hirschhorn (1979) found that more than 85% of pollock adults had spawned prior to their earliest sampling in May, indicating that most spawning occurred in March and April.

C. Reproductive Behavior

Spawning and prespawning fish move high in the water column, forming dense schools (Takakura 1954, Serobaba 1974). Eggs are

planktonic and are found primarily within 30 m of the surface (Serobaba 1967, 1974).

D. Age at Sexual Maturity

Pollock begin to recruit to the spawning population at age 2, but age classes 4 and 5 contribute most to potential reproduction of the population (Smith 1981, Chang 1974).

E. Fecundity

Estimates of individual female fecundity are difficult to achieve because ovaries of female pollock contain oocyte populations composed of two or three size classes. The percentage of each size class released during spawning is uncertain (Smith 1981, Foucher and Beamish 1977). Serobaba (1971) found fecundities of 37,000 to 312,000 eggs per female in fish of lengths of 40 to 80 cm in the Bering Sea. Thompson (1981) found fecundities of 199,000 to 996,600 for lengths of 32 to 49 cm off the Pacific coast of Canada.

F. Frequency of Breeding

Pollock breed yearly.

G. Incubation Period

Length of incubation is dependent upon temperature. Incubation time from fertilization to 50% hatching is 10 days at 10°C but up to 27.4 days at 2°C (Hamai et al. 1971). Newly hatched larvae are 3.5 to 4.4 mm in length and apparently float upside down at the water surface (Gobunova 1954). The yolk sac is absorbed at about 7.0 to 7.5 mm (22 days at 2°C) (Yusa 1954, Hamai et al. 1971).

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

A. Timing of Movements and Use of Areas

In the Bering Sea, winter concentrations have been found between Unimak Island and the Pribilof Islands, with some concentrations east of the Pribilofs (Salveson and Alton 1976) and northwest of the Pribilofs along the continental slope (Japan Fishery Agency 1974). Summer feeding concentrations in the Bering Sea are found north of the Pribilofs and to the west and northwest of St. Matthew Island.

A major spawning concentration of pollock is found in the spring in Shelikof Strait (Alton and Deriso 1982). This concentration disperses before summer, and it is not known where that population resides at other times of the year (ibid.).

B. Migration Routes

In the Bering Sea, pollock follow a circular pattern of migration, moving inshore to the shallow (90 to 140 m) waters of the continental shelf to breed and feed in the spring (March) and moving to warmer, deeper areas of the shelf (160 to 300 m) in the winter months (December-February) (Chang 1974). Hughes (1974) noted a similar movement of pollock in the Gulf of Alaska.

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

Water temperature affects the length of incubation, rate of growth, and survival of juvenile pollock (Hamai et al. 1971).

Pollock are a major prey item for several animals, including fur seals (Salveson and Alton 1976), seabirds (Hunt 1981), and other fish.

Estimates have indicated that in the eastern Bering Sea marine mammals consume about 1.13 million tons of pollock annually, an amount approximating the commercial pollock catch in that region (Laevastu and Larkins 1981). In Southeast Alaska, juvenile walleye pollock are one of the most common foods of troll-caught Pacific salmon (*Oncorhynchus* spp.) (Wing 1977).

In the Bering sea, juvenile pollock have been identified as a major prey item of adult pollock. Because of this, cannibalism may have an important effect on the dynamics of the population (Laevastu and Favorite 1981, Smith 1981, Takahashi and Yamaguchi 1972).

Cooney et al. (1979) suggested that weather conditions at the time of first feeding of larval pollock may be very important for their survival. Conditions resulting in a reduction of water surface turbulence allow plankton to become concentrated and may lead to an increased feeding efficiency (and therefore increased survival) of the pollock larvae.

B. Human-related

A summary of possible impacts from human-related activities includes the following:

- Alteration of preferred water temperatures, pH, dissolved oxygen, and chemical composition
- Introduction of water soluble substances
- Increase in suspended organic or mineral material
- Reduction in food supply
- Human harvest
- Seismic shock waves

(See the Impacts of Land and Water Use volume of this series for additional impacts information.)

VIII. LEGAL STATUS

Pollock within the 200-mi limit are managed by the North Pacific Fishery Management Council (NPFMC) within their groundfish fishery management plan. More details of management status can be found in the pollock Human Use section of this document.

IX. LIMITATIONS OF INFORMATION

There are large gaps in the available pollock life history information; more information is available, however, for Bering Sea stocks than for those in the Gulf of Alaska.

Interactions between pollock and other species, particularly marine mammals, need to be studied (Smith 1981). A better understanding of movements of pollock stocks and interchange between stocks is also

important (ibid.). Density-dependent mechanisms (such as the effect of spawning population size on age-class abundance) need to be examined in more detail to help determine the optimal population size (ibid.).

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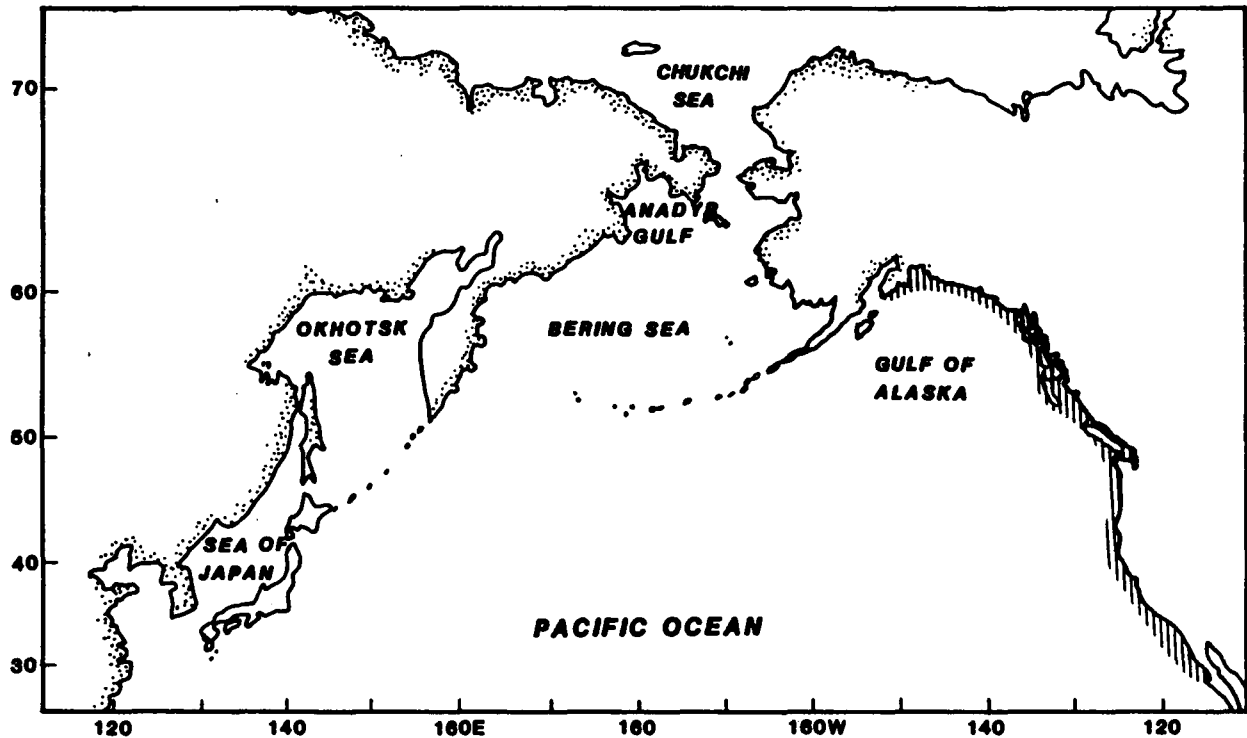
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Yelloweye Rockfish Life History and Habitat Requirements
Southcentral Region



Map 1. Range of yelloweye rockfish (Hart 1973, Morrison 1982a, Rosenthal 1983)

I. NAME

- A. Common Name: Yelloweye rockfish
- B. Scientific Name: Sebastes ruberrimus
- C. Native Names: See appendix A.
- D. Species Group Representation

Little life history information is available for this or any other nearshore rockfish species in Alaska. This account is largely derived from two nearshore bottomfish reports written by Rosenthal et al. (1981, 1982).

Different species of nearshore rockfish may be pelagic or demersal, schooling or solitary. The species composition of the rockfish community changes according to depth, with some species found mainly in nearshore, shallow areas and others found mainly in deeper, offshore areas. Differences also exist in the timing

of life history functions, maximum age, and size of rockfish species (Rosenthal et al. 1982).

The yelloweye rockfish is a solitary, demersal species found in relatively deep areas and is one of the longest-lived species. Larger yelloweye rockfish may exceed 80 to 90 years (Morrison, pers. comm.). It matures later than most species and reaches a larger size (Rosenthal et al. 1982).

Yelloweye rockfish is sought out by shallow-water bottomfish fishermen in Southeast Alaska and represents at least 50% of the commercial landings of that group (by numbers) (ibid.). They also were important in a limited 1980-1981 rockfish fishery in the outer Cook Inlet District in Southcentral Alaska, making up approximately 15% of that catch by numbers (Morrison 1982a). Because of their commercial importance, yelloweye rockfish have been chosen to represent nearshore rockfish in these accounts.

II. RANGE

A. Worldwide

Yelloweye rockfish are found from Ensenada, Baja California, through California, Oregon, and British Columbia to Prince William Sound and outer Cook Inlet, Alaska (Hart 1973, Morrison 1982a, Rosenthal 1983).

B. Regional Distribution Maps

To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for each region. Yelloweye rockfish distribution maps in this series are at 1:1,000,000 scale. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of selected fish and wildlife species has been prepared and may be found in the Atlas that accompanies each regional guide.

C. Regional Distribution Summary

Yelloweye rockfish are found in nearshore and offshore areas of Southcentral and Southeast Alaska. (More detailed Southcentral information is presented in the rockfish Distribution and Abundance narrative in volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)

III. PHYSICAL HABITAT REQUIREMENTS

Yelloweye rockfish are found in the commercial rockfish catch in Southeast Alaska at depths from 20 to 130 m, with the greatest number found at depths from 75 to 130 m (Rosenthal et al. 1982). Gotshall (1981) reported that yelloweye rockfish are found in depths up to 365 m. Yelloweye size increases with depth (ibid.). They are found around steep cliffs, rocky reefs, offshore pinnacles, and boulder fields (Rosenthal et al. 1982, Rosenthal 1983, Carlson and Straty 1981).

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

Yelloweye rockfish are opportunistic feeders, consuming a variety of organisms, including fish, rock crabs, lithodid crabs, caridean shrimps, and gastropod snails. Fish consumed include cods (*Gadidae*), sand lances (*Ammodytes hexapterus*), herring (*Clupea harengus pallasii*), lumpsuckers (*Cyclopteridae*), and other rockfishes, especially Puget Sound rockfish (*Sebastes emphaeus*), and including young yelloweye rockfishes (Rosenthal et al. 1982).

B. Types of Feeding Areas Used

Yelloweye rockfish presumably feed in rocky areas, where they are usually found.

C. Factors Limiting Availability of Food

Rosenthal (1983) noted extensive overlaps in the diets of many nearshore rockfish, indicating a potential for competition among these species.

D. Feeding Behavior

Yelloweye rockfish have been observed to capture prey with rapid bursts of speed (Rosenthal et al. 1982).

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Spawning habitat for yelloweye rockfish has not been described; however, Rosenthal et al. (1981) noted that rockfish (including yelloweye) appear to move to deeper waters (246 m) when they reach maturity.

B. Reproductive Seasonality

Rockfish are ovoviparous, meaning they are internally fertilized and release live young. Morrison (1982b) found that female yelloweye rockfish in lower Cook Inlet in early June contained larvae still in early stages of development. Rosenthal (1983) found females with preextrusion larvae in the northeastern Gulf of Alaska in late June and July. Rosenthal et al. (1982) states that females release larvae in June, July, and August in Southeast Alaska and that mating apparently takes place in late fall or early winter.

C. Reproductive Behavior

Breeding of yelloweye rockfish has not been observed; however, male blue rockfish (*Sebastes mystinus*) off the coast of California have been observed to follow a sequence of stereotyped courtship movements (Helvey 1982). It is possible that other rockfish, including yelloweye, have similar breeding behavior.

D. Age at Sexual Maturity

Yelloweye rockfish are late maturing. Females in Southeast Alaska reach 50% sexual maturity at 50 to 52 cm; males reach 50% sexual maturity at 52 to 60 cm (Rosenthal et al. 1982). Aging techniques, which involve reading growth lines on the surface of yelloweye otoliths, indicate that these lengths correspond to an age of 14 to 15 years for females and 16 to 19 years for males (Rosenthal et al. 1981). The aging technique of breaking otolith

and burning the inside surface to accentuate the growth lines generally has produced older age estimates (Rosenthal et al. 1981; Morrison, pers. comm.).

- E. Frequency of Breeding
Yelloweye rockfish breed annually.
- F. Fecundity
Hart (1942) stated that the fecundity of an 8.9 kg yelloweye rockfish was 2,700,000.
- G. Incubation Period
Rosenthal (1983) stated that breeding takes place in winter months and that young are released in June, July, and August.

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

The average length of yelloweye rockfish in the commercial catch increases with depth (Rosenthal et al. 1982). This indicates that yelloweye move to progressively deeper areas as they grow (ibid.). Yellowtail and dusky rockfish (Sebastes flavidus and S. ciliatus) near Auke Bay, Alaska, have been reported to move into crevices and sheltered areas in November-April, possibly in response to a drop in water temperature (Carlson and Barr 1977). Rosenthal et al. (1982) found that canary and rosethorn rockfish (Sebastes pinniger and S. helvomaculatus) increased in relative abundance in the winter commercial horizontal longline catch, as compared to summer. He speculated that this may be due to a shift to a more bottom-dwelling existence by these normally pelagic species. In contrast, the relative abundance of yelloweye rockfish in the commercial catch decreased in the winter.

VII. NATURAL FACTORS INFLUENCING POPULATIONS

- A. Natural
Yelloweye larvae and young are undoubtedly eaten by other rockfish. Small yelloweye rockfish have been found in the stomachs of larger yelloweyes (Rosenthal et al. 1982).
- B. Human-related
A summary of possible impacts from human-related activities includes the following:
 - Alteration of preferred water temperatures, pH, dissolved oxygen, and chemical composition
 - Introduction of water-soluble substances
 - Increase in suspended organic or mineral material
 - Reduction in food supply
 - Human harvest
 - Seismic shock waves(See the Impacts of Land and Water Use volume in this series for additional information regarding impacts.)

VIII. LEGAL STATUS

Stocks of yelloweye rockfish within the 3-mi limit are managed by the Alaska Department of Fish and Game. More details of management status

can be found in the groundfish Human Use section of volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.

IX. LIMITATIONS OF INFORMATION

Very little life history information on nearshore rockfish in Alaska is available.

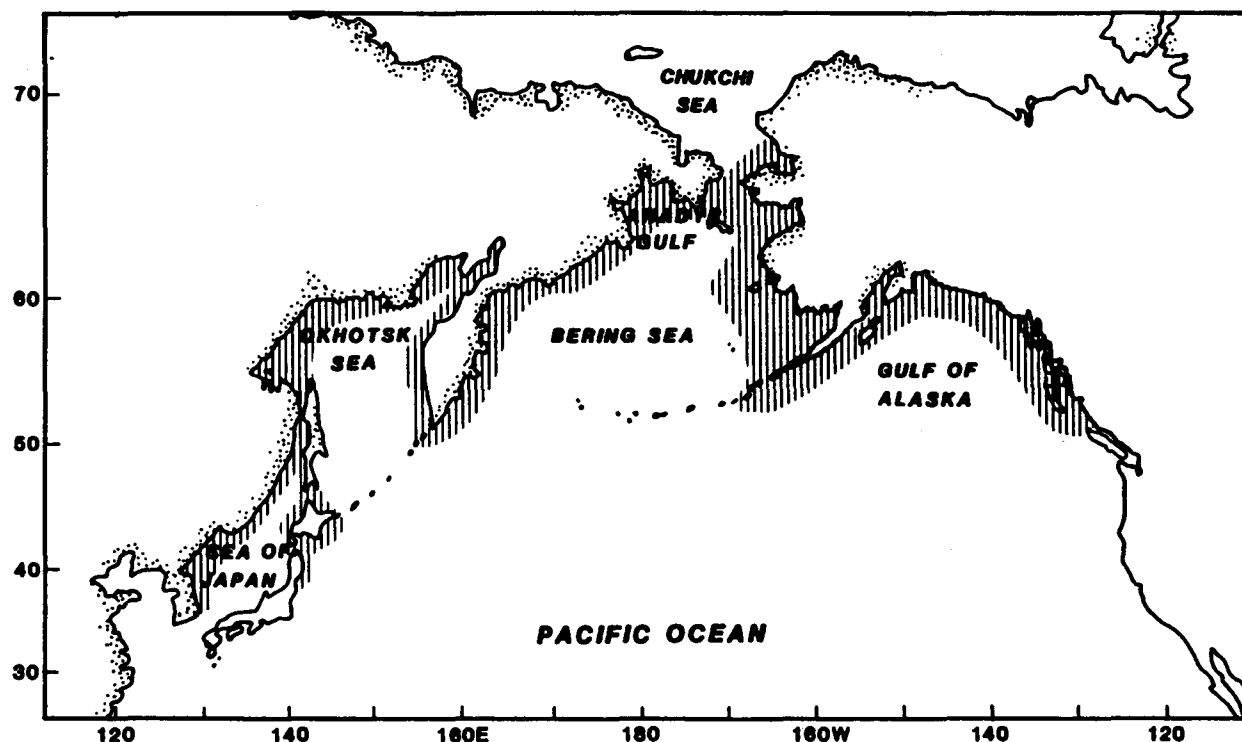
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Yellowfin Sole Life History and Habitat Requirements Southwest and Western Regions



Map 33. Range of yellowfin sole (Salveson and Alton 1976)

I. NAME

- A. Common Name: Yellowfin sole
- B. Scientific Name: Limanda aspera
- C. Native Names: See appendix A.

II. RANGE

- A. Worldwide

The yellowfin sole is found in continental shelf and slope waters of the North Pacific Ocean, the Bering Sea, and the Chukchi Sea. Its range along the Pacific coast of North America extends from Vancouver Island north to the Chukchi Sea and along the Asian coast from the Gulf of Anadyr south to Hokkaido Island and along the Asian mainland to about 35° N off South Korea (Bakkala 1981).

B. Regional Distribution Maps

To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for each region. Yellowfin sole distribution has been mapped at 1:1,000,000 scale. The maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of selected fish and wildlife species has been prepared and may be found in the Atlas that accompanies each regional guide.

C. Regional Distribution

1. Southwest. Dense concentrations of yellowfin sole are found in the Bering Sea in the vicinity of Unimak Island and west of St. Paul Island. Lesser winter concentrations have also been found in the area of St. George Island and in Bristol Bay (ibid.). (For more detailed information, see the yellowfin sole Distribution and Abundance narrative in volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)
2. Western. Yellowfin sole occur throughout the Western Region along the continental shelf and slope waters from depths of 5 to 360 m (Bakkala 1981). In the summer, yellowfin sole are distributed in waters of less than 100 m from the Alaska Peninsula to as far north as Norton Sound (Bakkala et al. 1982). Main concentrations of yellowfin sole in the Western Region are limited to waters south of Nunivak Island during the summer (ibid.). (For more detailed information, see the yellowfin sole Distribution and Abundance narrative in volume 2 of the Alaska Habitat Management Guide for the Western and Interior regions.)

III. PHYSICAL HABITAT REQUIREMENTS

Yellowfin sole are found at depths from 5 to 360 m, though in Gulf of Alaska, Cook Inlet, and British Columbia waters they are confined to shelf waters of generally 100 m or less (Salveson and Alton 1976.) Evidence suggests that water temperature and the extent of winter ice cover in the Bering Sea affect the rate of northern summer migrations and the summer distribution patterns of yellowfin sole (Bakkala 1981). Evidence indicates also that year-class strength of yellowfin sole in the Bering Sea is affected by variations in water temperature (ibid.). Strong year classes have been associated with years when June bottom water temperatures were relatively warm (2.0 to 4.5°C); weak year classes correspond to relatively cold June bottom temperatures (near 1.0°C) (ibid.).

Fadeev (1970) stated that yellowfin sole are found mainly in areas with sandy-muddy bottoms and predominately fine sediments. Yellowfin sole have also been found at times over sandy and silty-sand bottoms but never in large numbers on gravel or pure silt sediments (Fadeev 1970, Salveson and Alton 1976).

IV. NUTRITIONAL REQUIREMENTS

A. Preferred Foods

Skalkin (1963) found that the diet of yellowfin sole in the Bering Sea varied with both location and depth. The major food items in yellowfin sole stomachs from the southeastern Bering Sea included small amphipods, mysids and euphausiids, bivalve mollusks, and ascidians. Other frequently consumed prey were sea urchins, shrimp, and brittle stars. Yellowfin sole from the Kodiak area feed on fish and polychaetes in the spring and summer (Rogers et al. 1980). Fish consumed include smelt (*Osmeridae*), Pacific sand lance (*Ammodytes hexapterus*), and Pacific cod (*Gadus macrocephalus*). Rogers et al. noted that the yellowfin sole did not concentrate on any one food item but had a large variety of foods in their diet.

B. Feeding Locations

Yellowfin sole feed most intensively during the summer, when they are found in shallow (40 to 60 m) waters (Skalkin 1963, Smith et al. 1978). Sole are mainly benthic feeders; however, when benthic organisms are scarce, they are able to feed on organisms found off the bottom (Fadeev 1970).

C. Factors Limiting Availability of Food

Weather conditions and water current patterns that result in concentrations of plankton in rearing areas are probably important for the survival and growth of yellowfin sole larvae, as with other marine species (Cooney et al. 1979).

Fadeev (1965) noted the slow growth of yellowfin sole in the Bering Sea compared to Asian populations and suggested that growth in the Bering Sea is limited by food abundance.

D. Feeding Behavior

In the Bering Sea, yellowfin sole on the wintering grounds generally do not feed until late April, though cases of intense winter feeding have been reported (Fadeev 1970). Feeding intensity remains low as the fish migrate to shallow (less than 100 m) water in May (Skalkin 1963, Smith et al. 1978). In June and July, feeding is most intense, and another feeding peak occurs in September (Skalkin 1963). In fall, as the fish move back to the wintering grounds, feeding once again drops off (Smith et al. 1978).

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

In the Bering Sea, spawning is most intense south and southeast of Nunivak Island (Bakkala 1981). Spawning has also been observed between Nunivak and St. Lawrence islands (Kashkina 1965) and in Bristol Bay (Bakkala 1981, Fadeev 1965). Musienko (1970) reported that spawning in the Bering Sea occurs at depths up to 50 m in waters with a bottom salinity of 32.1 to 33.7 o/oo, a surface salinity of 30.1 to 33.1 o/oo, and temperatures of 4.41 to 11.4°C at bottom and 6.4 to 11.4°C at surface.

- B. Reproductive Seasonality
In the Bering Sea, spawning begins in early July and probably ends in September (Musienko 1970). Kashkina (1965) suggested that spawning probably occurs later and is completed within a shorter time in the northern Bering Sea than in the south. In the Kodiak Island nearshore zone, "ripe" yellowfin sole were found by Rogers et al. (1980) from May to August.
- C. Reproductive Behavior
Soviet investigators have reported that yellowfin sole rise to the surface during spawning (Salveson and Alton 1976).
- D. Age at Sexual Maturity
Females may begin to mature as early as age 5 (with a length of 19 cm), but most mature at age 9 (length 30 to 32 cm) (Fadeev 1963, 1970). Males mature earlier than females. Some males may mature at age 4 (length 14 cm); most mature at age 5 (length 16 to 18 cm) (ibid.).
- E. Fecundity
Fecundity is related to size, with a 32.1-to-34-cm female producing 1.5 million eggs and a 40.1-to-42-cm female producing 3.3 million eggs (Fadeev 1963).
- F. Frequency of Breeding
Yellowfin sole breed annually.
- G. Incubation Period
Yellowfin sole eggs are pelagic. Laboratory studies indicate that hatching occurs in about four days at 13°C (Pertseva-Ostroumova 1961). Yolk sacs are absorbed after three days (Bakkala 1981). Partially metamorphosed young have been found at lengths of 16.5 to 17.4 mm. Lengths greater than that are not found in the plankton, so it is assumed that after that size larvae have metamorphosed and begun a bottom existence (ibid.). These larvae are perhaps four to five months old (Morris 1981).

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

- A. Timing of Movements and Use of Areas
Yellowfin sole in the eastern Bering Sea follow complex bathymetric and geographical movements (Salveson and Alton 1976). During the winter (September to March), adults (older than age 7) are concentrated in large schools on the outer shelf and upper slope at depths of 100 to 360 m, with highest trawl catches found at depths of 100 to 200 m (Salveson and Alton 1976, Bakkala 1981, Fadeev 1970). These fish are in two main concentrations: the largest north of Unimak Island and another west of St. Paul Island (Bakkala 1981). In spring (May), these wintering groups move into shallower (100 m) water, generally to the northeast (Bakkala 1981, Salveson and Alton 1976). By summer, the Unimak wintering group is found in outer Bristol Bay between the 40 and 100 m depth contours (Bakkala 1981). The migration patterns of the St. Paul wintering group have not been as well defined, but fish found in the vicinity of Nunivak Island in the summer may be from this group (Bakkala 1981, Salveson and Alton 1976).

With the approach of winter, both groups move back into deep water, probably in response to the advance of pack ice that covers portions of the Bering Sea in winter (Bakkala et al. 1982). In warmer years, yellowfin sole may remain in shallow, central shelf waters throughout the winter (ibid.).

Young (less than eight years old) yellowfin sole are found year-round in Bristol Bay (Fadeev 1970).

Fadeev (1965) reported that in the winter yellowfin sole rise from the bottom at night. These movements are apparently not associated with food, as sole generally do not feed during the winter months. Fadeev (1965) also reported that these fish follow daily horizontal movements.

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

Yellowfin sole is heavily consumed by Pacific halibut (Hippoglossus stenolepis) (Novikov 1964). Novikov noted a close relationship between the distributions of halibut and of yellowfin sole in the summer and stated that the distribution of halibut in the Bering Sea in summer is determined largely by the movements of yellowfin sole (ibid.). Yellowfin sole may also fall prey to other fish and marine mammals such as beluga whales (Delphinapterus leucas) and fur seals (Callorhinus ursinus) (Salveson and Alton 1976).

B. Human-related

A summary of possible impacts from human-related activities includes the following:

- Alteration of preferred water temperatures, pH, dissolved oxygen, and chemical composition
- Introduction of water-soluble substances
- Increase in suspended organic or mineral material
- Reduction in food supply
- Human harvest
- Seismic shock waves

(For additional impacts information, see the Impacts of Land and Water Use Volume of this series).

VIII. LEGAL STATUS

Yellowfin sole are managed by the North Pacific Fishery Management Council as part of their fishery management plan for groundfish (NPFMC 1979). They are also incidentally protected by the North Pacific Fishery Management Council's closures of trawl fisheries to protect halibut stocks (Salveson and Alton 1976).

IX. LIMITATIONS OF INFORMATION

Because yellowfin sole are not abundant in the Gulf of Alaska, little information can be found concerning this species in that area.

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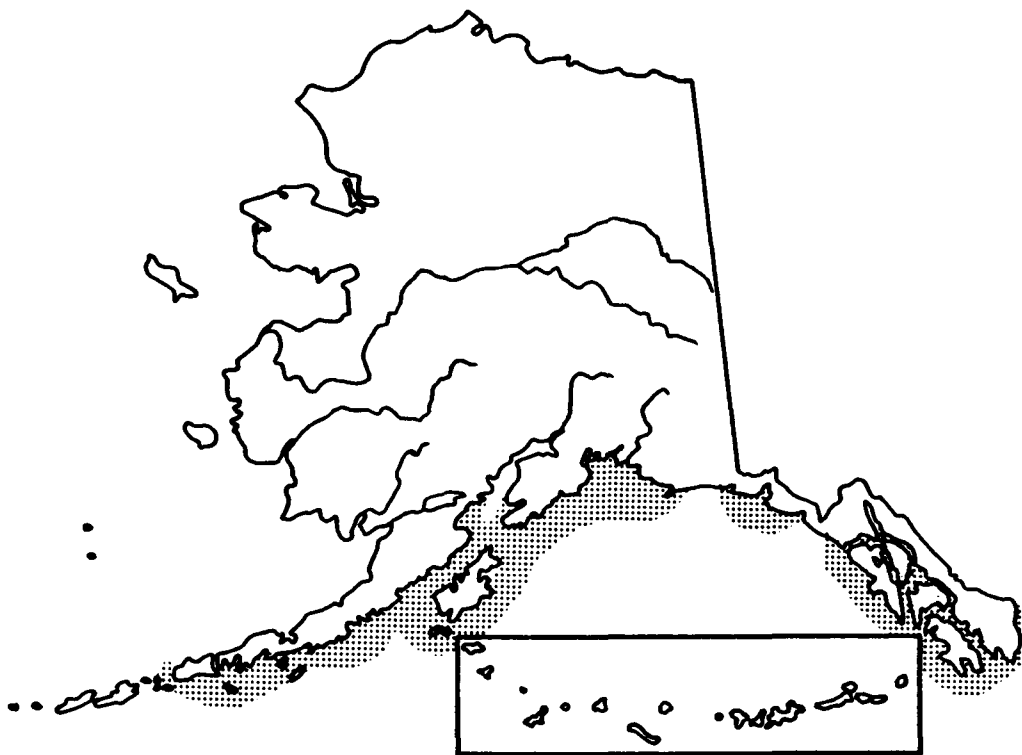
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Shellfish

Dungeness Crab Life History and Habitat Requirements
Southwest and Southcentral Regions



Map 1. Range of Dungeness crab (ADF&G 1978; Kessler, pers. comm.; Otto, pers. comm.)

I. NAME

- A. Common Names: Dungeness crab, market crab, common edible crab, Pacific edible crab, commercial crab, dungeoness crab
- B. Scientific Name: Cancer magister Dana
- C. Native Names: See appendix A.

II. RANGE

- A. Worldwide
Dungeness crabs occur in shallow nearshore waters of the North Pacific Ocean along the western North American coast, ranging from Unalaska Island, Alaska, south to Monterey Bay, California (ADF&G 1978).

- B. Statewide
Cancer magister range from Dixon Entrance to Unalaska Island.
- C. Regional Distribution Maps
To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for each region. Dungeness crab distribution information in this series is at 1:1,000,000 scale. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of selected fish and wildlife species has been prepared and may be found in the Atlas that accompanies each regional guide.
- D. Regional Distribution Summary
Dungeness crabs inhabit estuaries and the open ocean area from the intertidal zone to depths greater than 50 fathoms. The greatest abundance is found on mud or sand substrates (Hoopes 1973).
 - 1. Southwest. Concentrations occur in the Kodiak and South Peninsula areas. (For more detailed narrative information, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)
 - 2. Southcentral. Concentrations occur in the Prince William Sound and lower Cook Inlet areas. (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)
 - 3. Southeast. Dungeness crabs occur throughout nearshore marine areas in Southeast Alaska and Yakutat Bay.

III. PHYSICAL HABITAT REQUIREMENTS

- A. Water Quality
Laboratory studies define the optimum range of temperature and salinity for larvae to be 10.0 to 13.9°C and 25 to 30 parts per thousand (0/00), respectively (Reed 1969). Water temperatures appear to influence crab distribution; Dungeness crabs are scarce in warm brackish water (McKay 1942). Changes in salinity influence shallow water distribution. Large Dungeness crabs have been found to retreat from areas of reduced salinity (Cleaver 1949).
- B. Water Quantity
 - 1. Larvae. Larvae are planktonic and associated with the nearshore location of adult females in spring (Mayer 1972).
 - 2. Postlarvae and juvenile. Postlarval crabs are most abundant on sandy bottom, inshore areas shallower than five fathoms. Juvenile crabs may seek refuge from predators by hiding among seaweeds (Hoopes 1973). Studies at Grays Harbor, Washington, indicated juvenile crabs were abundant in subtidal areas and intertidal flats covered by shellhash and eelgrass (Armstrong and Gunderson 1985).
 - 3. Adult. Adults inhabit depths of from less than 1 to 100 fathoms (Hitz and Rathjen 1965; Nippes, pers. comm.). The preferred substrate is a sand or sand-mud bottom,

although adult Dungeness crabs may be found on almost any bottom substrate (ADF&G 1978).

IV. NUTRITIONAL REQUIREMENTS

A. Preferred Foods

1. Juveniles. The diet of juveniles is similar to that of adults and is comprised of crustaceans and molluscs.
2. Adults. The diet of adults consists of crustaceans (shrimp, crab, barnacles, amphipods, and isopods), clams, polychaetes, and juvenile crabs (McKay 1942, Hoopes 1973).

B. Feeding Behavior

Dungeness crabs are carnivores. Laboratory experiments show that freshness of prey is important in inducing feeding response (McKay 1943). Aquaria-kept crabs have been noted to capture and devour sticklebacks with remarkable speed. Consistently, fish prey were held by the chelae and eaten head first. Dungeness crabs have also been observed to chip away the edges of oysters and bivalves to feed. Crabs were observed crushing barnacles with their chelae (ibid.). Small bristles on the claws are extremely sensitive to the touch of prey. Dungeness crabs have been known to hunt prey items by probing with partially open claws (Butler 1954). Stomach contents of Dungeness crabs from Grays Harbor, Washington, were found to differ among size classes. Small crabs (less than 60 mm carapace width) preyed most heavily on bivalves. Crabs from 61 to 100 mm carapace width preyed less on bivalves and more on crustaceans and juvenile fish. Larger crabs (greater than 100 mm carapace width) preyed mostly on small fish. Crangonid shrimp was the most important prey item for all groups (Stevens and Armstrong 1985).

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Adults move to shallow water for mating.

B. Reproductive Seasonality

Mating occurs during the spring molt period, which is as late as August in certain areas (Rogers et al. 1980; Nippes, pers. comm.).

C. Reproductive Behavior

During mating, the male grasps the female with chelae, then holds her beneath himself so that the sterna are in contact. The male tries to restrain the female during the molt but allows her to return to an upright position (Cleaver 1949, Butler 1960, Snow and Nielsen 1966). Mating occurs within one hour and 30 minutes after the female molts. The postmating embrace has been observed to last two days (Snow and Nielsen 1966). The oviduct is closed after mating by a secretion that hardens in sea water, and spermatazoa are sealed in the oviduct, remaining viable for several months to fertilize eggs upon extrusion (McKay 1942).

D. Age at Sexual Maturity

There is little information available regarding age at maturity for Dungeness crab in Alaska. Though he does not specify the

location, Hoopes (1973) states that sexual maturity is attained at about two years for males and three years for females. This corresponds to a carapace width greater than 110 mm for males and 100 mm for females for crabs from Queen Charlotte Islands (Butler 1960). Both sexes mature at the eleventh or twelfth postlarval molt (Butler 1961). In British Columbia, sexual activity is not appreciable until a crab obtains a carapace width of 140 mm (Butler 1960). Molting may occur annually in mature adults (Mayer 1972).

E. Fecundity

Fecundity is related to the size of the female. Larger females carry more eggs than smaller females (Hoopes 1973). A single egg mass has been documented to contain 1,500,000 eggs. There is speculation that a female may spawn 3,000,000 to 5,000,000 eggs in a life time (McKay 1942).

F. Frequency of Breeding

Males are polygamous. Females can mate only after the molt during the spring (Hoopes 1973). In Southeast Alaska, available data indicate that most males molt between the late winter and mid summer months. Females appear to molt and mate during the summer months (Koeneman 1985).

G. Incubation/Emergence

Females carry viable sperm in oviducts throughout the summer. Eggs pass through the oviduct, are fertilized, and then are carried under the females abdomen during the fall months (ibid.). Females can fertilize multiple clutches with stored sperm (Hilsinger, pers. comm.). In British Columbia, egg bearing occurs from October through June (McKay 1942). In Southeast Alaska, small studies indicate females carry eggs from September through March (Koeneman 1985). Eggs are carried by the female from 7 to 10 months (Hoopes 1973). In the Oregon area, larvae emerge from egg masses from December to April (Reed 1969). Larvae progress through five zoeal stages by a series of molts, with each taking three to four months. There is only one megalops stage resembling juvenile crab (Poole 1966). The megalops stage settles out of the water column as a postlarval or juvenile crab after a larval period of 128 to 158 days (ibid.). In Kodiak, larvae spend up to three months in plankton (AEIDC 1975), and the peak larval release occurs in spring or early summer (Kendall et al. 1980). Juvenile crabs grow rapidly, molting six times within the first year. The carapace width (CW) at the end of the first year is about 25 mm, and after the second year CW is about 102 mm (Hoopes 1973). Molting periods last from one to two days. The growth rate for both sexes is similar until sexual maturity is attained, after which males grow faster (ibid.).

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

A. Larvae

Eggs are not planktonic but are carried by the female. The eggs hatch into free-swimming larvae during the spring after having

been carried by the female for 7-10 months (Hoopes 1973). Larvae are thus planktonic and are found in nearshore areas in spring. Early distribution of larvae is therefore dependent upon the distribution of adult females. However, larvae become dispersed with time.

Larvae in inshore areas are mostly found in the upper portion of the water column during the day (10 to 30 m), dispersing to depths of 50 to 90 m at night (Kendall et al. 1980).

B. Juveniles

Juvenile crabs have been known to settle out in a variety of habitats, ranging from open coast to estuaries (Gunderson et al. 1985).

Small crabs have been associated with strands of eelgrass or masses of detached algae, which are believed to provide protection (Butler 1956). Young crabs have been found buried in intertidal sand in February and during the spring months (McKay 1942).

C. Adults

Adult crabs migrate offshore during the winter months and return to nearshore waters in the early spring and summer months (McKay 1942, 1943; Cleaver 1949, Butler 1951). At Grays Harbor, Washington, it is believed that mating of crabs may occur within the harbor area. All spawning takes place offshore. Larvae develop offshore and eventually return to the nearshore zone and enter the estuary as megalops in April or May. The first stages settle in or near mudflat areas, where they consume abundant small bivalves and crustaceans. All size classes are lower in abundance during the winter, possibly returning in spring months. Changes in habitat preference are based more on dietary preference than upon other environmental parameters. Eventually, females leave the estuary for spawning (Stevens and Armstrong 1985). Adult Dungeness crab at Grays Harbor were found to follow shrimp (Crangon spp.), an important prey item, into littoral areas at night (ibid.).

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

Larvae are preyed upon by salmon and herring (Heg and Van Hying 1951, McKay 1942). Cannibalism is common among crabs in life stages beyond the megalops stage (Waldron 1958). Juvenile crabs have been preyed upon by wolf eels (Anarrhichthys ocillatus) and Pacific halibut (Hippoglossus stenolepis) (McMynn 1951). Lingcod (Ophiodon elongatus), rockfish (Sebastes spp.), wolf eels, and Pacific halibut are voracious predators upon adults (Waldron 1958).

B. Human-related

A summary of possible impacts from human-related activities includes the following:

- Alteration of preferred water temperatures, pH, dissolved oxygen, and chemical composition
- Alteration of preferred substrate

- Alteration of intertidal areas
 - Increase in suspended organic or mineral material
 - Reduction in food supply
 - Reduction in protective cover (e.g., seaweed beds)
 - Obstruction of migration routes
 - Shock waves in aquatic environment
 - Human harvest (including handling of nonlegal crabs)
- (See the Impacts of Land and Water Use volume of this series for additional impacts information.)

VIII. LEGAL STATUS

The Dungeness crab is managed by the Alaska Department of Fish and Game.

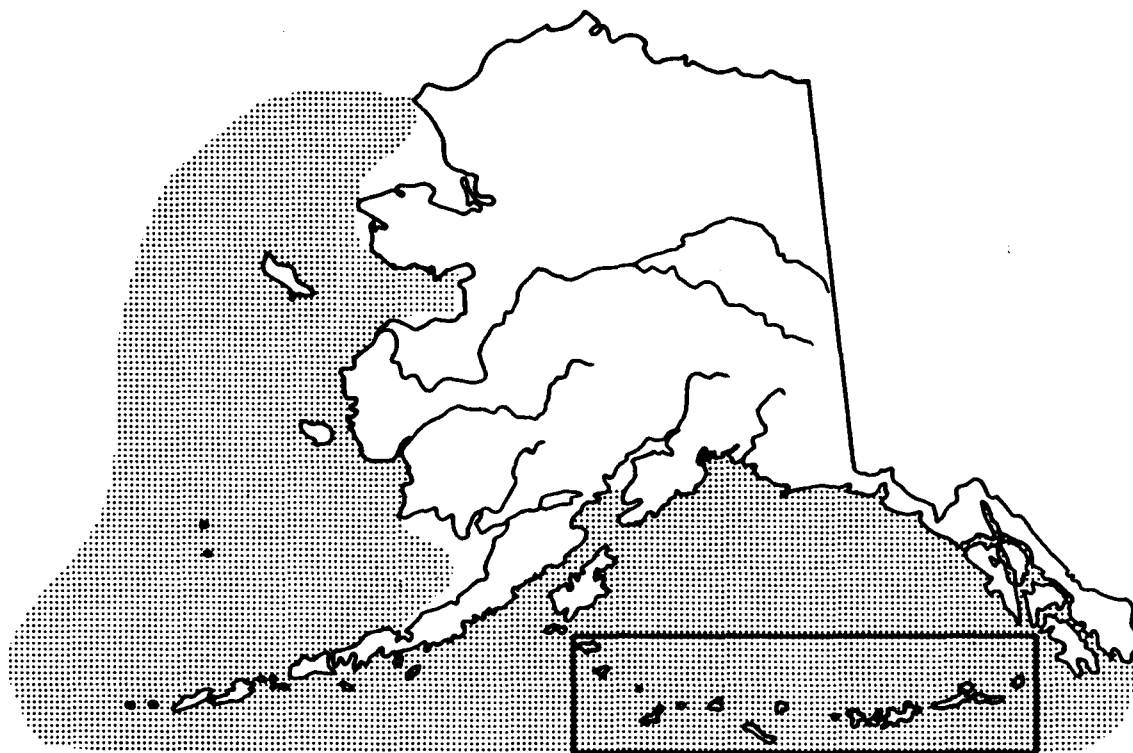
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King Crab Life History and Habitat Requirements
Southwest, Southcentral, Arctic, and Western Regions



Map 1. Range of king crab (ADF&G 1978)

I. NAME

- A. Common Names: King crab, golden king crab, brown king crab, blue king crab, red king crab
- B. Scientific Names: Paralithodes camtschatica (red king crab)
Paralithodes platypus (blue king crab)
Lithodes aquispina (brown or golden king crab)
- C. Native Names: See appendix A.

II. EXTENT TO WHICH SPECIES REPRESENTS GROUP

Red king crab (Paralithodes camtschatica) is the most abundant species. Blue king crab (Paralithodes platypus) is not as abundant but morphologically is similar to red king crab. Golden king crab inhabits deeper water (greater than 100 fathoms) than the other two species, and its relative abundance is unknown.

Because of the emphasis upon red king crab and the resulting availability of information on its abundance, the following summary emphasizes the life history of the red king crab.

III. RANGE

A. Worldwide

Red king crab is not only the most abundant of the three commercial species; its distribution is the most widespread. In Asian waters, red king crab is found from the Sea of Japan northward into the Sea of Okhotsk and along the shores of the Kamchatka Peninsula. The northern limit on the Asian coast is Cape Olyutorsky. On the west coast of North America, distribution extends northward from Vancouver Island, British Columbia, to Point Barrow (MacGinitie 1955). Red king crab is not found in the North Atlantic or in the southern hemisphere. The distribution of blue king crab extends along the North Pacific rim from the Sea of Japan to Southeast Alaska, including the Bering and Chuckchi seas. Golden king crab inhabits deeper areas along the continental slopes of the North Pacific Ocean from the Sea of Japan to Vancouver Island, including the Bering Sea (NPFMC 1980; Otto, pers. comm.).

B. Statewide

Red king crab generally occurs along the coast of southeast Alaska to the Bering Strait. Blue king crab has a similar latitudinal range but is distributed in widely separated discrete populations (Somerton 1985).

C. Regional Distribution Maps

To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for each region. King crab distribution maps in this series are at 1:1,000,000 scale. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of selected fish and wildlife species has been prepared and may be found in the Atlas that accompanies each regional guide.

D. Regional Distribution Summary

1. Southwest. Major concentrations of red king crab are located near Kodiak Island, the south Alaska Peninsula, the Aleutian Islands, and in the southeastern Bering Sea. Golden king crab is found in the same area described above and is abundant in the Aleutian Islands area (NPFMC 1980; Otto, pers. comm.). Isolated populations of blue king crab occur in the Kodiak and Bering Sea area. (For more detailed narrative information, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)
2. Southcentral. Major concentrations of red king crab are located in lower Cook Inlet and Prince William Sound. Golden king crab is found in the same area. Isolated populations of blue king crab occur in the Prince William Sound area. (For

- more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)
3. Arctic and Western. King crabs are found throughout the Western Region and in the Arctic Region as far north as Point Barrow. The distribution of red king crab covers most of the eastern Bering Sea and is generally associated with the continental land mass. A concentration of red king crab is found in Norton Sound (Otto 1981). Blue king crab tends to be associated with the offshore areas near St. Lawrence and St. Matthew islands (ibid.). Golden king crab is found in the eastern Bering Sea along the continental shelf break in deeper waters and is most abundant in the Aleutian Islands (ibid.). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for either the Arctic or the Western and Interior regions.)
 4. Southeast. Golden king crab occupies fjords and trenches of Southeast Alaska.

IV. PHYSICAL HABITAT REQUIREMENTS

A. Water Quality

King crabs are unable to withstand wide variations in salinity and are adapted to cold water (Eldridge 1972). Distribution of the red king crab in the southeastern Bering Sea is dependent upon bottom temperatures. Water temperatures where this species occurs range from -1 to 10°C (Bartlett 1976). Summering adult male and female red king crabs inhabit a temperature range of from 0 to 5.5°C. Maximum abundance of female red king crab occurs at a temperature range of from 3 to 5°C, and maximum abundance of males at 1.5°C (Stinson 1975). Water temperatures influence the frequency of molting. Larvae of red king crab can molt successfully in water temperatures between 2 and 12°C, but a decrease in temperature from 10 to 5°C delays the development time (Kurata 1959, 1960a, 1960b, 1961). Laboratory studies geared toward the culture of red king crab indicate that the optimum temperature for development from fertilization to egg stage was 3 to 8°C and about 3°C from the zoea stage to hatching (Nakanishi 1985). The optimum temperature for culture at the zoea, glaucothoe, and young crab stages was also 8°C. The tolerance range of temperature and salinity, however, was decreased at the glaucothoe and young crab stages (ibid.).

B. Water Quantity

Red and blue king crab larvae are pelagic. Female and small male red king crabs are most abundant at intermediate depths (Eldridge 1972). Juveniles are most abundant in inshore waters and relatively shallow waters of less than 75 fathoms, and they have been found to depths of 58 fathoms (NPFMC 1980). After the fifth molt, juvenile crabs inhabit rock crevices, kelp patches, or other protective niches (Jewett and Powell 1981). Young red king crabs less than one year of age and 3 to 12 mm in carapace length exist mainly as solitary individuals among rock crevices, kelp patches,

and other protected areas, where they settle as larvae (Powell and Nickerson 1965a). Red king crabs 9 to 19 mm in carapace length are common on barnacle-encrusted dock pilings in the Kodiak area. Adult red king crabs appear to prefer a mud or sandy substrate (Eldridge 1972) and have been found at depths of 200 fathoms (NPFMC 1980). Golden king crabs in Prince William Sound have been found in the deep-water trench running from Hinchinbrook Entrance in the westward arc to Knight Island Passage (ADF&G 1978). Catches of golden king crab in British Columbia fjords found the greatest preponderance of juvenile king crabs at depths of 50 to 800 m, adult males from 101 to 150 m, and adult females from 151 to 250 m (Sloan 1985). Adult male and female blue king crabs were primarily found on a sand/mud substrate in the Bering Sea at depths greater than 60 m (Palacias et al. 1985). Juvenile blue king crabs caught in trawl surveys in the Bering Sea were found predominantly in areas with rocky shellhash substrates (ibid.). It is believed that shellhash serves as a refuge from predators and that survival of juvenile blue king crab is dependent upon the presence of shellhash substrates. Survival of the blue king crab is therefore limited to the presence of one or more of those mollusc species responsible for developing rocky shellhash substrates (Palacias et al. 1985, Armstrong et al. 1985).

V. NUTRITIONAL REQUIREMENTS

A. Preferred Foods

1. Larvae. Larvae feed primarily on diatoms.
2. Juveniles. The preferred diet of postlarval red king crab on the west Kamchatka shelf were hydroids (Lafoeina maxima) (Tsalkina 1969). In lower Cook Inlet, postlarval red king crab ingested detrital materials, diatoms, Bryozoa, harpacticoid copepods, ostracods, and sediment (Feder and Jewett 1981).
3. Adults. The diet differs according to the geographic region. Red king crab feeds on dominant benthic forms (Kun and Mikulich 1954, Kulichkova 1955). In the southeastern Bering Sea, a number of food habit studies have been performed. Food items have been cockles (Clinocardium ciliatum), a snail (Solariella sp.), a clam (Nuculana fossa), brittle stars (Amphiuridae), a polychaete worm (Cistenides sp.), and snow crab (Chionoecetes sp.) (Feder and Jewett 1980). Tarverdieva (1976) found the main foods to be polychaete worms, sanddollars (Echinarachnius parma), gastropods of the families Trochidae and Naticidae, and pelecypods (Yoldia, Nuculana, Nucula, Cyclocardia). Cunningham (1969) determined brittle stars (Ophiura sarsi), basketstars (Gorgoncephalus sp.), and sea urchins (Stongylocentratus sp. and Echinarachnius parma) to be main foods. Following in importance were mollusks (Nuculana radiata, Clinocardium californiense, Chlamys sp.); snails (Solariella sp. and Buccinidae); crustaceans (crab: Hyas coarctatus alutacesus,

Erimacrus isenbeckii, and Pagurus sp.); and sand fleas (Amphipoda). McLaughlin and Hebard (1961) determined major food items to be molluscs (bivalves), echinoderms, and decapod crustaceans. The diets of the two sexes were not found to be significantly different. King crabs in the Bering Sea must often compete for food with other bottom-feeding organisms (snow crabs, sea stars, Pacific cod, yellowfin sole, Alaska plaice rock sole, and flathead sole) (Feder and Jewett 1981, Takeuchi 1959). Pearson et al. (1984) determined that polychaetes were the most important items, followed by sand dollars (Echinorachnius parma) and clams (Tellina sp.), in terms of caloric contribution to the diet of red king crab in the southeastern Bering Sea. His studies accounted for the rapid digestion rates of soft-bodied invertebrates that are rarely seen in conventional stomach analyses.

The diet of red king crab in the Gulf of Alaska (Kodiak and Afognak islands) is diverse. Prey in Izhut Bay at Afognak Island were fishes, probably capelin (Mallotus villosus), which was an unusual occurrence. In Kiliuda Bay at Kodiak Island, prey consisted of clams, and on the outer Kodiak shelf, crabs, clams, crustaceans, and fishes were important; crabs from shallow bays at Kodiak Island preyed upon clams (Protothaca stamina, Macoma sp.), cockles (Clinocardium sp.), and acorn barnacles (Balanus crenatus). There were significant differences in the food quantity consumed among sampling areas, time periods, depths, and crab sizes (Feder and Jewett 1981). Predation upon sea stars (Pycnopodia hilianthoides and Evasterias troschelii) has been observed and deemed important, especially when crabs are foraging in shallow waters in late spring and summer (Feder and Jewett 1981, Powell 1979).

Lower Cook Inlet red king crabs also manifested regional differences in food habits. Crabs in Kachemak Bay fed on clams (Spisula polynyma), whereas crabs from Kamishak ate mostly barnacles. Diets of postlarval king crabs in Cook Inlet contained detrital material, diatoms, bryozoa, harpacticoid copepods, ostracods, and sediment (Feder et al. 1980).

B. Feeding Behavior

The king crab is omnivorous during the juvenile and adult phases of its life (Eldridge 1972). Laboratory studies performed by Rice et al. (1985) found that food consumption by juvenile red king crab increased linearly with an increase in temperature.

VI. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

The preferred habitat for reproduction of red king crab is shallow water of less than 50 fathoms and offshore ocean banks (ibid.).

Molting and mating have been observed in 10 to 90 ft of water in areas where kelp is common (Jewett and Powell 1981).

In the Kodiak area, breeding red king crabs were concentrated at depths of three to eight fathoms within the lower zone of kelp and boulders. In this area, breeding crabs appeared to prefer kelp areas where Alaria, Costaria, and Laminaria were common. Rocks and kelp probably provided protection to the soft female during edysis (molt) and the subsequent mating (Powell and Nickerson 1965b).

B. Reproductive Seasonality

Red king crab females molt and mate from February through May. Males of the same species molt earlier than females, and young adults of both sexes molt earlier than old adults. Mature males tend to molt biennially or even triennially. Males molt prior to arriving on the mating grounds and therefore arrive in hard-shell condition (Eldridge 1972). Around Kodiak Island, female red king crabs begin to move toward the mating grounds in November. Young females and older males reach the spawning grounds first (Powell, pers. comm.). Powell and Nickerson (1965b) found that red king crabs in the Kodiak area molted and mated from mid February through the third week of April. The female migration to the spawning grounds begins about the same time as that for males. In Cook Inlet, the timing of the mating period for red king crabs differs slightly between bays. In Kachemak Bay, red king crabs begin spawning in February, with a peak in April. Kamishak Bay red king crabs may spawn slightly later (ADF&G 1978). Examination of female blue king crabs from the Bering Sea indicates that large females are unable to produce a fully developed ovary in one year and therefore reproduce biennially, whereas females smaller than 110 mm tend to reproduce annually (Jensen et al. 1985).

Differences in reproductive biology are evident in groups of Bering Sea golden king crabs from closely adjacent areas (Otto et al. 1985). In the Bering Sea, available information indicates that spawning of golden king crab occurs over a protracted period extending from at least February to April (ibid.). Female golden king crabs caught in British Columbia fjords are continuous aseasonal spawners with similar proportions of egg-bearing individuals found at all times of the year (Sloan 1985). In the same area, red king crabs exhibited strong seasonal reproductive patterns (Sloan 1985).

C. Reproductive Behavior

After the larvae hatch, females molt and then mate (McMullen 1969). Upon arrival at the spawning grounds, females may emit a pheromone that attracts males (NPFMC 1980). Males select females according to size and behavior. Female crabs can mate only in the soft-shell condition (Jewett and Powell 1981), and those not mating after molting will not extrude eggs (ADF&G 1978). For mating to be successful among females of each congregation, an adequate number of capable males must be present in the vicinity during the brief receptive period following female ecdysis (molt).

Mating will be unsuccessful for females waiting for a partner longer than five days after molting (Powell et al. 1974). Male king crabs will grasp females at the base of both claws while facing them, "embracing" for up to 16 days. After the female molts, the male crab releases her old shell and reclasps the female (Jewett and Powell 1981). Small males probably produce fewer spermatophores than large males, possibly resulting in a diminished ability to fertilize the greater egg masses of large females. Copulation and deposition of sperm on the female's gonopores can occur only after the female molts and before ovulation (Powell and Nickerson 1965b).

D. Age and Size at Sexual Maturity

There is a wide enough variation in size at maturity to suggest that age and growth rate in red king crabs are also important factors in reaching sexual maturity (Hilsinger 1983). Age is difficult to assess in king crabs because all hard parts of the crab that could be used for aging are lost during the molt. In the Kodiak area, the carapace length of mature female red king crabs ranges from about 93 mm to 120 mm. About 50% of the females are mature at about 100 mm (Powell et al. 1972). In the southeastern Bering Sea, sexual maturity for female red king crabs has been attained between a minimum carapace length of 86 to 102 mm (Wallace et al. 1949). Females appear to breed shortly after attaining sexual maturity (Haynes and Lehman 1969). In female crabs, molting is correlated with reproduction (Powell and Nickerson 1965b).

Male red king crabs as small as 86 mm carapace length have been found capable of mating. They attain sexual maturity at a smaller size and younger age than do females. It is uncertain, however, whether the small mature males are functioning adequately as brood stock. In captivity, Gulf of Alaska male red king crabs were found to reach 50% maturity at 86 mm (Powell et al. 1972).

Male red king crabs grow larger than female red king crabs. Male red king crabs may grow as large as 24 lb in 15 years, whereas a female red king crab of the same age would be only 10 lb (NPFMC 1980). In the Bering Sea, size at maturity increases with decreasing latitude for both golden and red king crabs (Jewett et al. 1985, Powell et al. 1983). Golden king crabs inhabiting fjords in northern British Columbia were found to mature at about 114 mm carapace length for males and 105.5 mm carapace length for females (Jewett et al. 1985).

E. Fecundity

The number of eggs produced by the female increases with carapace size. In Kodiak waters, small female red king crabs may carry 50,000 to 100,000 eggs, with large females carrying 400,000 eggs (Eldridge 1972). In Cook Inlet, fecundity has been reported to range from 25,000 to 390,000 eggs (Haynes 1968). The low numbers of eggs carried by some females could be attributed to partial fertilization of large females by smaller males (ibid.). It could also be related to the food supply and age of the individual

female because males very rarely mate with females larger than themselves (Hilsinger, pers. comm.; Powell et al. 1972). Female golden king crabs from northern British Columbia have been found to carry up to 27,000 eggs (Jewett et al. 1985). The egg size of Lithodes spp. is about double the size found in Paralithodes spp. (Haynes 1968, Sasakawa 1975). Size at maturity for golden king crabs from different areas in the Bering Sea is somewhat different by area. Male crabs from the eastern Aleutians area mature at about 130 mm carapace length, and females from the same area reach maturity at about 111 mm carapace length. Male and female golden king crabs from the Pribilof Islands District mature at about 107 and 120 mm carapace length, respectively. Male and female golden king crab from the St. Matthew area mature at the respective size of 92 and 97.7 mm (Jewett et al. 1985). Based on observation of presence of eggs on the pleopods, 50% of the female blue king crabs sampled from St. Matthew Island and the Pribilof Islands reached sexual maturity at about 81 mm and 96 mm, respectively (Somerton 1985). The size at which sexual maturity was attained for 50% of the female blue king crabs examined from Olga Bay of Kodiak Island and from Prince William Sound reached 94 and 87 mm, respectively (ibid.). Size at maturity of male blue king crabs differed considerably between sampling locations. The size at maturity, based upon the relationship of chela growth to carapace size, of 50% of the male blue king crabs from St. Matthew Island and the Pribilof Islands in the Bering Sea were 77 and 108 mm, respectively. Fifty percent of the Olga Bay and Prince William Sound male blue king crabs were believed to mature at 87 and 93 mm, respectively (ibid.).

F. Frequency of Breeding

Molting occurs before mating each year. Female red king crabs after five years probably molt annually (Powell and Nickerson 1965b). Female red king crabs apparently mate with only one male (Eldridge 1972). The mating ability of males varies with their size and is affected by the time of year they molt (ibid.). Males of varying sizes and shell ages have been shown to mate successfully (producing fertilized clutches of greater than 75%) with four to nine females (Powell et al. 1974). Captive males are polygamous and have been documented to mate with 14 females during one season (Jewett and Powell 1981).

Female molting is closely associated with reproduction, with one molt occurring annually prior to extrusion of the eggs (Gray and Powell 1966). After attaining sexual maturity, possibly in the fourth and fifth year, adult red king crabs molt annually for several years, and then some individuals begin to skip molt at approximately seven years of age (Powell and Nickerson 1965b). Male red king crabs that molt during the mating season may not mate after molting because molting may have interfered with mating. Molting areas for male red king crabs may be distant from the mating grounds. Males who skip molt two consecutive years may die after the next breeding period (Haynes and Lehman 1969).

Males generally molt annually, but males older than eight years may shed their exoskeletons once every two or three years (Manen and Curl 1981). These skip-molt males may play an important role in the reproductive success of stocks, compared to newly molted males whose mating ability is hampered by the process of molting (ibid.).

G. Incubation/Emergence

Female red king crabs carry their eggs externally for about 11 months. Eggs develop into prezoeae within five months of fertilization and remain in this state while carried by the female. Just before mating, prezoeae hatch and molt into zoeae larvae, which assume a pelagic existence (Eldridge 1972). Egg development may be slowed by colder temperatures. Eggs hatch during a three-month period from March through June. Peak hatch periods and larval abundance in the eastern Bering Sea occur from early May through mid July. Larvae are concentrated along the north Aleutian shelf from Unimak Island into Bristol Bay (Manen and Curl 1981). The time interval between molts progressively increases from a minimum of three weeks for early postlarval juveniles to a maximum of three years for adult males (NPFMC 1980).

During the first year, juvenile red king crabs undergo 11 molts and in the following year 8 molts (Manen and Curl 1981). Eggs of blue king crab from the Bering Sea show a rate of development similar to that of red king crab, indicating an ovigerous period of 11-12 months (Jensen et al. 1985).

VII. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

A. Larvae

Released red king crab larvae are pelagic, with some swimming ability. Studies indicate that ocean currents distribute larvae into nursery areas that are shallow and close to shore. In Cook Inlet, red king crab larvae are present in the plankton from mid February to late June. Larvae remain planktonic about 30 to 40 days. After the fifth molt, larvae become benthic. In Cook Inlet, the demersal-benthic settling generally occurs from mid April to late August but is heaviest during July through August (ADF&G 1978). The red king crab juvenile form occurs after the sixth molt. Movements and development of golden king crab at this stage are mostly unknown. However, Sloan (1985) indicates that isolated fjords in British Columbia serve as retention areas for larvae of golden king crab hatched in the same area.

B. Juveniles

First-year red king crab juveniles assume a solitary benthic existence in relatively shallow water and in the Gulf of Alaska are abundant in waters close to shore (Eldridge 1972). Large concentrations of juveniles have been found at depths of 29 fathoms (Powell and Reynolds 1969).

During their second year, red king crab juveniles aggregate into large groups called "pods." Pods are maintained until the crabs

reach sexual maturity. Upon reaching sexual maturity, crabs segregate by sex and size. Pods are believed to provide protection against predators. Pods are found year-round and are comprised of both males and females of similar size. Pods appear to disband when crabs feed or change location. The development and movements of golden and blue king crabs at this stage are unknown. Subadult and adult aggregations of red king crab are more scattered and circular compared to pod formation (Powell and Nickerson 1965a).

From the first through the fifth instar stage of development (6-8 mm carapace length), juvenile blue king crabs are pure white in coloration. Juvenile blue king crabs from this size up to 25 mm carapace length may remain white or may turn brown, orange, purple, or may attain a molted coloration. It is believed that the diversity in coloration or light and dark shading may prevent predation upon year classes that randomly settle on heterogeneous substrates (Armstrong et al. 1985).

C. Adult

Adults inhabit deeper water than juveniles (Eldridge 1972). Males segregate from females except during the mating season (ibid.). Adult red king crabs also segregate by size within sex-segregated groups (NPFMC 1980). King crabs follow distinct annual migrational patterns associated with the mating season, moving to shallow water of less than 50 fathoms along the shoreline and onto offshore ocean banks in the Gulf of Alaska. Young adults precede old adults, and males migrate before females (Powell and Nickerson 1965b). A molting and mating/spawning migration occurs in the spring, and a feeding migration offshore occurs in the fall (Marukawa 1933). The migration of red king crabs to shallow water in the Kodiak area begins in January and continues through April (NPFMC 1980). Migration timing in the eastern Bering Sea is believed to be similar but later than that of the Kodiak stock (ADNR/USFWS 1983). In Cook Inlet, red king crabs undergo seasonal migrations consisting of an inshore movement in spring and summer and an offshore movement to deeper waters in fall/winter. In Kachemak Bay, the inshore spawning migration begins in late December and extends through May. Peak movement is in early March. Offshore movement in the area, which is termed the feeding migration, begins in September and extends through November. This movement is a slow foraging process rather than a direct journey into deeper water (ADF&G 1978).

Golden king crabs caught in northern British Columbia Fjords were found at significantly greater depths than were red king crab. Water depths inhabited by golden king crab are related to both parasitized and unparasitized king crabs (Sloan 1985). Sloan also proposes that juvenile female golden king crabs found in fjords recruit in relatively shallow water at depths less than 100 m. Females of the same area and species mate and extrude eggs usually at less than 150-m depths and incubate eggs from between 150 to 250-m depths. Spawned-out females dominate the unparasitized

female population at depths greater than 200 m. These crab may inhabit these depths for a year and may then migrate to depths ranging from 50 to 150 m, where lesser migratory adult males most frequently occur. The behavior of parasitized golden king crabs of both sexes in fjord areas was similar to spawned-out or "matted setae" females and are the largest component of the crab population at a depth range of 200 to 400 m (ibid.).

VIII. FACTORS INFLUENCING POPULATIONS

A. Natural

1. Predation. A high mortality of larvae occurs from predation by planktivores. Sculpins, cod, and halibut have been reported to prey on juvenile king crabs (Eldridge 1972). Horsehair crabs (Erimacrus isenbeckii) have been observed to prey upon juvenile king crabs when the pod was disbanded after being disturbed by divers. Sculpins (Hemilepidotus hemilepidotus) also prey upon juveniles (Powell and Nickerson 1965a).

Adult crabs are particularly susceptible to predation when in the soft-shelled stage. Halibut have been reported to prey upon soft-shelled adult crabs (Eldridge 1972). Sea otters and bearded seals have also been observed predators upon adult crabs (Feder and Jewett 1981).

2. Disease and parasites. Adult crabs are affected by diseases or parasites. Instances of the following afflictions occur:
 - Rust disease: infestation of exoskeleton by chitin-destroying bacteria; affects P. camtschatica and P. platypus in the North Pacific (Sindermann 1970)
 - Rhizocephalan: Briarosaccus callosus infects P. platypus, P. camtschatica, and L. aequispina (This parasitic barnacle will inhibit molting, cause "parasitic castration," and retard gonad development [NMFS 1983, Sloan 1985].)
 - Nemertean worm (Carcinomertes sp.) infestations have been found in red king crab egg clutches and have been known to prey on the eggs (Wickam et al. 1985). Carcinomertes has been documented in Kachemak Bay (Cook Inlet) king crabs. Infestation has coincided with reduced egg clutches and high egg mortality (Merritt, pers. comm.; NMFS 1983).
 - Acanthocephalan, a parasitic pseudocoelomate found in connective tissue of the midgut of the king crab, causes damage to the intestinal wall. This organism has been documented in king crabs from Cook Inlet and Bristol Bay (NMFS 1983).

B. Human-related

A summary of possible impacts from human-related activities includes the following:

- Alteration of preferred water temperatures, pH, dissolved oxygen, and chemical composition

- Alteration of preferred substrate
- Alteration of intertidal areas
- Increase in suspended organic or mineral material
- Reduction in food supply
- Reduction in protective cover (e.g., seaweed beds)
- Obstruction of migration routes
- Shock waves in aquatic environment
- Human harvest (including handling of nonlegal crabs)
- Transportation of diseased crab leading to possible epizootic diseases and outbreaks

(See the Impacts of Land and Water Use volume of this series for additional impacts information.)

IX. LEGAL STATUS

A. Managerial Authority

King crab fisheries throughout Alaska are managed by the State of Alaska under regulations defined by the Alaska Board of Fisheries. King crab fisheries in the Bering Sea-Aleutian area are managed under a policy defined by the Alaska Board of Fisheries and the North Pacific Management Council (McCrary 1984).

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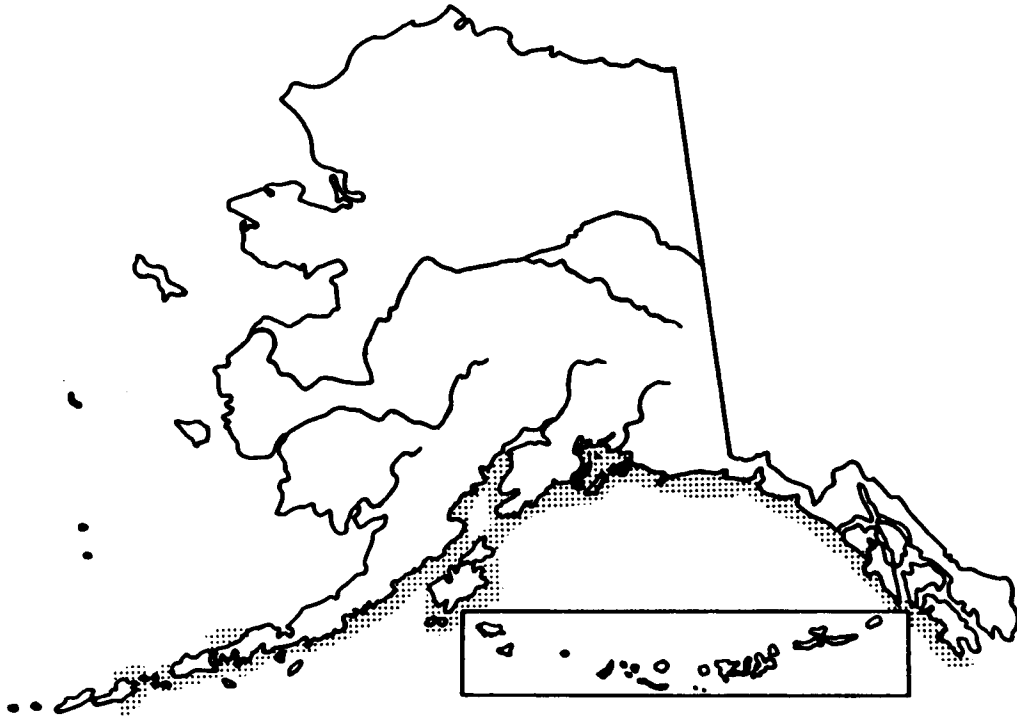
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Razor Clam Life History and Habitat Requirements
Southwest and Southcentral Regions



Map 1. Range of razor clam (Nickerson 1975)

I. NAME

- A. Common Name: Razor clam
- B. Scientific Name: Siliqua patula
- C. Native Names: See appendix A.

II. RANGE

- A. Worldwide
The razor clam is found from Pismo Beach, California, to the Bering Sea (Amos 1966).
- B. Regional Distribution Maps
To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for each region. Razor clam distribution maps in this series are at 1:250,000 scale. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor

responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of selected fish and wildlife species has been prepared and may be found in the Atlas that accompanies each regional guide.

C. Regional Distribution Summary

1. Southwest. Commercial quantities of razor clams in Southwest Alaska occur on beaches in the Swikshak area of the Alaska Peninsula (Paul and Feder 1976). (For more detailed narrative information, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)
2. Southcentral. Commercial quantities of razor clams in Southcentral Alaska occur on beaches near Cordova and on the west side of Cook Inlet (ibid.). Large populations of razor clams are also found on the east side of Cook Inlet, where an active razor clam personal use harvest occurs. (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)

III. PHYSICAL HABITAT REQUIREMENTS

A. Water Quantity

Razor clams are found intertidally to a depth of several meters (Keen 1963) on exposed beaches of the open coast (Nosho 1972). Nickerson (1975) found the highest density of razor clams to be at the 0 tide level (0 corresponds to the level at mean low water), with the upper habitable tide level estimated to be +4.50 ft at Cordova. He speculated that the upper habitable level is related to the tidal regime and therefore varies from one area to the next, with the highest estimated habitable level being +6.26 ft at Polly Creek on the west side of Cook Inlet (Nickerson 1975, calculated from values arrived at in his Cordova study). Nickerson also found that larger and older clams are found at lower tide levels, possibly because clams at lower levels are exposed to more nutrient-bearing sea water. McMullen (1967), however, did not find this relationship to be valid for razor clams collected at tide levels ranging from -5.0 to -1.1 at Clam Gulch and Deep Creek beaches on the east side of Cook Inlet.

B. Water Temperatures

Sayce and Tufts (1972), in laboratory experiments, found that razor clams suffered 100% mortality when exposed to 25°C sea water for a period of eight hours. Sayce and Tufts speculated that razor clams on Washington beaches may infrequently be exposed to these high temperatures and that mortality from high temperatures may account for some of the fluctuations in razor clam populations in Washington.

C. Substrate

Productive beaches include those consisting of fine sand with some glacial silt (Karls Bar at Orca Inlet near Cordova), fine sand, volcanic ash and some glacial mud (Swikshak and Hallo Bay near Kodiak), coarse white sand (Deep Creek area of Cook Inlet), and fine sand-clay-gravel mixture (Clam Gulch on Cook Inlet).

Nickerson (1975) and Nickerson and Brown (1979) found an inverse relationship between substrate clay levels and the density of one-year-old razor clams. When the level of fine substrate particles (0.005 mm in diameter) reached 2.2% or more, one-year-old razor clams were not found.

IV. NUTRITIONAL REQUIREMENTS

- A. Food Species Used
Razor clams are filter feeders, consuming detritus and drifting plankton (ADF&G 1978).
- B. Types of Feeding Areas Used
Razor clams feed within the intertidal zone.
- C. Factors Limiting Availability of Food
Nickerson (1975) noted that larger clams are found at lower tide levels and speculated that their apparently faster growth may be due to longer exposure to nutrient-rich sea water. Razor clam growth accelerates in spring, when the food supply increases, and continues at a rapid rate through summer (Nosho 1972). Nelson (1982) noted that investigators dealing with other species of clams have found that heavy concentrations of adult clams in an area may reduce the food supply and adversely affect the survival of juveniles, which are not as able to compete for food and space. He (1982) speculated that these observations may also apply to razor clams.
- D. Feeding Behavior
Adult razor clams lie buried in the sand, their siphons protruding above the surface. Food particles are brought in along with water through the incurrent tube, then are filtered out of the water by the gills and passed to the mouth for ingestion (ADF&G 1978).

V. REPRODUCTIVE CHARACTERISTICS

- A. Reproductive Habitat
Razor clams breed within the intertidal zone.
- B. Reproductive Seasonality
Nosho (1972) states that razor clam spawning occurs when water temperatures reach 13°C, which usually occurs in July in Alaska. Nickerson (1975), however, found that the onset of spawning is more strongly related to cumulative temperature units (defined as the cumulative degrees [Fahrenheit] of the maximum daily deviation ± 32 F that were observed from January 1 to the time of spawning). He found that spawning occurred when 1,350 or more temperature units had accumulated, usually between late May and mid July in the Cordova area (ibid.).
- C. Reproductive Behavior
Spawning occurs over a period of several weeks (Nosho 1972). Eggs and sperm are released through the excurrent siphon, and fertilization takes place in the open water (ibid.).
- D. Age at Sexual Maturity
Attainment of sexual maturity is more closely related to size than to age (Nickerson 1975), clams reaching maturity at a length of

approximately 100 mm (Nosho 1972, McMullen 1967). Growth rate (and thus age at maturity) varies greatly among populations. Spawning of Clam Gulch razor clams, for example, may occur as early as age 2 (McMullen 1967), whereas 65% of clams on Cordova beaches reach maturity at age 3 (Nickerson 1975).

E. Frequency of Breeding

Razor clams breed annually (Nelson 1982).

F. Fecundity

Fecundity of female razor clams increases with size. Nickerson (1975) found that fecundity estimates of razor clams 40 to 180 mm (valve length) ranged from 0.3 to 118.5 million ova per clam.

G. Incubation Period

Eggs hatch into free-swimming, ciliated larvae (veligers) within a few hours to a few days of release, with the rate of development dependent on temperature. Larvae exist as free-swimming veligers for 5 to 16 weeks (Oregon Fish Commission 1963), after which they develop a shell and settle to the bottom.

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

Clam veligers are dependent upon water currents to carry them to desirable habitat (ADF&G 1978).

Young razor clams up to 10 mm (valve length) are capable of voluntary lateral movement along the beach surface to about 60 cm (Nickerson 1975). Large razor clams are believed to be incapable of voluntary lateral movement, though relocations may occur as a consequence of rapidly shifting substrate, or washout (ibid.). Razor clams are, however, capable of very rapid vertical movements (several feet per minute).

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

Mortality of larval and juvenile stages is extremely high, and their survival, rather than the number or fecundity of spawning adults, is believed to determine the size of each year class (Nelson 1982).

Razor clams in the veliger stage are preyed upon by plankton feeders. Veligers are dependent upon favorable water currents to wash them to desirable settling habitat (ibid.).

Reduced food concentrations retard growth and may weaken juveniles (ibid.).

Survival of year classes of razor clams is highly variable. McMullen (1967) attributed the apparently weak 1965 year class at Clam Gulch to unseasonably cold weather that delayed spawning that year. The young clams were probably not ready to settle until fall, when low tides and cold weather exposed and froze them.

Influxes of fresh water, caused by high-flowing streams or heavy rain, result in increased mortality of adult and young razor clams (ibid.).

Adult razor clams are consumed by starfish, drilling snails, crabs, rays, octopuses, flatfishes, ducks, and gulls (Feder and Paul 1974, ADF&G 1978).

B. Human-related

A summary of possible impacts from human-related activities includes the following:

- Alteration of preferred water temperatures, pH, dissolved oxygen, salinity, and chemical composition
- Introduction of water-soluble substances
- Alteration of preferred water-circulation patterns and depth
- Increase in suspended organic or mineral material
- Increase in siltation and reduction in permeability of substrate
- Reduction in food supply
- Seismic shock waves
- Human harvest

(See the Impacts of Land and Water Use volume of this series for additional impacts information.)

VIII. LEGAL STATUS

Sport and commercial harvests of razor clams are regulated by the Alaska Department of Fish and Game.

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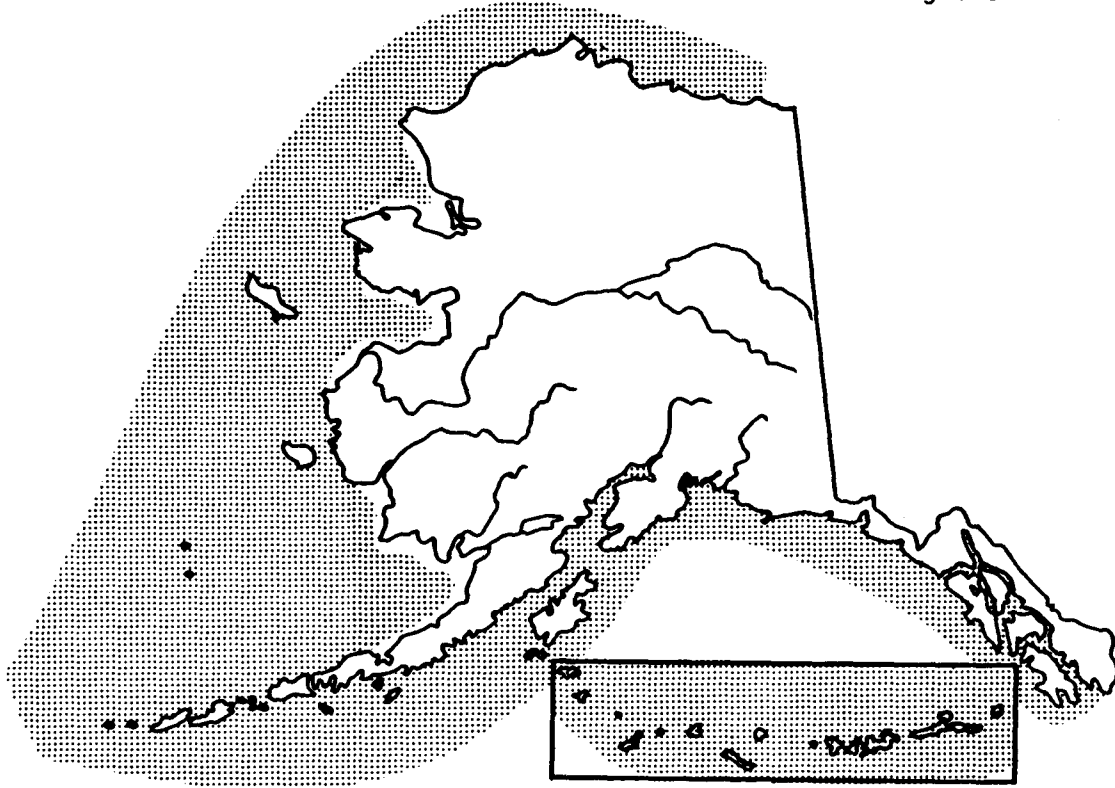
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Shrimp Life History and Habitat Requirements
Southwest, Southcentral, Western, and Southeast Regions



Map 1. Range of shrimp (ADF&G 1978)

I. NAME

A. Common and Scientific Names: Northern pink shrimp or deep sea prawn (Pandalus borealis Kroyer); humpy shrimp or flexed shrimp (Pandalus goniurus Stimpson); spot shrimp or spot prawn (Pandalus platyceros Brandt); coonstripe shrimp (Pandalus hypsinotus Brandt); sidestripe shrimp or giant red (Pandalopsis dispar Brandt).

B. Native Names: See appendix A.

II. EXTENT TO WHICH SPECIES REPRESENTS GROUP

Although nine species of pandalid shrimp (family Pandalidae) are found in Alaskan waters, only five species are commercially important in Alaska (Barr 1970a).

III. RANGE

A. Eastern Pacific Ocean

1. Pink shrimp. The range of the northern pink shrimp extends from the Chukchi Sea, Point Barrow, southward to the Columbia River mouth in Washington (Butler 1980).
2. Humpy shrimp. This species has been found from the Chukchi Sea southward to Puget Sound (ibid.).
3. Coonstripe shrimp. The range of coonstripe shrimp extends from Norton Sound in the Bering Sea to the Strait of Juan de Fuca (ibid.).
4. Spot shrimp. This species ranges from Unalaska Island, Alaska, southward to San Diego, California (ibid.).
5. Sidestripe shrimp. Distribution of sidestripe shrimp extends from the Bering Sea, west of the Pribilof Islands, southward to Manhattan Beach, Oregon (ibid.).

B. Statewide

1. Pink shrimp. Concentrations of northern pink shrimp are located in lower Cook Inlet, Kodiak, Shumagin Islands, along the south side of the Alaska Peninsula, and in the Aleutian Islands. Pink shrimp are also found along the east side of the Kenai Peninsula, in Prince William Sound, Yakutat Bay, throughout Southeast Alaska, and near the Pribilof Islands in the eastern Bering Sea (ADF&G 1978; McCrary, pers. comm.).
2. Humpy shrimp. Concentrations of humpy shrimp are found off southeastern Kodiak Island and the Shumagin Islands, Prince William Sound, Cook Inlet, and the Bering Sea.
3. Coonstripe shrimp. This species is primarily found in lower Cook Inlet, off Kodiak Island, among the Shumagin Islands in Yakutat Bay, and throughout Southeast Alaska.
4. Spot shrimp. This species has been reported in lower Cook Inlet, off Kodiak Island, along the Alaska Peninsula, in Prince William Sound, and in Southeast Alaska.
5. Sidestripe shrimp. Concentrations of sidestripe shrimp have been located off Kodiak Island, the Shumagin Islands, in the Bering Sea, lower Cook Inlet, and Yakutat Bay in Southeast Alaska (ADF&G 1978; Anderson, pers. comm.; Merritt, pers. comm.; Koeneman, pers. comm.).

C. Regional Distribution Maps

To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for each region. The maps in this series depict shrimp distribution at 1:1,000,000 scale for the Southwest and Southcentral regions. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of selected fish and wildlife species has been prepared and may be found in the Atlas that accompanies each regional guide.

D. Regional Distribution Summary

A summary of habitat characteristics associated with each species of shrimp and its geographic range within the state is provided in table 1. A more detailed description of the distribution and abundance of shrimp in each region is published in volume 1 of the Alaska Habitat Management Guide (AHMG) for the Southwest Region, volume 2 of the AHMG for the Southcentral Region, and volume 2 of the AHMG for the Western Region. Distribution and abundance narratives for shrimp were not prepared for the Southeast and Arctic regions.

IV. PHYSICAL HABITAT REQUIREMENTS

A. Water Quality

Distribution of pandalid shrimp is in part dependent upon the water's temperature and salinity. Immature shrimp are tolerant of a broad range of temperature and salinity values and are often abundant in relatively shallow depths, where these two parameters are variable. Older, sexually mature shrimp prefer greater depths, where these two parameters are more stable and less variable. With the exception of humpy shrimp, these pandalid species have been found in a temperature range of 7 to 11°C along the coast of British Columbia (Butler 1964). Humpy shrimp are apparently selective of colder water temperatures. In laboratory studies, pink shrimp were found to have narrow thermal requirements for reproduction, with low temperatures (3-6°C) generally more favorable than high temperatures. Different thermal regimes resulted in differences in the time and duration of spawning and in the abundance of egg-bearing females. Larval production, larval survival, and developmental and growth rates were enhanced by higher (9°C) rearing temperatures, regardless of feeding levels. The size and viability of newly hatched larvae are significantly influenced by the thermal history of females during the egg-bearing period (6-7 months). Low incubation (3°C) and higher rearing (9°C) temperatures tended to increase larval and survival growth rates (Nunes 1984). In the Bering Sea, concentrations of pink shrimp were located at 0.5°C (Ivanov 1964b). In the Bering Sea, pink shrimp do not inhabit the warmest part of the shelf but have been found in stable, more inshore regions associated with moderate periods of ice cover and less influenced by winter turnover. Sidestripe shrimp in the Bering Sea are found primarily along the shelf's edge (Anderson, pers. comm.).

Salinity ranges appear to differ by species. The salinity range of pink shrimp in British Columbia waters has been reported from 23.4 to 30.8 parts per thousand (o/oo) (Butler 1964). Butler (1964) reported salinity ranges for coonstripe shrimp from 25.9 to 30.6 o/oo, for spot shrimp from 26.4 to 30.8 o/oo, and for sidestripe shrimp from 26.7 to 30.8 o/oo. During the winter, pink shrimp are generally absent from inner bay waters of less than 30 fathoms when bottom temperatures may be less than 2°C and ice

Table 1. General Characteristics of the Five Important Species of Alaska Shrimp

Species	Approximate Maximum Size (Inches)	Shrimp Per Pound	Geographical Range in Alaska	Type of Gear Used for Commercial Harvest	Type of Bottom	Usual Depth of Capture (Fathoms)	Greatest Depth of Capture (Fathoms)
Pink	6-1/2	60-160	Pribilof Islands-Bering Sea- Southeast Alaska	Trawls	Smooth mud	20-100	350
Sidestripe	8-1/2	20-100	Central Bering Sea- Southeast Alaska	Trawls	Smooth mud	Greater than 20	350
Humpy	4-3/4	80-180	Bering Strait-Southeast Alaska	Trawls	Smooth mud, sand, organic debris	10-100	100
Coonstripe	8	30-100	Norton Sound-Southeast Alaska	Trawls, pots	Smooth mud, sand, rocky areas	25-50	100
Spot	11	6-25	Unalaska-Southeast Alaska	Pots	Rough, rocky	Greater than 30	266

Source: Barr 1970a.

cover may be present. At the same time, where pink shrimp are most concentrated, temperatures may range from 1 to 2°C warmer than those of innermost bays of comparable depth (ADF&G 1978). ADF&G studies have shown that pandalid shrimp tend to be distributed in two ways: 1) Younger age groups are located in shallower areas, whereas older age groups are deeper; and 2) older age groups occur offshore, and younger age groups are inshore. Apparently, older, sexually mature shrimp, especially oviparous females, prefer deeper water, where temperature and salinity parameters are less variable. Younger shrimp, particularly those prior to first sexual maturity, are tolerant of a broader range of salinities and temperature and are therefore often abundant in nearshore or shallower areas, where these two parameters are generally more variable (ibid.).

B. Water Quantity

The depth at which pandalid shrimp are found depends upon the species and their stage of development. Shrimp larvae are found in shallower waters than adults, ranging from about 5 to 35 fathoms in depth. From ages one to two years, pink shrimp juveniles begin utilizing bottom habitats of from 20 to 40 fathoms, though dense aggregations may be found at 50 to 70 fathoms. Adult pink shrimp inhabit water depths of from 10 to 350 fathoms (Rathjen and Yesaki 1966). The depths at which coonstripe shrimp occur are similar to the depth range of humpy shrimp, which is 3 to 100 fathoms (Fox 1972). Spot shrimp have been found to occur in depths from 2 to 266 fathoms (ibid.), and sidestripe shrimp are commonly found in depths ranging from 20 to 351 fathoms (Ronholt 1963).

C. Substrate

Substrate preference appears to be species-specific. Pink and sidestripe shrimp appear to prefer smooth, mud bottoms. Humpy shrimp primarily occur in areas with a substrate of smooth mud, sand, or organic debris. Coonstripe shrimp prefer areas of smooth mud, sand, or organic debris. Unlike the other species, spot shrimp are primarily found in rough, rocky areas (ADF&G 1978, Butler 1980).

V. NUTRITIONAL REQUIREMENTS

A. Preferred Foods

Adult pandalid shrimp feed both by scavenging dead animal material and by preying on such living organisms as amphipods, euphausiids, annelids, and other shrimps (ibid.).

B. Feeding Locations

Larvae feed in the water column. Juveniles and adults are benthic and water column feeders. Stomach contents of spot shrimp caught near Vancouver included polychaete worms and unidentified crustaceans. Humpy and pink shrimp from Barrard Inlet in Washington were found to feed upon mysids and polychaete worms.

C. Factors Limiting the Availability of Food

No information was available.

D. Feeding Behavior

Adults are carnivorous bottom feeders (ibid.). Pink shrimp larvae feeding rates increased with increasing temperatures. Among starved larvae, higher temperatures lowered the threshold concentrations of prey organisms required for successful first feeding. The amount of food required by larvae to complete development was significantly reduced at higher temperatures (Nunes 1984).

VI. REPRODUCTIVE CHARACTERISTICS

A. Breeding Habitat

The normal distribution of adults and breeding habitat covers a wide range of depths, varying by area and species. Breeding habitat is not considered vastly different from the normal annual distribution of adults, except that depths occupied in fall and winter tend to be deeper than those occupied in spring and summer for all species. Commercial fisheries commonly operate on concentrations of adults during the breeding season in areas and depths that produce adults all year (McCrary, pers. comm.).

B. Breeding Seasonality

The timing of spawning differs by geographical range for pandalid shrimp, where temperature is the controlling factor. For pink shrimp at the northern extremities of its range, incubation of eggs is longer because of an earlier spawning and later hatching date (Rasmussen 1953, Allen 1959). Generally, eggs ripen in the ovaries of the females. Breeding and egg deposition occur from late September through mid November (ADF&G 1978). In the Bering Sea, breeding occurs from June through November (Anderson, pers. comm.).

C. Reproductive Behavior

Only female shrimp undergo an external physiological change during the reproductive season. Just prior to spawning, the female molts into a shell specialized for carrying the eggs (Barr 1970a). Within 36 hours after the female molts into breeding dress, the male attaches a sperm mass to the underside of the female between the last two pairs of pereopods (walking legs), where the eggs will be fertilized (Needler 1931). The female extrudes the eggs through a pair of openings at the base of a pair of legs, and the eggs are carried backward and attached to the setae on her abdominal appendages. The developing eggs remain attached to the setae until they hatch (Needler 1931, Barr 1970a).

D. Age at Sexual Maturity

The age at which sexual maturity is reached differs by species and by geographical location within a species. Pink shrimp in the Pribilof area of the Bering Sea and in the Kodiak and Shumagin islands areas of the Gulf of Alaska are estimated to reach maturity at 2.5 years (Ivanov 1964a, McCrary 1971). The same estimate of age at maturity is believed to be true for sidestripe shrimp and, to a lesser extent, for coonstripe and humpy shrimp in Kodiak and Shumagin islands waters. Pink, humpy, coonstripe, and

sidestripe shrimp species in Southeast Alaska waters have been found to mature at 1.5 years (McCrary 1971).

Pandalid shrimp may occur in one of three forms as they mature sexually. These include the protandric male form, the "primary female" form, or the "secondary female" form. Protandric pandalid shrimp mature first as males, then later in their life cycle transform into females. The age at which the transition from male to female occurs also varies by species and by geographical location within species. Individuals of a given species mature less rapidly if they inhabit waters in a colder portion of their range. Generally, most shrimp function two years as a male before becoming female (ADF&G 1978). In British Columbia, humpy shrimp mature as males during their first autumn and again as females at 1.5 years of age (Butler 1964). Pink shrimp, coonstripe shrimp, spot shrimp, and sidestripe shrimp generally mature as males at 1.5 years (Butler 1964, Dahlstrom 1970). An individual that has become female remains so throughout its life.

"Primary females" are shrimp that mature directly as females and are never protandric. Though primary females have been documented in pink shrimp populations off the coast of British Columbia, their occurrence in Alaskan waters is believed to be rare (Butler 1964).

"Secondary female" development entails the appearance of female characteristics that are repressed before maturity is reached. When the secondary female attains sexual maturity it remains female for the rest of its life. Secondary females have been documented in Southeast Alaska populations of pink, humpy, and coonstripe shrimp but have not been documented in other Alaskan waters (ADF&G 1978).

The life span of pink shrimp in Kachemak Bay has been documented to be at least five or six years (Barr 1970a). In Kachemak Bay, the transformation from male to female begins about late April and may not be complete until August or September (ibid.).

E. Fecundity

Eggs per clutch for pink shrimp have been found to range in number from 478 to 2,117. In Southeast Alaska, the fecundity range for pink shrimp was from 809 to 1,642; sidestripe shrimp ranged from 674 to 1,454; humpy shrimp from 971 to 3,383; coonstripe shrimp from 1,083 to 4,583; spot shrimp from 4,044 to 4,528. Fecundity is related to the size of the shrimp, with larger shrimp producing more eggs (Alaska OCS 1980).

F. Frequency of Breeding

Reproduction of shrimp is usually annual and synchronous (Anderson, pers. comm.). Shrimp usually mature sexually as males. After spawning one or more times, they pass through a transitional phase and subsequently spawn as females. Transformation may occur so rapidly that an individual spawning one year as a male will spawn the following year as a female (Fox 1972). In Kachemak Bay, spawning usually begins in late September and ends in mid October

(Barr 1970a). In British Columbia, pink shrimp breed in mid November (Butler 1980).

G. Incubation Period/Emergence

In the Gulf of Maine, females carry eggs for five to six months prior to hatching (Haynes and Wigley 1969). In Alaskan waters, eggs are carried from 6 to 11 months. This phase is usually longer in Bering Sea waters than in the Gulf of Alaska and southeastern waters (Anderson, pers. comm.). The female does not molt or grow in the five to six months needed for eggs to complete development and hatch. However, the female will molt about two weeks after the eggs hatch and then return to her nonbreeding shell type (Barr 1970a). Hatching usually occurs from March through April for pink and coonstripe shrimp, and for sidestripe shrimp it may extend into June or July (Butler 1980). For pink shrimp, the lengths of the spawning, carrying, and hatching periods vary inversely with the water temperatures (Haynes and Wigley 1969). The normal incubation period for sidestripe shrimp in British Columbia is about 5 1/2 months. Hatching begins in March and in most cases is complete before the end of April (Butler 1980). The ovigerous (egg holding) period for humpy shrimp is from late November to April (ibid.). Pink shrimp are also ovigerous from November until spring. For spot shrimp, eggs are carried by one female, after spawning is over in October, for 5 to 5 1/2 months. Egg bearing for coonstripe shrimp begins in late November or early December and lasts into the spring months (ibid.). Newly hatched larvae are about three-sixteenths of an inch long (Barr 1970a). Laboratory studies indicate that most eggs hatch at night during periods of vigorous pleopod movement by the female. Usually, the female remains quiet for about 10 minutes, then moves her pleopods vigorously while clinging to something or while swimming freely in the water. The motion lasts for about one minute, during which time 5 to 25 larvae are liberated. The process is repeated until the whole brood is released. Hatching of an entire clutch may require two days. Larvae are planktonic for about two to three months; they pass through six stages to become juveniles (in adult form), at which time they become benthic (Berkeley 1930).

VII. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

A. Larvae

The larvae, which are planktonic, drift passively or swim weakly at mid-water depths, where they feed on organisms smaller than themselves.

In British Columbia, freshly hatched larvae were found in the vicinity of the spawned adults. The larvae then move to shallower areas, ranging from 9 to 64 m in depth, where they spend the first summer (ibid.). Overall, little information is available regarding the life history of shrimp during the planktonic stage (Koeneman, pers. comm.).

B. Juvenile

In British Columbia, juvenile pink, coonstripe, sidestripe, and spot shrimp move to deeper water during their first winter to join the adult population (ibid.).

C. Adult

Pink shrimp have displayed fairly distinct seasonal onshore-offshore migrations. They use shallow, nearshore, and inner bays primarily from spring through fall. With the onset of winter and colder temperatures in nearshore and inner bays, pink shrimp migrate to warmer offshore areas (ADF&G 1978).

Female pink shrimp have been reported to move inshore as their eggs develop in late fall and early winter (Haynes and Wigly 1969). Pink shrimp have also engaged in diel vertical migrations, which appear to be related to feeding behavior because shrimp feed mainly on euphausiids and copepods, which have the same movements (Barr 1970b).

Kachemak Bay studies have shown that pink shrimp leave the bottom in late afternoon or evening, returning to the same area about dawn (ibid.). The period of time the shrimp remained away from the sea bottom varied directly with the season's number of hours of darkness.

VIII. FACTORS INFLUENCING POPULATIONS

A. Natural

Pandalid shrimp are subject to a high level of predation, both as planktonic larvae and as benthic adults. Predators include Pacific hake, Pacific cod, sablefish, lingcod, sand sole, rockfish, Pacific herring, pollock, grey whale, humpback whale, spiny dogfish, skates, rays, Pacific halibut, salmon, octopuses, and harbor seals (Fox 1972, USDC 1979, Butler 1980). Marine birds such as the pigeon guillemot, common murre, and oldsquaw duck were also found to prey upon pink shrimp (USDC 1979). Parasites and disease also cause mortality of shrimp populations. The black spot gill disease has been documented in shrimp from the Kodiak area. The gill lamellae of the shrimp are destroyed, and a chitinous growth covers the damaged area, creating a "black spot" (Fox 1972, Yevich and Rinaldo 1971).

Sylon hippolytes has parasitized Pandalus jordani, P. borealis, P. platyceros, and many noncommercial shrimps. High infection rates are present in many Southeast Alaska spot populations (less than 20% in some populations) (Shirley, pers. comm.). Bopyroid isopods (Bopyrus spp.) also parasitize most species of pandalid shrimp (Fox 1972).

Temperature appears to control the reproductive process in pink shrimp, particularly during the period between egg formation and egg development (Nunes 1984).

Laboratory studies have indicated that pink shrimp zoeae that hatch during a warm year, at a temperature of 6°C, require 63% more calories for metabolic requirements than zoeae of the same weight hatching at 3°C. Therefore, it is possible that the

increased energy requirement of zoeae at increased temperatures may exceed the zoeae's ability to find and ingest food items (Paul and Nunes 1983).

B. Human-related

A summary of possible impacts from human-related activities includes the following:

- Alteration of preferred water temperatures, pH, dissolved oxygen, and chemical composition
- Alteration of preferred substrate
- Alteration of intertidal areas
- Increase in suspended organic or mineral material
- Reduction in food supply
- Reduction in protective cover (e.g., seaweed beds)
- Obstruction of migration routes
- Shock waves in aquatic environment
- Human harvest

(See Impacts of Land and Water Use of this series for additional impacts information.)

IX. LEGAL STATUS

A. Managerial Authority

Shrimp populations are managed by the Alaska Department of Fish and Game under policy regulations and management plans adopted by the Alaska Board of Fisheries.

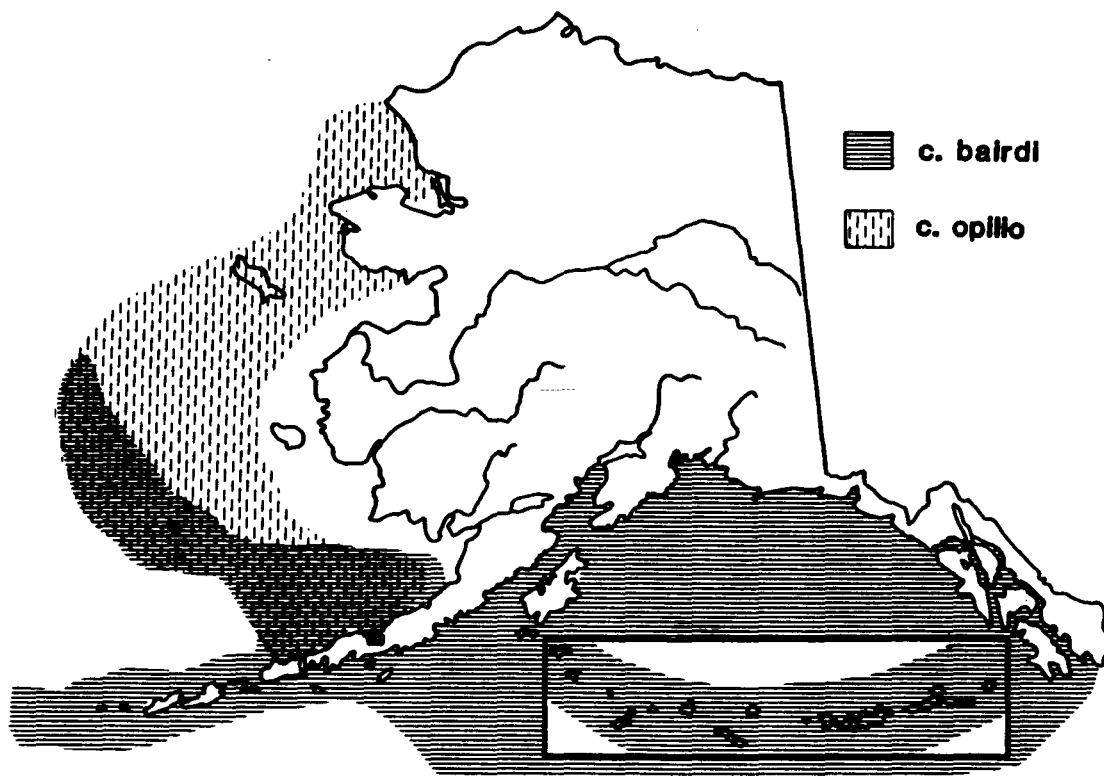
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Tanner Crab Life History and Habitat Requirements
Southwest, Southcentral, Arctic, and Western Regions



Map 1. Range of Tanner crab (ADF&G 1978; Kessler, pers. comm.; Otto, pers. comm.)

I. NAME

- A. Common Names: Tanner crab, snow crab, queen crab, spider crab
- B. Scientific Names: Chionoecetes bairdi, C. opilio,
C. angulatus, C. tanneri
- C. Native Names: See appendix A.

II. EXTENT TO WHICH SPECIES REPRESENTS GROUP

Chionoecetes bairdi and C. opilio are the only species of Tanner crab commercially harvested in the North Pacific (NPFMC 1981). A hybrid of C. bairdi and C. opilio occurs in the eastern Bering Sea. C. tanneri and C. angulatus, although of minimal commercial interest, have been found in the Bering Sea and Gulf of Alaska.

III. RANGE

A. Worldwide

Tanner crabs have a circumarctic distribution, extending into the temperate waters on the east and west coasts of North America.

C. bairdi occurs primarily in the eastern Pacific Ocean from Oregon (Hosie 1974) northward to the Aleutian Islands and the eastern Bering Sea. C. bairdi also exists in the western Pacific Ocean near Kamchatka. C. opilio occurs from the eastern Bering Sea northward to the Beaufort Sea and in the western Atlantic Ocean south to Casco Bay, Maine (Garth 1958). C. angulatus and C. tanneri occur in deeper water in the North Pacific from the California Coast north to the Bering Sea (NPFMC 1981; Colgate, pers. comm).

B. Statewide

C. bairdi occurs from Southeast Alaska north to the southeastern Bering Sea along the continental shelf edge to the United States-USSR convention line. C. opilio occurs in the Bering Sea (ADF&G 1978).

C. Regional Distribution Maps

To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for each region. Tanner crab distribution maps in this series are at 1:1,000,000 scale. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of selected fish and wildlife species has been prepared and may be found in the Atlas that accompanies each regional guide.

D. Regional Distribution Summary

1. Southwest. Concentrations of C. bairdi occur in the Kodiak Island, Bristol Bay, and South Peninsula/Aleutian Islands areas. C. opilio occurs in the eastern Bering Sea, with greatest concentrations north of 58° north latitude. (For more detailed narrative information, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)
2. Southcentral. Concentrations of C. bairdi occur in the Prince William Sound and lower Cook Inlet areas. Small-sized Tanner crabs (C. bairdi) have also been found in upper Cook Inlet, primarily in the Central District (Kyle, pers. comm.). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)
3. Arctic and Western. Concentrations of C. bairdi have been located in a broad band extending from inner Bristol Bay westward along the outer continental shelf edge to 187° west longitude (Otto et al. 1984). C. opilio occurs from the Bering Strait south to Unimak Island, with the exception of the northern or eastern shores of Bristol Bay, immediately south of Unimak Island (Otto 1981, Otto et al. 1984). (For more detailed narrative information, see volume 2 of the

Alaska Habitat Management Guide for either the Arctic or the Western and Interior regions.)

IV. PHYSICAL HABITAT REQUIREMENTS

A. Water Quality

Adult distribution is restricted by low salinity and high temperature. Laboratory experiments show that mortality of C. opilio occurs if the crabs are exposed to salinities of less than 22.5 parts per thousand (o/oo). C. opilio reaches 50% mortality after 18.8 days when the temperature has been held at 16°C (McLeese 1968). C. bairdi is found in warmer slope and outer continental shelf waters of the southern Bering Sea where average temperatures are 4.5°C. C. opilio is located in colder waters where the mean temperature is 2.4°C (NPFMC 1981).

B. Water Quantity

Tanner crabs of all sizes are abundant in water as shallow as 10 m (Donaldson, pers. comm.). Juveniles occur at varying depths (NPFMC 1981); they have been found to settle out along the sea bottom at depths between 298 and 349 m (Ito 1968). C. bairdi at size 6.5 mm carapace width (CW) off Kodiak Island have been found at depths of 18 m, and at 12 mm size CW they have been located at depths of 55 to 168 m (NPFMC 1981). In Cook Inlet, early benthic stages (C. bairdi smaller than 20 mm) were found at depths greater than 50 m. In this same study, small crabs were most abundant at 15- and 166-m depths (Paul 1982a). In Southeast Alaska, many C. bairdi smaller than 40 mm have been located in Lisianski Strait as deep as 230 m (Carlson and Straty 1981).

Adult C. bairdi occur between shore water and 473 m, with major concentrations at less than 300 m. C. opilio has been found between 13 m and 454 m, with major concentrations usually at less than 155 m (NPFMC 1981, Somerton 1981, Colgate 1983).

C. Substrate

The preferred substrate of C. bairdi has been described as green and black mud, fine gray and black sand, and shell (Garth 1958). Postlarval and juvenile C. bairdi near Kodiak Island have been observed both in this habitat and among patches of epiphytic growth such as hydroids and bryozoans. In lower Cook Inlet, a nursery area for juvenile C. bairdi was found among dense centers of spongelike material (Jewett 1982).

V. NUTRITIONAL REQUIREMENTS

A. Preferred Foods

1. Larvae. Larvae feed on plankton in the water column.
2. Juveniles. The diet of juveniles is uncertain. They are believed to feed on detritus, crustaceans, and molluscs accumulated on the sea floor (NPFMC 1981).
3. Adult. Identifiable stomach contents for C. opilio and C. bairdi in the Bering Sea were primarily polychaetes, crustaceans, and molluscs (Tarverdieva 1976). C. opilio consumes polychaetes and brittle stars (Feder and Jewett

1981). In Norton Sound, stomach contents of C. opilio included clams (Nucula tenuis) (Feder and Jewett 1978). Important food items for C. bairdi in the Kodiak area were arthropods (mainly juvenile C. bairdi), fishes, and molluscs (Jewett and Feder 1982). Clams (Macoma spp.), hermit crabs (Paqurus spp.), and barnacles (Balanus spp.) were documented in stomachs of C. bairdi in lower Cook Inlet. In Prince William Sound, the diet of C. bairdi contained polychaetes, clams, C. bairdi, crustaceans, and detritus (Feder and Jewett 1981).

- B. Feeding locations
Larvae feed in the water column; juvenile and adult crabs are benthic.
- C. Factors Limiting Availability of Food
Adverse climatic conditions may affect the availability of plankton during the larval release period, and primary prey species may have suffered a population decline, either or both of which circumstances would limit the availability of food (Donaldson, pers. comm.)
- D. Feeding Behavior
Larvae are planktivores; adults are benthic omnivores.

VI. REPRODUCTIVE CHARACTERISTICS

- A. Reproductive Habitat
Directed studies regarding preferred mating habitat have yet to be performed.
- B. Reproductive Seasonality
Mating occurs during two periods that overlap, in winter and early spring: 1) females molting to maturity (primiparous) are mated by males right after ecdysis during the winter, and 2) multiparous females (carrying fully developed eggs) undergo egg hatch and either mate or use stored sperm to fertilize the new egg clutch in the spring (Colgate, pers. comm.; Paul et al. 1983). In laboratory studies, females not bred on the day of their maturity molt extruded either nonfertilized eggs or no eggs at all (Paul et al. 1983). The breeding season for C. bairdi near Kodiak Island is from January to May (Donaldson 1975).
- C. Breeding Behavior
Males and females integrate on the mating grounds. It is suspected that the male is attracted to the female by her release of a chemical or chemicals (Adams 1979). Males mate with primiparous females just after the females undergo terminal molt to maturity. This puberty molt occurs only once in the female's life (Ito 1963, Watson 1972). Spermatozoa are then transferred to and stored in the female's seminal receptacles. Eggs released during future ovulations may be fertilized by spermatozoa stored since the first mating. If the female is unattended by a male during her molt to maturity, ovulation may occur; however, the eggs will remain infertile (Adams 1979). In captivity, old-shell female C. bairdi can mate as multiparous females or produce normal-size

egg clutches of viable eggs utilizing sperm stored for two years (Paul et al. 1983). These characteristics are not known for C. opilio. Male Tanner crabs are capable of mating at the size at which they reach maturity (Donaldson 1975). A male may fertilize up to six females in one season (Watson 1972).

D. Age and Size at Sexual Maturity

Female C. bairdi in the Gulf of Alaska reach sexual maturity at about five years and males at six years (Donaldson, pers. comm.). Female C. bairdi undergo their final molt as they reach maturity (Donaldson et al. 1981). Studies in the Gulf of Alaska have shown that 50% of the female C. bairdi have reached maturity at 83 and 97 mm at the molt to maturity. Among male C. bairdi, 90 mm appears to be the size at which the molt to maturity occurs. Such an animal would grow to 112 mm. In the Sea of Japan, maturity of male C. opilio occurs in six to eight years (Ito 1970, Sinoda 1968). In the Gulf of Alaska, it is estimated that just over six years is required for the average male Tanner crab (C. bairdi) to reach maturity (Donaldson et al. 1981).

E. Fecundity

The fecundity of Tanner crabs increases from their first to their second reproductive year, then decreases slightly in succeeding years. Fecundity may be less the first year because of the energy requirements of the first molt (Somerton 1981). The number of eggs carried by the female is a linear function of carapace width (Hilsinger 1975). In the Bering Sea, the fecundity range for C. bairdi is from 89,000 to 424,000 eggs (NPFMC 1981) and in the Gulf of Alaska, 85,000 to 231,000 eggs (Hilsinger 1975). The fecundity of C. opilio in the Gulf of St. Lawrence has been found to range from 20,000 to 40,000 eggs (Watson 1969). The average percentages, by location, of adult females not carrying egg clutches between 1977 and 1981 were as follows: Kodiak, 5.8%; the eastern Aleutians, 2.3%; Sand Point, 3.6%; and Cook Inlet, 3.5%.

F. Frequency of Mating

Complete hardening of the shell (exoskeleton) may occur 16 to 71 days after the molt (Adams 1982). Old-shell mature females have been found capable of mating after the terminal molt (Donaldson 1977). Primiparous, or first-mating, female C. bairdi mate and deposit egg clutches from mid winter to early spring. Multiparous females hatch clutches and deposit new eggs in the spring. Primiparous females must breed within one week after the final molt in order to produce viable egg clutches (Paul 1982b). Male C. bairdi can mate twice on the same day or several times within a week in captivity. At each occurrence, males typically deposit enough sperm to fertilize several egg clutches (Paul et al. 1983). In the Kodiak area, scuba divers observed males of 70 to 160 mm (average 112 mm) carapace width grasping pubescent females. Males were always larger than the females they grasped. In the laboratory, clutches of viable eggs were produced by primiparous females whose mates were 65 to 140 mm in carapace width. Even though the sizes of the males these females mated with were

variable, over 90% had sufficient numbers of stored sperm to fertilize subsequent egg clutches (ibid.).

G. Incubation Period/Emergence and Larval Development

Eggs are fertilized as they are released and are retained in the brood chamber, where they remain 11 months to a year (Bartlett 1976, Somerton 1981). The spring egg hatch is synchronized to the availability of prey food (Ito 1967, Watson 1970). Egg hatching (larval release) appears to coincide with plankton blooms (NPFMC 1981). Peak hatching in the Bering Sea occurs in mid May (Drury 1980). In the southeastern Bering Sea, larvae of C. opilio appeared in plankton two weeks prior to the hatchout of C. bairdi. Larval development of Tanner crab is dependent upon the temperature regime and the condition of the plankton on which they feed (Incze et al. 1982). Planktonic larvae molt and progress through several distinct stages prior to settling to the bottom as juveniles. Growth rates from the larval to the juvenile stages are dependent upon temperature (NPFMC 1981). In Wakasa Bay (Sea of Japan), the developmental period between the larval and juvenile stages for C. opilio may last about 63 days at water temperatures of 11 to 13°C (Kon 1970). The duration of the development to each zoeal stage is a minimum of 30 days (Incze et al. 1982). The duration of the megalops stage may be longer than 30 days for larvae of both C. opilio and C. bairdi (ibid.). The size of juvenile crabs between molts increases from about 25 to 36% for each of the first six molts preceeding the molt to maturity (Donaldson et al. 1981).

VII. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

A. Larvae

Tanner crab larvae are planktonic. Plankton studies indicate that larvae undergo diurnal vertical migrations in response to the movement of the plankton bloom (ibid.). Distribution of Chionoecetes (spp.) in the Sea of Japan is associated with upwelling (Abe 1977). In the Sea of Japan, where spawning occurs from January to April, prezoae (Chionoecetes spp.) move from depths of 225 to 275 m almost directly toward the sea surface after phototaxis (Kon 1967). From March to May in the Sea of Japan, crabs at the second zoea stage inhabit depths of 25 to 100 m, and in May they drop to about 150 to 200 m as a result of increasing sea-surface temperatures (Kon 1982). In the Sea of Japan, the metamorphosis from the second zoea stage to megalops occurs in early April at 150 to 200 m, where the temperature ranges from 6 to 12°C. After metamorphosis, zoeae move to a deeper stratum (Kon 1969). In the southeastern Bering Sea, sea ice may influence the distribution of C. opilio by affecting the food supply and phytoplankton bloom (Somerton 1982). Larvae do not show distinct depth stratification by size, although the species form aggregations of like individuals at the same stage of development upon metamorphosis. Distribution of megalops is patchlike on the substrate, where like groups seek a particular

habitat, and are not arranged as bands along depth contours (NPFMC 1981). The direction and magnitude of currents in the Bering Sea do not transport C. opilio and C. bairdi larvae off the continental shelf (Kinder and Schumacher 1982).

B. Juvenile

Environmental factors such as ocean currents and water temperature determine the depth and location at which juvenile Tanner crabs settle (Adams 1979). Juveniles settle out along the sea bottom at depths between 298 and 349 m (Ito 1968). The distribution of juvenile crabs is widespread (NPFMC 1981). The relative abundance of adults and juveniles differs between species: for C. opilio, some areas where juveniles are found to occur harbor few adults. Both juvenile and adult C. bairdi occur concurrently throughout their range in the eastern Bering Sea. In Bristol Bay, mature C. opilio and C. bairdi are sedentary and remain in identifiable cohorts near the area where they mature.

C. Adults

Tagging studies show that adult C. bairdi perform only limited movements, which average 15 mi around Kodiak (Donaldson, pers. comm.), that are neither directional nor clearly seasonal. Mature males perform their seasonal breeding migration apparently at random, possibly guided by pheromones released by the female. In the Bering Sea, C. bairdi segregate by size group. At about five years of age for females and six years of age for males, the two sexes separate into sex-specific schools (ADNR/USFWS 1983). Female C. tanneri are sedentary and males migratory. During winter (from Washington to California), males move to depths occupied by females for breeding and return to shallow water after a short period of mixing with females (NPFMC 1981). Distribution of C. opilio is related to the edge of the sea ice in the eastern Bering Sea, as the sea ice affects phytoplankton bloom and food availability (Somerton 1982).

VIII. FACTORS INFLUENCING POPULATIONS

A. Natural

1. Predation. Most information regarding predation is on larval crabs. Few reports are available on the predation of juveniles and adults. The best data are available for C. opilio, C. bairdi, and C. opilio elongatus. A total of 37 predators have been documented as preying upon the genus Chionoecetes from different areas. Predators include at least 7 species of invertebrates, 26 species of fish, and 4 species of marine mammals (Jewett 1982).
 - a. Eggs. Predation on eggs by the nemertean worm (Carcinonemertes spp.) has been documented (Hilsinger 1975).
 - b. Larvae and juvenile. Chionoecetes (spp.) is the most frequently reported predator upon Chionoecetes. Large crabs (greater than 40 mm CW) near Kodiak Island were more cannibalistic than small crabs (less than or equal

to 40 mm). Red king crabs (Paralithodes camtschatica) have been documented in Kodiak and the Bering Sea as predators of Tanner crabs where distributions overlap. In the Kodiak area, stomachs of king crabs greater than or equal to 65 mm CW contained juvenile C. bairdi. Tanner crabs have also been documented as dominant prey for Bering skates (Raja interrupta), Alaska skates (R. parmifera), and wottled eel pouts (Lycodes palearis). C. bairdi from 1.8 to 70 mm CW have been documented as the most frequently occurring prey for Pacific cod taken near Kodiak Island during the months of June and July. An estimate of 1.5×10^{10} crabs are eaten annually by the Kodiak cod population of 6.9×10^7 fish (Jewett 1982). Tanner crabs have comprised a large percentage of diets for four species of sculpins (cottidae). In the Gulf of Alaska and Kodiak Island area, yellow Irish lords (Hemilepidotus jordani) and the great sculpin (Myoxocephalus polyacanthocephalus) preyed significantly upon Tanner crabs. The great sculpin seems to prefer mature female Tanner crabs (Hilsinger, pers. comm.). Flatfishes (Pleuronectidae), particularly the rock sole (Lepidopsetta biliniata), were found to feed on Tanner crabs. In the northerly areas of the Bering Sea, Tanner crabs are especially important as prey of bearded seals (Jewett 1982).

- c. Adult. Predators upon adults include Pacific cod and octopuses (Ellson et al. 1950). Adults appear to have few predators, although those in molt would be vulnerable to large fish, octopuses, and sea stars (Hilsinger, pers. comm.).

2. Diseases:

- a. Black Mat Syndrome. BMS, or Trichomaris invadens, is a marine fungus that has been found to infect Tanner crab, primarily in the Gulf of Alaska. Black tarlike modules encrust the shell and may break off into the meat during processing. The fungus appears to be debilitating, possibly inhibiting molting, and is believed to be fatal to the animal (Hicks 1982, Sparks and Hibbits 1978).
- b. Rust disease. Chitin-digesting bacteria induce lesions on the crab shell that soften, pit, and blacken the shell. Examination of chitin-digesting bacterium on Oregon crabs indicates that 47% were photobacterium sp. (Grischkowsky and Follett 1982).
- c. Other bacterial agents. Studies performed by the ADF&G indicate that Pseudomonas sp., Moraxella sp., and Flavobacterium sp. proved lethal to Tanner crab under laboratory condition (ibid.).

B. Human-related

A summary of possible impacts from human-related activities includes the following:

- Alteration of preferred water temperatures, pH, dissolved oxygen, and chemical composition
 - Alteration of preferred substrate
 - Alteration of intertidal areas
 - Increase in suspended organic or mineral material
 - Reduction in food supply
 - Reduction in protective cover (e.g., seaweed beds)
 - Obstruction of migration routes
 - Shock waves in aquatic environment
 - Human harvest (including handling of nonlegal crabs)
- (See the Impacts of Land and Water Use volume in this series for additional information regarding impacts.)

IX. LEGAL STATUS

A. Managerial Authority

The Tanner crab resource is managed under a joint State-Federal Fisheries Management Plan covering all management areas. The Alaska Department of Fish and Game regulates the fishery in areas where most fishing occurs in territorial waters (Lower Cook Inlet, Prince William Sound, Yakutat, Southeast Alaska) and manages jointly with the National Marine Fisheries Service (NMFS) where significant fisheries exist beyond 3 mi. In Kodiak, south Peninsula, Aleutians, and Bering Sea areas, both state and federal emergency orders are jointly issued to close or open fisheries. The NMFS manages the foreign fishery, and both state and federal management regimes are guided by policies in the Fishery Management Plan developed by the North Pacific Management Council in coordination with the Alaska Board of Fisheries (McCrary 1984).

X. LIMITATIONS OF INFORMATION

Little information is available on the early life history of the Tanner crab, its migrational patterns, and the causes of its mortality. Reliable techniques for calculating the age of Tanner crabs need to be developed.

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C. Abbreviations

ACMP	Alaska Coastal Management Program
ADCED	Alaska Department of Commerce and Economic Development
ADCRA	Alaska Department of Community and Regional Affairs
ADEC	Alaska Department of Environmental Conservation
ADF&G	Alaska Department of Fish and Game
ADL	Alaska Department of Labor
ADNR	Alaska Department of Natural Resources
ADR	Alaska Department of Revenue
AEIDC	Arctic Environmental Information and Data Center
AOU	American Ornithological Union
BBCMP	Bristol Bay Cooperative Management Plan
BLM	Bureau of Land Management
CFEC	Commercial Fisheries Entry Commission
CIRPT	Cook Inlet Regional Planning Team
EPA	Environmental Protection Agency
EPS	Environmental Protection Service (Canada)
ERL	Environmental Research Laboratory
FAO	Food and Agriculture Organization of the United Nations
GMS	Game Management Subunit
GMU	Game Management Unit
IMS	Institute of Marine Science
INPFC	International North Pacific Fisheries Commission
IPHC	International Pacific Halibut Commission
IUCN	International Union of Conservation of Nature and Natural Resources
ISEGR	Institute of Social, Economic and Government Research
LCI	Lower Cook Inlet
MMS	Mineral Management Service
NEGOA	Northeast Gulf of Alaska
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration

NPFMC	North Pacific Fishery Management Council
NPS	National Park Service
NWAFIC	Northwest and Alaska Fisheries Center
NWR	National Wildlife Refuge
OCSEAP	Outer Continental Shelf Environmental Assessment Program
OMPA	Office of Marine Pollution Assessment
PWS	Prince William Sound
PWSRPT	Prince William Sound Regional Fisheries Planning Team
UCI	Upper Cook Inlet
USDC	United States Department of Commerce
USDA	United States Department of Agriculture
USDI	United States Department of Interior
USDL	United States Department of Labor
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service

D. Wildlife Management Goals and Objectives

The following are the goals and subgoals that form the basis for wildlife management by the Alaska Department of Fish and Game. The first goal applies to all species managed by the department. Application of the second goal and the selection of one or more of its subgoals varies by species and/or area managed.

Outline: WILDLIFE MANAGEMENT GOALS*

- I. TO PROTECT, MAINTAIN AND ENHANCE WILDLIFE POPULATIONS AND THEIR HABITATS FOR THEIR INTRINSIC AND ECOLOGICAL VALUES SO ESSENTIAL TO THE MAINTENANCE OF A HEALTHY ENVIRONMENT AND THE WELFARE OF MAN.
- II. TO PROVIDE FOR OPTIMUM BENEFICIAL USE OF WILDLIFE BY MAN.
 - A. To provide for subsistence use of wildlife by Alaskan residents dependent on wildlife for sustenance.
 - B. To provide for diversified recreational uses of wildlife.
 - C. To provide for scientific and educational use of wildlife.
 - D. To provide for commercial use of wildlife.

* Source: 1980 ADF&G Wildlife Management Goals.

WILDLIFE MANAGEMENT GOALS

- I. TO PROTECT, MAINTAIN AND ENHANCE WILDLIFE POPULATIONS AND THEIR HABITATS FOR THEIR INTRINSIC AND ECOLOGICAL VALUES SO ESSENTIAL TO THE MAINTENANCE OF A HEALTHY ENVIRONMENT AND THE WELFARE OF MAN.

Wildlife and man are interdependent constituents of an environment shared with all other living things. Recognition of this fundamental relationship is reason enough to preserve wildlife and to maintain its natural role in the environment. In addition, there is great value in assuring for man's benefit and enjoyment the continuance of an environment as biologically rich and diverse in the future as in the present. For the people of the State and the Nation Alaska's wildlife is an invaluable source of inspiration, sustenance, and recreational and economic benefits. It is capable of providing benefits to man in perpetuity if its welfare is safeguarded. Because wildlife is especially vulnerable to human activities, it requires the most careful stewardship man can provide.

The foremost consideration in protecting and maintaining indigenous wildlife populations is providing habitat in the amount, kind and quality necessary to meet the requirements of wildlife species. Wildlife populations cannot survive without adequate habitat, and efforts to protect animals directly without also protecting their habitat or correcting habitat deficiencies often prove to be ineffectual.

Alteration of habitat is one primary way man affects wildlife populations. Although some species can inadvertently benefit from certain habitat alterations resulting from man's activities, many others can be adversely affected. Long-term habitat degradation usually results in reduced numbers and fewer species of wildlife. Even where habitat are purposely modified to benefit populations of particular species, reductions in populations of other species may be unavoidable.

Protection, maintenance, and manipulation of wildlife habitat are important management activities of the Department. Important wildlife habitats will be identified and protective legislation, classification or designation of such habitats will be sought. Land management agencies, organizations, and individuals will be encouraged to protect wildlife habitats from degradation or to minimize adverse impacts of development or other land uses on land under their control. Where appropriate, habitat may be restored or improved to enhance selected wildlife populations.

Wildlife as well as its habitat must be protected from the detrimental influences of man. Disturbances injurious to wildlife must be minimized. Competition and conflicts with domestic animals must also be minimized and the introduction of undesirable exotic animals avoided. The introduction of diseases carried by domestic animals, transplanted wild animals, or animals kept as pets must be prevented. Use of wildlife must be regulated to ensure that allowable use tolerances are not exceeded. Illegal and wasteful uses

must be controlled to assure protection of the resource and to maximize human benefits from its use.

Greater public appreciation for and awareness of wildlife and its requirements are necessary for public support for effective programs to protect and benefit wildlife. Successful, progressive wildlife management requires objective decisions based on the best biological information that can be gathered by competent professionals.

II. TO PROVIDE FOR OPTIMUM BENEFICIAL USE OF WILDLIFE BY MAN

Optimum beneficial use of wildlife is that use which 1) does not adversely affect the wildlife populations, 2) results in desirable products of use, and 3) is based on desirable allocations of such products among users. Such use, in the aggregate, serves to maximize benefits to be people of Alaska and the Nation.

Depending on the objectives of management, there are many levels and kinds of use which can be considered "optimum". Wildlife can support a variety of uses on a continual basis so long as its capability to sustain such use is not impaired. Because values placed upon wildlife vary, management must provide opportunities for an array of different uses if benefits are to be realized by all concerned. Also, because there are finite limits to wildlife populations and the uses they can support, management must provide for simultaneous uses wherever possible if benefits are to be optimized. Although different uses are generally compatible, some conflicts do occur, and sometimes provision for some uses may require the exclusion of others. Regulatory separation of incompatible uses in time and space can reduce conflicts and facilitate an optimum level and mix of beneficial uses.

Attainment of the following subgoals should ensure that the people obtain optimum beneficial use from Alaskan wildlife.

SUBGOAL A. To provide for Subsistence Use of Wildlife by Alaskan Residents Dependent on Wildlife for Sustenance.

Direct domestic utilization of wildlife is important to many residents for sustenance and to many other citizens as a valuable food supplement. Beyond directly satisfying food requirements, domestic utilization of wildlife helps preserve Alaskan cultures and traditions and gives gratification to the strong desire of many Alaskans to harvest their own food. These attributes of subsistence use are considered genuinely important to the physical and psychological well-being of a large number of Alaskans. Accordingly, subsistence receives priority among the various beneficial human uses.

Within legal constraints and the limits of resource capabilities, wildlife will be allocated to subsistence users on the basis of need. Needs of individuals, families, or cultural groups differ in type and degree and it is recognized that subjective judgement will be an unavoidable necessity in establishing actual need. Elements considered in establishing the level of

need include cultures and customs, economic status, alternative resources (including availability of social services), place of residence, and voluntary choice of life style. Limitations on the productivity of wildlife stocks may limit continued increases in the number of subsistence users.

In some circumstances subsistence users also may be participants in recreational or commercial harvesting. Where subsistence users can satisfy their needs by recreational or commercial methods, special regulations for subsistence priority should be achieved by existing regulatory techniques, such as open and closed seasons, bag limits, control of methods and means of take, and controlled use areas. Even when special regulations are necessary, commercial and recreational uses might not need to be prohibited entirely prior to any restrictions on subsistence uses. But, in any case, traditional and customary subsistence users would continue to receive a priority harvest opportunity in regulatory systems.

Management of wildlife populations for subsistence use may involve manipulation of the numbers and/or sex and age structure of the population. Where possible, differential use or sex or age segments of wildlife populations will be used to accommodate subsistence or other use demands. Wildlife populations generally will be managed to optimize sustained productivity. Recreational and commercial uses will be permitted where and to the extent that they do not interfere with or preclude subsistence resource use.

SUBGOAL B. To Provide for Diversified Recreational Uses of Wildlife

In many areas of the state, recreation, in its various forms, is the dominant use of wildlife. In addition to sport hunting and trapping, recreational uses include observation and photography, both incidental to other activities and as the primary objectives, and wilderness experience, including the aesthetic rewards of being aware of or observing animals in natural interactions with their environment. The Department has the responsibility to provide for these diverse, yet generally compatible uses.

The emphasis of management for recreational use will be to provide opportunities for varied recreational experiences rather than to maximize the yield of animals, even though success in observing or taking animals is recognized as an important element in user satisfaction. Varied experiences are often provided through de facto differences in biological, physical, and demographic characteristics of various areas and through regulated factors such as participation rates, methods and means of use, timing of use, and bag limits.

Quality of experience is an important concern to many recreational users. Although aesthetics are a matter of individual preference, elements of quality most commonly identified include low user densities, controlled methods of transport, undisturbed wilderness character, minimal intrusions by other users, and a reasonable expectation of success. The opportunity to observe or be selective for large animals is another aesthetic consideration which may add significantly to the recreational experience.

At the other end of the recreational use spectrum are those uses allowing unrestricted opportunities for user participation. Beyond limiting use to optimum sustained yield levels, management for maximized opportunity provides for unlimited participation and traditional freedom of choice of access methods.

SUBGOAL C. To Provide for Scientific and Educational Use of Wildlife.

The Alaskan environment, including its wildlife, is a unique natural laboratory for the scientific study of ecosystems and wildlife biology, and for the educational enrichment of the people. Such studies are necessary to achieve a scientific basis for identifying and evaluating management options. Scientific study and education have taken place in many areas of Alaska, reflecting the general compatibility of such use with other uses of wildlife. Occasionally, undisturbed or closely controlled conditions are necessary study requirements and justify the designation of areas primarily for scientific and educational purposes. Requirements for such actions specify the extent to which other uses, both consumptive and nonconsumptive, would be encouraged or restricted. In some cases, intensive population or habitat manipulation may be necessary to achieve study objectives.

SUBGOAL D. To Provide for Commercial Use of Wildlife.

Commercial use of wildlife includes the direct consumptive and non-consumptive use of animals where sale of the products or by-products of animals is the primary objective. Indirect commercial use includes services which support recreational or other noncommercial users, and marketing systems utilized for wildlife products. Direct commercial use of wildlife in Alaska today is limited primarily to furbearers and marine mammals which have traditionally supported such use. Principal service industries include guiding, taxidermy, meat processing, photography, and wildlife-related tourist services.

Commercial uses of furbearer and marine mammal resources, responsible for much of the early exploration and settlement of Alaska, still support important industries in rural areas of the state and provide needed supplemental income to many bush residents. However, changing economic and social values and the increasing importance of recreational uses generally are reducing the relative economic importance of direct commercial uses of wildlife. On the other hand, industries serving the continually growing recreational uses of wildlife are becoming more important.

Management will provide for commercial use of wildlife only when it does not threaten the welfare of any wildlife resource, when it is in the economic interest of the people of Alaska, and when it is compatible with other uses. Where commercial use conflicts with other uses it will usually be restricted or eliminated in favor of other uses. Commercial activities which depend on recreational users will usually be restricted or eliminated in favor of other uses. Domestication of wildlife for commercial purposes usually will be opposed, but where allowed it will be strictly regulated to prevent abuse to the resource or inhumane treatment of individual animals.

WILDLIFE MANAGEMENT OBJECTIVES*

Based on these wildlife management goals and subgoals, objectives for the strategic management plans of individual species are selected from the following:

To protect, maintain, and enhance the (species) population in concert with the components of the ecosystems and to assure its capability of providing sustained opportunities to

- 1) view and photograph wildlife;
- 2) subsistence use of wildlife;
- 3) participate in hunting wildlife;
- 4) hunt wildlife under aesthetically pleasing conditions;
- 5) be selective in hunting wildlife;
- 6) scientific and educational study of wildlife;
- 7) commercial use of wildlife;
- 8) protect human life and property in human-wildlife interactions.

Management objectives vary not only according to the concerned species, but also, in many cases, according to the areas involved and the demands made upon the wildlife resource. Because these demands can change with the passage of time, particular management objectives may need to be revised.

Examples of management guidelines are presented in the individual strategic management plans. These guidelines are used to qualify or quantify in a more specific way the recommended management under a specific set of objectives for any particular area. The guidelines are statements about the following:

1. The wildlife population: its size, sex, age structure, and productivity.
2. Use: season length and timing, bag limits, number or distribution of hunters or other users, access, transport, viewing, and aesthetic enjoyment.
3. Habitat: alteration or protection.

* Departmental memo, ADF&G, Division of Game, June 14, 1980.

E. Sea Ice

I. DEFINITIONS OF ICE TERMS

This selective list of ice-related terms is taken from the Handbook for Sea Ice Analysis and Forecasting (Stringer et al. 1984) and is consistent with World Meteorological Organization definitions (Stringer, pers. comm.). Terms are arranged to describe the various stages of growth of ice and the various forms and conditions of ice.

New ice. This term includes frazil ice, slush, grease ice, and shuga, all categories of ice up through a thickness of 10 cm. Only grease and slush ice will be defined here.

Slush. Slush is snow that has fallen into sea water that is colder than the snow's melting point, thus creating a viscous floating mass of ice crystals in the water.

Grease ice. When the fine needles, or platelets, of ice first formed in the freezing process (frazil ice) coagulate to form a soupy layer at the sea surface, it reflects less light, has a dark matte appearance, and is called grease ice.

Pancake ice. When new ice (or occasionally even thicker ice) is broken up by swells, roughly circular pieces from 30 cm to 3 m in diameter and up to 10 cm thick often form. These pancakes have a raised rim as a result of striking and rubbing against each other in the swell.

Young ice. The thickness of young ice ranges from 10 to 30 cm. It is subdivided into gray ice (10-15 cm, likely to raft under pressure) and gray-white ice (15-30 cm, likely to break up and form a pile or ridge of broken ice under pressure).

First-year ice. Young ice that is greater than 30 cm in thickness but that has not gone through a melt season is called first-year ice.

Old ice. Old ice has survived at least one melt season and is divided into second-year ice and multiyear ice, although the term multiyear ice is often used to refer to all old ice. Old ice is stronger than ice that has not been through a melt season, when pockets of brine trapped in the ice during the freezing process drain.

Fast ice. Also called landfast ice, fast ice is sea ice that has formed along or become attached to the shore or shoals and that does not move horizontally with respect to the shore, although it may move vertically with fluctuations in sea level. Fast ice can form in place or can be from the attachment and consolidation of individual floes of any age. It may extend a few meters or several kilometers from shore. In shallow water, fast ice may

be attached to the bottom (anchor ice) but in deeper water, especially toward its seaward edge, it may be floating.

Flaw. The flaw is the line between the fast ice and drift ice. A variety of conditions may be found in the flaw zone. It may consist of a series of polynyas (see definition below) along the fracture separated by linear regions where drift ice has been piled into a shear ridge (see definition below). Regions of the flaw may be filled with small pieces of floating ice (brash ice) or may refreeze with new or young ice.

Drift ice. This very broad term includes any ice other than fast ice regardless of its arrangement.

Pack ice. Pack ice is drift ice that covers 70% or more of the sea surface.

Fracture. A fracture is any break or rupture, regardless of width, through fast ice, pack ice covering 90% or more of the sea surface, or even a single ice floe. Fractures may be filled with brash ice or young ice. The sides of a fracture usually look as though they could be rejoined to form a uniform ice sheet.

Crack. A fracture less than 1 m in width is a crack.

Lead. A lead is a fracture sufficiently wide to permit navigation by surface vessels. A shore lead or flaw lead is located between the drift ice and the fast ice. The term lead is often incorrectly used interchangeably with fracture.

Polynya. A polynya is an irregularly shaped opening enclosed by ice. As opposed to a fracture, the sides of a polynya could not be refitted to form a uniform ice sheet. Polynyas may contain brash ice or young ice. A recurring polynya is one that occurs at approximately the same location every year.

Shear ridge. Shear ridges are usually sinuous piles of ice created as a result of differential motion between two regional ice bodies (often the drift ice against the fast ice). The shear zone is an area of many parallel bands of piled ice, often with vertical walls 2 to 3 m in height.

Pressure ridge. Pressure ridges are relatively short, somewhat irregular piles of ice and are usually more local in nature than shear ridges. They are usually the result of purely compressional forces within the ice rather than of compression plus sliding.

Rough or flat ice. The topography of both fast ice and drift ice is described subjectively by the terms rough or flat ice but can be more precisely defined by giving the percentage of the ice within the area of interest that is deformed from the horizontal and the relief or height of the deformed areas.

II. THE ICE YEAR

The following discussion is taken primarily from Burns et al. (1981) and Stringer et al. (1980) and the references therein.

A. Autumn.

In September or early October, new ice begins to form inshore in the Beaufort Sea, beginning earlier in the west than in the east. In most years, extensive new ice forms in the Chukchi Sea by mid October and by late November or December in the northern Bering Sea. Up to a month before the formation of new ice in the Bering Sea, a few large chunks of multiyear ice from the polar pack drift southward through Bering Strait; they often strand on the north coast of St. Lawrence Island. Surface waters may become supercooled with the frequent strong northerly winds and high seas, with anchor ice formed along exposed coasts and broad strips of grease and slush ice formed at sea parallel to the wind. During calm periods, vast areas of new and young ice form, which raft when compressed by subsequent wind and swells. Protected embayments (e.g., Kotzebue Sound, Port Clarence, Norton Bay) are the first to be iced over completely.

B. Winter.

The winter drift ice is a highly dynamic ice sheet that moves primarily southward. Primarily northerly and northeasterly winds push it against the northern coasts of Alaska and Chukotka, forming extensive masses of jumbled, grounded ice inshore. Although some movement of ice in the Bering Sea is toward the north when the wind is from the south, the net transport of ice is toward the south in winter and early spring. As the drift ice pushes through Bering Strait, it is compressed into pressure ridges in the middle and shear ridges at the edges. South of the strait is a divergence zone, an area of low or no compression; numerous fractures and polynyas develop as the pack expands. New ice forms in the openings, adding to the mass of the pack as it advances.

Not all of the ice in the Bering Sea is derived from the Chukchi; most of it is generated in the Bering Sea itself. The prevailing northerly wind that piles ice in deep, dense masses on the north side of Chukotka, St. Lawrence Island, the Seward Peninsula, and St. Matthew and Nunivak islands also blows the ice away from their southern coasts, forming recurring polynyas where new ice continually is generated.

Near shore, especially in sheltered bays, a sheet of landfast ice forms; the flaw is the area where the relatively stable fast ice interacts with the moving pack ice. Depending on the rate and direction of movement of the pack, the flaw may be a narrow fracture a few millimeters wide or a zone tens of kilometers wide including large amounts of brash and new ice.

At its southern edge, the pack tends to be open and made up of smaller floes than farther north. Tongues of broken and melting ice extend several kilometers into the open sea, forming the ice "fringe." For several kilometers back into the pack from the fringe zone, the ice is subjected to ground swells from the open sea that break up large ice fields, creating large amounts of brash in the interstices and defining the ice "front" zone.

The principal general categories of sea ice habitats used by marine mammals are 1) fast ice, 2) persistent flaw, 3) polynyas that are centers of new ice formation, 4) divergence zones, and 5) the ice front.

C. Spring.

The sea ice generally reaches its southernmost limit for the year in late March or April. The maximum southern extent of the ice can vary by as much as 6° of latitude (about 665 km) from year to year but tends to be not far from the southern edge of the continental shelf in most years.

Although the ice continues to move generally southerly and southwesterly in April, leads and polynyas become larger because the increasing temperature precludes the formation of new ice in polynyas and divergence zones. By late April, winds in the Bering Sea become more variable and weaker, and the ice stops moving south. By mid to late May, rising surface water temperatures have melted thin ice, and numerous holes have formed in thicker floes. In years of maximal advance of the ice (heavy ice years), the rate of melting of the pack is slower than in years of less extensive ice formation. By the end of May, the ice sheet that covered nearly the entire shelf of the Bering Sea is reduced to a few rafted remnants of heavy, broken ice that cover less than one-fourth of that area, and these too disappear in June or early July.

In the Chukchi Sea, the pack remains largely intact through April, although the flaw along the Alaskan coast becomes more persistent and ice-free in March and April. Slightly later, an increasingly evident east-west fracture pattern develops in the southern Beaufort Sea from Barrow toward Banks Island. Usually by late May or early June, the southern part of the Chukchi pack loosens significantly, probably due to the influx of warmer water from the now nearly ice-free Bering. By the end of July, the Chukchi pack is usually reduced to one-third or less of its former extent, and by August, even the Beaufort shows extensive opening.

D. Summer.

The ice sheet is at its annual minimum in late summer, when it exists primarily over the abyssal part of the Arctic Ocean but also extends southward over the continental shelves of the northernmost continents and islands. It is relatively thick and old, comprised mostly of multiyear accumulations of sea ice and glacial ice from the Greenland and Ellsmere ice caps. The polar pack moves generally clockwise around the polar basin (i.e., from east to west off northern Alaska). The average rate of movement of the polar pack relatively nearshore in the Beaufort Sea is on the order of 10 km/day.

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