Alaska Habitat Management Guide

Southcentral Region
Volume I:

Life Histories and Habitat Requirements of Fish and Wildlife

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

Juneau, Alaska
1985

Contents

Volume 2 contains narratives on the distribution, abundance, and human use of selected species of fish and wildlife.

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Acknowledgements

This project is under the direction of the Commissioner of the Department of Fish and Game, Don W. Collinsworth, the Director of the Division of Habitat, Norman Cohen, and the Deputy Director, Bruce H. Baker.

Many individuals have been involved in the production of this second Alaska Habitat Management Guide. All narratives were reviewed first by project staff and distributed for both technical and departmental reviews. The names of reviewers and other contributors are compiled in appendix A in volume 2.

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* LH=life history and habitat requirements; DA=distribution and abundance; HU-C=human use-commercial fishing; HU-T=human use-trapping; HU-H=human use-hunting; HU-P=human use-personal use/subsistence fishing; HU-S=human use-sportfishing.

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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 Carl Yanagawa, Regional Supervisor of the Division of Habitat for the Southcentral Region (Region II), 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 untimely death earlier this year.

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 progress 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

This project presents 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.

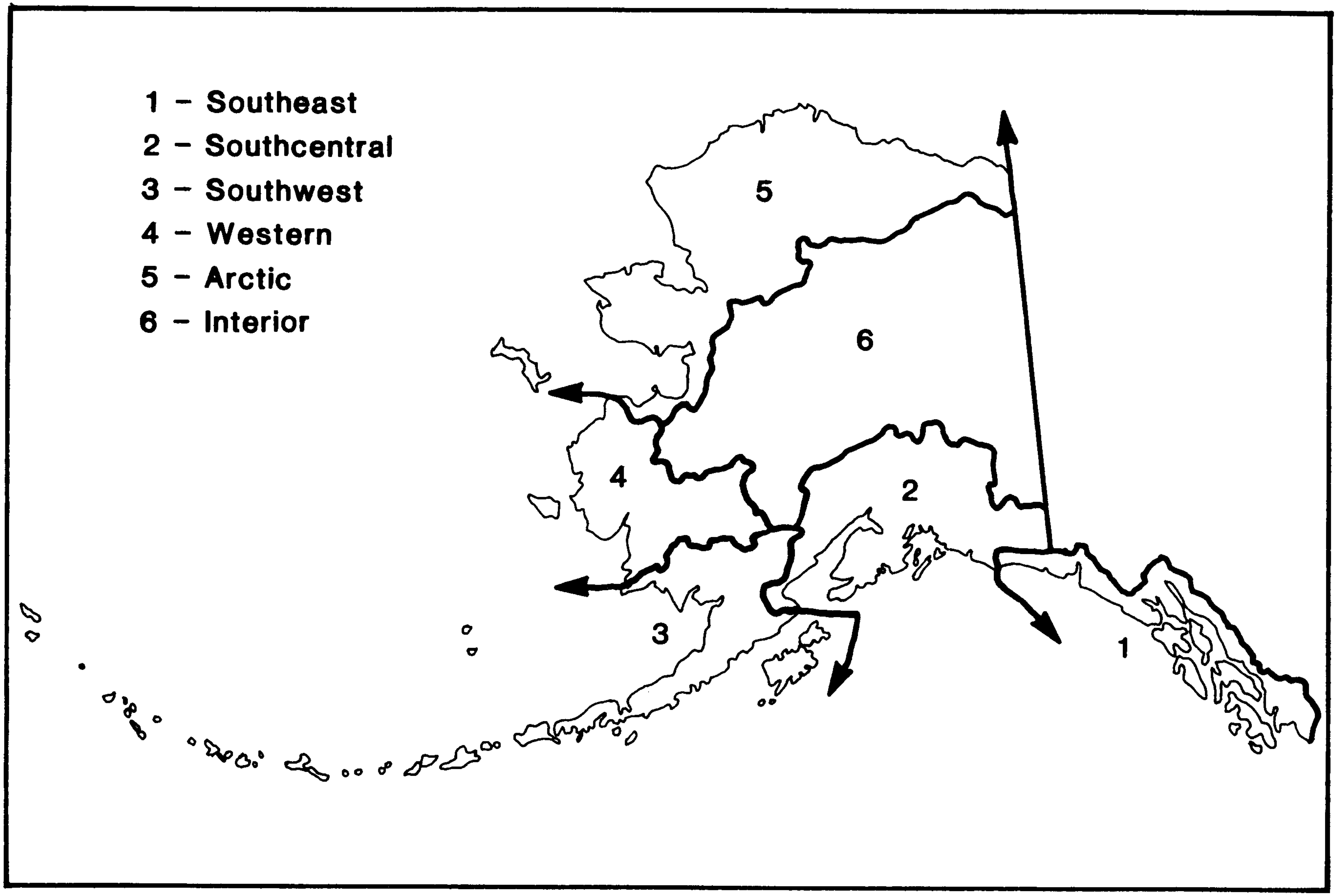
Essential to assessing what might happen to fish and wildlife if their habitats are altered is information about what effects or impacts are typically associated with particular kinds of developmental activities. The habitat management guides therefore also provide summaries of these known effects. This 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 (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 indicated in figure 1. Material from the project's database can be used,



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

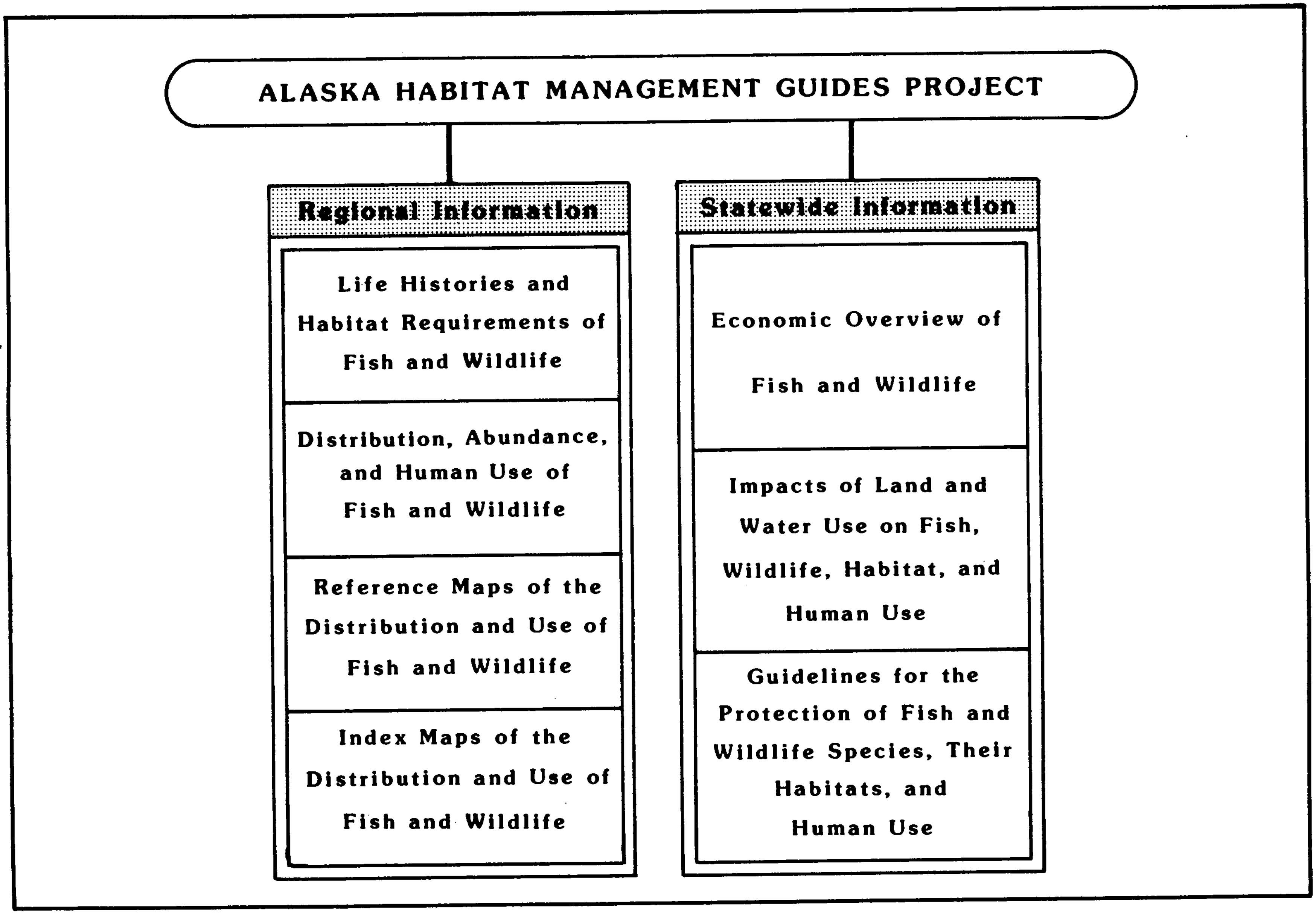


Figure 1. Types of narratives and maps produced by the Alaska Habitat Management Guides Project.

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 Guides Volumes

The guides reports on impacts and guidance are being developed as statewide volumes, in which information is presented for statewide as well as for specific regional concerns. The statewide volume on impacts will summarize the effects of major types of development activities and land and water uses on fish and wildlife, their habitats, and their use by people. The activities discussed will be those actually occurring in the state or expected to occur in the future. This survey of impacts will be founded upon the most recent pertinent literature and upon the information presented in the species life histories and habitat requirements. The guidance volume will in turn be a synthesis of information based upon the impacts literature and the life history and habitat requirements information.

The following uses of land and water resources and types of development occur or are likely to occur in Alaska, and they will therefore be addressed in the statewide impacts and guidance volumes:

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

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

A statewide volume is being developed to provide an overview of the regional economies, especially in regards to uses of fish and wildlife within each region. The necessary data on the fish and wildlife related sector will be by no means complete but will nevertheless afford a conservative estimate of such values within the regions. Economic data on commercial fisheries, for example, are relatively well documented. In those regions with significant commercial fishing activity, the relative value of fish and wildlife will be better represented. However, continuing effort is being made by the department and other agencies to improve the capability of accurately describing the socioeconomic importance of fish and wildlife to the people both within and outside the State of Alaska.

A separate statewide volume describing the life history and habitat requirements of selected fish and wildlife species is being prepared region by region; therefore the information in the Southcentral guide addresses the species requirements in the Southwest and Southcentral regions. Other information will be added as reports are prepared for the remaining regions.

Southcentral Region

Organization and Use of the Guide

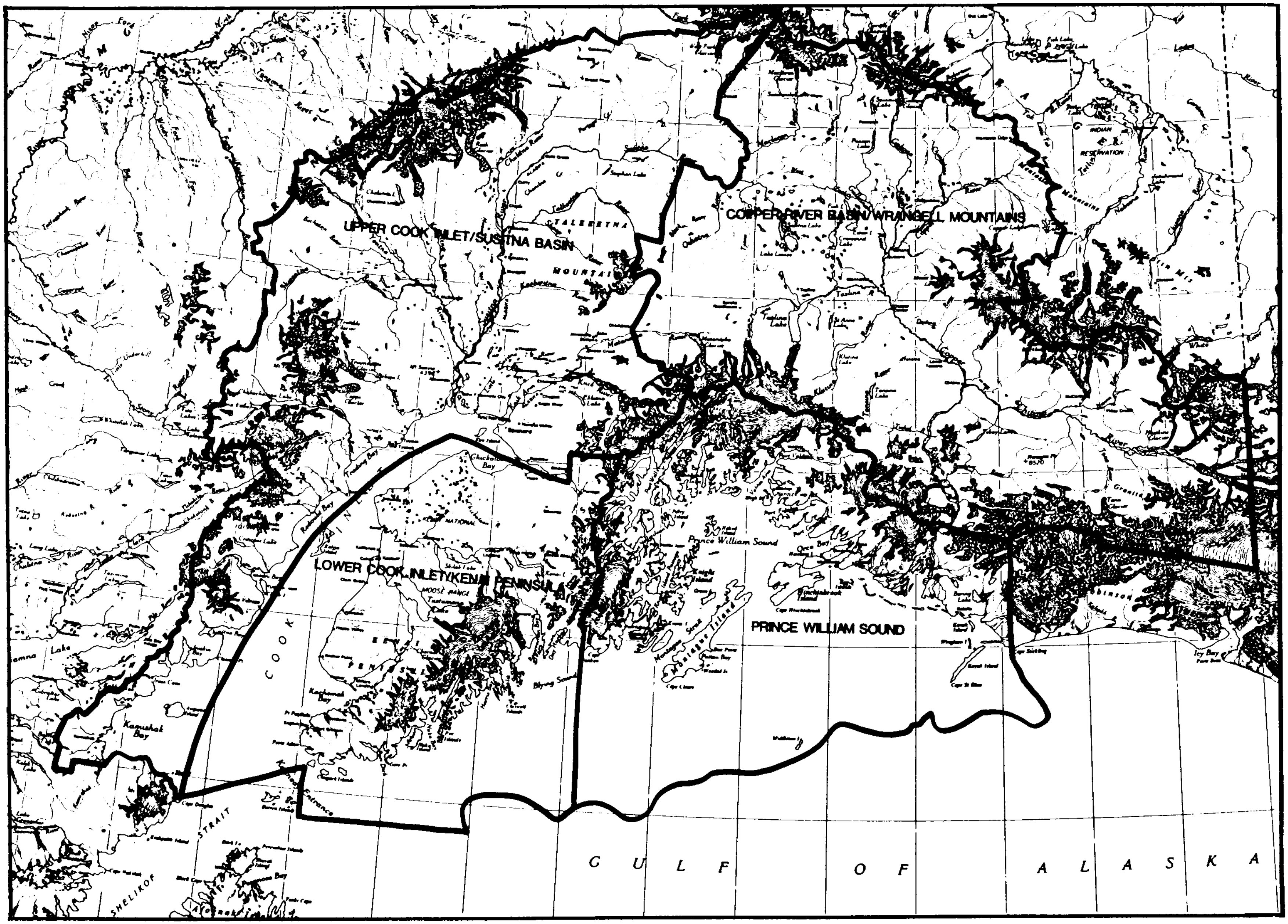
Narratives. The two narrative volumes of the guide to the Southcentral Region are closely related and interdependent. The first highlights important aspects of selected species life histories, emphasizing the interrelationships of the species with their habitats. The second, or distribution and human use volume, provides the most current estimates of species' distribution and relative abundance and delineates the regional and subregional patterns, locations, and types of human uses of fish and wildlife resources. This portion of the guide provides an understanding of the importance of fish and wildlife to the people within and outside the Southcentral Region.

The life histories include information for both the Southwest and Southcentral regions, as mentioned in the preceding overview section. For one species (Sitka black-tailed deer) we have also included habitat requirements for Southeast Alaska. The reason for the inclusion is that the most pertinent information has been collected from the Southeast Region and is largely applicable as well to the Southwest and Southcentral regions.

Because of the wide spectrum of human uses of fish and wildlife, this portion of the second volume is divided into five topical categories. These include 1) hunting and trapping, 2) commercial fishing, 3) sportfishing, 4) personal use harvest, and 5) subsistence and other local uses. For categories 1 through 4, data are presented by selected species, and the information pertains to the entire region and the specific management areas within the region, as appropriate. All reports by species are based upon data collected by the Divisions of Game, Sport Fish, and Commercial Fisheries, as well as by the Commercial Fisheries Entry Commission, the International Pacific Halibut Commission, North Pacific Fisheries Management Council, and the National Marine Fisheries Service.

For the fifth category of human use information, the Southcentral Region has been divided into four subregions (map 2) to portray community use patterns of local fish and wildlife resources. These subregions are 1) Upper Cook Inlet/Susitna Basin, 2) Lower Cook Inlet/Kenai Peninsula, 3) Copper River Basin/Wrangell Mountains, and 4) Prince William Sound. The patterns of use described in these narratives are based primarily upon community studies coordinated by the Division of Subsistence, with additional source materials from other anthropological studies on the history and patterns of activity in the subregions.

Maps. A major portion of the guides project in the Southcentral Region was committed to the production of updated fish and wildlife maps at two scales of resolution. Species distributions and human use were mapped at a reference scale of 1:250,000 and then were mapped at the index scale of 1:1,000,000. Some reference maps for marine species were actually prepared



Map 2. The four subregions of the Southcentral Region.

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 catalogues 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 the Southcentral Region, there are approximately 421 reference maps that depict fish and shellfish species distribution, wildlife species distribution, community or subsistence use of fish and wildlife, and commercial, recreational, personal, and general use of fish and wildlife.

Species Selection Criteria

Each species covered in the guides was selected because it met the following criteria: 1) its habitat is representative of some portion of the spectrum of the Southcentral Region's habitats (this criterion ensures that regional habitats are well represented); 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, abundance, and distribution was available.

Based on the above criteria and the prioritized requests of each division, the species list for the Southcentral Region was developed to include 30 individual species, plus species groups, including seabirds (25), dabbling and diving ducks (19), geese (10), furbearers (11), and shrimp (5). The individual species are as follows:

Sea otter	Arctic grayling	Halibut
Harbor seal	Arctic char/Dolly Varden	Pacific cod
Steller sea lion	Rainbow/steelhead trout	Pacific ocean perch
Sitka black-tailed deer	Lake trout	Sablefish
Caribou	Burbot	Walleye pollock
Moose	Sockeye salmon	Yellowfin sole
Dall sheep	Pink salmon	Pacific herring
Bald Eagle	Chum salmon	Dungeness crab
Trumpeter swan	Chinook salmon	King crab
	Coho salmon	Tanner crab
		Razor clam

Many other species, <u>including but not limited to the following</u>, are also important to consider when making land or water management decisions or plans:

Brown bear	Black bear	Northern pike
Mountain goat	Wolf	Whitefish
Beaver	Lynx	Cutthroat trout

Land otter	Marten	Eulachon
Mink	Humpback whale	Lingcod
Minke whale	Belukha whale	Hardshell clams
Fin whale	Killer whale	Starry flounder
Dall porpoise	Harbor porpoise	Sand lance
Peregrine falcon	Osprey	Stickleback
Ptarmigan	Grouse	Sculpin

Overview of the Southcentral Region

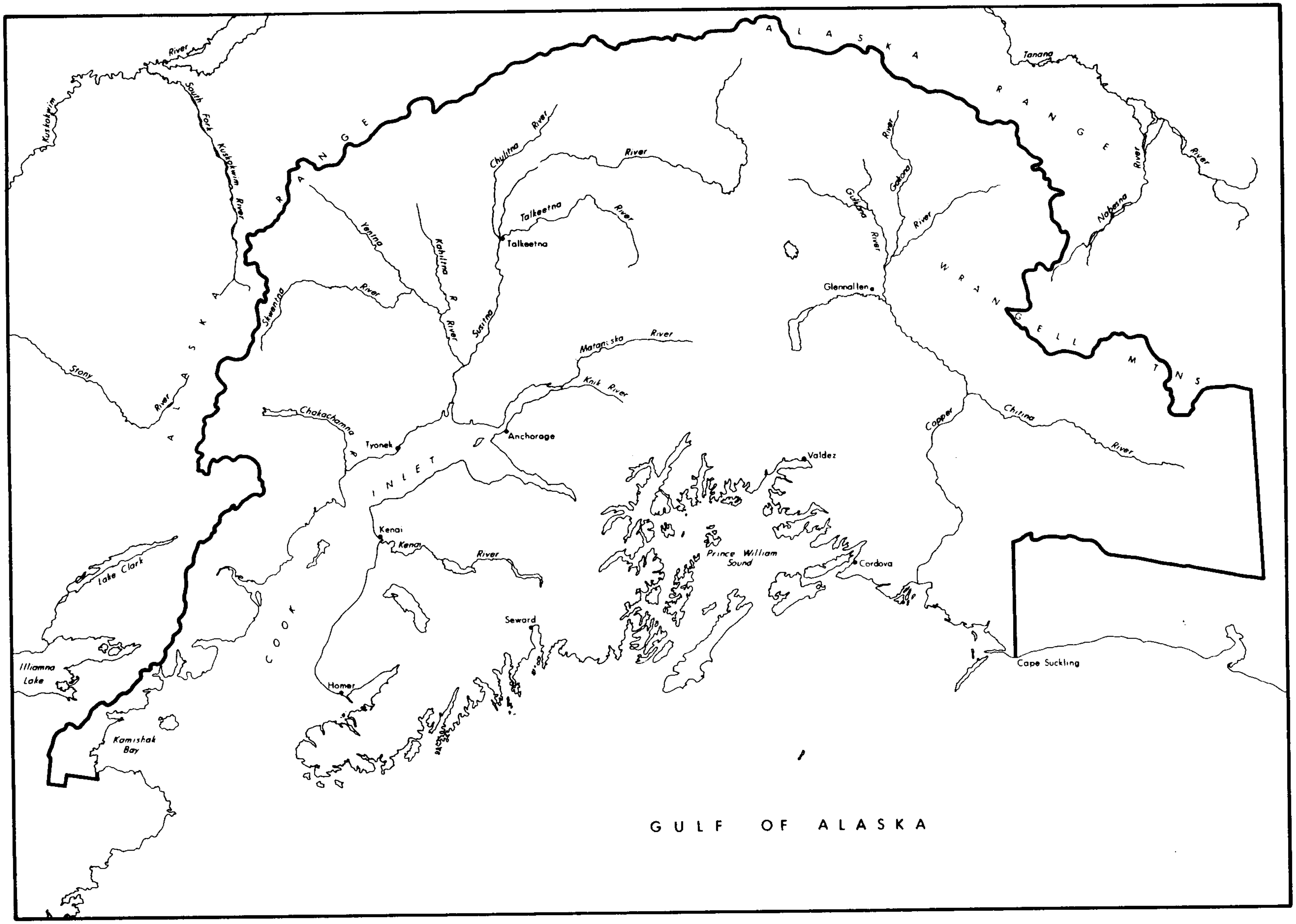
The Southcentral Region (map 3) includes the Chugach, Talkeetna, Wrangell and Kenai mountains and the southern slopes of the Alaska Range. A few of the larger river basins in the region include the drainages of the Susitna, Beluga, Chakachatna, Big, Crescent, Kasilof, Kenai, Matanuska, Copper, and Bering 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.[1]

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 fiord-like coastline rising to mountains up to 12,000 feet. 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 south 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.

[1] 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.



Map 3. The Southcentral Region.

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 popular, 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.

Human Activities in the Region

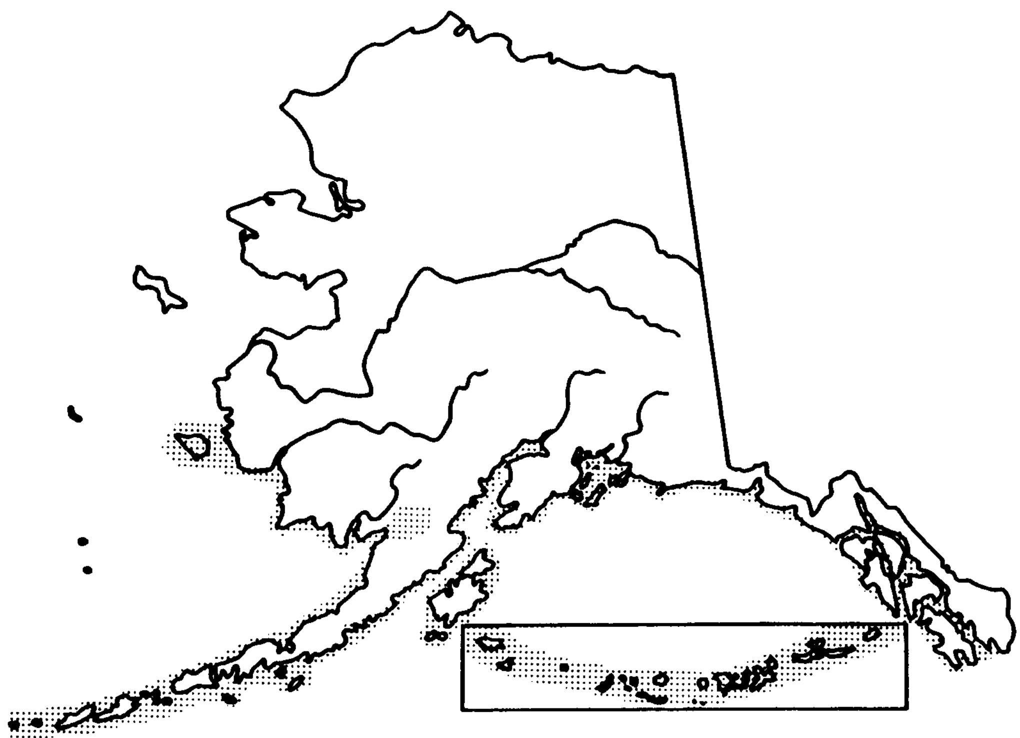
As one would expect from the abundance of fish and wildlife in the Southcentral Region, many human activities revolve around the commercial, sport, subsistence, and personal uses of these resources. Commercial fishing, seafood processing, and guiding of hunters and fishermen are important segments of the regional economy. Major fishing ports in the region include Cordova, Valdez, Seward, Homer, and Kenai. Noncommercial harvest for recreation and food is a goal 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.

Marine Mammals

Harbor Seal Life History and Habitat Requirements
Southwest and Southcentral Alaska



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)

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'stev (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 westard 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 Summary

To supplement the distribution information presented in the text, a series of bluelined reference maps has been prepared for each 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. 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.

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), flat fishes (Pleuronectidae), eulachon (Thaleicthys 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, Gercia 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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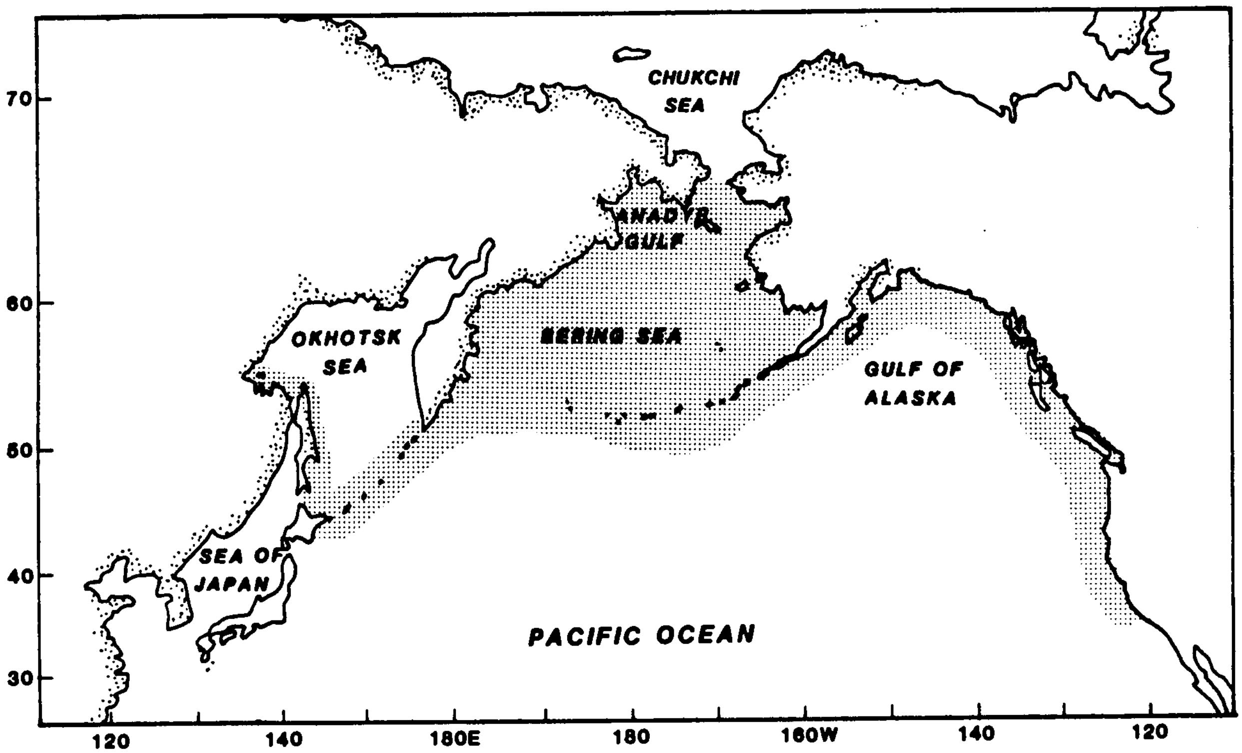
Steller Sea Lion Life History and Habitat Requirements
Southwest and Southcentral Alaska



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

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 Summary

To supplement the distribution information presented in the text, a series of bluelined reference maps has been prepared for each 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. 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.

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 then 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 pallasi*), 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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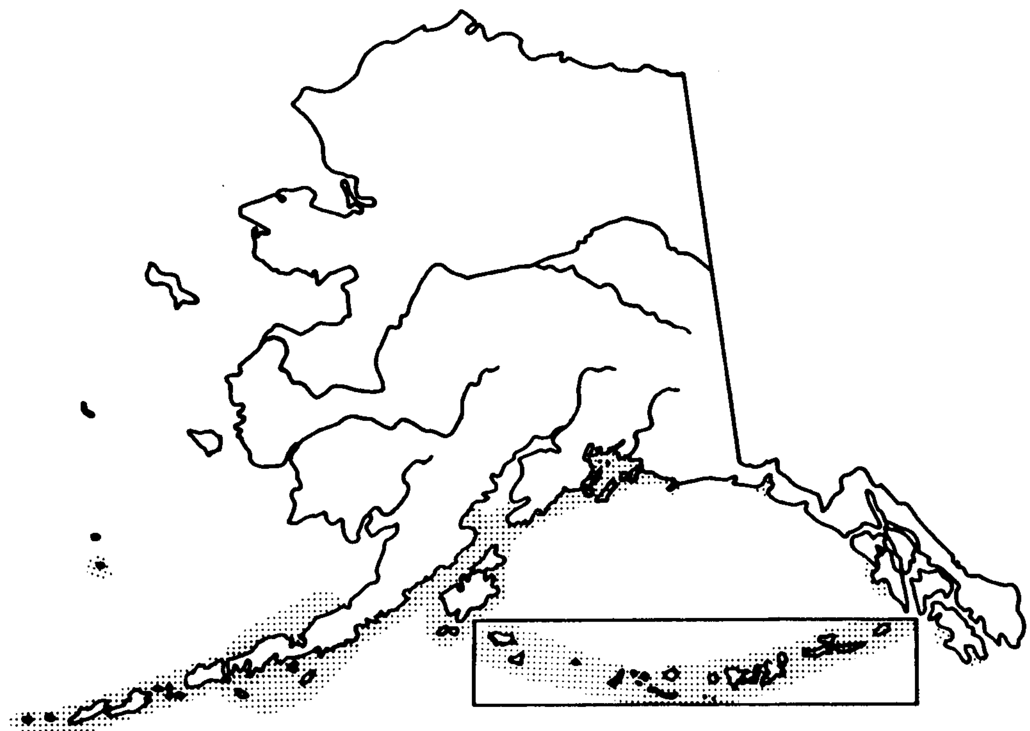
Sea Otter Life History and Habitat Requirements
Southwest and Southcentral Alaska



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

I. NAME
   A. Common Name: Sea otter
   B. Scientific Name: Enhydra lutris

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 otter's 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 Summary

To supplement the distribution information presented in the text, a series of bluelined reference maps has been prepared for each 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. 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.

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 suppport 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 cm^2 (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. 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. 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:

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 (*Chionocoetes 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. laperousii*), 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. 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.).

a. Primary. 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).

b. Secondary. 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 SC 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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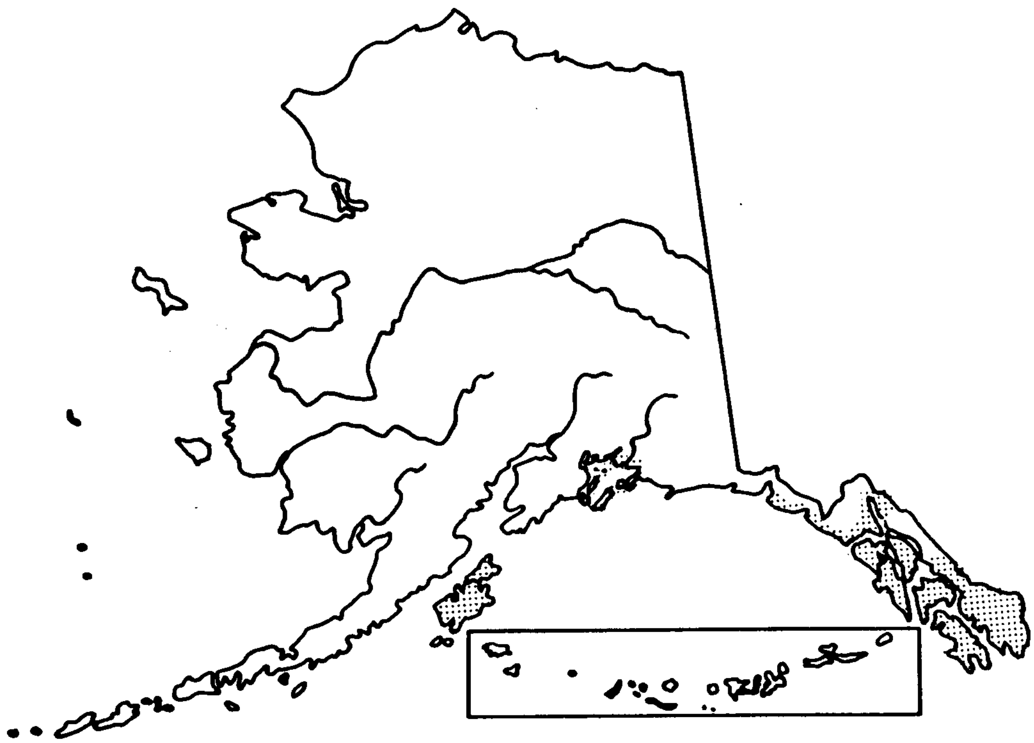
Terrestrial Mammals

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



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

I. NAME
   A. Common Name: Sitka black-tailed deer
   B. Scientific Name: <u>Odocoileus hemionus sitkensis</u>

II. RANGE
   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 Summary

To supplement the distribution information presented in the text, a series of bluelined reference maps has been prepared for each 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. 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.

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 Region. Deer occur naturally throughout the coastal islands of southeastern 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, birch, scattered spruce patches, and dense alder thickets along steep draws are used for cover by deer on Kodiak Island (Smith 1979). Low-elevation coastal Sitka spruce 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, Walmo 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 (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 cadadensis*) and five-leaved bramble (*Rubus pedatus*), are highly preferred where available (Schoen and Kirchhoff 1983b, Schoen et al. 1982).
      a. Winter (December-March):
         1. Primary. Bunchberry and five-leaved bramble are primary foods on Admiralty and Chichagof islands under winter conditions of both little snow accumulation and of snow accumulation in open areas with snow-free areas common under the canopy of an

Table 1. Food Species Used

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

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 Kirchhof 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).

2. Secondary. 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):
   1. Primary. 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).
   2. Secondary. Secondary foods are Aleutian heather (Phyllodoce aleutica), western hemlock (Tsuga-heterophylla), Labrador tea, and rockweed (Hanley et al. 1984).

c. Summer (mid June-September):
   1. Primary. 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 Habley et al. 1984). Klein (1963, 1965) also described deer cabbage, skunk cabbage, and sedges (Carex biflora, Carex lyngbyel spp., cryptorarpa, and Carex macrochaeta) as the most important summer forage species.

2. Secondary. Secondary foods are plantain (Plantago maritima), Sitka vetch (Vicia gigantea), early blueberry (Vaccinium ovalifolium), seaside arrowgrass (Triglochin maritimum), swordfern (Polystichum munitum), beach rye-grass (Elymusarenaria-spp. mollis), 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 especially 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).

(For more detailed information on deer feeding areas in Southeast Alaska, which may apply to the rest of the Alaskan deer range, the reader is referred to Dr. John Schoen's published research.)

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 asplenifolia 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, salmonberry (Cornus-Vaccinium-Rubus) understory (Schoen et al. 1981a, Schoen and Kirchhoff 1983b). Winter use is correlated with Vaccinium, Cornus, and Coptis (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 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 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 varrying 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 deposition 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, intermediate in low-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. lichins are also highly digestible but have low protein content (Schoen and Wallmo 1979).
2. Spring/summer/early fall. Long photosynthetic periods and alpine plant adaptions 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).
Deer populations have both migratory and resident components, with migratory animals residing at higher elevations during all seasons (ibid.)

2. Use of edge. Deer do not increase winter use of edge habitats between clear-cuts and old-growth habitat types (Kirchhoff et al. 1983).
3. Snow conditions. Deer will pass through 12-to-18 inches of snow (to feed on ferns) (Smith 1979).

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, one could assume that they give birth at relatively low elevations in heavy cover (Smith 1984).
2. Southcentral Region. The ADF&G (1976a) reports that fawns are usually born in fringes of trees adjacent to lowland muskegs or beaches.
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 in 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 pregnacy 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 (Ragelin 1979). Summer range condition and extent is a primary factor affecting the size of animals, population densities, and the age structure of the population. 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 effects 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 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 post-logging 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 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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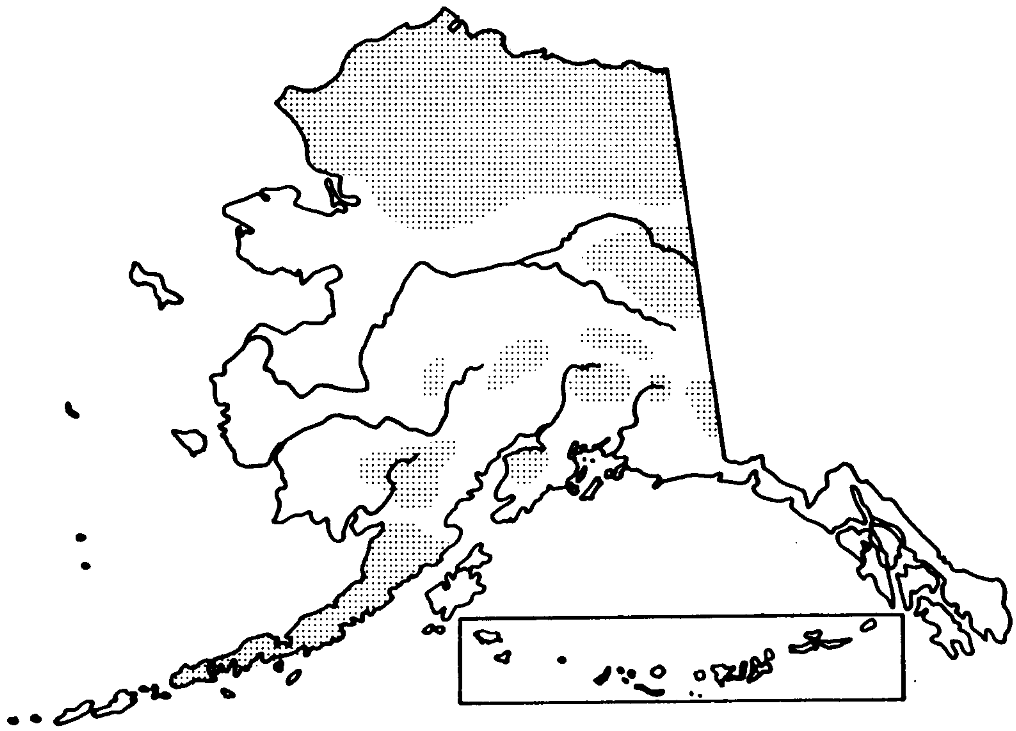
Caribou Life History and Habitat Requirements
Southwest and Southcentral Alaska



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

I. NAME
   A. Common Name: Caribou, tuntu (Yupik), vejex (Denaina)
   B. Scientific Name: Rangifer tarandus granti (Banfield 1961)

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 Summary
      To supplement the distribution information presented in the text, a series of bluelined reference maps has been prepared for each 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. 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.

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.) (For more detailed narrative information, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)
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). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

During summer, caribou tend to concentrate their feeding activity in moist boggy areas where sedges (*Carex* spp.) predominate. 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, supply a substantial food source to wintering caribou (Skoog 1968).

B. Terrestrial Cover Requirements

The use of ridge tops, frozen lakes and bogs, and other open areas for resting is a 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).

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).

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).

IV. NUTRITIONAL REQUIREMENTS

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

1. Winter (mid October to mid April). Lichens are utilized when available. The most important fruticose lichen species relative to palatability, abundance, and use include the following: Cladonia alpestris, C. rangiferina, C, sylvatica, C. mitis, and Cetraria nivalis, plus various species of arboreal lichens from the genera Alectoria, Evernia, and Usnea.

2. Spring (mid April to mid June) and Summer (mid June to mid August). During spring and summer, there is a continuous process of shifting to plant species that are approaching phenological growth stages rich in available nutrients. Various grasses (mostly Festuca altaica, Calamagrostis canadensis, and Hierochloe alpina) and sedges (notably Carex bigelowii, C. membranacea, C. podocorarpa, and Eriophorum vaginatum) are among the first new-growth vegetation and are used extensively. The catkins of willow (especially Salix alaxensis, S. planifolia ssp., pulchra, and S. glauca) are also among the first new growth to be used. As the season progresses the leaves of willow, resin birch (Betula glandulosa), and dwarf birch (B. nana) are used extensively during June and July. Many species of sedge and grass (especially those of the genera Alopecurus, Arctagrostis, Dupontia, Festuca, Poa, Puccinellia, Calamagrostis, and Hierochloe), 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.
During late summer, mushrooms (especially those of the _gemus Boletus_) may be eaten extensively when available.
Throughout the spring and summer, caribou will continue to take small quantities of lichens, dried plant parts, stems, and evergreen parts.

3. Fall (mid August to mid October). During the fall, the quantity, quality, and palatability of the summer forage decreases, and the caribou's diet gradually shifts toward the more restrictive winter forage. The leaves of willow 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).
2. Spring. Migration to calving areas occurs during this period, and the types of areas used can be highly variable, depending upon the spring melt and green up. During some years, there is a quick migrational transition from wintering calving areas. As soon as spring plant growth begins, caribou switch to areas where early growth species occur (Lieb, pers. comm.).
3. Summer. Areas of use consist primarily of treeless uplands where heath tundra, alpine tundra, and sedge wetland associations dominate. In response to insect harrassment, caribou frequently use wind-swept ridges (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 mm (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 snow-melt and the consequent

availability of new vegetation (Lent 1979). Should a late snow-melt or a late snowstorm occur, use of otherwise preferred early green-up vegetation may be restricted (Skoog 1968).

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).
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 localized 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).

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. Parturition generally occurs from mid May through the first week of June (ibid.).

C. Reproductive Behavior
1. Breeding. Bulls do not gather harems but rather join existing bands of cows and young. One or more bulls tend to become dominant within the band, 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, rutting 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 Provincal 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 fertile at 1.3 to 2.3 years of age (Skoog 1968, Dauphine 1976).

E. Fecundity

Adult females of 2.5 years old and older have pregnancy rates of about 80% and produce one offspring per year. Feamales 3.5 years old and older have pregnancy rates of about 90% (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), however, suggested that weaning takes place between September and December and mostly occurs prior to November.

VI. FACTORS INFLUENCING POPULATIONS

A. Natural

Emigration, which may be density-related, can cause large fluctuations in herd sizes. 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 control (Skoog 1968, Bergerud 1978, Miller 1982, Gassaway et al. 1983). Fire has destroyed large expanses of winter range but in fact may not cause major fluctuations in population numbers because of shifts in habitat use (Skoog 1968).

B. Human-related

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

° Competition with introduced (wild or domestic) animals

- Alteration of habitat
- Harrassment, active and passive
- Barriers to movement, physical and psychological
- Overharvest, expecially when associated with high predation rates
- 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 managerial authority over caribou. See the Human Use section for a more detailed description of managerial considerations.

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. Finally, the effects of fire on caribou habitat and distribution are not clearly understood.

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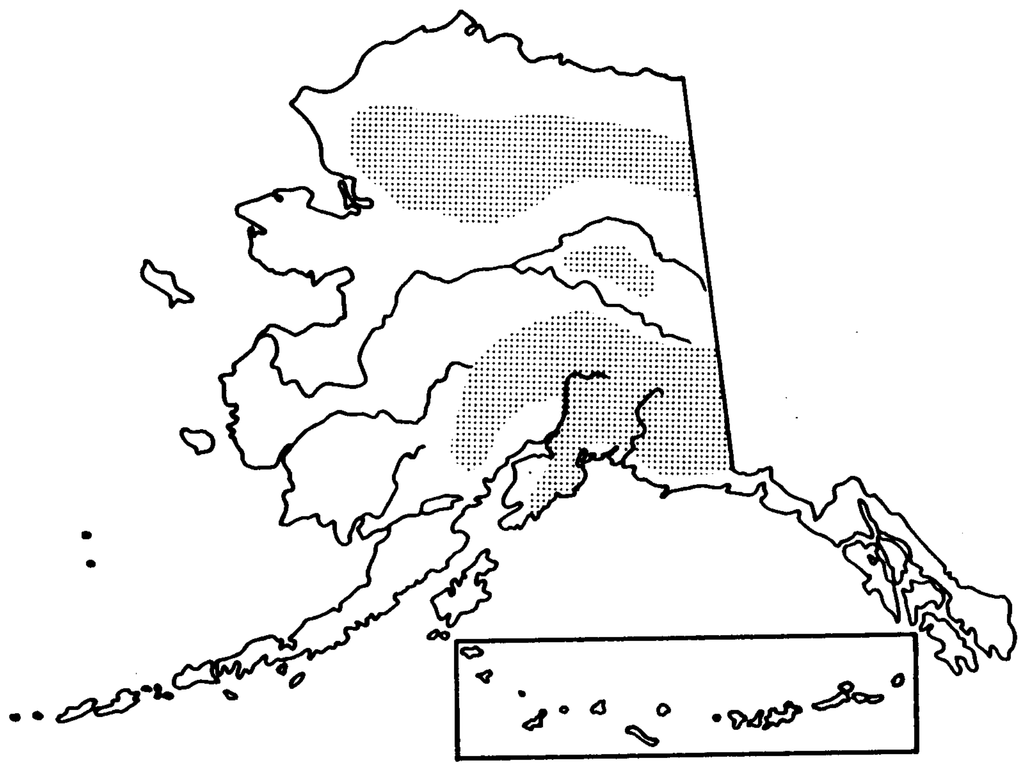
Dall Sheep Life History and Habitat Requirements
Southcentral Alaska



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

I. NAME
   A. Common Name: Dall sheep, Dall's sheep, Alaskan white sheep, thinhorn sheep (Nichols 1978a, Bee and Hall 1956)
   B. Scientific Name: Ovis dalli

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 Summary

To supplement the distribution information presented in the text, a series of bluelined reference maps has been prepared for each 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. 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.

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.)

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 are used; this habitat preference is most likely related to predator avoidance (Geist 1971, Murie 1944).

1. Winter. In winter, sheep utilize 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 northerly 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 (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 snow-melt (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 availability. 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, preferred foods:
   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 the majority 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 shrubs (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, preferred foods. As mentioned, sheep generally move to lower elevations in early spring (April) to take advantage of vegetation exposed by the snow-melt. Overwintered snow-cured grasses and sedges and lignified cranberry stems and associated 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, preferred foods:
   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 best 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 snow over 18 inches deep forced sheep to forage on wind-swept higher ridges for less 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).

   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. Food Species Used.)

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 lock, 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.).

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 (Nichols 1978b). 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 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 may result in the death of 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 to 30 months (ibid.).

E. Fecundity

Single births are usual, although twinning has been reported rarely (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 may be 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 appears to be minimal (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 osteomylitis (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 disease. Introduced diseases 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
- Harrassment, active
- Harrassment, passive: construction noise, aircraft traffic
- 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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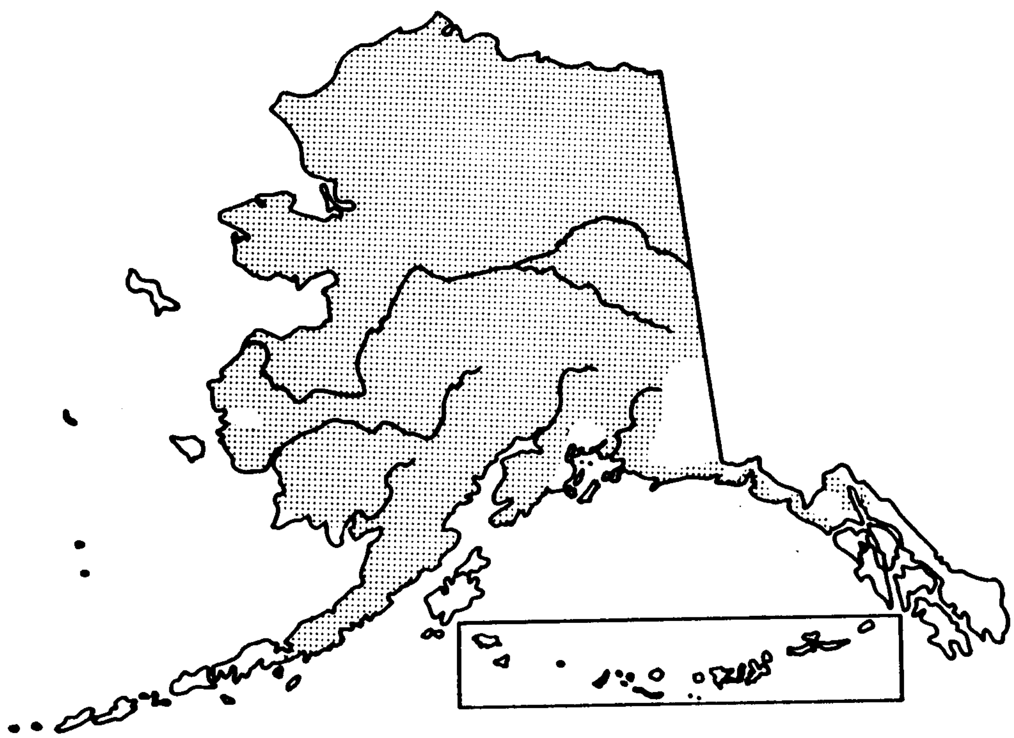
Moose Life History and Habitat Requirements
Southwest and Southcentral Alaska



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

I. NAME
   A. Common Name: Moose, Alaskan moose
   B. Scientific Name: Alces alces gigas (Peterson 1955)

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. 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, 1976b, 1976c). Moose are generally found at or below 4,000 ft elevations (Ballard and Taylor 1980, Ballard et al. 1984).

C. Regional Distribution Summary

To supplement the distribution information presented in the text, a series of bluelined reference maps has been prepared for each 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. 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.

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.)

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. NUTRITIONAL REQUIREMENTS, A. Food Species Used.)

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. NUTRITIONAL REQUIREMENTS, A. Winter). Coniferous tree stands may also provide seeded food and also serve as 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, aquatic and semi-aquatic vegetation as soon as snow- and ice-melt permit. 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 may be characterized by dense clumps of spruce (*Picea* spp.) interspersed with alder (*Alnus* spp.), or willow (*Salix* spp.), very likely serve as protective cover from the natural elements (ADF&G 1973), as well as from predators or other disturbances. Modafferi (1982 and 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 tricocarpa*) was the most commonly occurring vegetative type in calving areas and dominated in 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 the remainder of the year in the upper Susitna Valley. Most moose collared during the winter along the lower Susitna River flood plain 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 was (S. barclayi), 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 fruiticose 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 (Potomogeton spp.), which are found in wetlands, lakes, and ponds in water up to 8 ft deep are consumed (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 reduces 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 southwestern 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. Feeding locations.)

   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 from summer to and from winter range and daily winter activity may be influenced by initiation of first snow, snow depth, day length, and persistence of. 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). In Southcentral Alaska, moose generally confine their winter movements to areas less than 3,600 ft in elevation (Ballard et al. 1984). 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).

D. Feeding Behavior

Peek 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 is little descriptive data regarding moose rutting habitat. Use of habitat during the rut may be be influenced by whether particular groups of moose are migratory or nonmigratory.

   Use of upland brush-willow habitat types reaches a peek during the breeding period, corresponding with elevational movements of moose (Didrickson and Cornelius 1977, Ballard and Taylor 1980, Ballard et al. 1982, 1984).
2. Parturition areas. Most studies conducted in the Southcentral Region have found calving to be widely dispersed (Didrickson and Cornelius 1977, Ballard et al. 1982, Modafferi 1982) (See III. B.2., Spring.)

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 (Coady 1982).

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 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 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. 1982).

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 will 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 an 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 for the remaining vegetation in areas where forage has been extensively depleted or deep-snow conditions force 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
- Competion with introduced animals
- Predation, increases
- Disease transmission from susceptibility to introduced 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. (See the Human Use section in volume 2 for a summary of moose management.)

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 Refuge, Alaska 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).

X. 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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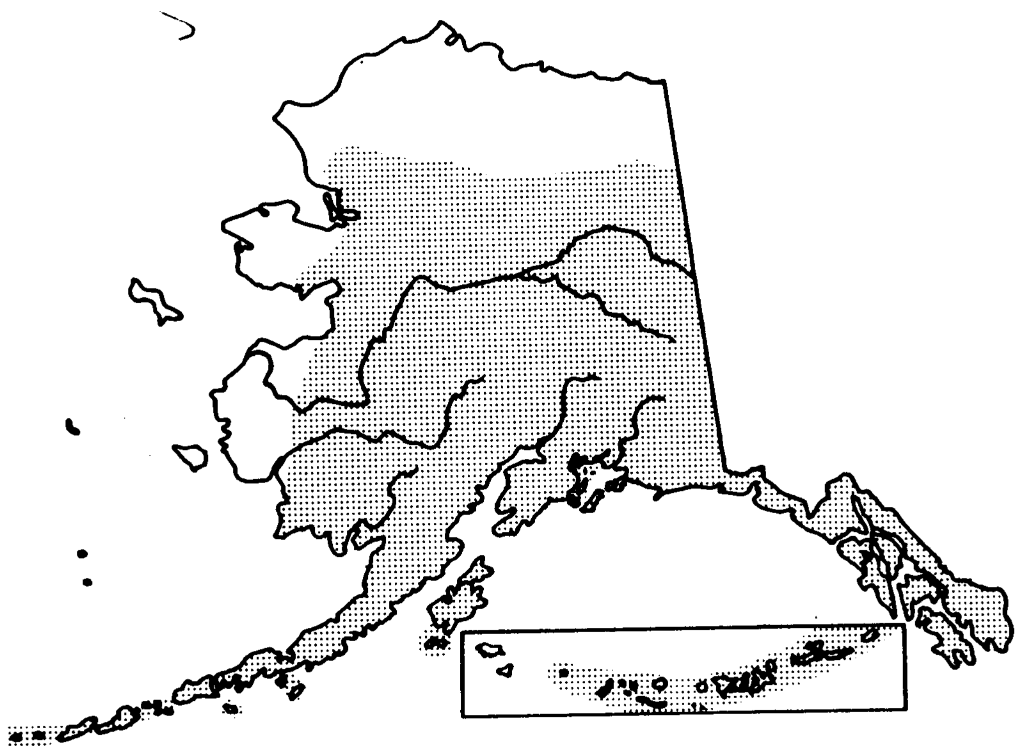
Bald Eagle Life History and Habitat Requirements
Southwest and Southcentral Alaska



Map 1. Range of Bald Eagle (ADF&G 1978)

I. NAME
   A. Common Name: Bald Eagle
   B. Scientific Name: Haliaeetus leucocephalus alascanus

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, 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 Western, Interior, and Southcentral Alaska (Gabrielson and Lincoln 1959).

C. Regional Distribution Summary

To supplement the distribution information presented in the text, a series of bluelined reference maps has been prepared for each 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. 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.

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.).

Bald Eagles breed commonly about the shores of Bristol Bay, around Iliamna and Clark lakes, and less abundantly in suitable localities on the coast of the Bering Sea, north to the Noatak River (Gabrielson and Lincoln 1959). (For more detailed narrative information, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region and volume 2 of the guide for the Southcentral Region.)

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, USDI 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 near clear streams, 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 eagles' summer diet. Also, eagles were found to utilize streams where spawning rainbow trout (*Salmo gardneri*) 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 coastline ridges, sea stacks, and on 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* spp.), 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 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).

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. Fratricide. 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 layed. 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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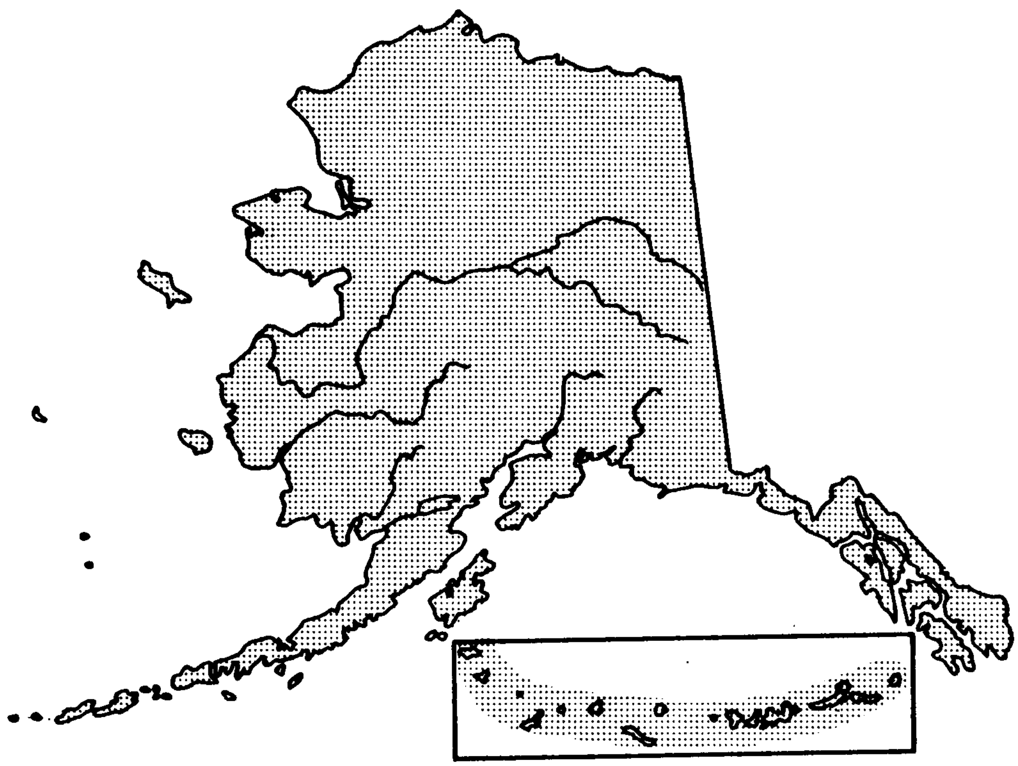
Dabbling Ducks Life Histories and Habitat Requirements
Southwest and Southcentral Alaska



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. 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 European 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.).

II. RANGE

A. Worldwide

Dabbling ducks are cosmopolitan in distribution, with variations in abundance related to seasonal changes (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 Summary

To supplement the distribution information presented in the text, a series of bluelined reference maps has been prepared for each 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. 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.

1. <u>Southwest</u>. 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. <u>Southcentral</u>. Dabbling ducks are found in favorable habitat throughout the Southcentral Region. Because of the lateness of snow-melt and vegetation growth at higher elevations, the most favorable habitat is located below 1,000 ft elevations. In the Southcentral Region, major concentrations occur during the spring and fall migrations along the tidal marshes of Cook Inlet (fig. 1). 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.)

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 Lensnik 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 mudflats; 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 mudflat 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 mudflat community was near the upper limit of the tide and was utilized mostly by fall-migrating ducks, resting and feeding in that type (ibid.).

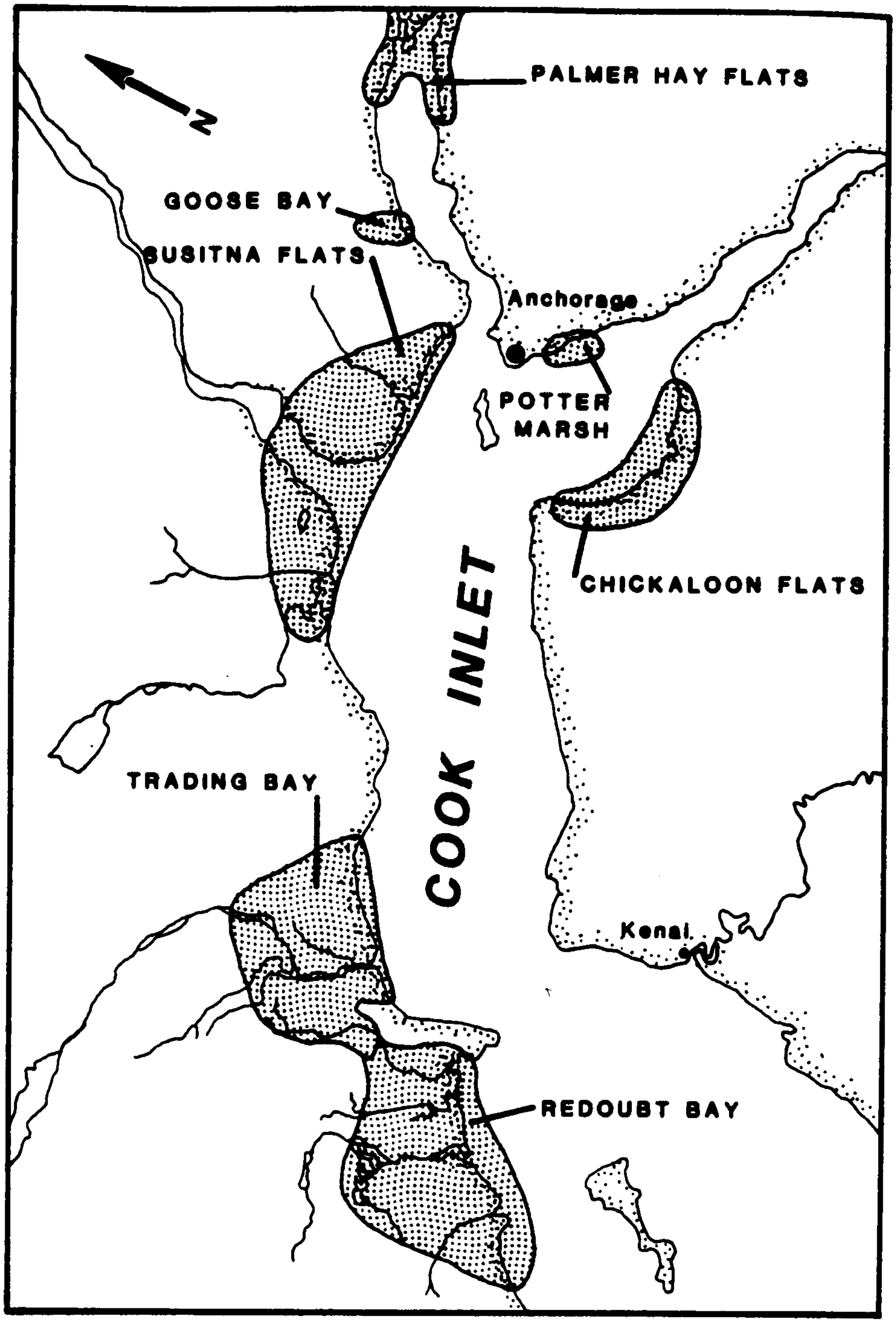
IV. NUTRITIONAL REQUIREMENTS

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 portions of the year. 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)

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.)



Map 2. Major coastal marshes of Upper Cook Inlet (Campbell 1984).

Spiders (Arachnoidea)
Salmon carcasses (*Oncorhynchus* spp.)
Crustaceans (Crustacea)
Mollusks (Mollusca)
Earthworms (Oligochaeta)
Stickleback (*Gaserosteus aculeatus*)
Acorns
Cultivated grains (e.g., corn, rice, wheat, barley)
Buttercup (*Ranunculus* spp.)

(Bellrose 1976, Bartonek 1972, Quimby 1972, Sugden 1973)

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, Krapur 1974). The rapid early growth of juveniles and the nutritional requirements of prebreeding and breeding adults require food sources high in protein (ibid.). Krapu (1974) observed that female pintails fed heavily on invertebrates before and during egg laying. Esophogeal contents before egg laying averaged 56 ± 27.1% animal matter, and during egg laying 77.1 ± 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 ± 22% animal matter in their esophagi, whereas older juveniles (Class IIIa and flying) had only 12 ± 20% animal matter in their diet. Adult American wigeons examined during the same study contained an average of 31 ± 34% animal matter (ibid.). This represents significantly more animal matter in the diet of the adult wigeon than has been recorded (Bellrose 1976, Johnsgaad 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, while 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. 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) (fig. 1.). Four genera of plants (*Carex*, *Scirpus*, *Potomogeton*, 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 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. Since 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. 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

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 (_Ranunculus_ spp.)	13.6	16.9
Pondweed (_Potamogeton_ spp.)	11.6	13.8
Unidentified grass CRD #3	5.1	10.8
Misc. foliage	5.6	---
Seeds		
Sedge (_Carex_ spp.)	12.4	38.5
Rushes (_Eleochris_ spp. & _Scirpus_ spp.)	8.1	16.9
Unidentified seed #7	7.1	16.9
Marestail (_Hippuris_ spp.)	3.3	16.9
Pondweed (_Potamogeton_ spp.)	---	---
Animals		
Diptera larvae (_Chironomidae_, _Ceratopogonidae_, _Tipulidae_)	13.4	29.2
Unidentified invertebrate eggs	4.2	4.6
Trichoptera larvae (_Brachycentridae_, _Limnephilidae_, _Polycentropodidae_)	3.8	23.1
Pelecypods (Sphaeriidae)	3.1	9.2
Gastropods	2.5	15.4
Stickleback (_Gaserosteus aculeatus_)	1.4	3.1
Miscellaneous (Hirudinids, Arachinids, Odonatids)	1.0	---

Source: Campbell and Timm 1983.

--- means no data were available.

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), and 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 in late winter and during 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 layed and the males retreat to molting areas.

D. Age At Sexual Maturity

All dabblers mature at one year of age (Timm 1975).

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.).

Table 2. Breeding Biology of Dabbling Ducks

Species	Nest Locations	Mating	Incubation	Clutch Size Range	Clutch Size Average	Sexual Maturity
Pintail	Dry ground, usually away from water	Late winter; arrive mated	22-24 days	1-12	6	For all dabblers, one year
Mallard	Ground, edges of of ponds, much variation	Late winter; arrive on breeding grounds mated	23-29 days, usually 26	1-15	8	
American wigeon	Dry ground, away from water, usually brushy area	May-June	24-25 days	1-12	6	
American green-winged teal	Dry ground, tall grass, bordering marshes	Late winter	21-23 days	1-18	9	
Northern shoveler	Hollows, on ground	May-June, with two males occasionally	21-23 days	1-14	7	

Source: Timm 1975.

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 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 by 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). 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

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.

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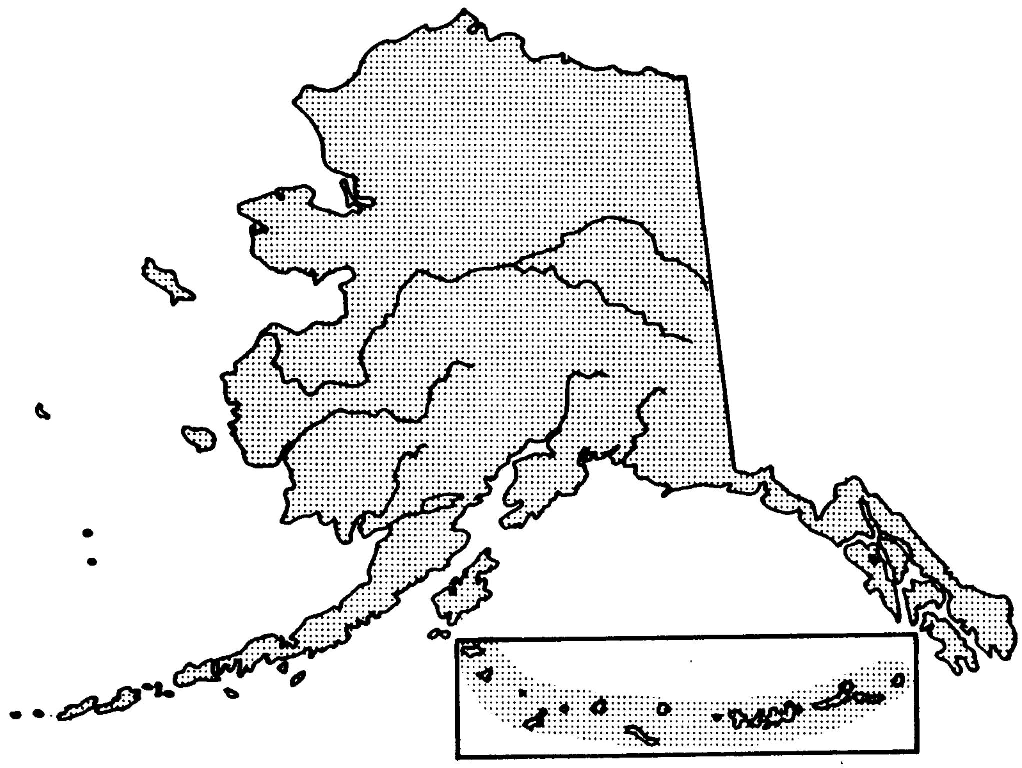
Diving Ducks Life Histories and Habitat Requirements
Southwest and Southcentral Alaska



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. 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).

D. 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 (Aytha collaris), mergansers, and other diving duck species use the region as well (ibid.).

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 Summary

To supplement the distribution information presented in the text, a series of bluelined reference maps has been prepared for each 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. 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.

1. Southwest Alaska. 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 Alaska. 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.)

III. PHYSICAL HABITAT REQUIREMENTS

King (pers. comm.) indicated that any coastal areas within the 60-ft depth contour could be considered important diving duck habitat. Diving ducks generally prefer protected estuarine habitats, 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).

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 larger, deeper 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 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 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 (*Empetrum*) 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.).

Table 1. Plant and Animal Species Utilized by Diving Ducks

Plant Species	Animal Species
Muskgrass (*Chara* spp.)	Caddis fly (Trichoptera)
Pondweed (*Potamogeton* spp.)	Midges (Tendipedidae)
Bulrush (*Scipus* spp.)	Mayfly (Ephemeroptera)
Sedge (*Carex* spp.)	Dragonfly (Odonata)
Milfoil (*Myriophyllum* spp.)	Flies (Diptera)
Duckweed (*Lemma* spp.)	Flies (Hemiptera)
Buttercup (*Ranunculus* spp.)	Leech (Hirudinea)
Ditch grass (*Ruppia maritima*)	Water strider (Corixidae)
Cattail (*Typha* spp.)	Mysids (Mysidae)
Pond lily (*Nuphar* spp.)	Amphipods (Amphipoda)
Bur reed (*Sparganium* spp.)	*Gammarus* spp.
Green algae (*Chlorophyceae*)	*Hyallela* spp.
	Crayfish (Crustacea)
	Water flea (*Daphnia* spp.)
	Snails (Gastropoda)
	Blue mussel (*Mytilus edulis*)
	Mussel (*Unio* spp.)
	Freshwater shrimp (*Palaemonetes* spp.)
	Clam (*Macoma* spp.)
	Clam (*Mulina lateralis*)
	Razor clam (*Solen sicarius*)
	Crab (*Cancer* spp.)

Source: Bartonek and Hickey 1969, Johnsgard 1975.

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 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.).

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.

B. Reproductive Seasonality

Most diving ducks have arrived at their breeding range by mid-to-late May (ibid.). Nest initiation extends from early-to-late June, depending on the species and weather conditions, with scoters generally the last to nest.

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.).

Table 2. Reproductive Characteristics of Diving Ducks

Species	Nest Location	Mating	Incubation	Clutch Size Range	Clutch Size Average	Sexual Maturity*
Greater scaup	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 of age
Lesser scaup	Ground, near marshy creeks, sloughs, ponds, concealed in tall grasses	May-June	25-28 days	6-15	9-12	"
Canvasback	Just clear of high water; in bulrushes and reeds of sloughs and swampy areas	May-June	24-28 days	---	7-9	"
Ringneck	Wet, boggy areas bordering marshes, ponds, sloughs; most barely above level of water	May-June	24-28 days	---	8-12	"
Bufflehead	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	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	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 of age
Surf scoter	Ground: carefully concealed, lined with a small amount of grass; will breed inland	Usually June	---	5-9	7	---

(continued)

Table 2 (continued).

Species	Nest Location	Mating	Incubation	Clutch Size		Sexual Maturity*
				Range	Average	
White-winged scoter	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 of life
Black scoter	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 of life
Barrow's goldeneye	Cavity of trees, dead stumps, preferably near water from ground to 50 ft	March-June	19-22 days	6-15	10	Most Barrow's breed at two years of age
Common goldeneye	Cavity of trees, or dead stump, preferably near water, from ground to 50 ft	March-June	20 days	5-19	8-12	Initially breed in their second or third year
Red breasted merganser*	Ground, close to water	April-May	30 days	5-11	7-8	Not known to breed before their second year
Common merganser*	Cavities of trees, from ground to 50+ ft, usually close to water	April-May	30-35 days	6-17	9-12	---

Source: Timm 1975.

* From Bellrose 1976.

--- means no data were available.

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, the average size of a clutch being between 7 and 12 eggs (ibid.).

F. Incubation Period
The incubation period varies by species but usually averages from 19 to 28 days (ibid.).

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.). Brood rearing occurs throughout July and August.

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).

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. Scoters and oldsquaws leave the tundra in mid July to molt at sea, often near estuaries. Scaup, goldeneye, and other divers will molt on large inland lakes that are perennial molting areas. The molt extends from mid July to the end of August (Bellrose 1976).

Steller's eiders migrate to their wintering areas on Izembek and other Alaska Peninsula lagoons prior to their molt. The molt period is variable, ranging from August through November (Johnsgard 1975).

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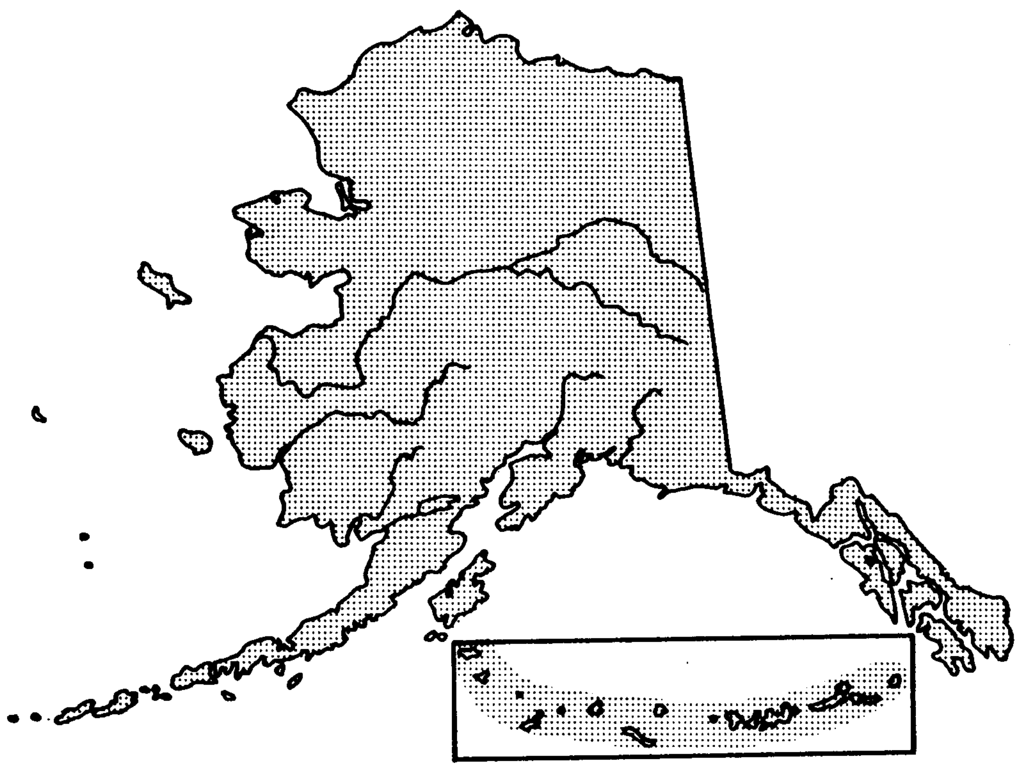
Geese Life Histories and Habitat Requirements
Southwest and Southcentral Alaska



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. Species Commonly Occurring in the Southwest Region
      In the Southwest Region, goose populations are comprised primarily of the Pacific flyway population of greater white-fronted goose (*Anser albifrons*); 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 (Chen caerulescens) occurs during migration (ibid.).

D. Species Commonly Occurring in the Southcentral Region

Goose species that commonly occur in the Southcentral Region include the lesser Canada goose (Branta canadensis parvipes), the dusky Canada goose (B. C. occidentalis), possibly the Vancouver Canada goose (B. C. fulva), the tule white-fronted goose (Anser albifrons gambeli), and, during migration, the lesser snow goose, greater white-fronted goose, and cackling Canada goose (Gabrielson and Lincoln 1959; Rothe', pers. comm.).

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.

C. Regional Distribution Summary

To supplement the distribution information presented in the text, a series of bluelined reference maps has been prepared for each 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. 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.

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.

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 (CRD), 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 CRD. 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.)

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 uplands, lagoons, and alluvial floodplains, whereas emperors use lagoon island sand and protected delta mud (Arneson 1980).

B. Southcentral

Geese are found in a wide variety of habitats, but are most common in alluvial floodplains, lagoons, and tidal mudflats. Canada geese, particularly in the Southcentral Region, use alluvial floodplains and coastal salt marshes extensively during their migrational stopovers (ibid.). Additionally, the saline sedge-grass flat habitat of Cook Inlet is thought to be important nesting habitat for tule geese (Timm 1982) (See tables 1 and 2 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 U.S. (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 spp.) (Rothe', pers. comm.). (See tables 1 and 2 for further information on food.)

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).

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 (*Carex Lyngbyaei* and *C. Ramenskii*), arrow grass (*Triglochin palustris* and *T. maritimum*), and alkali grass (*Puccinellia nutkaenis* & *P. phryganodes* (Timm 1982)	Apparently limited to saline sedge-grass habitat of western Cook Inlet; additional breeding areas possibly occur farther inland, in *Carex* & *Equisetum* riparian meadows and outwash plains (Timm 1982)
Lesser Canada goose	Wide variety of foods eaten, including cattails (Typhaceae), grasses, algae, waste grains, bulrushes, (*Scirpus* sp.), and clover; marine invertebrates utilized in coastal areas (Terres 1980); also sedges (*Carex* sp.), alkali grass (*Puccinellia* sp.), seeds of mare's tail (*Hippuris* sp.), goose foot (*Atriplex* sp.), tubers of arrow grass (*Triglochin palustris*) and crowberries (*Empetrum* 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: shrub habitat type and sedge habitat type are utilized as nesting habitat
Vancouver Canada goose	Plant material comprises bulk of summer food, with skunk cabbage (*Lysicheton americanum*) heavily utilized; also sea lettuce (*Ulva* sp.), blueberry (*Vaccinium* sp.), horsetail (*Equisetum* sp.), and grasses and sedges; winter foods probably include more animal matter (Lebeda 1980)	Majority of nests in dense confier forest, at base of large trees; one nest reported in tree top, and and nearby trees used for perching (Lebeda 1980)

Table 2. Preferred Foods and Breeding Habitat of Geese in the Southwest Region

Species	Preferred Food	Breeding Habitat
Pacific white-fronted geese	Plants used include 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); most snows occurring in SW & SC nest on Wrangell Island in USSR
Lesser snow goose	Snow goose diet is primarily salt marsh vegetation; berries and grasses often important diet in upland areas (Bellrose 1976)	Usually locate nesting colonies on low grassy tundra plains with few miles of sea, along broad shallow rivers near coast, and on islands in shallow lakes 10-80 mi inland (Bellrose 1976); most snows occurring in the SW and SC regions nest on Wrangell Island in USSR
Emperor goose	Major food sources: algae, eelgrass, pondweeds, 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 (*Puccinellia* 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)
Canada goose	Cackling geese feed predominately on sedges and creeping alkali grass (*Puccinellia phryganodes*); also seeds of *Hippuris* and *Atriplex* and tuber of *Triglochin palustris* (Sellers, pers. comm.) Major foods of Taverner's Canada goose: 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)

C. Feeding Behavior

Geese are essentially grazers and crop vegetation with their bills. During spring, tubers and rhizomes are often dug up, and in fall berries are often selected. 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).

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 3 and 4.)

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).

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).

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).

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	Molting: Flightless Period
Lesser snow goose	Seasonal migrants to SC Region; none known to breed in region						
Tule goose	Favored nest sites slightly elevated in saline sedge-grass flat habitat (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 cover type is grass-form; increase in nesting use of sedge cover type 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 vegetative material 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	Pairs are territorial and will defend nest sites; most nests are a depression on ground, with vegetation around rim (Bellrose 1976, Timm 1980)	24-30 days (Terres 1980)	1-12 eggs; avg. 4.3 (Terres 1980)	Some mature at 2 yrs. 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 Region

Species	Nest Location	Mating	Incubation	Clutch Size: Range	Clutch Size: Average	Sexual Maturity	Fledging Period	Molting: Initiation	Molting: 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 year 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 a scape 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.	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)
Pacific black brant	Nests placed in depressions or scrapes, with grass foundation and symmetrical ring of down (Bellrose 1976)	Courtship known to occur on winter grounds between mid January and April (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, 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)

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 CRD 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 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).

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

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).

IX. LIMITATION OF INFORMATION

The breeding grounds of the tule goose has 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.

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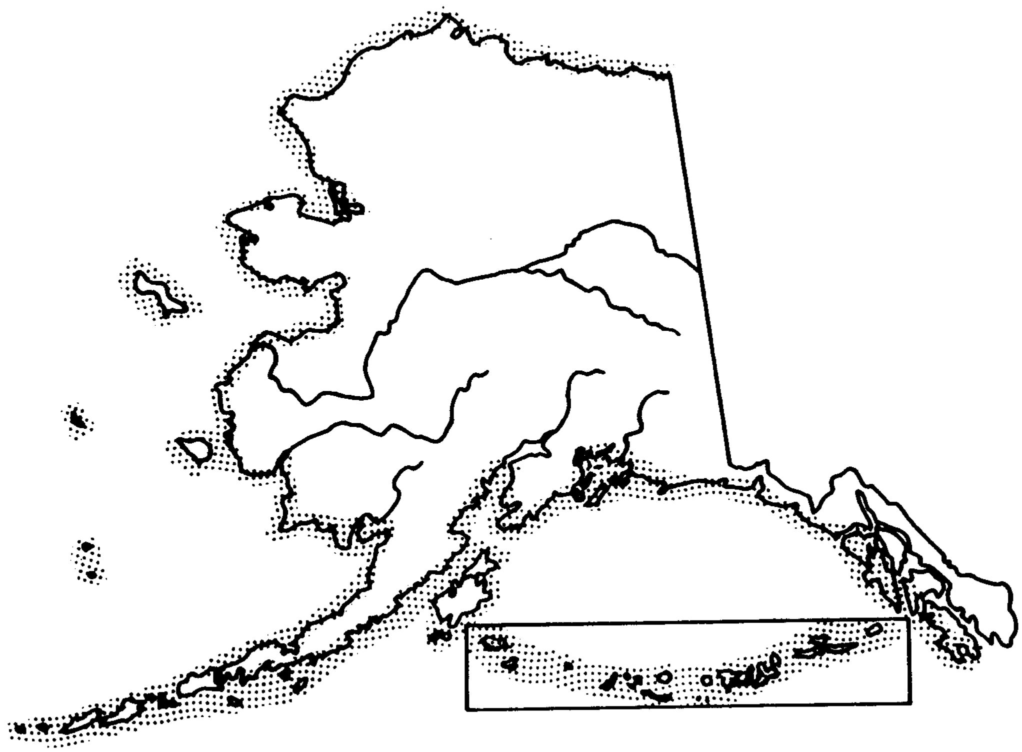
Seabirds Life Histories and Habitat Requirements
Southwest and Southcentral Alaska



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 (Diomedeidae), shearwaters and fulmars (Procellaiidae), storm-petrels (Hydrobatidae), cormorants (Phalacrocoracidae), gulls and terns (Laridae), and alcids (Alcidae), which include murres, 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 Summary

To supplement the distribution information presented in the text, a series of bluelined reference maps has been prepared for each 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. 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.

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 Region. 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. 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].)

2. Southcentral Region. 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 407,000 birds nesting there during the breeding season.

   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 volume 2 of the Alaska Habitat Management Guide for the Southcentral Region and the USFWS Catalog of Alaskan Seabird Colonies [ibid.].) Computerized distribution and abundance information is available from the USFWS (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 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

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 offshore 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 murres; 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 pounch 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 crespuscular in colony attendance	
Rhinocerous 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.

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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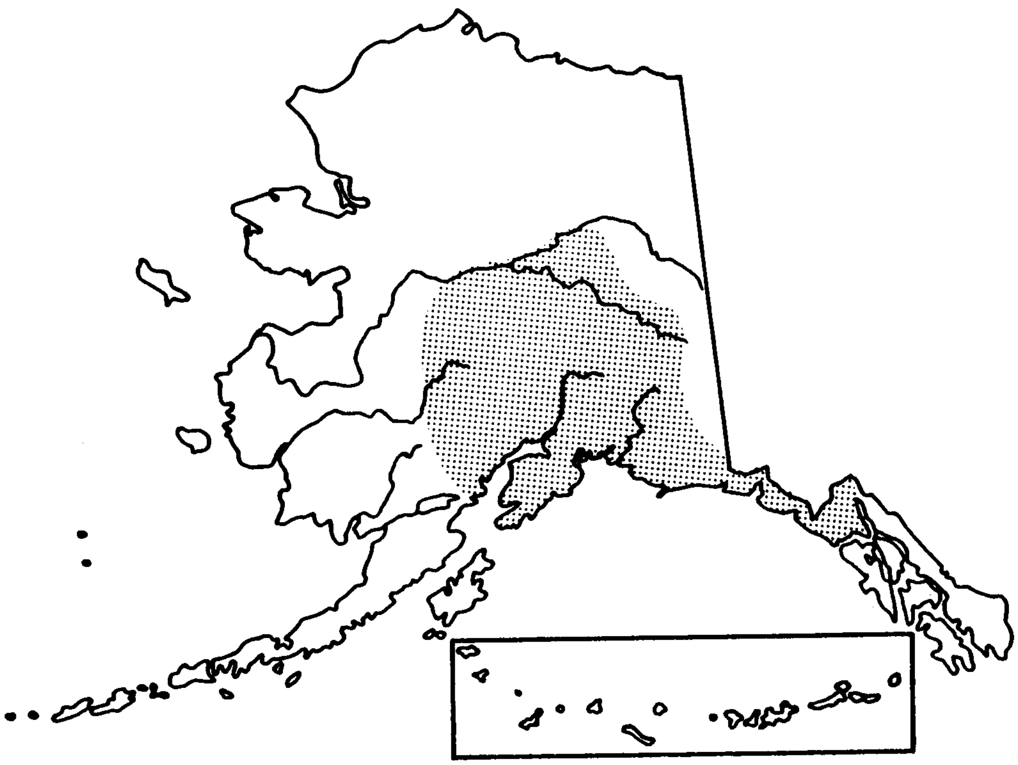
Trumpeter Swan Life History and Habitat Requirements
Southcentral Alaska



Map 1. Range of trumpeter swan (Bellrose 1976)

I. NAME
   A. Common Name: Trumpeter swan
   B. Scientific Name: Cygnus buccinator

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 Summary

To supplement the distribution information presented in the text, a series of bluelined reference maps has been prepared for each 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. 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.

1. 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).
2. Wintering areas. Birds winter on the open, freshwater outlets of Eyak Lake and Martin Lake near Cordova and on Skilak Lake on the Kenai Penninsula 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 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 marestail (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) (Banko 1960).

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 2000 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 only been collected 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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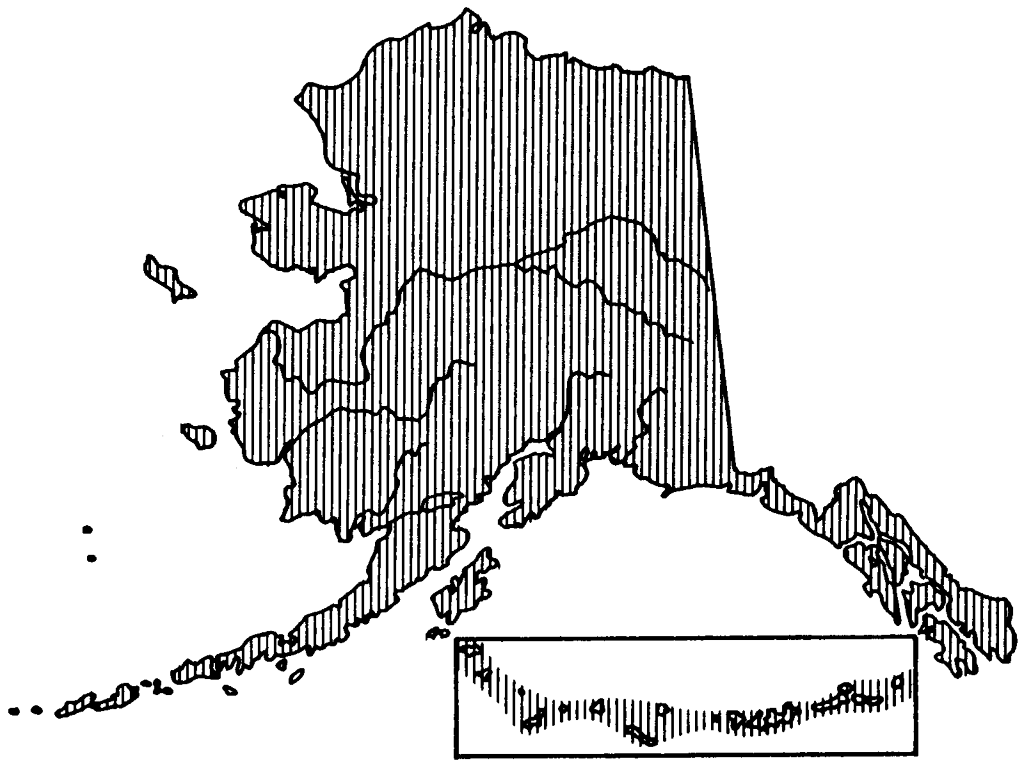
Freshwater/Anadromous Fish

Arctic Char/Dolly Varden Life History and Habitat Requirements Southwest and Southcentral Alaska



Map 1. Range of arctic char (ADF&G 1978)

I. NAME

Common Names: Dolly Varden, arctic char

Scientific Names: Salvelinus malma (Walbaum), Salvelinus alpinus (Linnaeus)

Dolly Varden and arctic char are two closely related salmonids of the subfamily Salmoninae. Because of their similarities they will be discussed jointly and referred to as char.

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 1980).

B. Regional Distribution Summary

To supplement the distribution information presented in the text, a series of bluelined reference maps has been prepared for each 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. 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.

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, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)
2. Southcentral. Char are widely distributed throughout the Southcentral area. Char are found in the Klutina River and Tonsina River drainages and small tributary streams to 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, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)

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 1980).

1. Water quality:
   a. Temperature. Recorded water temperatures during the spawning period range from 3 to nearly 13°C (ibid.), although char have been observed spawning in temperatures as low as 0.5°C (Moore 1975). In Southeast Alaska, spawning occurs when water temperatures are 5.5

to 6.5°C (Morrow 1980). Egg-hatching and alevin development is quite slow but does 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.

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). Char have been observed spawning in water depths of 0.2 to 4.5 m (Krueger 1981, ADF&G 1977b) and in 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).

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. A gravel layer over fertilized eggs in the redd protects eggs from sunlight and predation and reduces disturbance by ice and floods (Krueger 1981). Lakes, deep pools in large rivers, and spring areas provide critical freshwater overwintering habitat (ADF&G 1977a). Juvenile char burrow into substrate interstices and logging debris and slash to avoid cooling water temperatures (Elliott and Reed 1974).

B. Terrestrial

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). Older char prefer deeper and faster water that affords greater cover.

IV. NUTRITIONAL REQUIREMENTS

A. Preferred Foods

Fry begin active feeding as soon as they emerge. Juveniles feed on various winged insects, larvae of mayflies and midges, 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).

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

(Chironomidae) 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). Alaska Department of Fish and Game investigations have indicated that char captured during this migration contained an average of 8.6 sockeye smolts in their stomachs (Howe 1981).

Palmisano (1971) studied the food habits of anadromous char in lakes on Amchitka Island. He found that in lakes with firm bottoms adjacent to shore and with access to the sea, crustaceans, followed by aquatic insects, were the major foods; whereas in lakes with muddy bottoms, aquatic insects, followed by crustaceans, were the major foods. Char in landlocked lakes on Amchitka fed primarily on aquatic insects, fish, and fish eggs.

In marine waters, smelt, herring, juvenile salmon, sandlance, greenling, csulpins, flounder lrvae, 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).

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.). 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 (1980) 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

No information was found in the literature; however, inferences can be made from work on other salmonid species. Excessive sedimentation may inhibit production of aquatic plants and invertebrate fauna (Hall and McKay 1983) and reduce visual references. While in freshwater, the char may compete directly for food and space with such fishes as grayling, whitefish, sculpins, salmons, 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 1980). 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).

B. Reproductive Seasonality

All races spawn between the end of July and the beginning of December (Meacham 1977, Alt 1977). The peak of spawning activity in Southeast Alaska occurs between September and November (Blackett 1968, Blackett and Armstrong 1965).

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).

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 1980). Morrow (1980) 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 6 to 8 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 1980). 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 age four or five (Blackett and Armstrong 1965).

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 1980). In Alaska, the number of eggs generally ranges from 600 to 8,000 per female (ADF&G 1978, Morrow 1980, 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.

F. Frequency of Breeding

Though char do suffer a high post-spawning 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. Males are much less likely to survive spawning than females. 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. Freshwater char, in contrast to the anadromous type, almost always spawn annually (Armstrong and Morrow 1980).

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). Eggs hatch as 15-to-20-mm-long alevins (yolk sac fry) in March or 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, May, or June (ADF&G 1977a). In Valdez area streams, fry emerge from the gravel in April and May (Dames and Moore 1979).

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

A. Size of Use Areas

Little information was found in the literature on the size of use areas required by char. Armstrong and Elliott (1972) concluded that seasonal distribution of presmolt char was influenced by fluctuating flows and water temperatures. Upper-stream reaches, where water temperatures are consistently warmer in the winter, attract overwintering presmolt char.

B. Timing of Movements and Use of Areas

Resident lake 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 outmigrating sockeye smolt (McBride 1979). During late summer, char move to deeper lake waters, probably in response to a declining availability of sockeye smolt and to escape warming surface waters (Nelson 1966). Mature spawners usually move back to the lake margins to spawn in the fall.

Little is known about the life history of resident stream char. They are common in headwater streams during spring, summer, and fall and may move into lakes for short periods of time, but they also use lower reaches of streams. Overwintering occurs in deep pools of streams and rivers (Morrow 1980). Char in the Susitna River are thought to feed in the upper reaches of tributaries until fall and then migrate to the main stem to overwinter (Sundet and Wenger 1984).

Juvenile anadromous char rear in streams and lakes for two to seven years before outmigrating as smolt (ADF&G 1977a, ADF&G 1977b). Most immature and mature char emigrate from overwintering areas to marine summer feeding areas following ice breakup from April to June. 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 outmigration (Armstrong 1965 and 1970, Armstrong and Kissner 1969, Dinneford and Elliott 1975 and Elliott and Dinneford 1976).

Individuals remain at sea feeding in the estuary and along the coast for a period of a few weeks to seven months (Morrow 1980). While in the marine environment, char stay in coastal areas near the estuary and do not usually migrate distances greater than 100 mi (ADF&G 1977a, ADF&G 1977b). Char begin reentering fresh water in July and may continue through December, with spawners entering first, followed by immature fish and nonspawners (ADF&G 1977a). Both spawning and nonspawning char return to their natal stream or lake to spawn or overwinter (McBride 1979). In the Chignik River system on the Alaska Peninsula, char migrate to sea from April through June and return to Chignik Lake and Black Lake from late July through September to spawn and overwinter (Roos 1959). Emigration of spawned-out char to the sea or 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.

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 dessicate 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 imbed the substrate material and significantly reduce the available overwintering habitat for juvenile char (Bjorn 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).

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

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

VIII. LEGAL STATUS

A. Managerial Authority

The Alaska Department of Fish and Game, Division of Sport Fish, has managerial authority over char.

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 is very little data relating the various char life stages to the physical and chemical characteristics of their habitats.

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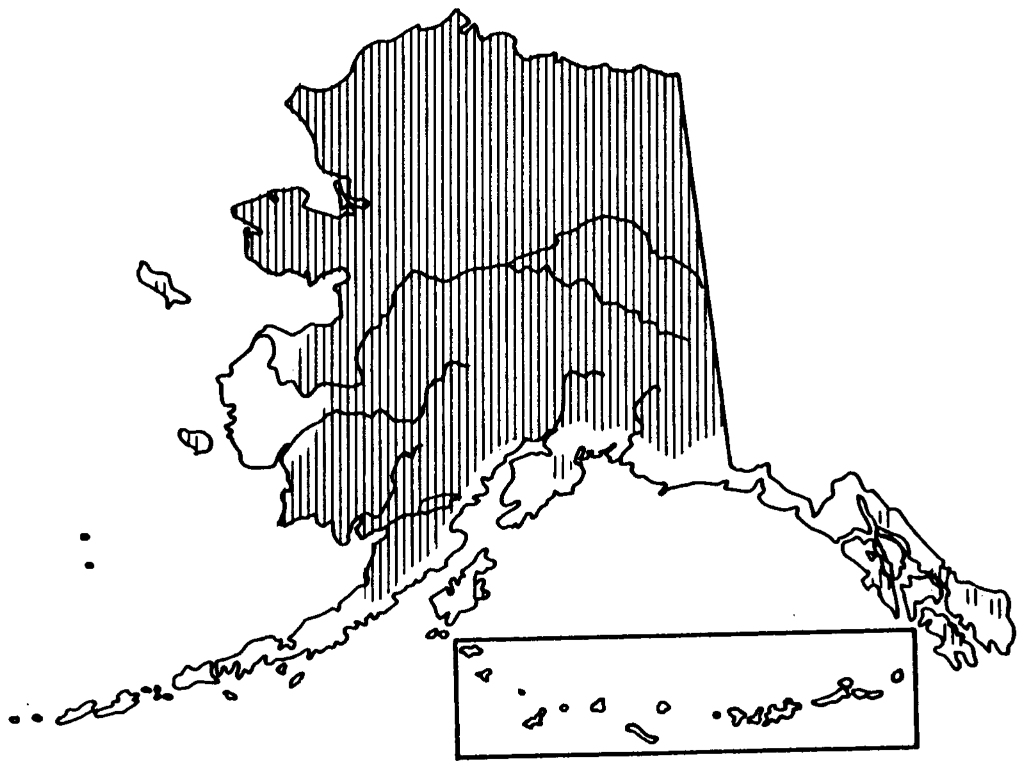
Arctic Grayling Life History and Habitat Requirements
Southwest and Southcentral Alaska



Map 1. Range of arctic grayling (ADF&G 1978)

I. NAME
   A. English Name: Arctic grayling
   B. Scientific Name: Thymallus arcticus (Pallas)

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 Summary

To supplement the distribution information presented in the text, a series of bluelined reference maps has been prepared for each 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. 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.

1. Southwest. Arctic grayling are found in clearwater streams of the 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, 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, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

1. Water quality. Grayling prefer clear, cold lakes and streams (ADF&G 1978), 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 often overwinter, therefore, in the same system 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 (Craig and Poulin 1975). La Perriere and Carlson (1973) found grayling tolerant of temperatures in excess of 20°C under laboratory conditions. 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, Schallock 1966, Wojcik 1955). Grayling in the Tangle Lakes area displayed signs of discomfort and experienced unusually high mortality when taken in waters with a temperature of 17°C (Wojcik 1955, cited in Netsch 1975). Development of eggs to hatching is directly influenced by water temperatures. Temperatures characteristically rise during the incubation period; therefore the eggs are not usually exposed to freezing. 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 Nieuwenhuyse 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. Studies conducted on the Susitna River indicate that grayling avoid high-turbidity waters (Suchanek et al. 1984).

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 desication or freezing of developing eggs and alevins (Wojcik 1954). High velocities or flooding could cause low fertilization, egg dislodgement, and/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). 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 1.2 m/sec in depths of 16 cm. Surface current velocities measured in territories of 22 males in the outlet of Mineral Lake (Interior Alaska) ranged from 0.34 to 1.46 m/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 back waters and flooded stream margins and side channels (Krueger 1981). Older YOY fish occupy progressively faster waters. Aquatic habitat occupied by rearing YOY fish in selected bog streams along the Trans-Alaska Pipeline System (TAPS) had mean column velocities of 0 to 0.15 m/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 0.175 to 0.262 m/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).

   Little is known about grayling migration to overwintering areas; however, current velocities in overwintering sites are probably very low (ibid.).

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 (ibid). 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 (Hammerstrom and McHenry, pers. comm., cited in 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 main stem Colville River (Bendock 1979)
- Gravel 0.5 to 7.6 cm in diameter (Kratt and Smith 1977)
- Relatively uniform distribution of particle sizes from 0.75 mm to 28.1 mm at the outlet of Mineral Lake (Tack 1973)

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). 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 (Hallberg, pers. comm., cited in Krueger 1981; Sautner and Stratton 1984).

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). Bishop (1971) found YOY grayling in the MacKenzie River system feeding on immature mayflies (Ephemeroptera); caddisflies (Trichoptera); and true flies, mosquitoes, and midges (Diptera). 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. 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, stoneflies (Plecoptera), dipterans, and caddisflies (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 1982). In three lakes in Southwest Alaska, Russell (1980) found Trichoptera larvae and adults and cyclopoid copepods to be the most common food items. Salmon eggs, smelt eggs, and shrews have been observed in grayling stomachs from the Naknek River in the Bristol Bay area (Russell, pers. comm.). Other food items include adult chironomids and other dipterans; coleopterans (beetles), and hymenopterans (bees, wasps) (Craig and Wells 1975); gastropods (Wojcik 1954, Russell 1980); 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). 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 (1966) 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 outmigration 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). Within rivers and streams, grayling usually spawn in riffles composed of gravel or rubble (see III.A.3., Substrate, this report). Grayling have also been reported spawning in slow, shallow backwater areas (Wojcik 1954), in a lake over large rubble and vegetated silt (Bendock 1979), in a stagnant pond among sedges over an organic bottom (Tack 1980), and over mud in a slough (Reed 1964).

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 1966, 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). 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.

Tack (1980) suggests that since grayling adults home to the feeding stream annually they probably also home to their natal stream to spawn. 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 feel that some grayling return annually to a particular stream to spawn.

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 Kuskowkwim River, lower Yukon River, Seward Peninsula, and Tanana River, fish reach maturity by age four, five, or six (Alt 1977, 1978, 1980; Armstrong 1982; Wojcik 1955). Most grayling begin spawning in the Bristol Bay area at age five (Russell 1980). Grayling from Crescent Lake on the Kenai Peninsula mature at age three or four (Engel 1973). Grayling in the upper Susitna River mature at age four or five (ADF&G 1983, Schmidt and Stratton 1984). In the Northslope systems, most grayling appear to mature later, at ages six to nine (Armstrong 1982, Craig and Wells 1975). 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 8 years, 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 (1966) 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/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).

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

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. Grayling move into smaller tributaries 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 (Armstrong 1982, Sundet and Wenger 1984). Immature fish generally follow closely behind adults. Immediately after spawning, many of the adults move out of the smaller streams to up-river summer feeding areas, but most juveniles remain in small streams until late August or September. 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). Lake-dwelling populations move into tributaries to spawn in the spring and may return to the lakes shortly after spawning (Engle 1973), or may remain in the tributaries until fall (Saunter and Stratton 1984). Grayling leave Deadman Lake in mid June and do not return until early September (ibid.).

C. Migration Routes

A river's 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).

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

Excessive water velocities can cause low fertilization, egg dislodgement, and alevin displacement (Nelson 1954; Tack 1971, 1974). 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 (<u>Salmo gairdneri</u> Richardson); arctic char (<u>Salvelinus alpinus</u> [Linnaeus]); round whitefish (<u>Prosopium cylindraceum</u> [Pallus]); northern pike (<u>Esox lucius</u> [Linnaeus]); and longnose suckers

(Catostomus catostomus [Forster]), also consume arctic grayling eggs and alevins (Bishop 1971, MacPhee and Watts 1976, Alt 1977).

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

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

VIII. LEGAL STATUS

The Alaska Department of Fish and Game, Division of Sport Fish, has managerial authority over arctic grayling.

IX. LIMITATION 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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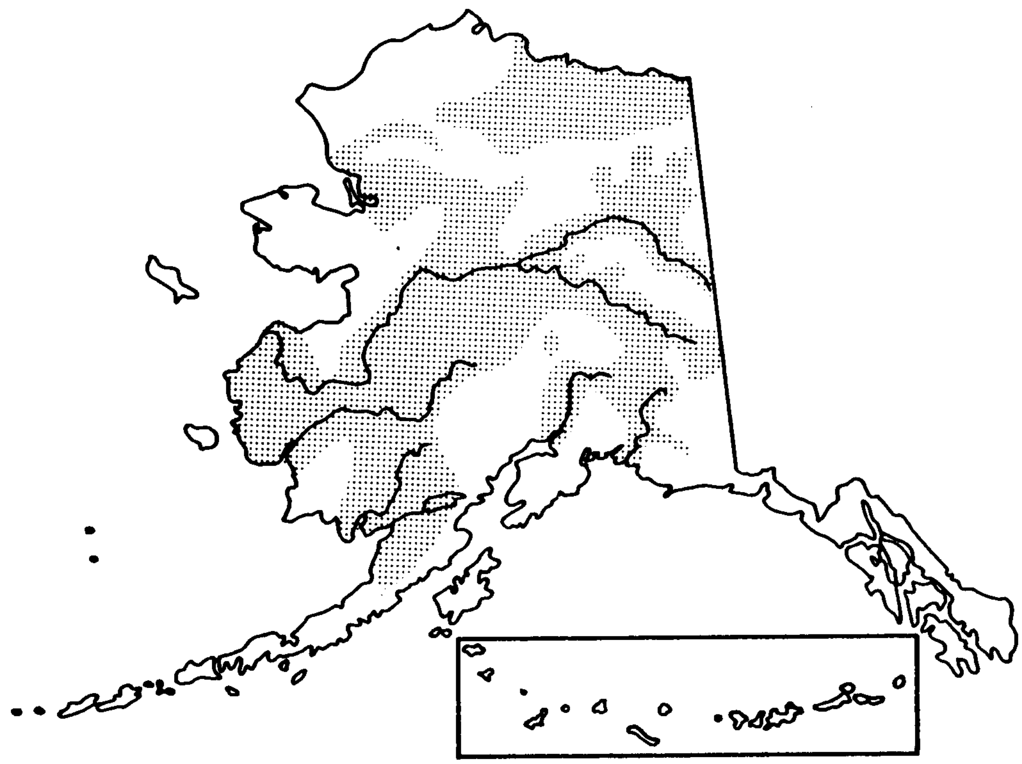
Burbot Life History and Habitat Requirements
Southcentral Alaska



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

I. NAME
   A. Common Name: Burbot
   B. Scientific Name: Lota lota (Linnaeus)
   C. Species Group Representation: Burbot is a member of the codfish family (Gadidae) and is the only species 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 Summary

To supplement the distribution information presented in the text, a series of bluelined reference maps has been prepared for each 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. 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.

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

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, embroyonic development, and hatching were observed in salinities up to 12 ppt, but the mortality rate increased at later embroyonic 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 mainstem 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 four to five, 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 mainstem (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 two to four in the southern part of their range but generally not until they reach ages six or seven in interior Alaska (Chen 1969). Colville River burbot reach sexual maturity at age seven (Bendock 1979), whereas most burbot in Moose Lake, near Glenallen, are sexually mature by age five (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 and c). One radio-tagged burbot moved downstream approximately 60 mi in the winter and then held its new position (ADF&G 1983b).

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 Department of Fish and Game, Division of Sport Fish, has managerial authority over burbot.

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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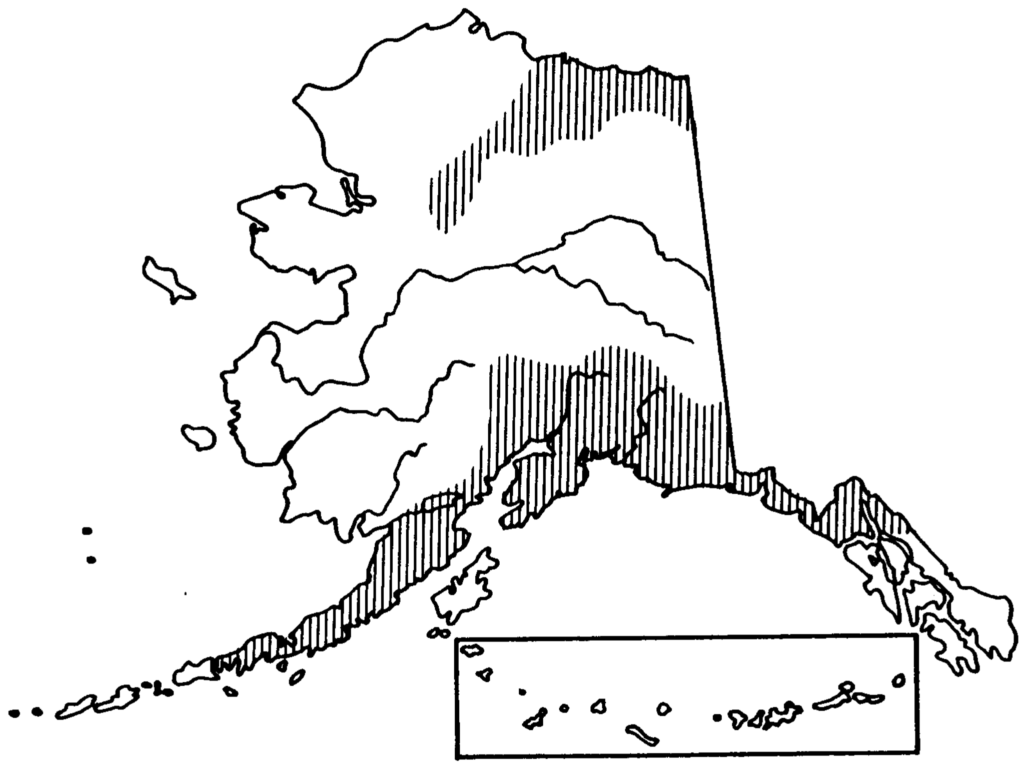
Lake Trout Life History and Habitat Requirements
Southcentral Alaska



Map 1. Range of lake trout (Morrow 1980)

I. NAME
   A. Common Name: Lake trout
   B. Scientific Name: Salvelinus namaycush (Walbaum)
      Lake trout are not a true trout (genus Salmo); most ichthyologists place them in the genus Salvelinus to emphasize their close relationship to other char (McPhail and Lindsey 1970).

II. RANGE
   A. Statewide
      Lake trout are distributed throughout highland lakes of the Brooks Range, the Arctic coastal plain, Bristol Bay, and the Kenai and upper Susitna and Copper river drainages (ADF&G 1978b). They are generally absent from lakes of the Northslope lowlands and the lower Yukon-Kuskokwim river basins (Morrow 1980, McPhail and

Lindsey 1970) and are not found in the Wood River system or in Alaska Peninsula systems south of Mother Goose Lake (Alt 1977).

B. Regional Distribution Summary

To supplement the distribution information presented in the text, a series of bluelined reference maps has been prepared for each 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. 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.

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, Paxon, Crosswind, Fielding, and Susitna lakes and Klutina Lake and River). They are found in several lakes on the Kenai Peninsula (e.g., Tustumena, Skilak, Hidden, Swan, Juneau, and Kenai lakes; also 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 1970). (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 quality:

a. Temperature. Lake trout can tolerate only a narrow range of temperatures, generally inhabiting waters with temperatures ranging between 4.4 and 10°C in the shallows during winter and in deeper waters below the thermocline during summer (Alt 1977, ADF&G 1978b, Rawson 1961). The upper limit of preferred temperature is reported to be 12°C (Ferguson 1958). Optimum spawning temperature is 8.8 to 10°C (ADF&G 1978).

b. The pH factor. Little information was found in the literature on the influence of pH levels on the survival and development of lake trout. Waters of the western North Slope inhabitated 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).

c. Dissolved oxygen (D.O.). No information was found on the influence of dissolved oxygen levels on the survival and development of lake trout in Alaska. Studies examining the eutrophication (increased suspension of phytoplankton and detritus) 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; no minimum concentrations were reported, however (Leach and Nepszy 1976).

d. Turbidity. Turbidity and resultant sedimentation from either runoff material or eutrophication could degrade inshore spawning areas used by lake trout (ibid.).

e. 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 11-13 parts per thousand.

2. Water quantity. Lake trout require lakes large enough and 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.

3. Substrate. Spawning typically occurs over a clean, rocky, or rubble bottom (Morrow 1980, ADF&G 1978b, Rawson 1961).

B. Terrestrial

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. They may spend several years hiding in the rubble of a lake bottom (Alt 1977, ADF&G 1978b).

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, detrius, insect (Diptera) larvae, and some small fish (Morrow 1980, ADF&G 1978b, Redick 1970). As lake trout mature, they begin to eat more fish and fewer invertebrates; some feed on plankton throughout their lives (Martin 1966). Preferred foods include fish (Coregonids, slimy sculpin [*Cottus cognatus* Richardson], ninespine stickleback [*Pungitius pungitius* Linnaeus], and juvenile salmon), snails, Diptera larvae, plant material, and small mammals (voles) (Alt 1977, 1978, Bendock 1979, Morrow 1980, Redick 1970, Scott and Crossman 1973). 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).

B. Types of Feeding Areas Used

Juvenile lake trout 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 (Redick 1970). 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).

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 (ibid.).

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 1970). Redick (1970) reported that all spawning in Susitna Lake appeared to occur between depths of from 2 to 5 m. Spawning sites are often associated with windy areas because of the water movements produced by wave action (ADF&G 1978b).

B. Reproductive Seasonality

Generally, lake trout spawn in late summer and early autumn, depending on latitude, water temperature, and the size and elevation of the lake (ADF&G 1978b, Scott and Crossman 1973). Spawning occurs as early as late August and early September in northern Alaska (McCart et al. 1972) to as late as November in Canada (Scott and Crossman 1973).

C. Reproductive Behavior

Males typically reach the spawning grounds first, select the spawning site, and then prepare it by brushing the mud and silt off the rocks with their body or tail fin or by rubbing them with their snouts. They do not dig a redd. A group of several males may clean an area of several dozen square meters (Martin 1957).

Females arrive a few days after the males. 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 V to VII but may not be achieved until as late as age XIII (Morrow 1980, ADF&G 1978b, Scott and Crossman 1973). In the lower Kuskokwim River and Kuskokwim Bay area, sexual maturity is not reached until ages VIII to XI (Alt 1977). Males usually mature a year earlier than females (Morrow 1980).

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 (ibid.).

E. Frequency of Breeding

Spawning frequency may vary from annually to about once in three years, but most adult lake trout spawn every other year (Morrow 1980, ADF&G 1978b, Rawson 1961).

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).

G. Incubation Period/Emergence

Incubation requires 15 to 21 weeks or more, depending on water temperature; and alevins (yolk-sac fry) usually hatch in mid February or late March (Eschmeyer 1955, Martin 1957). The alevins remain in the cover of the rocky substrate approximately a month until their yolk sac is absorbed; then the newly emerged fry move away from the spawning areas and into deeper water (Morrow 1980, Scott and Crossman 1973).

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 break-up 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°C 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. 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. Small lake trout are also preyed upon by burbot and northern pike (Redick 1970). Round whitefish have been reported consuming eggs of river-spawning lake trout (Loftus 1958), and burbot are reported to eat lake trout eggs (Anon. 1960).

B. Human-related

Freshwater habitat is critical to lake trout populations. Each system is a semiconfined environment in which the population spends all life phases, including the most sensitive life functions of spawning, rearing of young, and feeding. These activities frequently are undertaken in different locations within a lake or tributary or outlet stream and therefore require movement within the system. Disturbances that degrade lake trout spawning, rearing, or feeding habitats, degrade water quality, or block fish migration routes may adversely affect the population levels of lake trout that use the disturbed 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 lake/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 of this series for additional information regarding impacts.)

VIII. LEGAL STATUS

The Alaska Department of Fish and Game, Division of Sport Fish, has managerial authority over lake trout.

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. No information was found in the literature relating the various lake trout life stages to the chemical characteristics of their habitats. Little information was found on the effects of environmental changes. A better understanding of population dynamics, feeding habits, and river-spawning populations is necessary.

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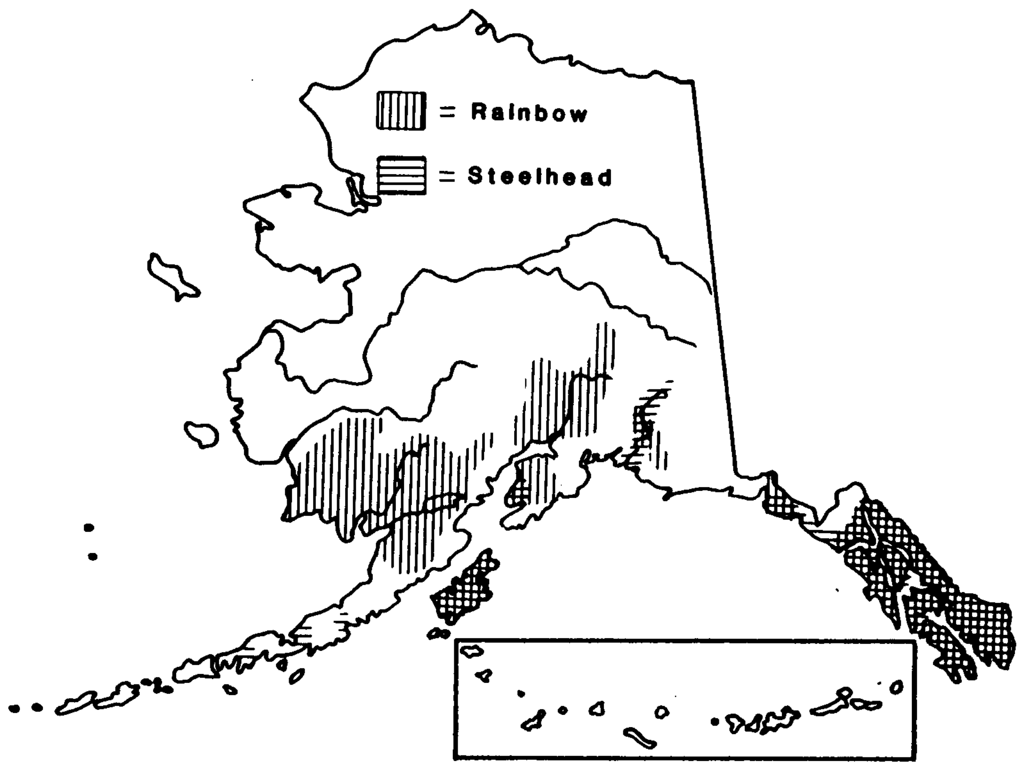
Rainbow Trout/Steelhead Trout
Life History and Habitat Requirements
Southwest and Southcentral Alaska



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

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 Summary

To supplement the distribution information presented in the text, a series of bluelined reference maps has been prepared for each 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. 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.

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 fmore detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)

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, acclimization to pH levels above 8.5 must take place gradulaly (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 Merkens 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). 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).

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).

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 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 Idavin creek in the Naknek drainage in southwestern 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 six and seven (Russell 1977). In the Susitna River, rainbow trout of both sexes spawn after age V (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 fist-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 percent 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 (Russel 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.

VII. 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 Department of Fish and Game, Division of Sport Fish, has managerial authority over rainbow and steelhead trout.

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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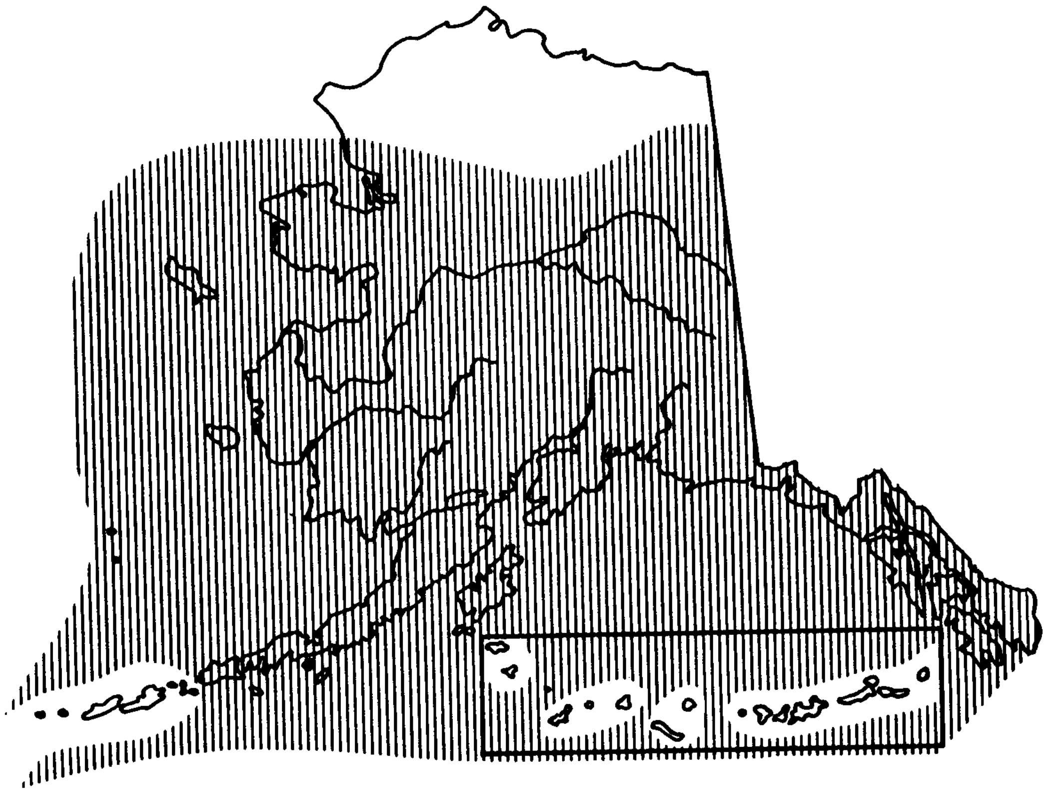
Chinook Salmon Life History and Habitat Requirements
Southwest and Southcentral Alaska



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

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 Summary

To supplement the distribution information presented in the text, a series of bluelined reference maps has been prepared for each 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. 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.

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 Menshikof 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, Homes 1982). Chinook salmon are found in one drainage on the southside 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 Willaims Sound area, the Copper River drainage accounts for most of the chinook salmon production (ADF&G 1977b, ADF&G 1978).

   (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 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 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 and Burrows (1965) found that 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 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 1310 cm/hr. He 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.

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) (Whitmore et al. 1960). He 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 (Bell 1973). 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 (Reiser and Bjornn 1979). 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. His 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.

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). 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 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 (Mayor 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 occurrred, 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 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 Farenheit - 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 m^2 in size. Mean values for mainstream Kenai River chinook salmon redds, however, are 6.38 m^2.

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). Outmigrating 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 outmigrations tended to be nocturnal.

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 outmigration. 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 year 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 [Yakutat] southward) are known to occur as immatures in the North Pacific Ocean as far west as 176°34'W (at 59°29'W), but no fish from these stocks have yet been found in the Bering Sea. For these stocks, it is known only that chinook salmon are widely scattered in the Gulf of Alaska and farther south but that their principal occurrence is in relatively large concentrations close to shore (ibid.).

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

Juvenile chinook salmon are preyed on by other fish (e.g., rainbow, cutthroat, Dolly Varden, coho salmon smolts, squawfish, 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, humans, 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

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

VIII. LEGAL STATUS

A. Managerial Authority

The Alaska Department of Fish and Game manages the fresh waters of the state and the marine waters to the 3 mi limit.

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.

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/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 collected/published. Most of the available information has been documented from Pacific Northwest and Canadian field and laboratory studies.

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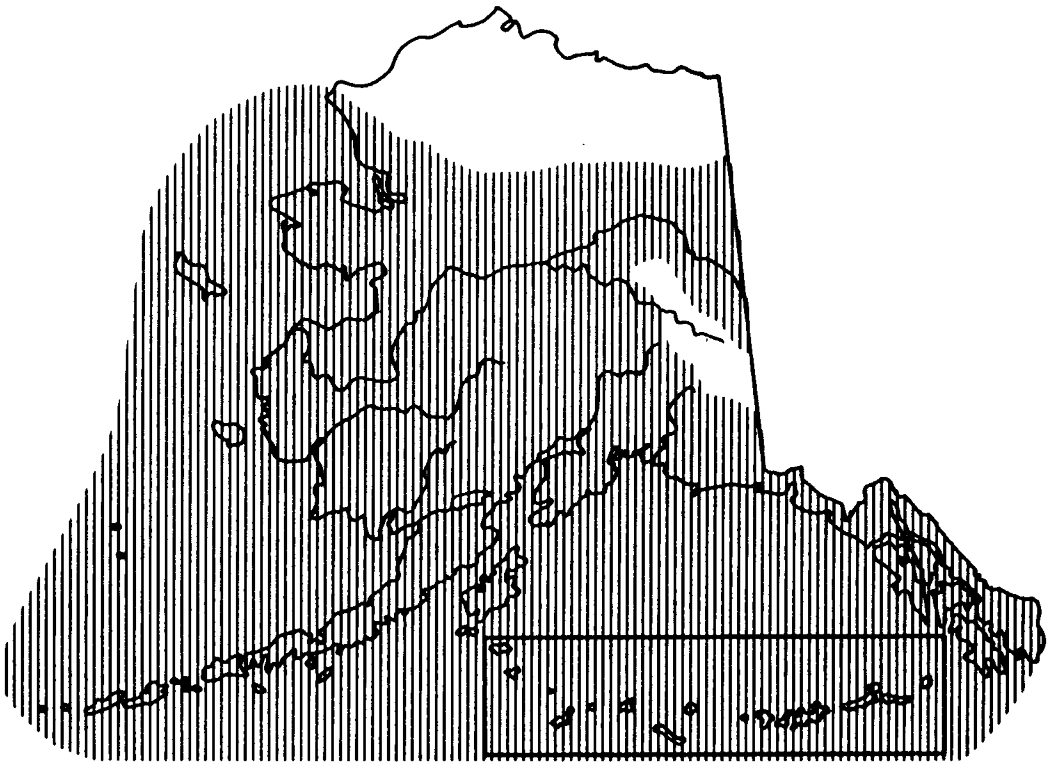
Coho Salmon Life History and Habitat Requirements
Southwest and Southcentral Alaska



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

II. RANGE
   A. Worldwide
   The coho salmon occurs naturally in the Pacific Ocean and its tributary drainage. 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 the Dixon Entrance (Southeast Alaska) north to the Yukon River. Evidence suggests

that coho are rare north of Norton Sound (ADF&G 1977).

C. Regional Distribution Summary

To supplement the distribution information presented in the text, a series of bluelined reference maps has been prepared for each 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. 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.

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 northside 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 1978). They are also found in numbers in the Copper and Katalla river drainages (ADF&G 1978, 1983c).

   (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 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 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 Gribanov, 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.0 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 quanitity:

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 the following spawning velocity (as measured 0.12 m above streambed) and minimum depth criteria for Oregon coho salmon as 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 production is from gravel and riffle-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 juvenile coho 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. 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 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, euphasiids, 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 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 system from the Bonasila River at least as far upstream as the Tanana (Morrow 1980). 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).

B. Reproductive Seasonality

In Alaska, coho salmon enter freshwater streams from mid July through November (Russell, pers. comm.). Actual spawning occurs between September and January (ADF&G 1977). 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 m^2 to 6.6 m^2, with a general average of about 2.8 m^2 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 age three or four. 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/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.

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 m^2. 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 outmigration 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.

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. Alaska Peninsula coho salmon spend only one year in salt water (Shaul, pers. comm.). Few details are known regarding the times of arrival of coho salmon off western Alaska streams, except that again they are late in the season and follow the runs of the sockeye and pink salmon (Morrow 1980, Godfrey 1965).

The beginning of intensive adult upstream migration is associated with the beginning of a rising tide and schooling off the mouth of a river, in brackish waters, and occurs during the period of the falling tide (Gribanov 1948). When in the river, they move upstream mainly during daylight hours (Neave 1943).

C. Migration Routes

Rivers and streams serve as corridors for smolt outmigration. 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).

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).

Godfrey (1965) states that the direction of movement from the high seas of returning North American coho salmon is not yet clear. It appears, however, that they enter the Gulf of Alaska in the early spring and summer from a southeasternly direction. An area of concentration builds up in the center of the gulf during late June, following which the coho salmon apparently disperse toward the coasts in many directions.

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 smolts, cutthroat and rainbow trout, Dolly Varden, squawfish 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, man, 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 volocity 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 information regarding impacts.)

VIII. LEGAL STATUS

A. Managerial Authority

The Alaska Department of Fish and Game manages the fresh waters of the state and marine waters to the 3-mi limit.

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 175th 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.

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 collected/published. Most of the available information has been documented 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/evolved over time and space to habitat conditions that can vary greatly.

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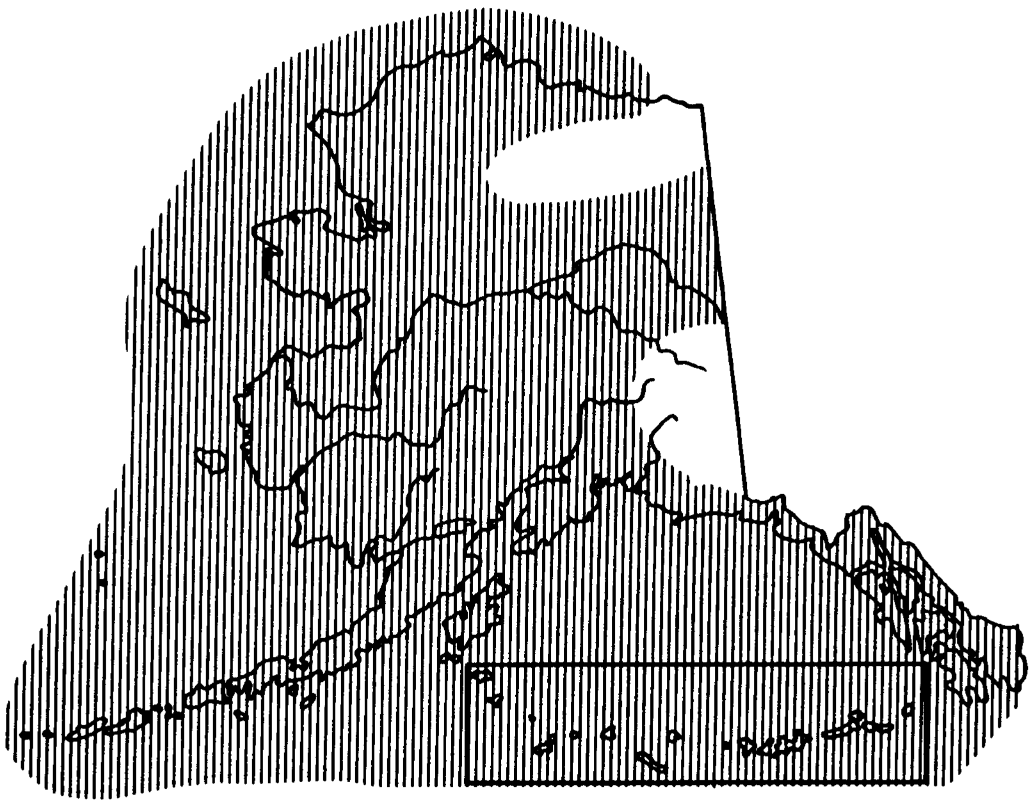
Chum Salmon Life History and Habitat Requirements
Southwest and Southcentral Alaska



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

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 Summary

To supplement the distribution information presented in the text, a series of bluelined reference maps has been prepared for each 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. 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.

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).

   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 is a moderate chum salmon producer (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 (Shaul, pers. comm.). 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 NcNeil, 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 linked to geographic distribution 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 is 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 1978).

(For more detailed narrative information, see volume 2 of the Alaska Habitat Managment Guide for the Southcentral Region.)

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

1. Water quality:

a. <u>Temperature</u>. 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).

Emergence from the gravel and downstream migration to the sea have occurred at temperatures between 3.0 and 5.5°C; peak movements, however, occur at warmer temperatures (i.e., 5.0 to 15°C) (Hale 1981). During laboratory experiments, Brett (1952) found the upper lethal temperature limit of chum salmon juveniles to be 23.8°C. Brett and Alderdice (1958) in later experiments showed the ultimate lower lethal temperatures of juveniles 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 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°C (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 Bjorrn 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, juveniles when presented with a choice between two channels with "laminar" flows preferred 350, 500, 600, and 700 ml/min flows to a flow of 200 ml/min, and the greatest response 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).

During spawning, chum salmon make redds in water depths ranging from 5 to 120 cm (Kogel 1965). Water velocity at spawning sites has ranged from 0 to 118.9 cm/sec (Hale 1981). The ADF&G (1977) states that optimum stream flow is 10 to 100 cm/sec (presumably for spawning and incubation).

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). 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." 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 distrubances. 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). 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). Those that must spend several days to weeks on their journey, however, feed actively on chironomid larvae, cladoceans (water fleas), copepods, nematodes, and a variety of mature and immature insects (Morrow 1980, Scott and Crossman 1973).

During their early sea life they feed on a wide variety of organisms, such as diatoms, many small crustaceans (e.g., chaetognaths, ostracods, cirripeds, mysids, cumaceans, isopods, amphipods, decapods), dipterous insects, and fish larvae. Copepods, tunicates, and euphasiids dominate the diet at sea (Morrow 1980, Scott and Crossman 1973). Other items eaten at sea include other fishes, pteropods, squid, and mullusks.

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 freshwater 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. Juveniles appear to be benthic feeders, relying on aquatic insects to supply the bulk of their food (Bakkala 1970). Adult feeding seems to be opportunistic and is based on availability of, rather than 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 ground water emergence. These areas tend to maintain water flows and temperatures warm enough to keep from freezing during the winter months (Morrow 1980, Hale 1981).

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 northern populations occuring from July to early September and for southern populations in October or November (Morrow 1980, Hale 1981). 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.).

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/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 interior and northern Alaska is not definitely known. 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 m^2 to 4.5 m^2 (Hale 1981). The ADF&G (1977) states that the optimum size is considered to be 3 m^2.

B. Timing of Movements and Use of Areas

Soon after emerging from the gravel, juvenile chum salmon begin moving to the sea. Downstream migration is usually at night near the surface of the water and in the center of the stream, where the currents are strongest. When the migrations cannot be made in one night, the young fish hide in the gravel by day (Bakkala 1970, Scott and Crossman 1973, Hunter 1959).

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."

C. Migration Routes

Rivers serve as corridors for smolt outmigration. 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 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 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, squawfish, and sculpins. . . . Kingfisher, merganser, other predaceous birds, and mammals are also responsible for a small loss. Even stonefly larvae and possibly other predaceous insects may prey on eggs and alevins. Water temperature, floods, droughts, other fluctuations in water level, spawning competion, and poor returns of adults, control number of young to a far greater extent." At sea, chum salmon are preyed upon by man, 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

The Alaska Department of Fish and Game manages fresh waters of the state and marine waters to the 3-mi limit.

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 managment 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.

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 collected/published. Most of the available information has been documented 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/evolved over time and space to habitat conditions that can vary greatly.
The distribution and abundance narrative for the salmon species, presented by ADF&G commercial fisheries management areas, follows the aggregated salmon life histories.

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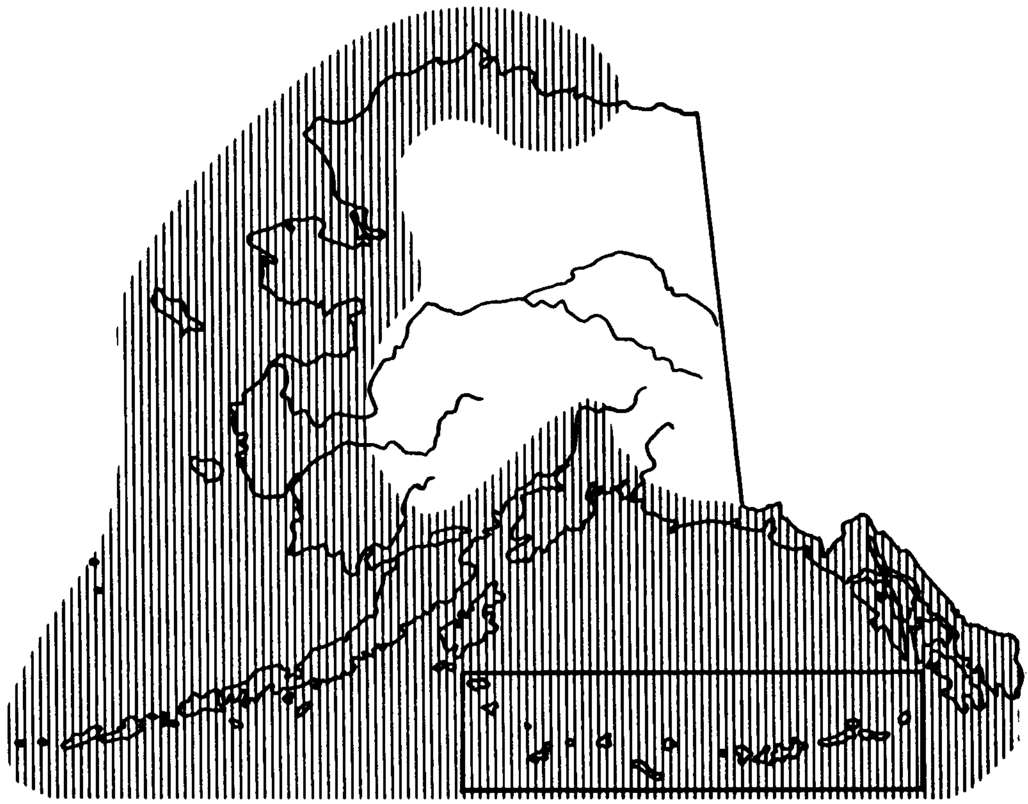
Pink Salmon Life History and Habitat Requirements
Southwest and Southcentral Alaska



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

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 Nandai 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 larger river systems such as the Kuskokwim and Yukon some may go as much as 160 km (Morrow 1980). They are known to move great distances in the Nushagak River drainage. 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 1984). Recent studies on the Susitna River in Southcentral Alaska have found spawning pink salmon at least 223 km upstream (ADF&G 1981).

C. Regional Distribution Summary

To supplement the distribution information presented in the text, a series of bluelined reference maps has been prepared for each 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. 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.

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 Menshikof 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

2 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 1981a).

   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 catagorized 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) utilized 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 1978).

   (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 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 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 (Baldridge, pers. comm. cited in Krueger 1981).

      Water velocity at spawning locations 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 (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 area 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, euphasiids, amphipods, ostracods), larvae of decapods, cirripedes and tunicates, and dipterous insects (Neave 1966). 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 euphasiids, amphipods, fish, squid, copepods, and pteropods (ibid.).

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 that 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). 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."

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/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). 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 longititude 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 north-central 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 Southwestern 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, squawfish, 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 man, 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).

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

The Alaska Department of Fish and Game manages fresh waters of the state and marine waters to the 3-mi limit.

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.

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 collected/published. Most of the available information has been documented from Pacific Northwest and Canadian field 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/evolved over time and space to habitat conditions that can vary greatly.

The distribution and abundance narrative for the salmon species, presented by ADF&G commercial fisheries management areas, follows the aggregated salmon life histories.

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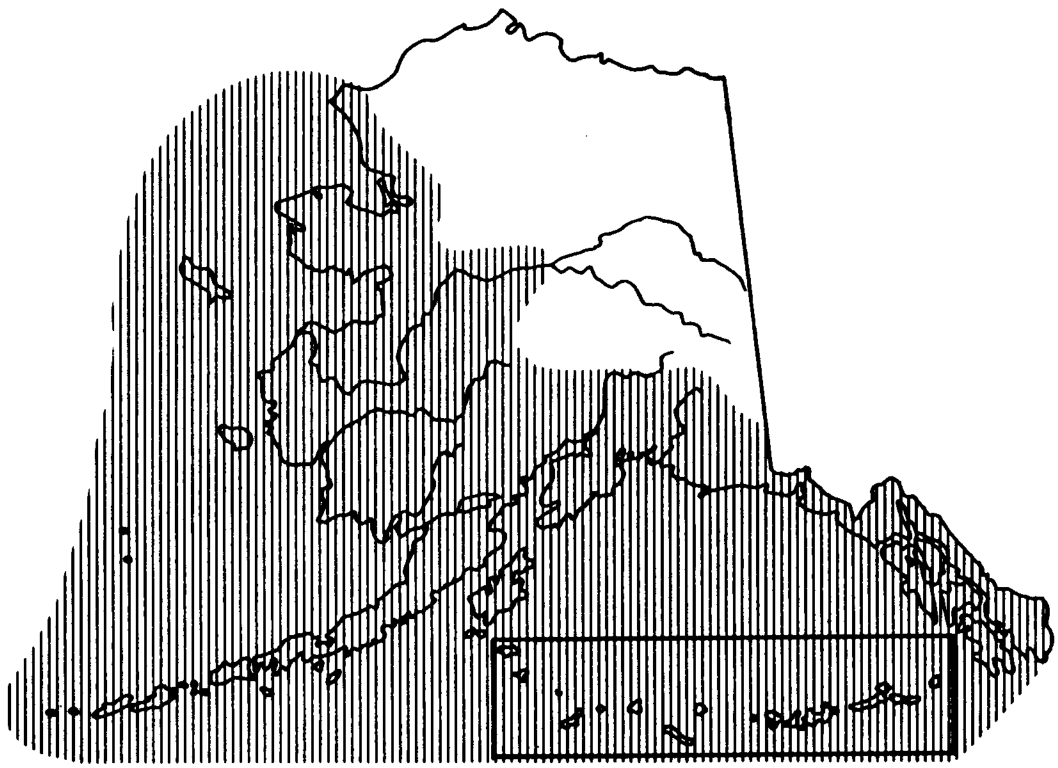
Sockeye Salmon Life History and Habitat Requirements
Southwest and Southcentral Alaska



Map 1. Range of sockeye salmon (ADF&G 1978, Morrow 1980)

I. NAME
   A. Common names: Sockeye salmon, red salmon, blueback salmon
   B. Scientific name: <u>Oncorhynchus</u> <u>nerka</u>

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 Summary

To supplement the distribution information presented in the text, a series of bluelined reference maps has been prepared for each 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. 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.

1. Southwest. In the Kodiak area, major sockeye salmon spawning and rearing waters include the Karluk, Red (or Ayakulik) River, and Upper Station systems. The Fraser Lake and Akalura Lake systems are growing in productivity (ADF&G 1977b).

   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 1977a).

   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 1977a), 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 1982). 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, with runs also found in the Bering, Eshamy, and Coghill systems (ADF&G 1978).

   (For more detailed narrative information, see volume 2 of the Alaska Habitat Guide for the Southcentral Region.)

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 the upper lethal temperature limit is 24.4°C (Brett 1952), and preferred temperatures range from 12° to 14°C (ibid.). Smolt outmigration from freshwater nursery lakes takes place between 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 substrate 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).

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, prickle 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 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 present, and 3) the numbers of other species of fish in the lake that compete with sockeye 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 1977). 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 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).

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 1977; 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 1977). 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 m^2, depending on the concentration of fish in the area, although under "normal" conditions a size of 1.6

m^2 to 2.9 m^2 is more likely (Foerster 1968). The ADF&G (1977) states that the redds of lake spawners are usually larger than 1.75 m^2 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 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) permability, 11) porosity, and 12) light (Reiser and Bjornn 1979, Foerster 1968). Generally speaking, factors 4 through 12 influence/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 m^2 as spawning territory. When competition for space is eliminated each female occupies an average area of 6.97 m^2. The ADF&G (1977) states that a redd (presumably in Alaska) generally averages 1.75 m^2 in stream spawning areas. No specific data on redd size in Alaskan lake-spawning areas was 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 outmigration occurs during June.

Following is a summary of ocean chronological distribution as stated 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. The timing and locations of their offshore migrations are unknown. In the winter as age 0.1 fish 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 0.1 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 0.1 fish moving northward, a migration that continues until August. During the summer the sockeye 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 0.1 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 0.2 fish is generally similar to that which they had as age 0.1 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 0.3 fish) winter in areas somewhat north of their age 0.2 range.

Both age 0.2 and age 0.3 groups occur in the Bering Sea in winter (the age 0.3 fish apparently in greater abundance than the age 0.2 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 0.0) 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 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, squawfish, rainbow trout, coho salmon, and prickly sculpin (Hart 1973). Adults may be preyed on by Pacific harbor seals (*Phoca vitulina richardsi*), bears, sea gulls, and man (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

The Alaska Department of Fish and Game manages the fresh waters of the state and marine waters to the 3-mi limit.

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.

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.

In addition, 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/evolved over time and space to habitat conditions that can vary greatly.

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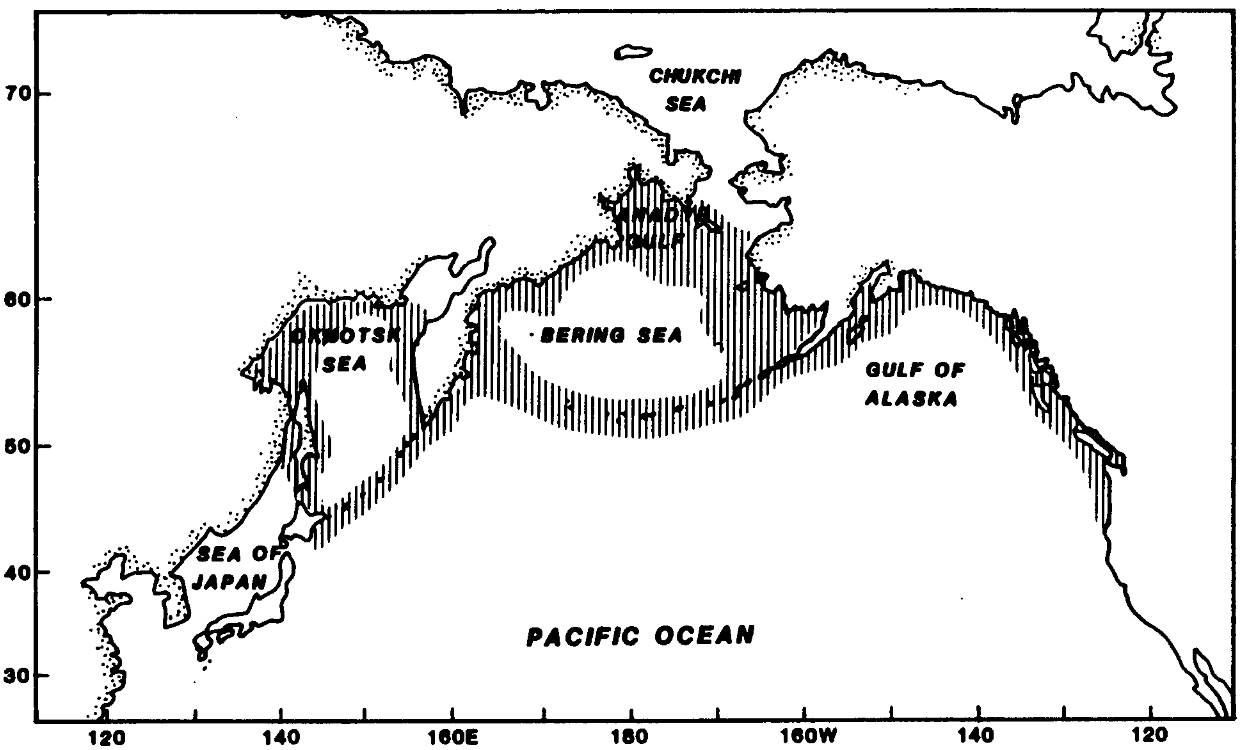
Marine Fish

Pacific Cod Life History and Habitat Requirements
Southwest and Southcentral Alaska



Map 1. Range of Pacific cod (Salverson and Dunn 1976)

I. NAME
   A. Common Name: Pacific cod
   B. Scientific Name: Gadus macrocephalus (Tilesius)

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 Summary
      To supplement the distribution information presented in the text, a series of bluelined reference maps has been prepared for each 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. 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.

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 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 mfore 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 catch per unit effort (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^{0}/00 (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 pallasi) 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.

In the Bering Sea, a 1980 Northwest and Alaska Fisheries Center (NWAFC) study reported that 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 two (49 cm in length). At age three (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 one fish found in inner continental shelf waters, age two and three on the central shelf, and age four 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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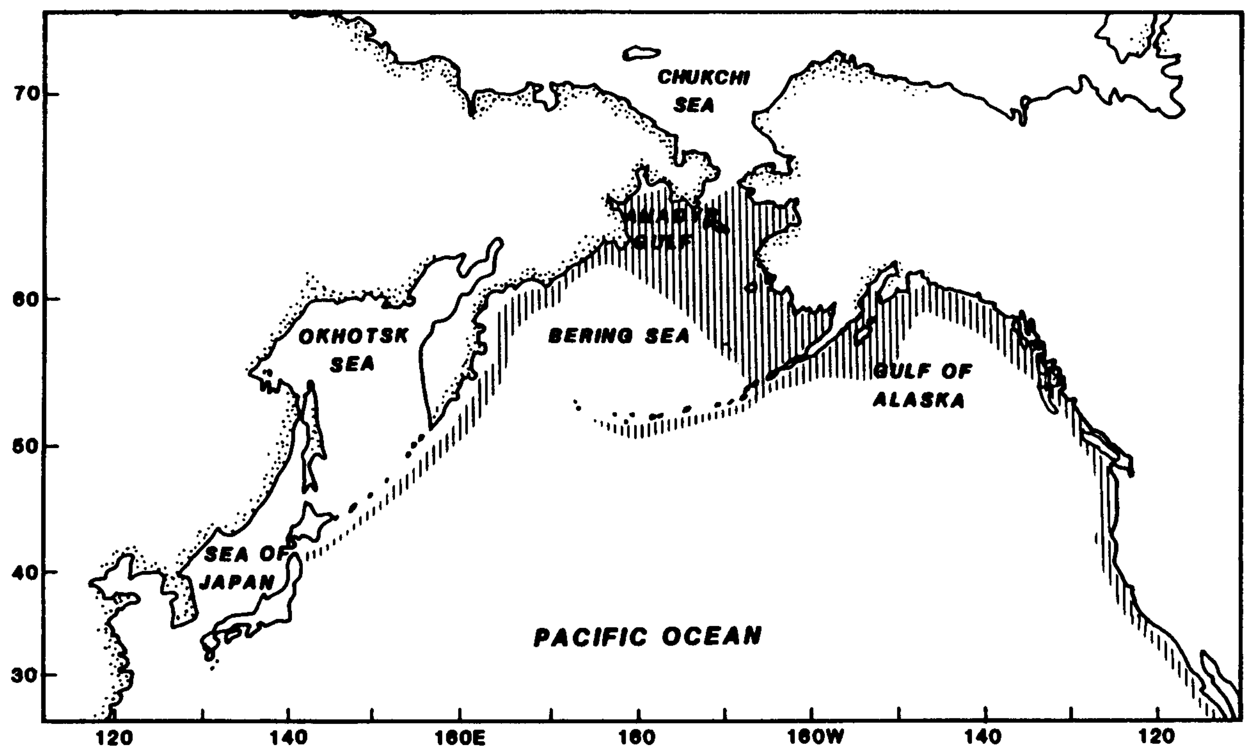
Pacific Halibut Life History and Habitat Requirements
Southwest and Southcentral Alaska



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

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 Summary
   To supplement the distribution information presented in the text, a series of bluelined reference maps has been prepared for each

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. 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.

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). (For more detailed narrative information, see 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 this publication. (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)

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
Spawning individuals concentrate along the continental shelf at depths from 228 to 456 m. Some spawning also occurs at many other locations (Bell 1981). Major spawning sites in the Southcentral Region include areas along the continental shelf east and west of Middleton Island, south of Cape Cleare, and in Amatuli Trough (St. Pierre, in press).

B. Reproductive Seasonality
In the Gulf of Alaska, breeding takes place from November to March (IPHC 1978). In the Bering Sea, Novikov (1964) reported spawning from October to March.

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 yr, at a length of 122 cm. Males in the Bering Sea averaged 7.5 yr and 72 cm at 50% maturity.

D. Frequency of Breeding
The long (approximately 12-yr) 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 Groundfish Management Plan 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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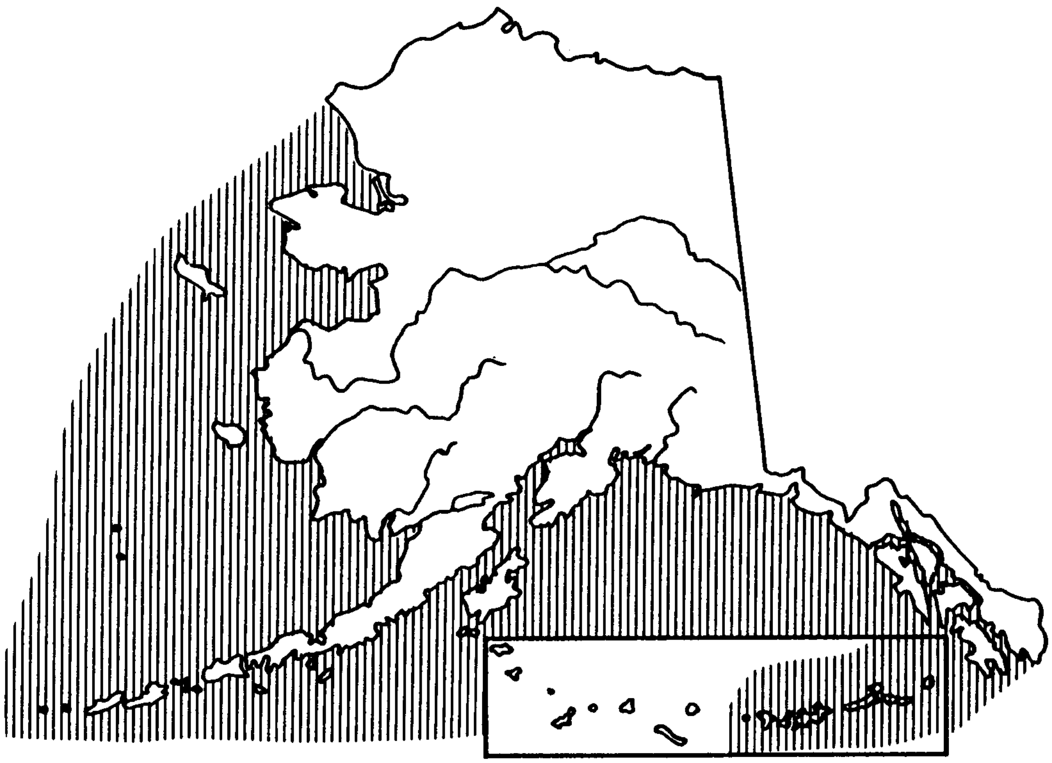
Pacific Herring Life History and Habitat Requirements
Southwest and Southcentral Alaska



Map 1. Range of Pacific herring (ADF&G 1978; Malloy, pers. comm.)

I. NAME
   A. Common Name: Pacific herring
   B. Scientific Name: Clupea harengus pallasi

II. RANGE
   A. Worldwide
      In North America, herring are found from San Diego Bay, California, to Cape Bathurst in the Beaufort Sea (Hart 1973). In Asia, they range from Taksi Bay to the Yellow Sea (Andriyashev 1954).
   B. Statewide
      In Alaska, herring are in a continuous distribution from Dixon Entrance in Southeastern Alaska to Point Barrow (ADF&G 1978).

C. Regional Distribution Summary

To supplement the distribution information presented in the text, a series of bluelined reference maps has been prepared for each 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. 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.

1. Southwest. Major concentrations exist in the Kodiak area, along the Alaska Peninsula and Aleutian Islands, and in Bristol Bay. (For more detailed narrative information, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)
2. Southcentral. Major concentrations exist in Prince William Sound and Lower Cook Inlet. (For more detailed information, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)

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 temperatures (Wespestad and Barton 1981). Immature herring may occupy less saline waters than adults (Taylor 1964). Juveniles, however, are found in a wide range of salinities in British Columbia, with most concentrations located at 25 parts pers 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 or preference for colder, less saline areas on their overwintering grounds on the continental shelf than do adult fish (Westpestad 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 and Port Heiden, herring appeared on the spawning grounds when temperatures reached 6°C. A temperature of 10°C has been documented in Bristol Bay during the spawning season (Warner and Shafford 1977). Water temperatures on Bering Sea spawning grounds between Norton Sound and Bristol Bay have ranged between 5.6° and 11.7°C (Barton 1979). Optimum temperature for egg development in the laboratory is from 5° to 9°C. Below 5°C, eggs die (Alderdice and Velsen 1971).

B. Water Quantity

Adults were found to overwinter at depths of 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 remain in shallower coastal waters after spring spawning in the Bering Sea (Pereyra et al. 1976, Bakkala and Smith 1978).

C. Substrate

See Reproductive Habitat, 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). The first food eaten by larval herring may be limited to relatively small, microscopic plankton organisms that the larvae must nearly run into to notice and capture. Early food items may be comprised of more than 50% microscopic eggs (Wespestad and Barton 1979).
2. Juveniles. Juveniles consume mostly crustaceans such as copepods, amphipods, cladocerans, decapods, barnacle larvae, and euphasiids. 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 has consisted of medium forms of zooplankton (Chaetognaths, mysids, copepods, and tunicates) (Kachina and Akinova 1972).
3. Adults. 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 preferred euphausiids, copepods (*Calanus* spp.), and arrow worms (*Sagitta* spp.) (Dudnik and Usoltsev 1964). In demersal areas, stomach contents 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. Rather than exhibiting a preference for certain food items, adult herring feed opportunistically on any large organisms predominating among the plankton in a given area (Kaganovskii 1955).

B. Feeding Locations

Feeding occurs primarily offshore 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 heavy phytoplankton blooms and poor feeding conditions exist on the outer shelf (Rumyantsev and Darda 1970). Herring may avoid areas of heavy phytoplankton bloom because of the low nutritional value of the phytoplankton and because their gills may become clogged by certain species of phytoplankton and their respiration thereby affected by certain species of phytoplankton (Henderson 1936).

C. Factors Limiting Availability of Food

Climatic conditions and ocean currents may affect the availability of food. On the rearing grounds, poor weather conditions, such as lack of sunshine, may delay the spring bloom of phytoplankton and therefore the development of zooplankton on which larvae feed. The result would be an insufficient food supply available at hatching to meet the energy needs of the larvae. Currents may carry larvae to places where the food supply is inadequate. 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

Adults generally feed prior to spawning and more intensively afterward (Svetovidov 1952). 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. Only 3.4% of the stomachs examined were completely full (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. Predominant vegetative types along the Bering Sea coastline are eelgrass (*Zostera* spp.), rockweed (*Fucus* spp.), and ribbon kelp (*Laminaria* spp.) (Barton 1978). In Prince William Sound, broad leaf kelp, *agarum*, and *laminaria* are the primary vegetation types (Rosenthal 1978). Spawning activity is related to water temperatures and occurs soon after water has become ice-free. Recorded water temperatures are approximately 3 to 5.5°C (Scattergood et al. 1959); 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 spawn in brackish bays and estuaries (Barton 1978).

B. Reproductive Seasonality

Alaskan herring are spring spawners. However, the timing of the spawning period differs geographically. Spawning occurs from May through mid June in Cook Inlet and the Kodiak area and from April through May in Prince William Sound (ADF&G 1978).

On the Bering Sea coast, reproductive 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).

C. Reproductive Behavior

Upon reaching sexual maturity, adult herring move inshore to shallow spawning grounds usually located in shallower waters (Hourston and Haegele 1980). In the eastern Bering Sea, older herring move inshore first (Barton 1979). Shore spawning behavior may be the result of low temperatures in deeper water (Svetovidov 1952). Spawning may last from a few days to several weeks (Barton 1979).

Environmental or physical stimuli such as storms, contact with fishes, and crowding may cause a few males to extrude milt, triggering a spawning reaction by the entire herring school (Hourston and Haegele 1980). In presence of suitable substrate, the fish rise to the surface and mill about, extending their genital papillae. The herring then arch their back and swim with short rapid body movements against the substrate, making contact with their pectoral fins and chin. Eggs or milt are extruded from the papillae, which also contact with the substrate (ibid.). 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). Females usually lay less than 100 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.). Shore spawning behavior may be the result of low temperatures in deeper water (Svetovidov 1952). Spawning may last from a few days to several weeks (Barton 1979).

D. Age at Sexual Maturity

Sexual maturity begins at age two. Most herring do not spawn until ages three and four. By age five, 95% of the population has matured (Rumyantsev and Darda 1970). Herring may live up to 15 years in the Bering Sea, with the strongest age classes being four to six (Barton 1978).

E. Fecundity

Fecundity increases with increases in body length and width (Nagasaki 1958) and appears to be greater in the Bering Sea than in the Gulf of Alaska (Rumyantsev and Darda 1970). Ages four to eight 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.

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). 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. Eggs die at temperatures below 5°C (Alderdice and Velsen 1971). Newly hatched larvae are about 8 mm in size. Larvae will grow to 30 mm in 6 to 10 weeks and begin to metamorphose into free-swimming 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).

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS AND DEVELOPMENTAL STAGES

A. Juveniles

In British Columbia, juveniles form schools that move out of bays as summer progresses (Taylor 1964), and the juveniles move from the spawning grounds to different rearing areas (Hourston 1959). In British Columbia and southeastern 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 speaking, 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).

In Alaska, the best information available regarding migration is on herring in the Bering Sea. Adults spend about eight months offshore (Morris 1981). In the eastern Bering Sea, populations that spawn in Bristol Bay and possibly north to the Yukon-Kuskokwim delta are believed to migrate south along the Alaska Peninsula to Dutch Harbor to major wintering grounds northwest of the Pribilof Islands (Shaboneev 1965). Migration to the winter grounds continues 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 (adults) arrive at wintering areas before immature herring (juveniles) (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). After spawning, adults 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).

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

1. Egg stage. Mortality during egg development is estimated at 20% (Hourston and Haegle 1980), 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). 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). 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 therefore at the larval stage that year-class strength is determined (Hourston and Haegele 1980).
   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 (ibid.). 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 in the juvenile stage at 20%. Juvenile herring are susceptible to predation by fish (salmon or dogfish), marine mammals, and seabirds. Food availability is no longer a limiting consideration at this life stage (ibid.). 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 of adult herring is about 30% (ibid.). The probability of mortality increases with age, particularly for males. Mortality rates increase at age five as a consequence of senility, disease, and spawning mortality

(Wespestad and Barton 1981). 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, and groundfish (Wespestad and Barton 1981). Natural mortality of herring through all life stages in the Bering Sea has been estimated to be 47% (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 the aquatic environment
- Human harvest

(See the Impact 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 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, and stock definition have yet to be established.

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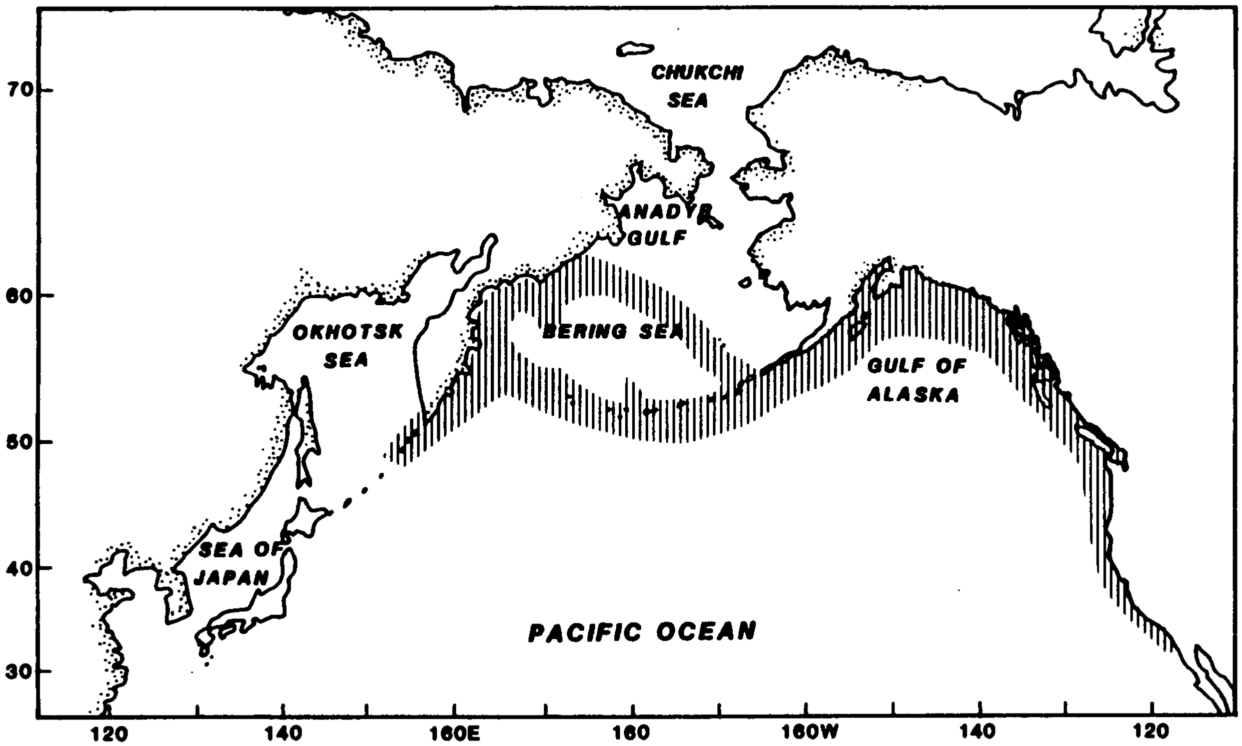
Pacific Ocean Perch Life History and Habitat Requirements
Southwest and Southcentral Alaska



Map 1. Range of Pacific ocean perch (Major and Shippen 1970)

I. NAME
   A. Common Name: Pacific ocean perch
   B. Scientific Name: Sebastes alutus

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 Summary
   To supplement the distribution information presented in the text, a series of bluelined reference maps has been prepared for each 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. 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.

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. (For more detailed narrative information, see 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 Luybimova (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 five, and all individuals are mature at age nine (Chikuni 1975). Fifty percent of the stock is mature at age seven (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 affect 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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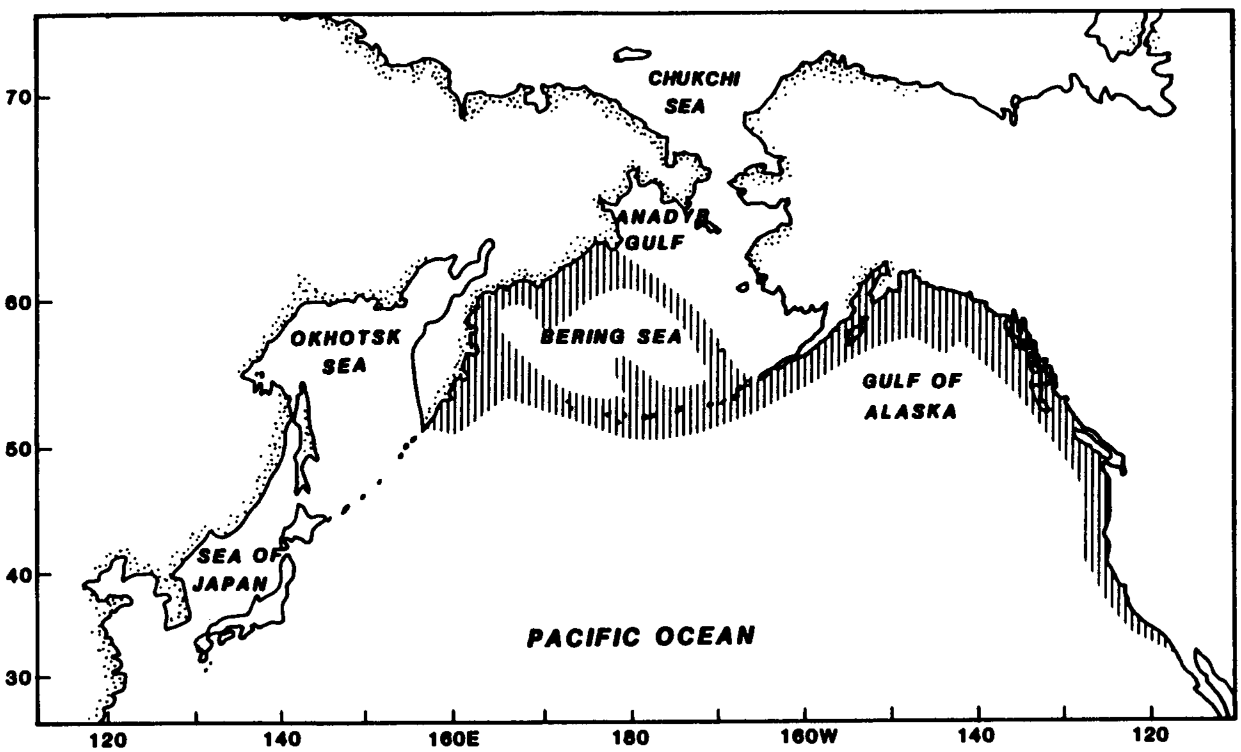
Sablefish Life History and Habitat Requirements
Southwest and Southcentral Alaska



Map 1. Range of sablefish (Low et al. 1976)

I. NAME
   A. Common Name: Sablefish
   B. Scientific Name: <u>Anoplopoma fimbria</u> (Pallas)

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 Summary

To supplement the distribution information presented in the text, a series of bluelined reference maps has been prepared for each 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. 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.

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 (*Cololabias 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 euphausids) 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

Shubnikov (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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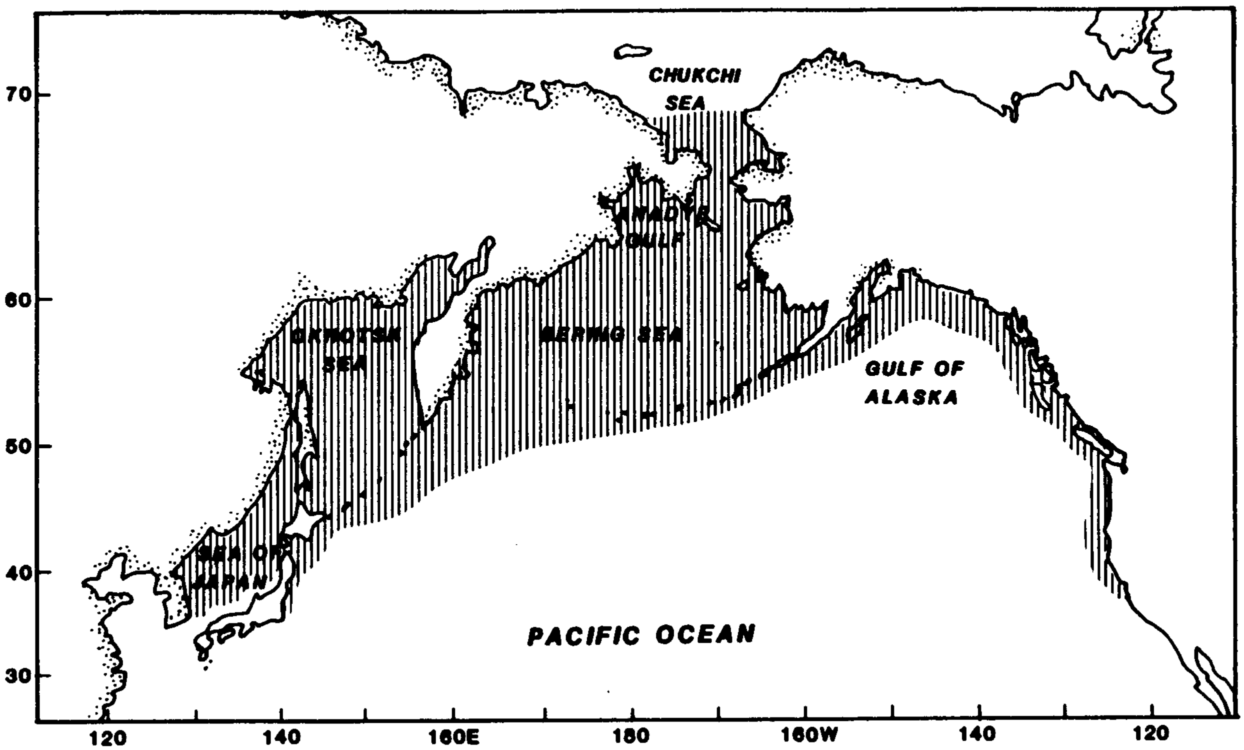
Walleye Pollock Life History and Habitat Requirements
Southwest and Southcentral Alaska



Map 1. Range of walleye pollock (Bakkala et al. 1983)

I. NAME
   A. Common Name: Walleye pollock
   B. Scientific Name: Theragra chalcogramma

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 Summary
      To supplement the distribution information presented in the text, a series of bluelined reference maps has been prepared for each 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. 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.

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 1973-76 (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 1973-76 (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 two, but age classes four and five 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 percent 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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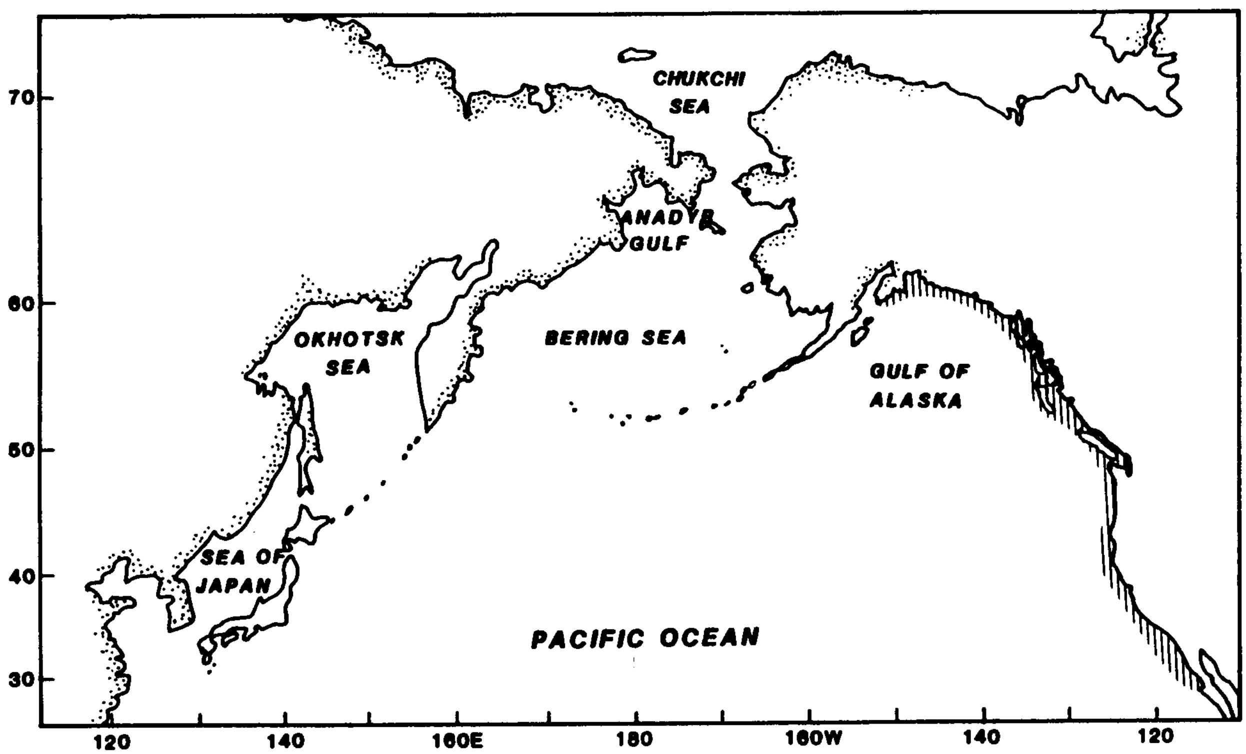
Yelloweye Rockfish Life History and Habitat Requirements
Southcentral Alaska



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. 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 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 Summary

To supplement the distribution information presented in the text, a series of bluelined reference maps has been prepared for each 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. 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.

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 Pallasi*), 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 pre-extrusion 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 regulated by the Alaska Department of Fish and Game. More details of management status can be found in the Human Use section of this report.

IX. LIMITATIONS OF INFORMATION

Very little life history information on nearshore rockfish in Alaska is available.

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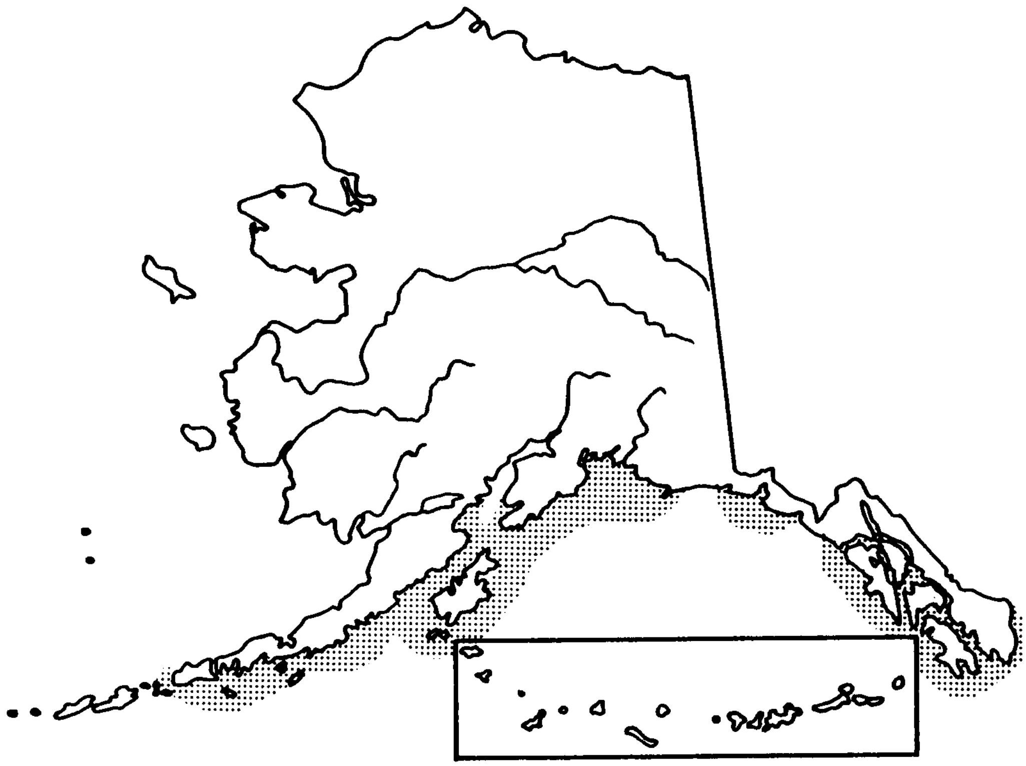
Shellfish

Dungeness Crab Life History and Habitat Requirements
Southwest and Southcentral Alaska



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

II. RANGE
   A. Worldwide
      Dungeness crabs occur in shallow nearshore waters of the North Pacific along the western North American coast, with the western limit at Unalaska Island and the southern limit at Monterey Bay (ADF&G 1978).

B. Statewide

Cancer magister range from Dixon Entrance to Unalaska Island.

C. Regional Distribution Summary

To supplement the distribution information presented in the text, a series of bluelined reference maps has been prepared for each 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. 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.

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.)

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. Postlarvals 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).
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, though 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).

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).

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). 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 crab 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

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).

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

Larvae are preyed upon by salmon and herring (Heg and Van Hyning 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 (*Anarrhicthys 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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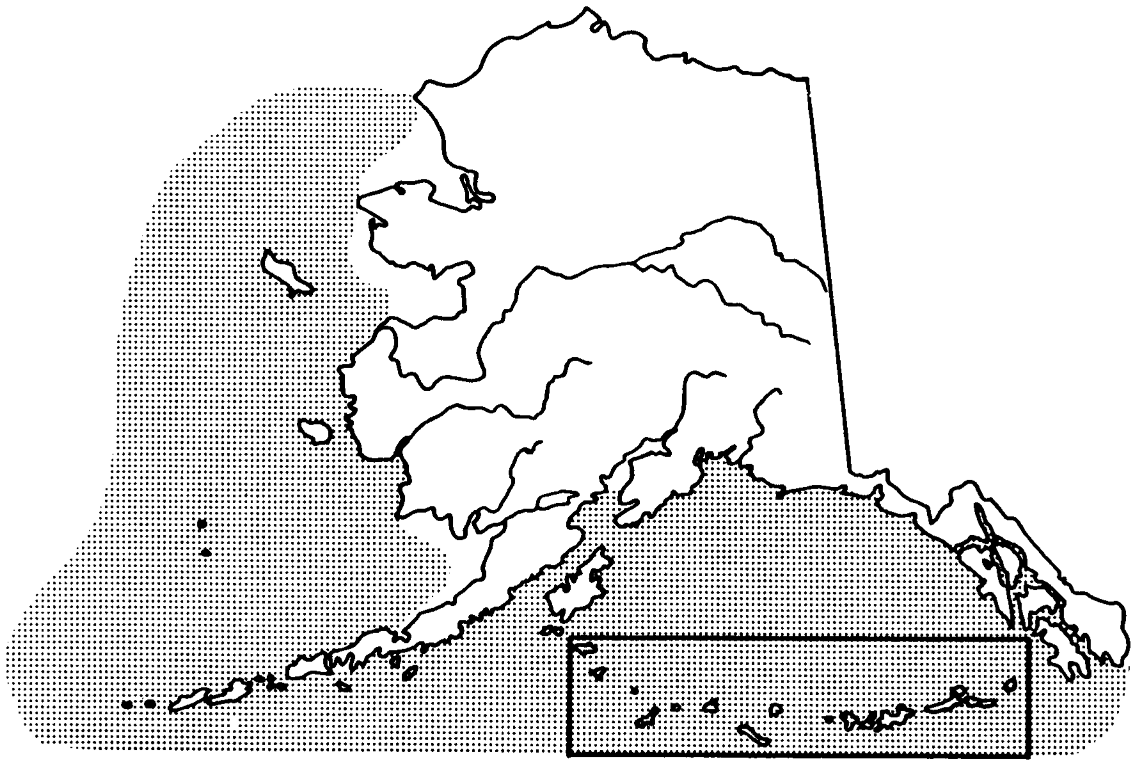
King Crab Life History and Habitat Requirements
Southwest and Southcentral Alaska



Map 1. Range of king crab (ADF&G 1978)

I. NAME

A. Common Names: King crab, golden king crab, brown king crab, blue crab, red king crab

B. Scientific Names: Paralithodes camtschatica (red king crab)
Paralithodes platypus (blue king crab)
Lithodes aquispina (brown or golden king crab)

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 or brown king crabs inhabit deeper water (greater than 100 fathoms) than the other two species, and their 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 red king crab life history.

III. RANGE

A. Worldwide

Red king crab is not only the most abundant of the three commercial species; it is the most widespread. In Asian waters, red king crabs are 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 Norton Sound in the Bering Sea. 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. Brown king crab appears least abundant in Alaskan waters, inhabiting deeper areas along the continental slopes of the North Pacific Ocean from the Sea of Japan to Vancouver Island, including the Bering Sea south to Vancouver, and the Okhotsk Sea south to Japan (NPFMC 1980; Otto, pers. comm.).

B. Statewide

See Worldwide.

C. Regional Distribution Summary

To supplement the distribution information presented in the text, a series of bluelined reference maps has been prepared for each 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. 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.

1. Southwest. Major concentrations of red king crab are located near Kodiak Island, the south Alaska Peninsula, and the Aleutian Islands and in the southeastern Bering Sea. Brown king crab is found in the same area described above (ibid.). 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. Brown 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.)

IV. PHYSICAL HABITAT REQUIREMENTS

A. Water Quality

King crabs are unable to withstand wide variation 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 king crabs inhabit a temperature range of from 0 to 5.5°C. Maximum abundance of females occurs at a temperature range of from 3 to 5°C, and maximum abundance of males at 1.5°C (Stinson 1975). After the fifth molt, juvenile crabs inhabit rock crevices, kelp patches, or other protective niches (Jewett and Powell 1981). Water temperatures influence the frequency of molting. Larvae 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).

B. Water Quantity

Larvae are pelagic. Females and small males are most abundant at intermediate depths (Eldridge 1972). Juveniles are most abundant in inshore waters and relatively shallow waters less than 75 fathoms, and they have been found to depths of 58 fathoms (NPFMC 1980). The red king crab in Cook Inlet occurs in depths up to 200 fathoms. 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). Crabs 9 to 19 mm in carapace length are common on barnacle-encrusted dock pilings in the Kodiak area. Adult red 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).

V. NUTRITIONAL REQUIREMENTS

A. Preferred Foods

1. Larvae. Larvae feed primarily on diatoms.
2. Juveniles. The preferred diet of postlarval crabs on the west Kamchatka shelf were hydroids (*Lafoeina maxima*) (Tsalkina 1969). In lower Cook Inlet, postlarval crabs ingested detrital materials, diatoms, Bryozoa, harpacticoid copepods, ostracods, and sediment (Feder and Jewett 1981).
3. Adults. The diet differs according to the geographic region. Crabs feed on dominant benthic forms (Kun and Mikulich 1954, Kulichkova 1955). In the southeastern Bering Sea, a number of food habit studies have been performed. Dominant 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.), sea urchins (Stongylocentratus sp. and Echinarachnius parma) to be main foods. Following in importance were mollusks (Nuculana radiata, Clinocarduim californiense, Chlamys sp.); snails (Solariella sp. and Buccinidae), crustaceans (crab: Hyas coarctatus alutacesus, Erimacrus isenbeckii, and Pagarus 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).

The diet of red king crabs 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 (Otto, pers. comm.). 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 troshelii) 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).

VI. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

The preferred habitat for reproduction 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 king crabs were concentrated at depths of 3 to 8 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

Females molt and mate from February through May. Males 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 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 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, timing of the mating period differs slightly between bays. In Kachemak Bay, king crabs begin spawning in February, with a peak in April. Kamishak king crabs may spawn slightly later (ADF&G 1978).

C. Reproductive Behavior

After the larvae hatch, females molt and then mate (McMullen 1969). 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 at Sexual Maturity

There is a wide enough variation in size at maturity to suggest that age and growth rate are also important factors in reaching sexual maturity (Hilsinger 1983). Age is difficult to assess in king crabs. In the Kodiak area, the carapace length of mature females 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 females 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. Molting occurs just before mating each year. Females after five years are probably annual molters (Powell and Nickerson 1965b).

Male 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 males were found to reach 50% maturity at 86 mm (Powell et al. 1972).

After attaining sexual maturity, possibly in the 4th and 5th year, adults molt annually for several years, and then some individuals begin to skip molt at approximately seven years of age (Powell and Nickerson 1965b). Males that molt during the mating season may not mate after molting because molting may interfere with mating. Molting areas for males 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).

Male king crabs grow larger than female king crabs. Male king crabs may grow as large as 24 lb in 15 years, whereas a female crab of the same age would be only 10 lb (NPFMC 1980).

E. Fecundity

The number of eggs produced by the female increases with carapace size. In Kodiak waters, small females 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.).

F. Frequency of Breeding

Females 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). 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 king crabs carry their eggs externally for about 11 months. Eggs develop into prezoea within five months of fertilization and remain in this state while carried by the female. Just before mating, prezoea hatch and molt into zoea 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 king crabs undergo 11 molts and in the following year 8 molts (Manen and Curl 1981).

VII. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

A. Larvae

Released 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, 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 juvenile form occurs after the sixth molt.

B. Juveniles

First-year 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, 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. Subadult and adult aggregations are more scattered and circular compared to pods (Powell and Nickerson 1965a).

C. Adult

Adults inhabit deeper water than juveniles (Eldridge 1972). Males segregate from females except during the mating season (ibid.). Adult 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 less than 50 fathoms along the shoreline and onto offshore ocean banks. Young adults precede old adults, and males migrate before females (Powell and Nickerson 1965b). Upon arrival at the spawning grounds, females may emit a pheromone that attracts males (NPFMC 1980). 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).

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)

- Rhizocephalen: infects P. platypus, P. camtschatica, and L. aquispina (This parasitic barnacle will inhibit molting, cause "parasitic castration," and retard gonad development [NMFS 1983].)
- Nemertean worm (Carcinomertes sp.) infestations have been found in king crab egg clutches and may be responsible for egg mortality. 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 pseudocoelonate 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)

(See the Impacts of Land and Water Use 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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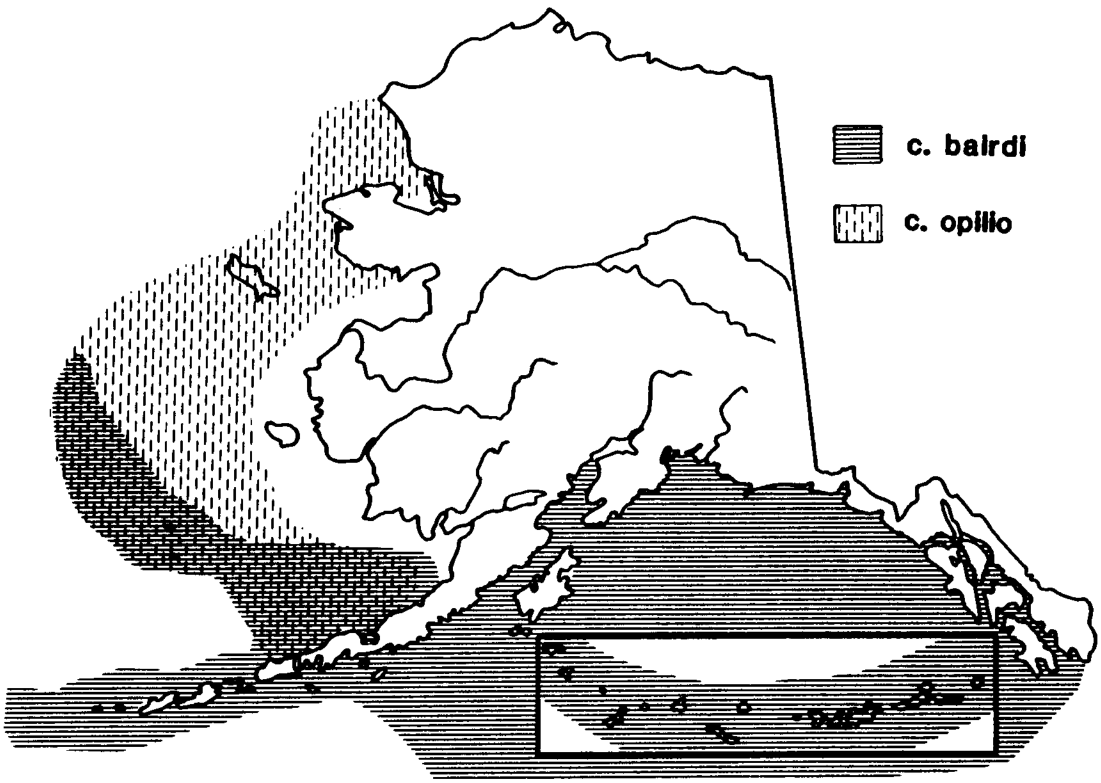
Tanner Crab Life History and Habitat Requirements
Southwest and Southcentral Alaska



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: <u>Chionoecetes bairdi</u>, <u>C. opilio</u>, <u>C. angulatus</u>, <u>C. tanneri</u>

II. EXTENT TO WHICH SPECIES REPRESENTS GROUP

<u>Chionoecetes bairdi</u> and <u>Chionoecetes opilio</u> are the only species commercially harvested in the North Pacific (NPFMC 1981). A hybrid of <u>C. bairdi</u> and <u>C. opilio</u> occurs in the eastern Bering Sea. <u>C. tanneri</u> and <u>C. angulatus</u>, though of minimal commercial interest, have been found in the Bering Sea and Gulf of Alaska.

III. RANGE

A. Worldwide

Tanner crabs have a circum-arctic 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 Southeastern Alaska north to the southeastern Bering Sea. C. opilio occurs in the Bering Sea (ADF&G 1978).

C. Regional Distribution Summary

To supplement the distribution information presented in the text, a series of bluelined reference maps has been prepared for each 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. 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.

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 crab 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.)

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 (NPMC 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). Crabs 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 (crabs 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 Tanner crabs smaller than 40 mm have been located in Lisianski Strait as deep as 230 m (Carlson and Straty 1981).

Adult C. bairdi and C. opilio have been found at respective depths of 473 and 454 m (NPFMC 1981). Major concentrations, however, are restricted to depths less than 300 m (Somerton 1981). C. angulatus occurs in deeper water, at depths to 2,972 m. Generally, C. bairdi is found at depths from shoal water to 473 m (Bering Sea to California), and C. opilio primarily occurs at depths of 13 to 155 m (Bering Sea, Arctic Ocean, and the North Atlantic Ocean from the West Coast of Greenland to Casco Bay, Maine) (Colgate 1983).

C. Substrate

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 sponge-like material (Jewett 1982).

V. NUTRITIONAL REQUIREMENTS

A. Preferred Foods

1. Larvae. Free-swimming 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 arthopods (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 overlapping periods 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, if primiparous _C. bairdi_ females are not bred soon after molting to maturity a _significant_ portion will not produce usable eggs (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 _C. bairdi_ can produce normal size egg clutches of viable eggs _utilizing_ sperm stored for two years (Paul et al. 1983). 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 at Sexual Maturity

Female Tanner crabs 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 the size of females at 50% maturity to be about 83 mm, reaching about 97 mm at the molt to maturity. Among males, 90 mm appears to be the size at which the molt to maturity occurs. Such an animal would grow to 112 mm. The stage at which terminal molt occurs for male Tanner crabs is still unknown (ibid.). 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). Little difference in average size at sexual maturity is apparent among areas (ibid.).

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 percentage, 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). However, old-shell mature females have been found capable of mating after the terminal molt (Donaldson 1977). The point at which male C. bairdi undergo terminal molt is undetermined (Donaldson et al. 1981). 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, free 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

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). Free-swimming 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 free-swimming. In the Sea of Japan, where spawning occurs from January to April, prezoae (Chionoecetes spp.) swim 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 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, zoea 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, though 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). 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). 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, and for C. bairdi the opposite is true. Both juveniles and adults occur 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, averaging 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. Vertical migration is not obvious (NPFMC 1981). 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. 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 camtshatica) 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 most frequently occurring prey for Pacific cod taken near Kodiak Island during the months of June and July. An estimate of 1.5 x 10^{10} crabs are eaten annually by the Kodiak cod population of 6.9 x 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 (Lepidopsettia 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, though those in molt would be vulnerable to large fish, octopuses, and sea stars (Hilsinger, pers. comm.).

B. Human-related

A summary of possible impacts from human-related activites 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 Impacts of Land and Water Use 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 Managment 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 Willaim Sound, Yakutat, Southeastern 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 NMGS manages the foreign fishery, and both state and federal managment regimes are guides 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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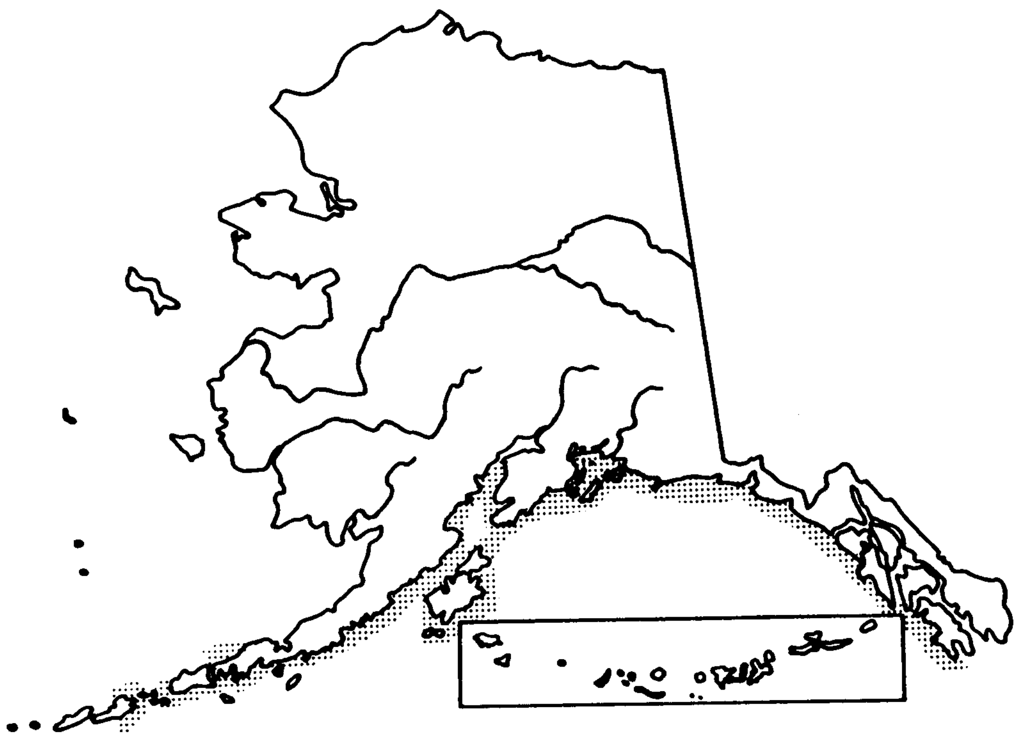
Razor Clam Life History and Habitat Requirements
Southwest and Southcentral Alaska



Map 1. Range of razor clam (Nickerson 1975)

I. NAME
   A. Common Name: Razor clam
   B. Scientific Name: *Siliqua patula*

II. RANGE
   A. Worldwide
      The razor clam is found from Pismo Beach, California, to the Bering Sea (Amos 1966).
   B. Regional Distribution Summary
      To supplement the distribution information presented in the text, a series of bluelined reference maps has been prepared for each 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. 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.

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 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 seawater 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 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 two (McMullen 1967), whereas 65% of clams on Cordova beaches reach maturity at age three (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 10mm (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 freshwater, 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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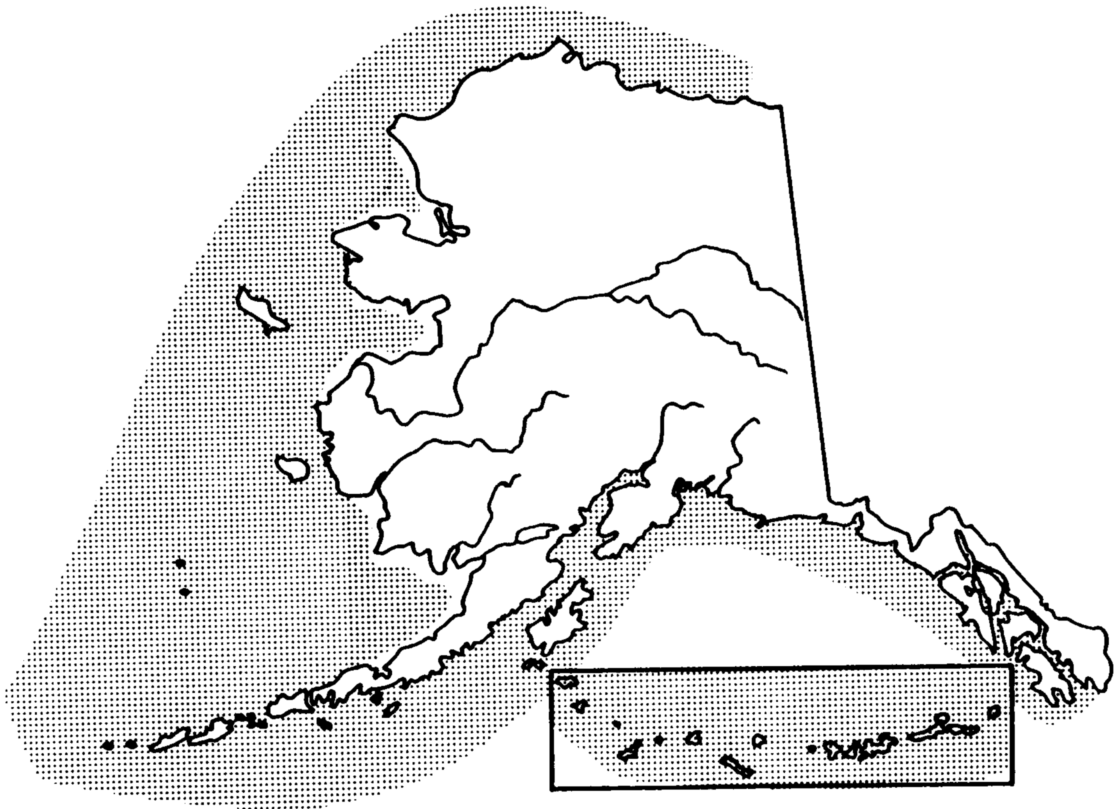
Shrimp Life History and Habitat Requirements
Southwest and Southcentral Alaska



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 (*Pandalopus dispar* Brandt).

II. EXTENT TO WHICH SPECIES REPRESENTS GROUP

There are five important species of shrimp caught by commercial fisheries in Alaska, all of which belong to the family Pandalidae.

III. RANGE

A. North America

The range of the northern pink shrimp extends from the Bering Sea southward to the Columbia River mouth in Washington (Rathjen and Yesaki 1966).

Humpy shrimp have been found from the arctic coast of Alaska southward to Puget Sound.

Coonstripe shrimp have been reported from the Bering Sea to the Strait of Juan de Fuca.

The range of the spot shrimp extends from Unalaska Island, Alaska, southward to San Diego, California.

Sidestripe shrimp are distributed from the Bering Sea, west of the Pribilof Islands, southward to Manhattan Beach, Oregon (ADF&G 1978).

B. Statewide

Greatest concentrations of northern pink shrimp are located in lower Cook Inlet, Kodiak, Shumagin Islands, and along the southside of the Alaska Peninsula west to Unalaska Island. Pink shrimp are also found along eastern Kenai Peninsula, Prince William Sound, Yakutat Bay, throughout Southeast Alaska, and near the Pribilof Islands in the eastern Bering Sea (ADF&G 1978, McCrary 1984).

Greatest concentrations of humpy shrimp are found off southeastern Kodiak Island and the Shumagin Islands.

Coonstripe shrimp are primarily found in lower Cook Inlet, off Kodiak Island, and among the Shumagin Islands.

Spot shrimp have been reported in lower Cook Inlet, off Kodiak Island, and along the Alaska Peninsula.

Sidestripe shrimp concentrations have been located off Kodiak Island, the Shumagin Islands, and in Lower Cook Inlet (ADF&G 1978; Merritt, pers. comm.).

C. Regional Distribution Summary

To supplement the distribution information presented in the text, a series of bluelined reference maps has been prepared for each 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. 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.

1. Southwest. See the statewide summary above, and for more detailed narrative information, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.
2. Southcentral. See the statewide summary above, and for more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.

IV. PHYSICAL HABITAT REQUIREMENTS

A. Water Quality

Distribution of pandalid shrimp is dependent upon the water's temperature and salinity. Immature shrimp are tolerant of a broad range of temperature and salinity and are often abundant in relatively shallow depths, where these two parmeters are variable, whereas 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 to colder water temperatures. In laboratory studies, pink shrimp were found to have narrow thermal requirements for larval production, 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, developmental and growth rates were enhanced by higher (9°C) rearing temperatures, regardless of feeding levels. 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). Tolerance to salinity appears to differ by species. The tolerance of pink shrimp to salinity in British Columbia waters has been reported to range from 23.4 to 30.8 parts per thousand (o/oo) (Butler 1964). Butler (1964) reported salinity tolerance 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 cover may be present. At the same time, where northern 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 one of 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 (ADF&G 1978).

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 depth at which coonstripe shrimp occur is 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 seabottoms. 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).

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 feeders.

C. Factors Limiting the Availability of Food

No information 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 as vastly different from the normal annual distribution of adults, except that depths occupied in fall and winter tend to be deeper than 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 1984).

B. Breeding Seasonality

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).

C. Reproductive Behavior

Within 36 hours after the female molts into breeding dress, the male attaches a sperm mass to her underside between the last two pairs of pereiopods (walking legs) (Needler 1931). Fertilization and oviposition occur as eggs are released from the oviducts and onto the sperm masses. Eggs then become attached to the forward four pairs of pleopods (abdominal appendages) and abdominal segments (ADF&G 1978).

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 found in the Pribilof areas of the Bering Sea and in the Kodiak and Shumagin islands areas are estimated to reach maturity at 2.5 years (Ivanov 1964a, McCrary 1971). The same estimate is believed to hold 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 hermophroditic male form, the "primary female" form, or the "secondary female" form. Hermaphroditic 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 as 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 hermaphroditic. Though primary females have been documented in pink shrimp populations off the coast of British Columbia (Butler 1964), their occurrence in Alaskan waters is believed to be rare (ibid.).

"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).

E. Fecundity

Pandalid shrimp exhibit high 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

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).

G. Incubation Period/Emergence

Females carry eggs for five to six months prior to hatching. Hatching usually occurs from March through April for pink shrimp, and for sidestripe shrimp it may extend into June or July. For pink shrimp, the lengths of the spawning, carrying, and hatching periods vary inversely with the water temperatures (Haynes and Wigley 1969). Laboratory studies indicate that most eggs hatch at night during periods of vigorous pleopod movement by the female. 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, at which time they become benthic (Berkeley 1930).

VII. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

A. Larvae

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.).

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 make the same movements (ADF&G 1978).

Kachemak Bay studies have shown that pink shrimp leave the bottom in late afternoon or evening, returning to the same area about dawn. The period of time that 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, sole, rockfish, spring dogfish, skates, rays, Pacific halibut, salmon, and harbor seals. 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).

Spot shrimp in the British Columbia area have been parasitized by a rhizocephalen (Sylon spp.) (Butler 1970). Bopyroid isopods (Bopyrus spp.) also parasitize most species of pandalid shrimp (Fox 1972).

It is apparent that the mechanism of stock recruitment for pink shrimp in Alaskan waters is markedly influenced by temperature. Temperature appears to control the reproductive process in pink shrimp, particularly during the period between egg formation and egg development (Nunes 1984).

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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