Alaska Habitat Management Guide

Southwest Region
Volume I:

Fish and Wildlife Life Histories, Habitat Requirements, Distribution, and Abundance

Produced by
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Division of Habitat

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See Volume 2 of the guide for the Southwest Region for information on the human use of fish and wildlife.

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

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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 Lance Trasky, Regional Supervisor of the Division of Habitat for the Southwest Region (Region IV), and of the contributions of Rai Behnert, who was the original coordinator of this project.

Introduction

Overview

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.

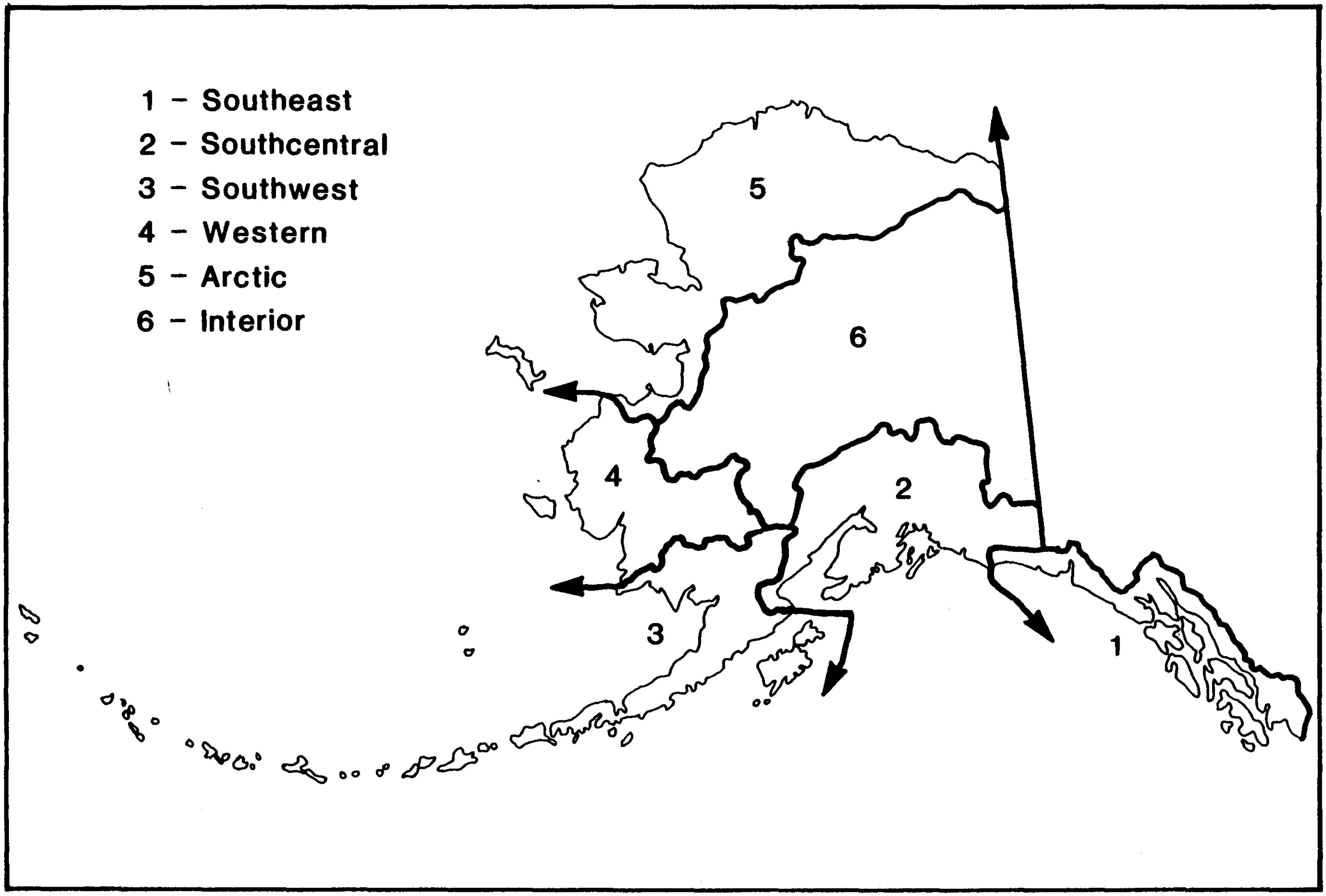
The AHMG presents the best available information on selected fish and wildlife species: mapping and discussing their geographical distribution; assessing their relative abundance; describing their life functions and habitat requirements; identifying the human uses made of them, including harvest data for rural communities; and estimating their value to residents of the state. 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.

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 particular questions regarding habitat management. For example, information on species' seasonal and geographic habitat use can be correlated with the written and mapped information on actual 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.



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

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. The cummulative effects of continuing, low-level impacts are not well known, nor are impacts that may affect nearshore habitats. Another subject for which limited data are available concerns the economic values associated with fish and wildlife resources. The commercial fisheries industries are the exception in this regard, since a substantial amount of information does exist on this economic activity. However, values associated with other activities are not well documented, including sport hunting and fishing, whether guided or unguided, trapping of both sealed and unsealed species, and various nonconsumptive uses of fish and wildlife. This last category includes such uses as photography, wildlife viewing, and various recreational activities that are not easily quantified.

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.

Statewide Guides

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 region 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

An additional statewide guide is being developed to discuss the economic values associated with the uses of fish and wildlife. The necessary data 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.

Southwest Region

Organization and Use of the Guide

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

A Map Atlas accompanies these narrative volumes. The mapped information is portrayed at 1:1,000,000 scale and can be used as an index for the more detailed 1:250,000-scale reference maps. The reference maps are available at the ADF&G offices of the region.

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 Southwest Region habitats (this criteria 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.

Overview of the Southwest Region

The Southwest Region (map 2) includes the area of Bristol Bay, the Gulf of Alaska south of Kennedy Entrance, including Kodiak and other islands, the Alaska Peninsula, the Aleutian Islands, the Pribilof Islands, the drainages of the Nushagak River, the Wood River/Tikchik lakes, and Togiak River of the Bristol Bay area.

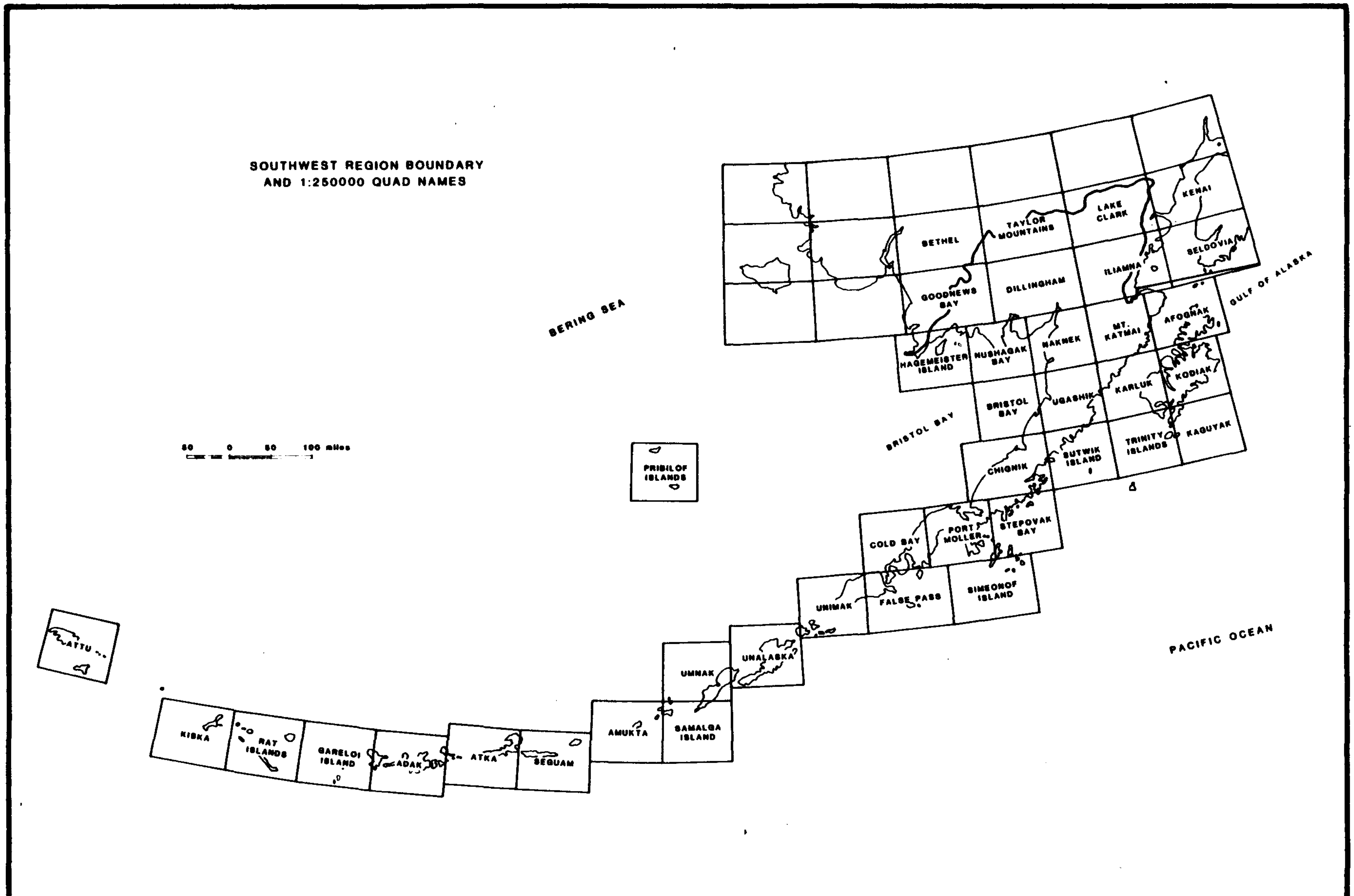
In the following sections, the biophysical and human resources of the region are briefly summarized. Readers desiring a more detailed and extensive discussion of these characteristics of the region should consult the Alaska Regional Profiles[1] and the Bristol Bay Area Plan[2] (BBAP).

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

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

__________. N.d. Alaska regional profiles: Southcentral Region. Prepared for the Office of the Governor and Joint Federal/State Land Use Planning Commission.

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



Map 2. USCG quads found in the Southwest Region

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

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

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

Human activities in the region. As one would expect from the concentration of fish and wildlife in the Southwest Region, human activities revolve around the commercial, sport, and subsistence uses of these resources. Noncommercial harvest, including subsistence, is a major activity in the region especially important in areas with no direct connection to the commercial fishing and processing industry. Bristol Bay is the world's largest sockeye salmon fishery and the state's largest salmon fishery, which is by far the dominant enterprise in the region. Dillingham and Naknek are the major ports, although fishing fleets work out of numerous smaller communities also. Major fish- processing areas include Kodiak, Unalaska/Dutch Harbor, Naknek, and Dillingham. Kodiak hosts the largest fishing fleet in the state, a large portion of which concentrates on shellfish.

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

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

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

Introduction

Fish and Wildlife

The narratives for fish and wildlife species provide an overview of those biological and physical factors that are important in evaluating the species' habitat needs and that are therefore also important in evaluating the effects of various land and water uses on the species. Each species narrative is comprised of two portions: 1) life history and habitat requirements and 2) distribution and abundance.

The life history discussion focuses on the species' relationship with its habitat, especially the relationship of each life stage or functional activity with its associated utilization of habitat. Because of this focus, the life history discussions provide references rather than comprehensive documentation for other species' life histories. For example, characteristics of each species' population biology are discussed in the context of the relationship between various reproductive parameters and the seasonal use of various habitats.

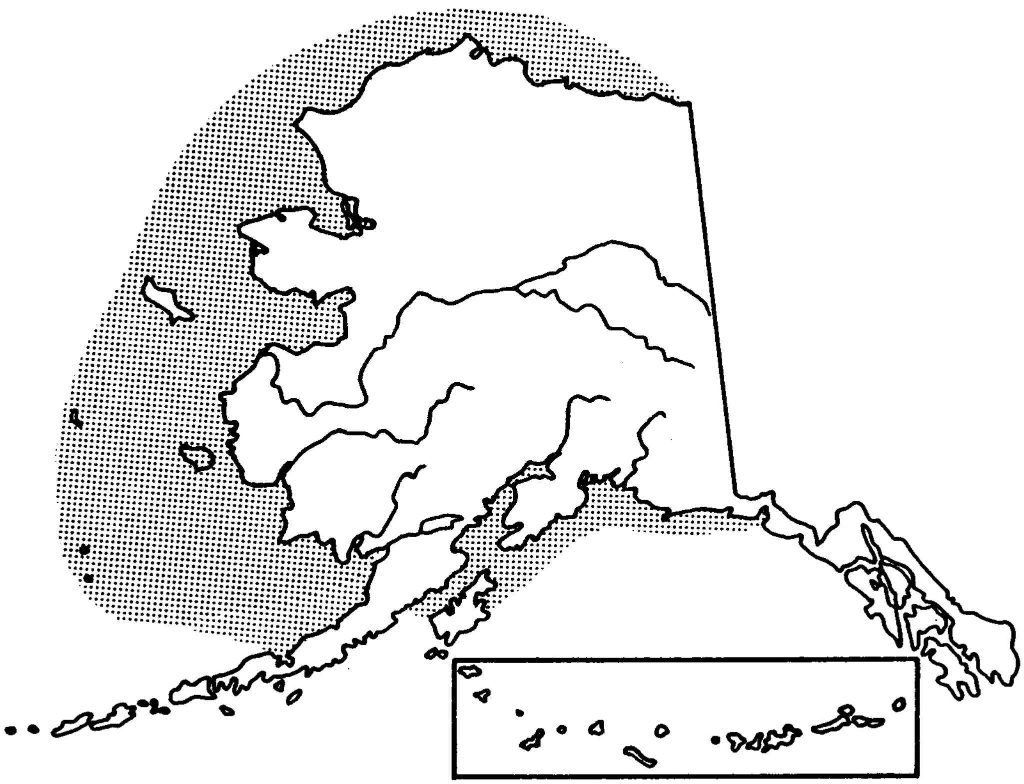
The distribution/abundance portion of the species information presented in this guide is comprised of two sections: 1) maps of species distribution, and 2) narratives of distribution and abundance. The mapped information, located in the Southwest Region Map Atlas, is portrayed at 1:1,000,000-scale and can be used as an index for the more detailed reference maps. The original reference maps for this information were prepared at a scale of 1:250,000, and copies are filed in ADF&G offices of the region. The index maps (1:1,000,000) show the regional and subregional patterns of fish and wildlife distribution, whereas the reference maps illustrate specific distribution categories in relation to more detailed features on the landscape. Although emphasis is placed on depicting seasonal concentration areas (e.g., brown bear concentrations on fish streams) and areas utilized for specific reproductive functions (e.g., calving areas, rookeries), for many species the general distribution is also mapped. "General distribution" in this context applies to areas that provide suitable habitat for the species and are within the known range of the species. Additionally, representative of the anadromous fish species, a separate map category, "unsurveyed areas," has been added in order to denote areas that have not been surveyed to determine whether or not fish are present. Definitions for the map categories are found in the Southwest Region Map Atlas.

The distribution maps are based on the most current available information for each species or species group. Area biologists and species experts should therefore be consulted for the most recent information, since this may change over time. The narratives on species distribution and abundance summarize the mapped information; and they also discuss historical distribution and abundance (10-20 year data base), in order to provide a context within which to evaluate current utilization of habitat. This discussion is particularly helpful in cases where the species utilization of its habitat may be affected by its current abundance. Where appropriate, these narratives also discuss the importance of the regional population of the particular species relative to its statewide or world populations.

Species were selected to represent regional habitats in order to best address specific habitat management concerns. Thus a species not included that has certain similar habitat relationships to those of an included species may be partially or wholly represented, in terms of habitat management concerns. Also, predator species that tend to have unclear direct relationships to habitat attributes will be partially represented regarding habitat management issues by the information presented for their prey species.

Marine Mammals

Belukha Whale Life History



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

I. NAME
   A. Common Names: Belukha, white whale
   B. Scientific Name: Delphinapterus leucas

II. RANGE
   A. Statewide
      1. The belukha whale ranges through the northern Gulf of Alaska from Yakutat Bay to Kodiak Island, with the center of abundance of the Gulf of Alaska stock being in Cook Inlet (Lowry et al. 1982).
      2. The center of abundance of the Bering Sea stock is in the Bering Sea. Some whales are resident; others migrate to the Chukchi Sea and to the Beaufort Sea as far east as Banks Island and as far west as the East Siberian Sea (Lowry et al. 1982, ADF&G 1977, Seaman and Burns 1981).

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

1. Water quality:

a. Salinity and turbidity. Belukhas have been observed in a wide variety of salinity and turbidity conditions, from open ocean to brackish and turbid river mouths and estuarine areas in Bristol Bay (Lowry, pers. comm.; ADF&G 1977; Seaman and Frost 1983). Fraker (1979) measured the salinity and turbidity of areas utilized heavily by belukhas in the MacKenzie River estuary. He concluded that they appeared to neither avoid nor select areas because of salinity or turbidity.

b. Temperature. Belukhas are found in a wide range of water temperatures, from 0°C in winter (Lowry 1983) to 18°C in estuarine areas in summer (MacKenzie River estuary: Fraker 1979). Fraker et al. (1979) observed that early in the season belukhas concentrated generally in the warmest water available (10 to 12°C) and that as the water temperature continued to increase they expanded their range until the 18°C isotherm was reached. He observed only a few belukhas in water temperatures above 18°C. In Bristol Bay, where water temperatures are generally more moderate than in the Arctic, water temperature is likely not a factor important to belukhas in their selection of areas of use (Lowry and Frost, pers. comm.).

2. Water depth. During summer, belukhas frequent the shallow coastal waters, lagoons, and estuaries of Bristol Bay (Seaman and Frost 1983). They occasionally feed in waters as shallow as 1 or 2 m (Frost, pers. comm.). They overwinter over the continental shelf in the southern and central Bering Sea, feeding on octopus, squid, and demersal fish (Seaman et al. 1982), which are found at depths from 30 to 365 m (Bakkala et al. 1981).

3. Substrate. No information has been located.

B. Ice

1. Effects on movements and distribution. Fraker (1979) reported that belukhas could travel up to 3 mi under ice without surfacing; however, entrapment by ice has been occasionally reported (Leatherwood and Reeves 1982, Seaman and Frost 1983). Belukha movements in the seasonal ice of the Bering Sea are restricted to areas of continual ice motion, in which leads and polynyas occur with no ice cover or covered by ice less than 8 cm thick, through which the belukha can break (Seaman and Frost 1983, Burns et al. 1981).

2. Conditions providing security from predators or other disturbances. Although killer whales (*Orcinus orca*) frequent the southern portion of the pack ice in early spring, the pack ice does offer more protection from killer whales than the open sea (Burns et al. 1981). Polar bears occasionally kill belukhas, especially calves; polar bears, however, do not range into the

unstable ice zone in the Bering Sea, where the majority of belukhas in the Southwest Region winter (ibid.).

3. Conditions providing protection from natural elements. Prolonged turbulence caused by winter storms in the Bering Sea is depressed by the overlying pack ice; this allows easier feeding in the underlying productive continental shelf waters (ibid.).

IV. NUTRITIONAL REQUIREMENTS

A. Preferred Foods

1. Primary. Belukhas of the Bristol Bay center of abundance feed primarily on schooling pelagic and semidemersal fishes, especially the five species of Pacific salmon (Oncorhynchus spp.), herring (Clupea harengus), smelt (Osmerus mordax), capelin (Mallotus villosus), and pollock (Theragra chalcogramma) (Seaman et al. 1982, Lowry et al. 1983). For belukhas that winter in the southern Bering Sea but migrate northward, saffron cod (Eleginus gracilis) and arctic cod (Boreogadus saida) are very important (Seaman et al. 1982).
2. Secondary. Secondary foods include flatfish (Pleuronectidae), sculpin (Cottidae), lamprey (Lampetra japonica), shrimp (Crangonidae), mollusk, and octopus (Seaman et al. 1982, Frost and Lowry 1981).
3. Seasonal utilization. Seaman et al. (1982) and Lowry et al. (1982) reported seasonal shifts in the diet of Bristol Bay belukhas as follows:
   - Late April/early May: smelt, eulachon
   - May: herring, capelin, and outmigrating smelt
   - End of May/early June: outmigrating sockeye salmon smolt
   - Mid June to August: adult salmon, especially sockeye salmon
   - Late summer/early fall: rainbow smelt (Osmerus mordax)
   - Winter: pollock, flatfish

B. Feeding Locations

Belukhas have been observed feeding at comparatively shallow depths (1 to 2 m in some estuarine areas; Lowry and Frost, pers. comm.) up to 50 fathoms (Braham et al. 1980). Specific feeding locations are dictated by the seasonal distribution of prey (Lowry 1983).

1. Winter. Belukhas feed (and reside) in the continental shelf waters of the Bering Sea, usually associated with the active zone of the pack ice (Lowry 1983, Seaman and Burns 1981).
2. Spring (late March/early April). The whales move to bays, estuaries, and river mouths, especially in Bristol Bay, as soon as they become ice-free (Seaman and Burns 1981).
3. Summer/fall (May to freeze-up). Whales of the Bristol Bay center of abundance remain and feed in estuarine areas and the mouths and mainstems of major rivers, especially of the Kvichak and Nushagak rivers (Lowry et al. 1982); migratory portions summer and feed in the nearshore areas of the northern Bering Sea and the Chukchi and Beaufort seas (ibid.).

C. Factors Limiting Availability of Food

No specific data have been located; however, because belukha distribution in the Southwest Region is closely tied to distribution of pelagic and semidemersal schooling fishes (Seaman et al. 1982), any environmental or human-caused factors that alter distribution or abundance of these fishes may affect belukhas also.

D. Feeding Behavior

1. Temporal variations
    a. Annual. Belukhas feed all year (ibid.).
    b. Diural. No data have been located.
2. Diving duration. The duration of feeding dives is usally less than two minutes (Lowry and Frost, pers. comm.).
3. Food size. In general, they eat fish that can be swallowed whole (Gurevich 1980), which means fish 5 to 74 cm long (Lowry and Frost, pers. comm.). Subadults may tend to eat more crustaceans (especially shrimp) and small fishes (e.g., saffron cod and herring) than adults, which can eat adult salmon; adult males may eat larger fish than those adult females eat (Lowry et al. 1982, Seaman et al. 1982).

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

The breeding habitat of the belukha is the moving pack ice of the Bering Sea (Burns et al. 1981).

1. Calving/nursery habitat. Fraker et al. (1979) and Lowry (1983) believe that the observed spring and summer movement to shallow, warmer areas may confer a thermal advantage upon all age classes, especially upon new calves without a thick blubber layer. In Bristol Bay, however, this shoreward movement commences in March or April (a few months prior to calving) and is more likely related to increased availability of food (smelt) than to providing a thermal advantage for calves (Lowry and Frost, pers. comm.)

B. Reproductive Seasonality

1. The breeding season is April to May (Lowry 1983).
2. The calving season occurs mostly in late June-July, but some calving occurs from mid May to early September (Seaman and Burns 1981; Lowry and Frost, pers. comm.)

C. Reproductive Behavior

Females nurse their young for up to two years (Lowry et al. 1982).

D. Age at Sexual Maturity

1. Females. Reproductive activity commences at four to five years (Seaman and Burns 1981), but maximum reproductive performance starts at seven to nine years (Ognetev 1981). They become physically mature at 9 to 10 years (ibid.).
2. Males. Reproductive activity commences at eight years (Lowry 1983); they become physically mature at 11 to 12 (Ognetev 1981).

E. Fecundity

Using a number of assumptions, Lowry (1983) estimates that the gross annual production of calves is 9%.

F. Frequency of Breeding
Belukhas breed every third year (Lowry 1983): breeding the first year, parturition the second, nursing for up to two years after parturition.

G. Gestation Period
Gestation requires 14.5 months (ibid.).

H. Lactation Period
Females lactate for two years and rarely breed the first year after calving (ibid.).

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

A. Home Range
This concept is not applicable to belukha whales.

B. Timing of Movements
See sections III. and IV. of this account.

C. Migration Routes
These are dependent on annual variations in the southerly extent and movements of the pack ice in the Bering Sea and on local weather conditions.

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

1. Predation. The main predator in the southern Bering Sea is the killer whale (*Orcinus orca*); natural mortality rates appear to be low (ibid.).
2. Competition. Although belukhas prey on the same fish species as a number of marine mammals and birds, their feeding habits are most similar to those of spotted seals (*Phoca largha*) and harbor porpoises (*Phocoena phocoena*) (ibid.). By exploiting pack ice habitat, belukhas avoid direct competition with harbor porpoises (Burns et al. 1981) during winter (Frost and Lowry, pers. comm.). Both their seasonal range and food habits, however, extensively overlap those of the spotted seal (Lowry 1983).

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

- Disturbance during calving
- Pollution of water and/or food supply
- Reduction in food supply
- Direct mortality due to collision with boats or entanglement in nets
- Interference with intraspecies communication caused by vessel traffic

VIII. LEGAL STATUS
Belukha whales are managed by the National Marine Fisheries Service, United States Department of Commerce, under provisions of the Marine Mammal Protection Act of 1972.

IX. LIMITATION OF INFORMATION

Relationships among summering groups are unclear: do they remain as discrete units, or is there considerable intermixing during winter (i.e., during the breeding season) when most of them are associated with the southern edge of the pack ice?

More precise information is needed concerning winter food habits.

More comprehensive estimates are needed to determine the whale's abundance.

The effects of commercial fisheries on the belukha (e.g., net entanglement) and vice versa are not well defined.

X. DISTRIBUTION

A. General Distribution

Belukhas are widely though not uniformly distributed throughout seasonally ice-covered waters of the northern hemisphere (Lowry 1983). The southern limit of normal belukha distribution is the St. Lawrence River in the Atlantic Ocean (Leatherwood and Reeves 1982), Yakutat Bay in the eastern Pacific Ocean, and the Sea of Okhotsk in the western Pacific Ocean (Seaman and Burns 1981).

B. Southwest Region

Belukhas from both the Alaskan stocks (Gulf of Alaska and Bering Sea) occur in the Southwest Region. Some animals from the Gulf of Alaska stock range as far southwest as Kodiak Island, although the center of abundance is in Cook Inlet (Lowry 1983).

1. Factors affecting movements. Most belukhas in the region are from the Bering Sea stock, and most of them winter in the southern Bering Sea at the ice fringe and front (Seaman and Frost 1983). As the ice recedes in the spring, a large portion of those wintering in the Bering Sea move northward and out of the region. The remainder move eastward in March and April to Bristol Bay, where they congregate in nearshore areas, especially at the mouths of rivers in Kvichak Bay (ibid.). In late March, April, and May, they concentrate at the mouth of the Naknek River, feeding on smelt and moving upriver as breakup progresses. Several weeks later they move to the mouth of the Kvichak River to feed on outmigrating sockeye salmon (*Oncorhynchus nerka*) smolts. During the calving season (June to August), belukhas are distributed throughout Kvichak and Nushagak bays. During this period, calving and feeding concentrations overlap considerably.

   Specific areas, such as the mouth of the Snake River, have been identified as calving concentration areas (BBCMP 1983, maps). Recent data from an expanded belukha research program have indicated that calving also occurs in Kvichak Bay (Frost, pers. comm.). Belukhas remain in inner Bristol Bay throughout the summer, exploiting the runs of different salmon species present. During the spring and summer they are not confined to salt water but may ascend the rivers to feed as far as King Salmon on the Naknek River, Portage Creek on the Nushagak River, and Levelock on the Kvichak River (Frost, pers. comm.)

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

Winter distribution of the Bering Sea stock is dependent on ice conditions. In years of heavy ice, they have been observed in the St. George Basin near the Pribilof Islands, western Bristol Bay, and Nunivak Island (ibid.).

XI. ABUNDANCE

The world population of belukhas is estimated to be approximately 22,000 to 32,000 whales (Leatherwood and Reeves 1982). The two Alaska stocks total approximately 14,000 to 18,000 animals (Lowry, pers. comm.), of which only 500 are in the Gulf of Alaska stock. The Bristol Bay summering group of the Bering Sea stock numbers only 1,000 to 1,500 animals (Frost and Lowry, pers. comm.).

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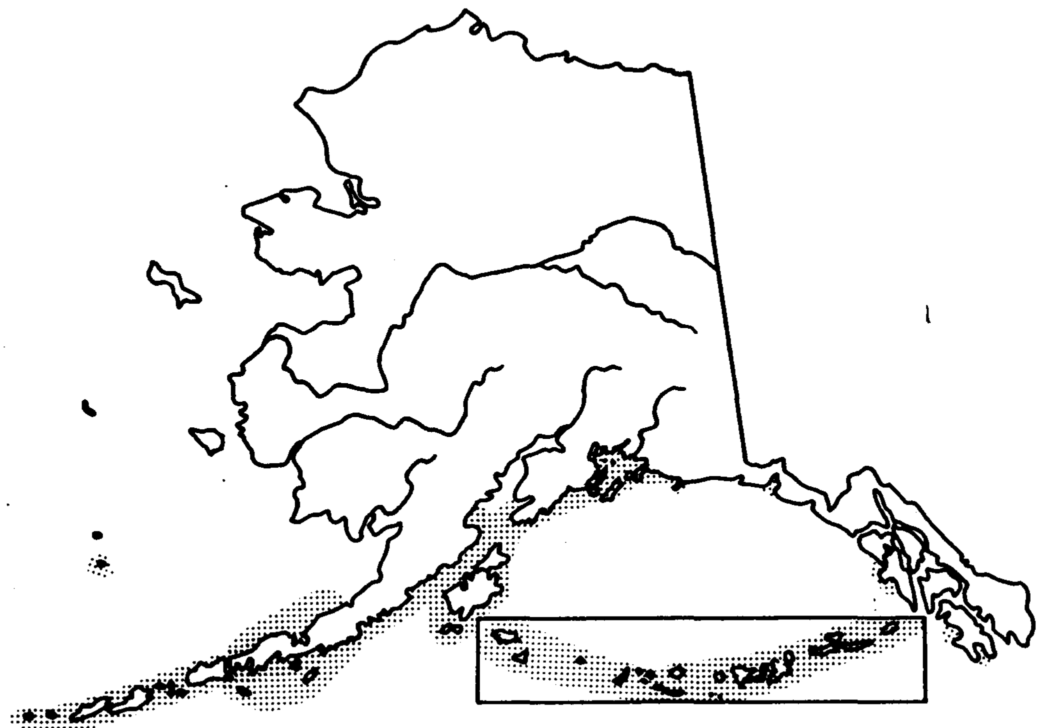
Sea Otter Life History



Map 2. 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 have inhabited the coastal areas of the North Pacific Ocean and the Bering Sea from the Russian Kamchatka Peninsula south to the Kurile Islands and Hokkaido Island (Japan), thence eastward to the Commander, Pribilof, and Aleutian islands, and along the North American coast from the Alaska Peninsula, Kodiak Island, and Prince William Sound to southern California (Kenyon 1969, Lensink 1962).

B. Statewide

Sea otters occur in Alaska in nearshore waters of the open coast, from Southeast Alaska (with small populations near Chichagof, Yakobi, and Coronation islands resulting from transplants in the 1960's) to Yakutat (where small groups have become established), through Prince William Sound, the southern 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. Occasional reports of sea otters have been made from the Pribilof Islands and northward, but permanent populations are not likely to occur in areas of winter sea ice (Kenyon 1969, Schneider and Faro 1975).

III. PHYSICAL HABITAT REQUIREMENTS

The two most important sea otter habitat requirements are an abundant, high-quality food supply and clean, uncontaminated water. Sea otters rely on a dense coat of fur to trap a layer of air and prevent water from penetrating to the skin. Any contamination of the fur will interfere with this insulating air layer, and the animal will quickly die of hypothermia (Schneider 1976b).

Abundant food at accessible depths is clearly the most important habitat requirement (Calkins and Schneider 1983). Sea otters require large quantities of food (20 to 25% of body weight/day) to support their high metabolic rate (Kenyon 1969). If this food source is not available, otter densities will remain low or populations will disperse.

These habitat requirements are essentially the same throughout the year.

Sea otters favor shallow water (usually less than 30 fathoms) 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 occur - southeast Bristol Bay, e.g. (Calkins and Schneider 1983). 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).

A. Security from Predators

No available information.

B. Protection from Natural Elements

1. Severe winter storms, with associated rough-water conditions, can prevent otters from foraging efficiently, resulting in serious food-related stress (Kenyon 1969).
2. Otters have been observed to regularly haul out on land during winter storms (ibid.).
3. Lee shorelines of prominent points or capes and offshore islets can provide protected areas (Lensink 1962).

IV. NUTRITIONAL REQUIREMENTS

Sea otters require 20 to 25% (average about 5 kg) of their body weight/day in order to maintain 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.). Sea otters generally feed on a wide variety of benthic invertebrates; however, when these organisms are scarce, otters are known to prey on other species - slow-moving fishes, e.g. (Kenyon 1969, Calkins and Schneider 1983).

A. Preferred Foods

Sea otters are opportunistic feeders, and their diet depends largely on what is available (Schneider, pers. comm).

1. In the Aleutian Islands, otters are known to eat many species of invertebrates and mollusks and some species of fishes (Kenyon 1969). The following are some of the species eaten by sea otters: Green sea urchin (Strongylocentrotus drobachiensis); mussel (Musculus vernicosa, Volsella volsella); sea stars (Leptasterias spp., Henricia spp.); Tanner crab (Chionoecetes bairdi); king crab (Paralithodes platypus); octopus (Octopus spp.); chitons (Cryptochiton stelleri); limpets (Acmaea spp.); snails (Buccinum spp.); sea cucumbers (Cucumaria spp.); Pearly monia (Pododesmus macroschisma); globefish (Cyclopterichthys glaber); red Irish lord (Hemilepidotus hemilepidotus); and rock greenling (Hexagrammos superciliosus).
2. No specific sea otter food studies are available from the north side of the Alaska Peninsula (Schneider, pers. comm.). However, it is believed 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 Sumerton 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 would be good food sources for sea otter (Schneider, pers. comm.).

B. Feeding Locations

1. Sea otters feed in shallow water, usually less than 30 fathoms. The maximum depth of food dives may be 50 fathoms (Kenyon 1969).
2. Sub-adult animals and females with pups usually occur in areas of higher prey density and in shallower, more protected waters than do adult males (Schneider 1981).
3. Sea otters generally range from 3 to 10 mi offshore, apparently following shallow water areas to forage. The farthest offshore observations range from 17 mi (Kenyon 1969) to over 30 mi (Schneider, pers. comm.).
4. Offshore foraging movements appear to be associated with weather conditions. After severe storms, concentrations tend to be nearshore, while after a calm period animals are distributed farther offshore (Schneider 1981).

C. Factors Limiting Availability of Food

1. Normal foraging activity in a high-density otter population could affect the food supply, thus affecting the otter population. Sea otters sometimes concentrate on a prey species, utilizing it until the availability or size is greatly reduced. This appears to have happened with sea urchins at Amchitka Island (Lensink 1962, Kenyon 1969, Estes and Palmisano 1974), clams in Prince William Sound (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).
2. 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.).

1. In general, feeding behavior accords with the following pattern:
   a. 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 ceasing by dark (Lensink 1962).
   b. About 51 to 55% of the daylight hours at Amchitka Island is spent foraging (Estes 1974, Kenyon 1969). This appears to be related to a poorer quality and quantity of food source.
   c. In contrast, in an area of high food availability, otters had to spend only 17% of the daylight hours foraging for food (Estes et al. 1982).
2. Sea otters use a rock or shell held on their chest to break open other food items (Kenyon 1969, Wild and Ames 1974, Estes 1974).
3. 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.

A. Reproductive Habitat

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

B. Reproductive Seasonality

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

C. Reproductive Behavior

1. Males may maintain exclusive areas of space (territories) within female areas during the breeding peak (Kenyon 1969).
2. Surplus males wait on the fringes of female areas for estrus females to approach (Schneider, pers. comm.).
3. Pairs remain together for several (three or more) days (Kenyon 1969).

D. Age at Sexual Maturity

1. Males reach sexual maturity at about five to six years (Schneider 1978).
2. Females are sexually mature at about three to four years (Schneider 1978, Kenyon 1969).

E. Fecundity

1. Single births are usual; however, twinning does occur. Survival of more than one pup is rare, because the female is unable to provide sufficient food (Schneider 1978, Lensink 1962, Kenyon 1969).
2. The gestation period averages 7.5 months, according to Schneider (1972) and 8 to 9 months according to Kenyon (1969). The fetus spends about one-half of this time in the unimplanted stage.
3. Pupping occurs throughout the year, although the peak is reached from April to June (Schneider 1981, Kenyon 1969).

F. Frequency of Breeding

1. The breeding interval is approximately two years (Schneider 1972, Kenyon 1969, Calkins 1971).
2. Females are physiologically capable of annual breeding, and this also appears to be related to the food supply (Calkins and Schneider 1983). 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).

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

A. Home Range

1. Sea otters occupy distinct geographical male and female areas at all seasons (Kenyon 1969)
   a. Male areas. Male areas contain males of all ages over one year, are 10 to 40 km apart, with discrete boundaries, often near exposed points, and may extend 4 to 12 km offshore. Shelter from rough seas and winds is limited. Haulout areas, if present, are included within these boundaries (Schneider 1978).
   b. Female areas. Female areas contain females with pups, subadults, and some males over six years old. These areas

tend to have the most abundant food sources and best foraging locations. The areas are larger than male areas, less discrete, are better protected from heavy seas and winds, and often contain offshore rocks and islets. Haulout areas, if present, are included within the zone (ibid.).

In the Aleutians, adult males over six years old move into female areas and compete with other males for space for breeding purposes (ibid.).

B. Timing of Movements and Use of Areas

Nonbreeding males appear to expand into unoccupied habitat first (Wild and Ames 1974, Schneider 1978).

Kenyon (1969) states that otters do not undertake seasonal migrations. Schneider (pers. comm.), however, reports that at least some males make seasonal movements of over 96+ km between male and female areas, probably associated with breeding. Some males probably travel from one male area to another, as far as 39 km in some cases (Schneider 1978). Deep open water areas are probable barriers to migration between areas of suitable habitat (Kenyon 1969).

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

1. Natural high-density otter populations may result in competition for food, with a resulting higher mortality rate for juvenile and older animals (Kenyon 1969, Lensink 1962).
2. Severe weather conditions with high winds and rough seas can prevent otters from obtaining adequate food supplies, resulting in a food-related stress syndrome and possible death (Kenyon 1969).
3. 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).
4. Predation by white sharks does occur in California and may be a significant mortality factor. However, this has not been documented in Alaska (Kenyon 1969).
5. Predation by killer whales is possible; however, it has not been documented in Alaska and is not considered significant (ibid.).
6. 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

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

- Entangelment in fishing nets or marine debris
- Mortality due to ingestion of, or contact with, petroleum or petroleum products

VIII. LEGAL STATUS

Sea otters are federally protected under the Marine Mammal Protection Acts (MMPA) of 1972. The legal harvest of sea otters by Native residents is provided for by this act. The State of Alaska has petitioned the federal government for renewed managerial authority over marine mammals.

IX. LIMITATIONS OF INFORMATION

Existing information on the sea otter needs to be completed or supplemented by the following:

- ° Further study of its food preferences and feeding habits in all areas of Alaska, especially in Prince William Sound (PWS)
- ° Recent distribution and abundance data for PWS, Southeast Alaska, and other areas where the Alaskan population is expanding
- ° Further study of the effects of oil contamination on the mammal's pelage
- ° Better data on the effects of low-seal pollution (human, chemical, and petroleum) on nearshore sessile invertebrates that otter feed on
- ° Research to determine whether, and to what extent, competition exists between commercial fishermen and otters for commercially important species of crabs and clams

X. DISTRIBUTION AND ABUNDANCE

Sea otters originally inhabited virtually all of the nearshore waters of the Southwest Region, except for those areas where sea ice regularly occurs. They were hunted to near extinction between 1742 and 1911. As few as 2,000 remained in the world, most in scattered groups in the region. Since 1911, there has been a dramatic recovery. Over 90% of Alaska's estimated population of 115,000 to 160,000 sea otters and perhaps 80% of the world's population occur in this region. Repopulation of vacant habitat has followed a predictable pattern. Populations typically build to higher levels than the habitat can support on a sustained basis then drop as animals emigrate to adjacent vacant habitat. This creates "fronts" of range expansion. Numbers of sea otters in suitable habitat may increase from a few scattered individuals to several thousand in two or three years as these fronts pass through the area. Consequently, many areas with current low densities will become important concentration areas within the next decade.

A. Near Islands

Sea otters were completely exterminated in the Near Islands. In the late 1950's, a few individuals appeared throughout the island group. The population since has increased to 1,000 to 1,500. Most of these occur around Attu (Estes, pers. comm.). Continued growth until densities similar to those found in the Rat Islands is expected.

B. Rat Islands and Delarof Islands

The Rat and Delarof islands contain much excellent sea otter habitat. Russian exploitation reduced the population of these islands to a very low level, but small populations survived in both island groups. The first substantial recovery of the sea otter from early exploitation was noted in 1935. By 1947, the Amchitka population reached a peak and exceeded the carrying capacity of the habitat. Subsequently, the population declined, probably as a result of overutilization of food species. A similar situation has occurred at most of the other islands in both groups.

The present total population of the Rat and Delarof islands combined is estimated at between 23,000 and 32,000 sea otters. Extensive studies by the USFWS and the ADF&G indicate that these islands are unlikely to support larger populations on a sustained basis, and it is unlikely that the pre-1742 population was significantly larger than the present population.

C. Andreanof Islands

The Andreanof Islands, which extend from Tanaga to Seguam Island, contain large areas of excellent sea otter habitat. Early exploitation reduced the population almost to the point of extinction in this group.

The Andreanof Islands are being repopulated in a stepwise manner. Tanaga probably was populated by excess animals from the Delarof Islands in the 1930's. When Tanaga's population reached a peak, large numbers moved to Kanaga. Kanaga's population peaked; then animals moved to Adak. In this way, each island from west to east has had a rapid increase then a decline as animals moved to the next island (Kenyon 1969). This process is currently nearing completion as densities around Amlia Island, the last area of vacant habitat, near a peak. The current population of the island group is probably around 40,000 to 50,000.

D. Islands of Four Mountains

The Islands of Four Mountains consist of a number of small, steep-sided islands. There is a limited amount of habitat suitable for sea otters. The population was completely exterminated before 1911. In 1969, several otters were reportedly sighted there, but their presence was not confirmed until 1979, when about 100 were seen (Johnson, pers. comm.). The population should increase over the next few years, but the lack of extensive areas of good habitat should limit the population to a few thousand animals.

E. Fox Islands

The islands from Samalga Island to Unimak Pass contain large areas of good sea otter habitat. At present, several small but rapidly growing concentrations exist in this group of islands, and increasing numbers of scattered individuals are being seen. However, most of the habitat is not occupied. The current population is estimated at 800 to 1,500. This area has the greatest potential for population increase in the Aleutian Islands.

F. North of Unimak Island and the Alaska Peninsula

Vast areas of shallow water exist north of Unimak Island and into Bristol Bay. A large, unique population of sea otter lives in this area. The animals apparently seldom come ashore and have been seen as much as 26 mi offshore. Pods of up to 1,000 sea otters are seen from 3 to 10 mi offshore, particularly in the Amak Island area. The eastern limit of distribution of the population fluctuates, depending on the severity of sea ice conditions (Schneider and Faro 1975). On the average, sea otters are abundant as far east as Port Moller, and smaller numbers are found in Port Heiden. Scattered individuals may occur beyond that point. The population was estimated at about 17,000 in 1976 (Schneider 1981).

G. Pribilof Islands

The Pribilof Islands are near the edge of the sea ice in winter and probably are at the northern limits of potential sea otter range in the Bering Sea. Old records indicate that a population of at least 5,000 to 7,000 sea otters may have existed there when the islands were discovered by the Russians. Early exploitation completely exterminated this population, and natural repopulation has not occurred. In 1959, seven otters were transplanted there, but none has been seen since 1961. In 1968, 57 otters were released at St. George Island by the ADF&G. There is some evidence that a few individuals have reached St. Paul Island from the Alaska Peninsula, perhaps by traveling with the retreating ice pack. A few individuals persist there (Gentry, pers. comm.), but the future of this population remains tenuous.

H. Sanak Island/Sandman Reefs

This area includes many offshore rocks and shallow areas. The sea otter population has been expanding from a center near Sanak Island for many years. The present population extends from the south shore of Unimak Island to the Pavlof Islands and includes all offshore islands and reefs. Only a rough estimate of 6,000 to 10,000 can be made at this time.

I. Shumagin Islands

A large population occurred in the southern Shumagin Islands for years. This population expanded northward, repopulating the northern islands in the early 1970's. The adjacent mainland is in turn currently being repopulated. The total population of the Shumagins is around 8,000 to 12,000 at the present time.

J. South Side of the Alaska Peninsula

The area from Cape Lazaref on Unimak Island to Kupreanof Point is currently being repopulated by the Sanak-Sandman and Shumagin populations. Few sea otters occur from Kupreanof Point to Castle Cape. A large, rapidly expanding population exists between Castle Cape and Puale Bay. This population is extremely dense in the Kujulik Bay area. There is still room for an increase beyond Amber Bay. This population probably contains 8,000 to 12,000 animals.

From Puale Bay to Hallo Bay only scattered animals are found. The Kujulik Bay population should continue to expand in both directions for many years. Another population extends from Hallo Bay into Kamishak Bay. This population probably numbers about 2,000. All of the four populations along the south side of the Alaska Peninsula should continue to increase until the distribution is continuous.

K. Kodiak

Portions of the Kodiak area, including the Barren Islands, Shuyak Island, Afognak Island, the Trinity Islands, and Chirikof Island, have good sea otter habitat, although some of the area is undoubtedly of poor quality. Kodiak was an important hunting area during the Russian exploitation, but the population was never completely wiped out. Today, a relatively large population exists at the north end of the group around Afognak, Shuyak, and the Barren islands. This population is rapidly expanding its range southward (Schneider 1976a). Significant numbers have recently appeared on Kodiak Island in the Kupreanof Strait area. This pattern should continue. In particular, climatic increases along the northeast shore of Kodiak Island are expected during the next decade.

A smaller population of perhaps a few hundred occupies the shallow waters between Kodiak Island and Chirikof Island. The total population of the archipelago is estimated at 5,000 to 7,000.

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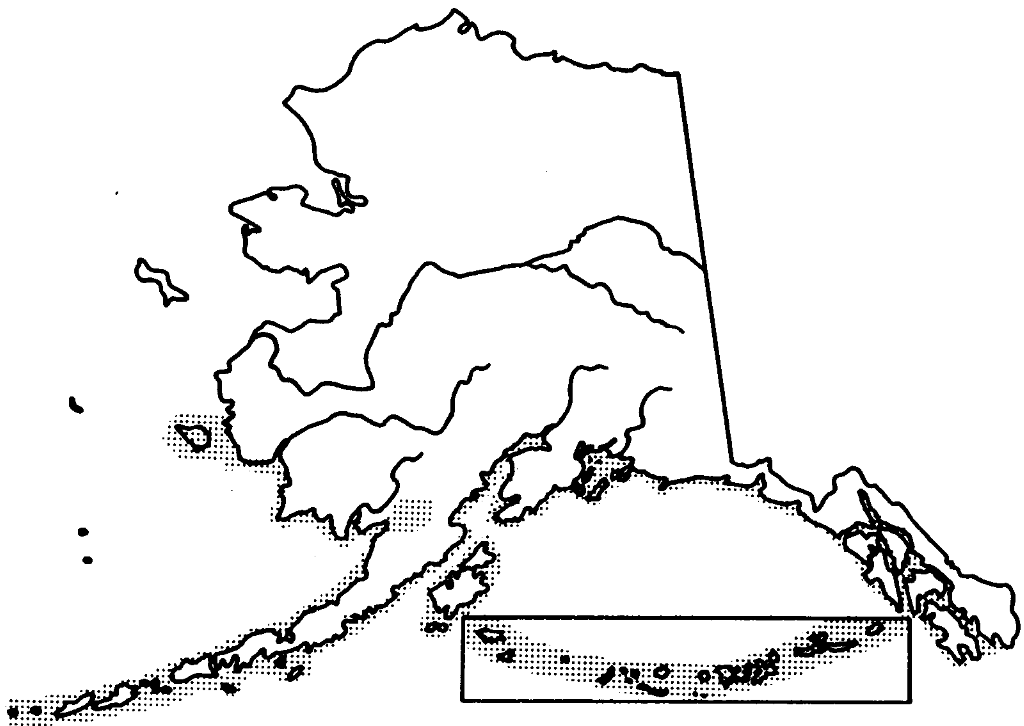
Harbor Seal Life History



Map 3. Range of harbor seal (ADF&G 1973)

I. NAME
   A. Common Name: Harbor seal
   B. Scientific Name: Phoca vitulina richardsi

II. RANGE
   A. Statewide
      Harbor seals inhabit coastal waters from Southeast Alaska to the Kuskokwim Bay/Nunivak Island region of Alaska (ADF&G 1976, Frost et al. 1982). They are also frequently found in major rivers where seasonal concentrations of food species occur.
   B. Regional
      Harbor seals occupy virtually all coastal areas in the Southwest Region. Illiamna Lake appears to support a year-round subpopulation (ADF&G 1976).

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

Harbor seals are typically found where water depths are less than 30 fathoms (ibid.). 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 (Wahl 1977, Fiscus et al. 1976, Spalding 1964).

B. Terrestrial

1. Haulout areas. 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 flows carved 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). 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. Preferred Foods

In the Gulf of Alaska, Pitcher (1981) 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. Stomach samples collected in the Aleutian Islands (Wilke 1957, Kenyon 1965, Lowry et al. 1979) included fishes, octopus, and crustaceans. Lowry and Frost (1981) stated that "recent reports from Bristol Bay fishermen indicate that large numbers of harbor seals are associated with schools of herring which spawn in the area in late May and June."

B. Feeding Locations

Harbor seals are opportunistic feeders and generally feed in close inshore shallow waters (FAO Adv. Comm. 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. Aggressive behavior related to breeding frequently occurs on land (Bishop 1967).

B. Reproductive Seasonality

1. Pupping. In Alaska, harbor seals generally give birth between late May and mid July, with most pups being born in 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. Age at Sexual Maturity

Both males and females become sexually mature between three and seven years of age (Bigg 1969, Pitcher 1977).

D. Litter Size

Generally one pup is born.

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

A. Use of Haulouts

Haulout areas are used for pupping, molting, and resting. Peak use occurs in June, August, and September and apparently tapers off in September and October, after which seals spend a greater portion of their time in the water (Pitcher and McAllister 1981).

B. Seasonal Moves

Harbor seals are generally considered relatively sedentary and nonmigratory (Bigg 1981). Seasonal occurrence in areas such as Bristol Bay and Nunivak Island, however, indicates that substantial seasonal movements may occur in some areas.

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

Little is known about the effects of food availability and predation on harbor seal populations.

B. Human-related

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

- ° Pollution of water and/or food supply
- ° Disturbance on haulouts/abandonment of pups
- ° Reduction of food supply
- ° Destruction of haulout sites
- ° Mortality from fishing gear

VIII. LIMITATIONS OF INFORMATION

Little is known about what factors - such as sources of food and predation - affect harbor seals, nor in what ways they may be affected. Information on abundance is also very difficult to obtain.

IX. LEGAL STATUS

The United States Department of Commerce and the National Marine Fisheries Service manage harbor seals under the Marine Mammal Protection Act of 1972.

X. SPECIAL CONSIDERATIONS

A. Molting

In the Gulf of Alaska, molting begins in early July and extends into early October. The peak of molting occurs in late July (Pitcher and Calkins 1979).

XI. DISTRIBUTION

There is little specific information on the distribution and abundance of harbor seals in the Bering Sea (Frost et al. 1982). Within the Southwest Region and more specifically along the north coast of the Alaska Peninsula, seals haul out on shoals and sandbars exposed during low tide. Everitt and Braham (1980) reported eight major hauling grounds. Of 25,000 harbor seals counted, 75 to 92% were concentrated at Port Moller, Port Heiden, and Cinder River. Seal Islands, Izembek Lagoon, including Moffet Point, and the Isanotski Islands are other major hauling areas. Egegik and Ugashik bays support lesser numbers. Seals have been seen hauled out at Cape Seniavin, Cape Lieskof, Amak Island, and Unimak Island (Frost et al. 1982). Nanvak Bay is a major hauling ground in northern Bristol Bay. In July and August 1975, however, 20 to 200 seals were seen hauled out at Hagemeister Island (ibid.).

Harbor seals have been observed hauled out on offshore reefs, rocks and ledges, beaches, and mud bars along the southern coast of the Alaska Peninsula and on Kodiak and the Aleutian islands. Seals enter lakes and rivers on a seasonal basis. Iliamna Lake appears to support one of the few year-round freshwater populations of harbor seals in the world, although there probably is interchange with Bristol Bay seals through the Kvichak River.

Peak use of haulouts begins in June during the pupping period and tapers off in September after molting is complete.

XII. ABUNDANCE

Lowry and Frost (1981) estimated the total population of harbor seals to be 30,000 in Bristol Bay and the Pribilofs and 85,000 in the Aleutians. Estimates of seal populations occurring in the Gulf of Alaska are incomplete.

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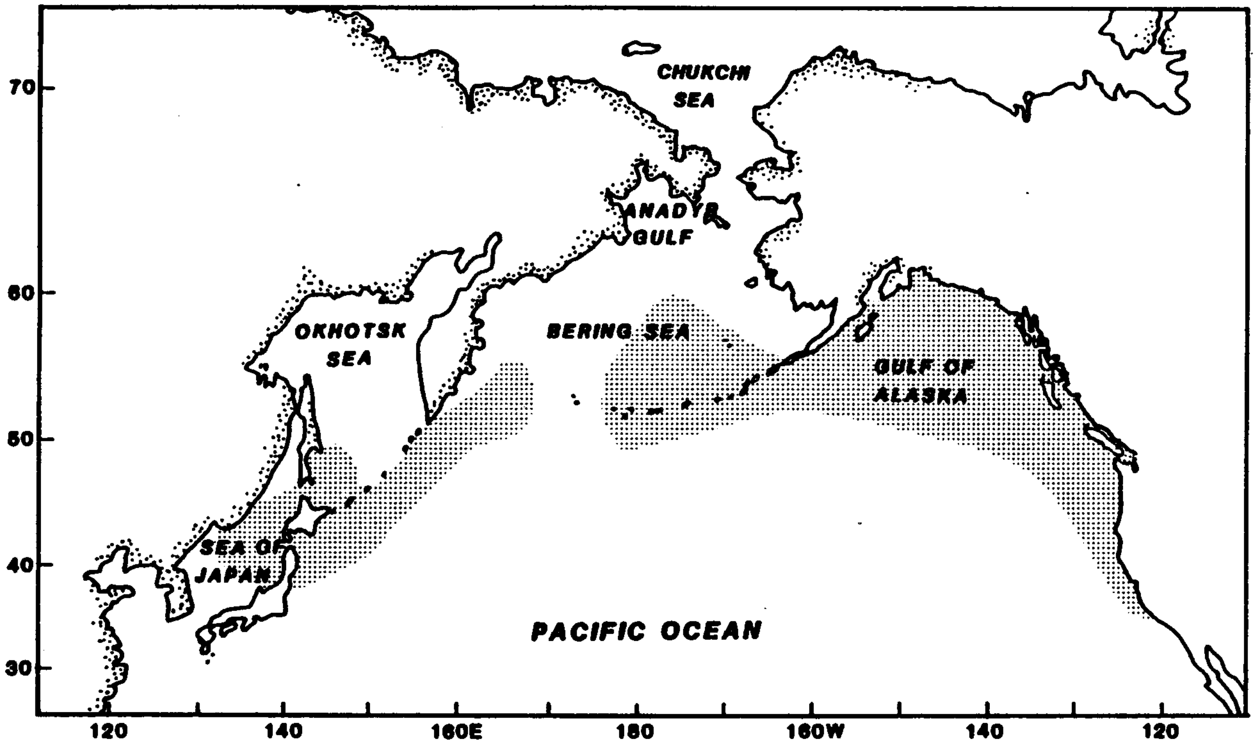
Northern Fur Seal Life History



Map 4. Range of northern fur seal (Anonymous 1980, Ronald et al. 1982, Lowry et al. 1982)

I. NAME
   A. Common Name: Northern fur seal
   B. Scientific Name: Callorhinus ursinus

II. RANGE
   A. Statewide
      Terrestrial distribution is limited to haulout and breeding rookeries on the Pribilof Islands; pelagic distribution includes most of the southern Bering Sea and the Gulf of Alaska and may include the eastern and western continental shelf portions of the northern Pacific Ocean (Ronald et al. 1982).

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

1. Water quality:

a. Temperature. Although found in water from -1 to 15°C, fur seals are most abundant where temperatures range between 8 and 12°C, which may be in response to food availability rather than reflecting a temperature preference (Ronald et al. 1982).

b. Depth. No direct information has been found; however, fur seals in the Bering Sea are generally distributed within or at the edge of the continental shelf and slope (Gentry 1981). They may descend to 100 m when feeding, and they have been recorded diving to 190 m (Berg 1977).

B. Terrestrial

The terrestrial habitat of the northern fur seal is confined to rookeries and haulout areas, mostly on the Pribilof Islands (Anon. 1980).

1. Physical characteristics. Fur seals use rocky outcroppings along shorelines with exposed beach areas (ibid.).

2. Functional use:

a. Protection from natural elements. No literature was found indicating that protection from natural elements is an important function of terrestrial haulouts for age classes other than pups; the strongly pelagic nature of fur seals (Gentry 1981) suggests that protection from the elements may not be important except for newborn pups and injured or sick subadults and adults.

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

IV. NUTRITIONAL REQUIREMENTS

A. Preferred Foods

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

1. Primary foods:

a. Gulf of Alaska. Nearshore (shallower than 200 m), they feed on herring (*Clupea harengus*) during February/early March; capelin (*Mallotus villosus*) during March - July; and sand lance (*Ammodytes hexapterus*) during May - July (Perez and Bigg 1981). Offshore (deeper than 200 m), they feed on rockfish (Scorpaenidae); Salmonidae; and squid (*Berryteuthis magister*, *Gonatopsis borealis*, *Loligo opalescens*) (ibid.).

b. Bering Sea. Capelin, sand lance, and Atka mackerel (*Pleurogrammus monopterygius*) are consumed in early summer; capelin, Salmonidae, herring, and walleye pollock (Theragra chalcogramma) in mid-to-late summer; squid in deeper water (Berryteuthis) in early summer; Gonatopsis in mid-to-late summer (Perez and Bigg 1981, Lowry et al. 1982).

2. Secondary foods:
   a. Gulf of Alaska. In the gulf, fur seals eat walleye pollock, Octopoda (Perez and Bigg 1981), and gadids (Anon. 1980).
   b. Bering Sea. In the Bering Sea, they eat sablefish (Anoplopoma fibria), deep sea smelts (Bathylagidae) (Perez and Bigg 1981), sandfish (Trichodon trichodon), and tomcod (Microgadus proximus) (Lowry et al. 1982).

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

C. Factors Limiting Availability of Food
1. Many prey species move to deeper water during daylight (Anon. 1980, Ronald et al. 1982).

D. Feeding Behavior
1. Prey selection. Fur seals swallow fish smaller than 25 cm whole while underwater (Ronald et al. 1982); this size prey constitutes most of their diet (Berg 1977).
2. Diel feeding patterns. Fur seals feed on Mallotus, Clupea, Ammodytes, squid, and Salmonidae primarily at night and dawn; they feed on Theragra primarily during the day; on Pleurogrammus monopterygius during the night or morning; in general, they feed mostly during the night (Perez and Bigg 1981).
3. Other. Fur seals often make repeated dives to the same depth, of less than five minutes duration (Gentry 1981).

E. Nutritional Requirements
1. In water of 5°C, fur seals require 12 to 13.5% of their body weight/day of fish for subadults and adults (Harry and Hartley 1981).
2. There is an inverse correlation between water temperature and food consumption in the normal range of the Bering Sea/Gulf of Alaska water temperatures (Lowry et al. 1982, Harry and Hartley 1981).

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

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

B. Reproductive Seasonality

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

C. Reproductive Behavior

1. Sexually mature males establish territories upon arrival at the rookery in May in a descending order of age; dominant bulls maintain territories closest to the beach front and exclude other males but do not actively herd or interfere with the females' movements; males remain full-time on females' territories until August (Gentry 1981).
2. Females:
   a. Breeding. The receptive female selects a territorial male, and copulation occurs soon thereafter (ibid.).
   b. Nursing. The female begins feeding excursions seven days postpartum; for the duration of lactation, females alternate several days of feeding at sea (usually within 160 km, Lowry et al. 1982) with two-day suckling visits to her pups on the rookery (Gentry 1981).

D. Age at Sexual Maturity

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

E. Fecundity

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

F. Frequency of Breeding

Fur seals breed annually (ibid.).

G. Gestation Period

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

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

A. Timing of Movements and Use of Areas

1. Adult males leave the rookeries in late August and winter in the northern Gulf of Alaska; the data are sketchy, however (Harry and Hartley 1981).
2. Females:
   a. Breeding/pupping season. Lactating females feed within 160 km (occasionally to 400 km) of the rookery (Lowry et al. 1982, Gentry 1981).
   b. Nonbreeding season. In November, adult females and subadults migrate south, usually within 50 to 110 km of shore (Berg 1977); some continue south to the Pacific Northwest; a large concentration winters nearshore to Baranof Island (Consiglieri and Braham 1982).
   c. Subadult males. Subadult males probably range throughout the Gulf of Alaska and the southern Bering Sea and do not come ashore for the first two to three years (Anon. 1980, Lowry et al. 1982).

B. Use of Areas

See IV.B., Feeding Locations, this report.

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

1. Pup mortality:
   a. On the rookery. Total pup mortality on the rookery varies from 5 to 20% (Gentry 1981, Anon. 1980). Gentry (1981) reported pup losses on the rookery as follows: emaciation, 34%; disease and parasitism, principally hookworm, *Uncinaria*, 59%; trauma (e.g., trampling, injury from males), 3%.
   b. At sea. Storms, predation by sea lions (3 to 6% in 1975), sharks, and killer whales are the principal causes of pup mortality. Total pup mortality estimates range from 38 to 72% (Berg 1977, Anon. 1980, Lowry et al. 1982).
2. Adult mortality. The total mortality up to and including age-class three may be up to 85% in some years (Ronald et al. 1982); however, mortality to older age classes is "very low" (Anon. 1980).
3. Competition with other species. Larga seals (*Phoca largha*) and ribbon seals (*Phoca fasciata*) feed on many of the same species as fur seals. Larga seals are in the Pribilof area only during winter and early spring, when fur seals are absent (Harry and Hartley 1981), whereas ribbon seals probably overlap northern fur seals in the southern Bering Sea during summer. Marine birds such as kittiwakes (*Rissa* spp), murres (*Uria* spp.), horned puffin (*Fratercula corniculata*), and tufted puffin (*Lunda cirrhata*) eat many of the same prey species as fur seals but mostly small sizes of these species (ibid.).

B. Human-related

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

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

VIII. LEGAL STATUS

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

IX. LIMITATIONS OF INFORMATION

A. Location of Male Wintering Concentrations Areas

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

B. Estimates of Man-Induced Mortality Other Than Harvest

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

X. DISTRIBUTION

Northern fur seals seasonally inhabit a vast area of the North Pacific Ocean. They can be found from north of the Pribilof Islands, south along the eastern side of the Pacific Ocean as far as the California - Mexico border (Anonymous 1980), and along the western side of the Pacific Ocean as far as Honshu, Japan (ibid.). Rookeries are located on the Pribilof Islands, San Miguel Island, and Kurile Islands (Ronald et al. 1982). Although there is some interchange of individuals between the eastern and western stocks it is less than 10% (Gentry 1981). The San Miguel stock was founded by female fur seals tagged in both the Pribilof and Commander islands. The San Miguel stock remains all year in the vicinity of California (ibid.).

A. Timing of Movements

Fur seal movements are dependent on the sex and age of the individual, season of the year, and the movements of their prey. During the breeding season, adult males remain on their territories at the rookeries. Females remain associated with the rookery but leave it to feed, occasionally as far as 320 km away but mostly within a 160 km radius. In late August, adult males leave their breeding territories and either move through the Aleutian passes to winter in the northern Gulf of Alaska or remain in the southern Bering Sea (Lowry et al. 1982, Gentry 1981, Anon. 1980).

In October, females and subadult males leave the rookeries and associated haulouts and move south through the Aleutian passes and fan out across the North Pacific Ocean. Eventually they become more concentrated along the continental shelf on the eastern and western sides. Females predominate on the eastern edge and migrate farther south than the subadult males. Pups of the year leave the rookeries last and move through the Aleutian passes in November and December. Little else is known about their movements until they return to the Pribilof Islands rookeries and haulouts as three-year-olds.

Movements northward toward the Pribilof Islands rookeries are initiated by the adult females in mid March. As the season progresses, subadults and adult males begin returning also. The adult males arrive in late April and begin establishing territories. Older pregnant females arrive in late June, and younger pregnant females several weeks later. Some subadult males straggle in all summer and occupy haulouts near the rookeries.

B. Distribution and Movements in the Southwest Region

Although a few individual fur seals may be present in all ice-free areas of the region, fur seals intensively use the following three areas:

1. Pribilof Islands area. In addition to use of the islands by fur seals as rookeries and haulouts, areas within a 100 mi radius are used during the summer by nursing females that are foraging (Lowry et al 1982); subadult males associated with the haulouts also forage in the area and in a zone between the Pribilof Islands and the eastern Aleutian Islands (ibid.);
2. Eastern Aleutian passes. Unimak Pass is extensively used by a majority of the Pribilof Islands stock (Lowry et al 1982) especially during the southward migration in the fall and the northward migration in the spring. Subadults all year and adult males wintering in the southeastern Bering Sea and northern Gulf of Alaska forage in this area also (MMS 1982). Akutan and Umnak passes are also intensively used (ibid.).
3. Gulf of Alaska. Portlock and Albatross banks are intensively used by foraging females and subadult males during the spring migration (Anon. 1980) and by subadults at any time of the year.

XI. ABUNDANCE

The world population of northern fur seals is estimated to be 1.8 million, of which approximately 1.25 million are associated with the Pribilof Islands (Gentry 1981, Lander 1980).

The major factor affecting the fur seal population is the commercial harvest (see Human Use chapter for details). Prior to initiation in 1786 of commercial exploitation of fur seals, the population is thought to have numbered 2.5 million (Gentry 1981). Because of changes in the extent to which the harvest was regulated, overharvesting has caused the population to decline severely twice since 1786. The most recent and severe decline occurred between 1867 and 1911. By 1911, the population had been reduced to fewer than 300,000 seals, at which time the North Pacific Fur Seal Convention was established (Ronald et al. 1982). As a result of restrictions established then, the population increased dramatically. The abundance of the Pribilof stock is thought to have decreased in recent years, perhaps because of mortalities caused by entanglements in net debris (Lowry, pers. comm.).

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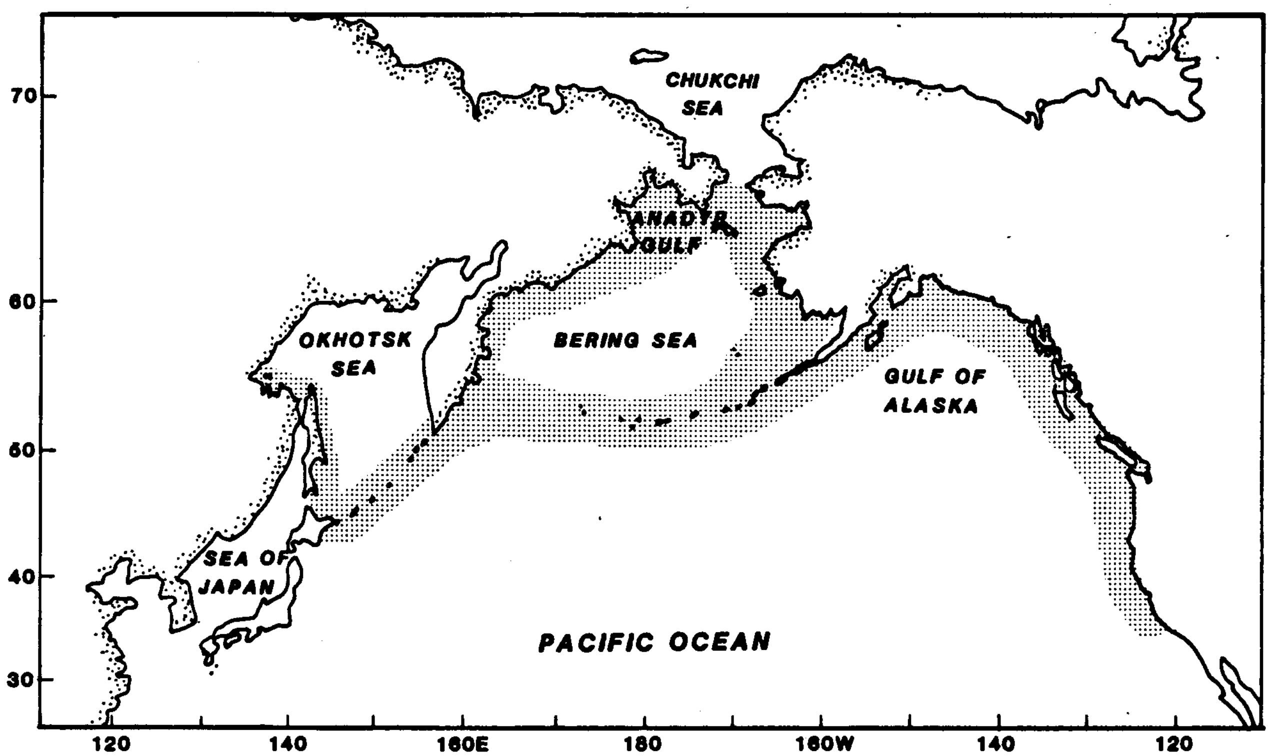
Sea Lion Life History



Map 5. Range of sea lion (Gusey 1978, Kenyon and Rice 1961)

I. NAME
   A. Common Names: Sea lion, Steller sea lion, northern sea lion
   B. Scientific Name: Eumetopias jubatus

II. RANGE
   A. Statewide and Beyond
   In Alaska, sea lions range in nearshore waters and offshore waters over the continental shelf from Southeast Alaska north throughout the Gulf of Alaska and west through the Aleutian Islands and Bering Sea. Their range extends along the west coast of North America to southern California and in the western Pacific from the Commander Islands and Sea of Okhotsk to northern Japan (Gusey 1978).

B. Regional

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). Important haulout areas are listed in table 1.

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

1. Water quality. Sea lions of both sexes lead a mostly pelagic life during their first two years (Calkins and Pitcher 1982). Kenyon and Rice (1961) observed sea lions as far as 85 nautical miles offshore; they have been observed following ocean-going trawling boats.
2. Water depth. Fiscus and Baines (1966) found that sea lions forage in relatively shallow water (less than 100 fathoms) nearshore, although, as noted above, Kenyon and Rice (1961) have observed them 85 nautical miles offshore.

B. Terrestrial

Terrestrial habitat requirements for sea lions revolve around rookeries, haulouts, and rest areas. Sea lions are rarely seen hauled out more than 20 m away from water (Sandergren 1970). Terrestrial habitats must also provide protection from natural elements.

1. Rookeries. Rookeries are terrestrial sites where adult males actively defend territories and where breeding and pupping take place (Calkins and Pitcher 1982). A rookery may be used as a haulout during nonbreeding periods of the year.
   Sandegren (1970) described the rookery area on Lewis Island, Prince William Sound, 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.
2. Haulouts. Haulouts are any areas where sea lions haul out on a regular basis but where few or no pups are born (Calkins and Pitcher 1982). A variety of areas are used, seasonally, as haulouts, but all types provide areas free of water at lower tide stages. These areas include large rocks awash at high tide (Harbor Pt.), rocky beaches flanked by sand beaches (Sitkagi Bluff), beaches with larger boulders (Cape St. Elias), and, rarely, sand bars exposed to storms and high tides (Middleton Island) (Calkins and Pitcher 1982).
3. Rest areas. Rest 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 rest areas were found; however, they are probably similar to other areas used by sea lions.
   a. Overhanging ledges, cracks, and caves in the rocks are important protection from intense solar radiation (Sandegren 1970).

Table 1. Significant Northern Sea Lion Haulouts,[a] Southwest Region

Name (Ident. No.)[b]	1973 Est. Abund.[c]	Recent Est. Abund.[d]	Sources[d] and Comments
Cape Newenham (___)	-	500-1,000	Frost et al.. 1982
St. George Island - Dolnoi Point (285)	2,500-3,000		N/A
St. George Island - Red Bluff (286)	500	-	N/A
Otter Island (288)	100	800	Frost et al.. 1982
Walrus Island (291)	5,000	1,170	" " "
Marmot Island (320)[e]	10,000	ca. 8,000	Calkins and Pitcher 1982
Latax Rocks (323)	3,300	1,164	Calkins and Pitcher 1982
Ushagat (328)	100	900	Calkins and Pitcher 1982
Southwest of Sud Island (___)	-	670	" " "
Sea Otter Island (___)	-	541	" " "
Sea Lion Rock (377)	500	432	" " "
Cape Barnabas (255)	1,000	364	" " "
Chiniak Island (257)	600	883	" " "
Puale Bay (265)	2,800	15,000	" " "
Outer Seal Rocks (266)	50	1,913	" " " Called this site "Cape Ikolik"
Twoheaded Island (251)	3,600	1,636	Although reported to be a rookery in the past, no longer considered so (Calkins and Pitcher 1982)
Chirikof Island (245)	500	5,000+	" " "
Chowiet Island (241)	5,000	9,926	" " "
Ugaiushak Island (240)	600	125	" " "
Atkins Island (215)	3,100	1,200	" " "
Castle Rocks (216)	400	541	" " "
Spitz Island (218)	700	25	" " "
Jude Island (206)	3,000	302	" " "

(continued)

Table 1 (continued).

Name (Ident. No.)	1973 Est. Abund.	Recent Est. Abund.	Sources and Comments
The Whaleback (209)	600	-	Considered a "stopover" not a haulout by Calkins and Pitcher (1982)
Amak Island (200)	2,000	2,316	Braham et al. 1980
Sea Lion Rock (201)	350	-	
Chernabura Island (192)	2,000	3,303	Calkins and Pitcher 1982
Sanak Island - South Rock (179)	3,200	1,600+	" " "
Akutan Island - North Head (158)	714	3	Braham et al. 1980
Akun Island - Akun Head (159)	2,000	3	Braham et al. 1980
Akun Island - Billings Head (160)	100	2,600+	Listed as rookery in St. George FEIS (MMS 1982) but not in Braham et al. 1980
Tanginak Island (161)	600	470	Listed as rookery in St. George FEIS (MMS 1982) but not in Braham et al. 1980
Tigalda Island - northeast end (163)	750	190	Braham et al. 1980
Aiktak Island (164)	600	1	" " "
Oksenof Point (168)	4,000	2	" " "
Cape Idak (140)	600	233	" " "
Unalaska Island - South Rock (___)	-	1,067	" " "
Whalebone Cape (146)	1,000	281	" " "
Reef Bight (___)	-	874	" " "
Old Man Rocks (___)	-	688	" " "
Bishop Point (___)		500	" " "
Uliaga (131)	500	194	Fiscus et al. 1981
Chuginidak Island (124)	700	913	" " "
High Rock (115)	600	254	" " "
Agligadak Island (101)	250	993	" " "
Agligadak Reef (___)	-	2,463	" " "
Sviechnikoff Island (97)	700	869	" " "

(continued)

Table 1 (continued).

Name (Ident. No.)	1973 Est. Abund.	Recent Est. Abund.	Sources and Comments
Cape Misty (96)	750	107	" " "
Ikiginak Island (81)	500	0	" " "
North Cape (82)	550	12	" " "
Sagchudak Island (85)	1,200	10	" " "
Amtagis Island (86)	800	0	" " "
Cape Potainikoff (___)	-	1,151	New haulout; Fiscus et al. 1981
Anagaksik Island (78)	700	124	Fiscus et al. 1981
Agitkin Island (79)	700	0	" " "
Argonne Point (63)	1,000	0	" " "
Hook Point (64)	1,500	0	" " "
Cape Yakak (65)	800	270	" " "
Swallow Head (68)	650	312	" " "
Gareloi Island (47)	2,500	0	" " "
Skagul Island (48)	500	0	" " "
Tag Island (49)	400	1,740	" " "
Amchitka Island (31)	600	-	Not surveyed
Semisopochnoi Island (32)	500	-	" "
Pochnoi Point (33)	2,000	435	Fiscus et al. 1981
Buldir Island (17)	2,500	-	Not surveyed
Shemya Island (7)	2,500	-	" "
Alaid Island (6)	1,500	-	" "
Cape Sabak (5)	3,300	-	" "
Gillon Point (3)	3,000	-	" "
Cape Wrangall (1)	9,000	-	" "

Sources: Braham et al. 1980, Calkins and Pitcher 1982, Fiscus et al. 1981, Frost et al. 1982, MMS 1982.

a Haulouts, or locations in which no distinction is made between haulouts and rookeries (e.g., ADF&G 1978), where 500 or more animals were observed or estimated between 1970-1983; selection of 500 is arbitrary.

b Site name and identification number from ADF&G 1978, unless otherwise indicated.

c From ADF&G 1978.

d Most recent available literature.

e Haulout and rookery.

b. 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).

IV. NUTRITIONAL REQUIREMENTS

A. Preferred Foods

1. Primary. 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); rockfishes (Scorpaenidae).

   a. Walleye pollock was the predominant prey, composing 58% of the total volume and occurring in 67% of stomachs with food (Pitcher 1981, Calkins and Pitcher 1982).

   b. Pacific herring and squids were used extensively by sea lions in Prince William Sound but were less important elsewhere in the Gulf of Alaska (Pitcher 1981).

   c. Predation on salmon and capelin was regional and appeared to be limited to seasonal (April-September) nearshore distribution of these species (Pitcher 1981, Calkins and Pitcher 1982). Sea lions from central California and Oregon fed mainly on bottomfish, whereas those in Alaskan waters fed mainly on schooling fishes (Fiscus and Baines 1966). A sea lion taken in May on the Fairweather Grounds in the eastern Gulf of Alaska had eaten three salmon (ibid.).

2. Secondary. Pitcher (1981) described additional food sources from the Gulf of Alaska as including shrimps (Decapoda); Tanner crab (*Chionoecetes* spp.); spider crab (*Hyas* spp.); skate (*Raja* spp.); Pacific sandfish (*Trichodon trichodon*); harbor seal (*Phoca vitulina*).

3. 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. Feeding Locations

1. Sea lions typically feed nearshore or in relatively shallow water (less than 100 fathoms) on the continental shelf. However, although they may travel considerable distances from haulout areas to feed (Fiscus and Baines 1966), 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 to 12) and individuals occur far from land (ibid.).

2. 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).

C. Factors Limiting Availability of Food

1. Some food species are present nearshore only during certain periods of the year (ibid). Salmon and capelin are abundant near Kodiak during spring and summer (ibid.). Capelin are abundant near Unimak Pass during summer (Calkins and Pitcher 1982, Pitcher 1981).
2. Sea lions appear to feed on most abundant prey species in the area (ibid.). An increase of pollock in the sea lion diet is concurrent with an increase in pollock stocks in the Gulf of Alaska (Calkins and Pitcher 1982, Pereyra and Ronholt 1976).

D. Feeding Behavior

1. Daily cycle. During May-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). Males with semi-aquatic territories (partially above and below the high-tide line) were most involved in breeding activity (ibid.).

B. Reproductive Seasonality

1. Sandegren (1970) found that in Prince William Sound most pups were born from 29 May through 1 July, with a peak from 10 to 12 June.
2. Calkins and Pitcher (1982) 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).
3. Breeding occurs from 10 to 14 days after females give birth (Sandegren 1970).
4. Breeding on Sugarloaf and Marmot islands (Gulf of Alaska) occurs between late May and mid July, with a peak between 7 June and 4 July (Calkins and Pitcher 1982).

C. Reproductive Behavior

1. Sea lions are polygynous, and most breeding is done by territorial bulls that defend territories against other bulls (Sandegren 1970).
2. Some bulls maintain territories for over 60 days (ibid).
3. Cows initiate breeding with distinct behavior directed towards territorial bulls (ibid.).

4. Females leave their young for the first time 5 to 12 days after birth (ibid.). Males do not attend or protect pups.
5. 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.).
6. The mother-offspring bond is long-lasting, and adult females have been observed nursing both a pup and a subadult (Calkins and Pitcher 1982, Sandegren 1970).

D. Age at Sexual Maturity
1. Females mature between three and eight years, with most maturing at four (Calkins and Pitcher 1982). One observation of a female breeding at two years of age was reported (ibid.).
2. 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 mature before they are able to defend territories (ibid.).

E. Fecundity
1. Females have a single pup (Pitcher and Calkins 1981).
2. The pregnancy rate for females 8 to 20 years old in the Gulf of Alaska was 87% (Calkins and Pitcher 1982).
3. The projected birth rate (after prenatal mortality) for mature females in the Gulf of Alaska was 63% (Calkins and Pitcher 1982) and 68% in California (Gentry 1970).
4. Sea lions appear to delay blastocyst implantation until late September or October (ibid.).

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

A. Migration
1. Calkins and Pitcher (1982) have reported indications of a gradual dispersal of sea lions away from the rookeries of their birth along all haulouts across the north Gulf of Alaska, including Prince William Sound and to and past Cape St. Elias into Southeast Alaska. This represents a nearshore movement of 1,500 km.
2. Sea lions tagged near Queen Charlotte Island in British Columbia were observed at Cape St. Elias, Gulf of Alaska, which is also a nearshore movement of approximately 1,500 km (Calkins and Pitcher 1982).
3. Marked sea lions have been observed at haulouts throughout the Gulf of Alaska, indicating there is considerable movement by individuals (ibid.).

B. Timing and Use of Areas
1. Generally, sea lions are dispersed throughout the Gulf of Alaska in winter, utilizing different haulouts than in summer (ibid.).
2. Sea lions begin concentrating at rookeries by mid May and peak by mid-to-late June. Rookery activity is over by October and animals disperse (ibid.).
3. Dispersal of young animals away from rookeries occurs following the first summer of life (ibid.).

4. Calkins and Pitcher (1982) have found in the Gulf of Alaska that many females return to the rookeries of birth.

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

1. Pup mortality of 12.5 to 14% was observed by Sandegren (1970) on rookeries in Prince William Sound. Injuries sustained from crushing or fighting adults were main causes of death.

B. Human-related

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

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

VIII. LEGAL STATUS

Sea lions are federally protected under the Marine Mammal Protection Act (MMPA) of 1972. The legal harvest of sea lions by Native residents is provided for by this act. The State of Alaska has petitioned the federal government for renewed managerial authority over marine mammals.

IX. LIMITATIONS OF INFORMATION

Existing information on sea lions is inadequate regarding the following:

- The numbers of animals killed or injured in competition with pelagic and nearshore commercial fishing operations
- The numbers of animals killed or injured by man-made debris (plastics, netting, etc.)
- Recent population estimates for the Alaskan or northern Gulf of Alaska coast and data on the species' distribution and migrational patterns
- The salient characteristics of sea lion rookeries and the incidence of pup mortality

X. DISTRIBUTION

A. General Distribution

Northern sea lions are the most widely distributed otariid in the North Pacific Ocean. Sea lions have been observed over the continental shelf from as far southeast as southern California to as far northeast as the Bering Straits and as far southwest as northern Japan (Lowry et al. 1982).

B. Regional Distribution

Sea lion distribution is determined by the location of haulouts and rookeries and by the movements of major prey species. Sea lions are abundant in the Gulf of Alaska from the eastern boundary (Barren Islands) of the Southwest Region to the Aleutian Islands (Calkins and Pitcher 1982) and in the Bering Sea from the Aleutian Islands as far northeast on the Alaska Peninsula as Cape Seniavin (Frost et al. 1982). There are no reported haulouts in southern and eastern Bristol Bay; there are haulouts in the Walrus Islands and Cape

Newenham, however, and sea lions are common throughout northwestern Bristol Bay (ibid.). The haulout at Cape Newenham is the northernmost haulout on mainland Alaska in the Bering Sea (ibid.).

Walrus Island (near St. Paul Island) is the northernmost significant rookery in the Bering Sea (ibid.). St. George Island has had two significant haulouts (Red Bluff and Dolnoi Point) and a rookery, but there are no recent reports to confirm the supposition that these still are used by significant numbers (ibid.). Otter Island (near St. Paul Island) is principally a winter haulout (ibid.).

C. Timing of Movements

Sea lions do not undertake timed migrations; however, portions of the population do exhibit approximate seasonal movements (Berg 1977), and there do appear to be gradual, directed dispersals (Calkins and Pitcher 1982).

1. <u>Seasonal movements</u>. Sea lions exhibit seasonal movements that appear to depend on at least three factors: the stage of the reproductive cycle, changes in prey abundance or seasonal concentrations of prey, and changes in weather conditions associated with changes in the season.

   In the Gulf of Alaska, Calkins and Pitcher (1982) found that seasonal movements are especially noticeable for the reproductive portion of the population, which is generally associated with rookeries during the period from May to October. Territorial adult males return to and remain at the rookeries throughout the breeding season. Breeding and pupping females are present intermittently during the season, returning only to feed the pups. Because most of the major rookeries are haulouts during the nonbreeding season (see tables 1 and 2), subadults and nonbreeding adults also are present prior to the breeding season. As the breeding season progresses, nonbreeding animals are forced out, and although many of them return to use the rookery as a haulout during the nonbreeding season, many of the subadults disperse. The large rookery at Sugarloaf Island (see table 2) is an exception: this rookery is not used as a haulout during the nonbreeding season, and most subadults leaving there do not return until they are breeding adults (Calkins and Pitcher 1982).

   In addition to seasonal movements associated with the reproductive season, movements associated with prey distribution also occur. Especially in the Kodiak area, salmon and capelin are abundant nearshore during the spawning season. During this period, sea lions in the area move to locations of prey concentration, such as the Portlock and Albatross Banks for capelin (BLM 1981) and nearshore in Kodiak and the south side of the Alaska Peninsula (Calkins and Pitcher 1982). Sea lions in the eastern Aleutians and Alaska Peninsula utilize Unimak Pass, especially during the capelin spawning period in spring. Unimak Pass is also used heavily at other times of the year by sea lions that are foraging and dispersing (MMS 1982).

   In late summer and early fall, a thousand or more animals regularly reach St. Lawrence Island (ibid), and a few are

Table 2. Significant Northern Sea Lion Rookeries[a] Southwest Region

Name (Ident. No.)[b]	1973 Est. Abund.[c]	Recent Est. Abund.[d]	Sources[d] and Comments
Marmot Island	ca. 10,000	ca. 13,122	Calkins and Pitcher 1982
Sugarloaf Island (325)	10,000	9,831	" "
Chirikoff Island (245)	500	6,848	" "
Chowiet Island (241)	5,000	9,926	" "
Atkins Island (215)	3,100	9,538	" "
Chernabura Island (192)	2,000	2,150	" "
Clubbing Rocks (181)	5,600	2,581	" "
Pinnacle Rocks (182)	980	5,479	" "
Ugamak Island (165)	13,400	5,100	Braham et al. 1980
Round Island (166)	6,000	302	" " "
Cape Morgan - Akutan Island (148)	15,700	6,000	" " "
Bogoslof Island (134)	3,707	3,300	" " "
Adugak Island (125)	1,275	2,000	" " "
Ogchul Island (126)	2,966	2,441	" " "
Yunaska Island (118)	800	2,249	Fiscus et al. 1981
North Shore (104)	4,000	6,493	Mostly Saddleridge Point (Fiscus et al. 1981)
Kassatochi Island (80)	200	2,166	Fiscus et al. 1981
Ulak Island (45)	1,500	2,374	" " "
Gramp Rock (51)	700	1,705	Possible rookery) Fiscus et al. 1981)
Lake Point (___)	-	972	New rookery (Fiscus et al. 1981)
Rat Island (25)	750	1,485	Fiscus et al. 1981
Amchitka Island "Column Rocks" (___)	-	1,749	New rookery (Fiscus et al. 1981)
Cape St. Stephen (18)	1,000	2,648	Fiscus et al. 1981
Lief Cove (Kiska)	-	5,642	New rookery (Fiscus et al. 1981)
Buldir Island (17)	2,500	4,122	Early (1980) in Fiscus et al. 1981
Alaid Island (6)	1,500	725	Early (1980) Fiscus et al. 1981
Cape Sabak (5)	3,300	6,512	Early (1980) in Fiscus et al. 1981
Gillon Point (3)	3,000	821	Early (1980) in Fiscus et al. 1981
Cape Wrangell (__)	9,000	2,783	Early (1980) in Fiscus et al. 1981

(continued)

Table 2 (continued).

Sources: Braham et al. 1980, Calkins and Pitcher 1982, Fiscus et al. 1981, Frost et al. 1982.

a Rookeries where 500 or more animals were observed or estimated between 1970-1983; selection of 500 is arbitrary.

b Site name and identification number from ADF&G 1978, unless otherwise indicated.

c From ADF&G 1978.

d Most recent available literature.

irregular visitors to the Bering Straits area (Frost et al. 1982). Presumably, these animals are following prey concentrations.

Although some of the animals present in the central and northern Bering Sea remain with the advancing ice front during fall and winter and haul out on to the ice, most of the Bering Sea animals move south to protected areas of the Aleutian Islands (MMS 1982). Animals in the Gulf of Alaska remain there in the winter but move to sheltered haulouts and in some cases to more protected geographic areas such as Prince William Sound (Calkins and Pitcher 1982).

2. Dispersal. Calkins and Pitcher (1982) present evidence for a "directed dispersal" (not a true migration, however) of subadults across the northern Gulf of Alaska to past Cape St. Elias. They also demonstrated a trend for these subadults to return as breeding adults to the rookeries of their birth.

XI. ABUNDANCE

The world population of northern sea lions is estimated to be 250,000 to 325,000 (MMS 1982), of which the Alaskan segment was estimated to comprise 200,000 in 1977 (Braham et al. 1980). It appears, however, that the estimate for the Alaskan portion is too low. Calkins and Pitcher (1982) observed a total of 66,636 animals (39,906 adults and 29,778 pups) during rookery surveys in the Gulf of Alaska east of Unimak Pass. Lowry et al. (1982) estimated a total of 97,720 animals for the Aleutian Islands and the Bering Sea; this estimate was based on rookery and haulout surveys. These two estimates total 164,356 animals and should be considered minimal because, although more of the population is concentrated on rookeries during the breeding season than at any other time of year, up to 40% of the total population may be at sea during this time (MMS 1982). Calkins and Pitcher (1982) used the rookery surveys as a basic figure, and used other demographic characteristics (e.g., sex ratio at birth, mortality rates) to extrapolate to an estimate of 135,666 animals (including pups) for the Gulf of Alaska portion.

The portion of the Alaska segment present in the Southwest Region can be estimated from the rookery and haulout counts conducted between 1977 and 1979 in various areas of the region (Calkins and Pitcher 1982, Fiscus et al. 1981, Braham et al. 1980). A total of 115,236 animals (including 36,948 pups) have been counted or estimated on rookeries in the Southwest Region (table 3). Because of the qualifications on the data, which are discussed later, this figure should be considered very conservative.

Braham et al. (1980) presented evidence to suggest that there has been a decline since 1968 of about 50% in the eastern Aleutian Islands portion of the population. This decline has been most noticeable at the Cape Morgan and Ugamak Island rookeries. There has been no concurrent increase in the Gulf of Alaska or central or western Aleutian Islands portions (Calkins and Pitcher 1982, Fiscus et al. 1981), suggesting that there actually has been a decline and not just a shift in distribution.

Lowry et al. (1982) mention that a decline in the Pribilof Islands portion has also been noted, but there has been no good documentation.

Table 3. Results of Surveys of Northern Sea Lion Rookeries - Southwest Region

Area Covered	Dates	Number of Animals Pups	Adults[a]	Total	Source
Gulf of Alaska: Barren Is. to Unimak Pass	6-7/79	28,399[b]	30,790[b]	59,189[b]	Calkins and Pitcher (1982)
Eastern Aleutians: Unimak Island to Samalga Pass	6-7/77	2,023[c,d]	14,940[c]	16,963	Fiscus et al. (1981) and Braham et al. (1980)
Central Aleutians: Samalga Pass to Kiska Island	6-7/79	4,324	18,625	22,949	Fiscus et al. (1981)
Near Islands	6-7/79	1,910	13,053	14,963	Early et al. (1980) as reported in Fiscus et al. (1981)
Pribilof Islands: Walrus Island	8/81	292	880	1,172	Frost et al. (1982)[e]
Southwest Region total		36,948[d]	78,288	115,236	

Sources: Braham et al. 1980, Calkins and Pitcher 1982, Fiscus et al. 1981, Frost et al. 1982.

a Includes all animals older than pups.

b Numbers derived from table 23 (Calkins and Pitcher 1982) for only those rookeries in the Southwest Region; numbers represent direct visual counts.

c Includes data from Braham et al. (1980) and Fiscus et al. (1976) as reported in table 55 in Fiscus et al. (1981); pup numbers are minimum estimates based on air-photo analysis.

d Does not include pup counts from Cape Morgan and Sea Lion Rock, both of which are major rookeries. See Fiscus et al. (1981) for details.

e Mostly reports between 1977 and 1982 for summer haulouts; no major rookeries have been recently identified north of Sea Lion Rocks, except Walrus Island.

A. Qualification on Data

Details about the limitations and assumptions for each survey can be found in sources listed in table 3. Several limitations on the data collected are common to all surveys; these include the following:

1. Although more of the sea lion population is concentrated on rookeries than at any other time during the year, up to 40% of the population has been estimated to be at sea at any given time (MMS 1982) and thus not present during the surveys. Thus the survey estimates can deviate from the true population number by up to 40%, although the actual percentage will likely not be known. For example, Calkins and Pitcher (1982), using demographic information applied to rookery counts, estimated that the number of sea lions older than pups in the Gulf of Alaska was almost three times the number counted in the rookeries; this fact suggests that far more than 40% of the population is not associated with the rookery at that time of year.
2. Weather conditions at the time of the survey can not only preclude surveys of portions of the area but also affect sightability, especially of pups. Pups could not be counted in 1977 at Cape Morgan and Sea Lion Rock, for example, because of poor visibility (Fiscus et al. 1981). Although aerial photography has largely replaced visual surveys, it is subject to many of the same problems of sightability as are visual surveys. Additionally, because of their smaller size, pups are usually undercounted on air photos. The estimates given by Braham et al. (1980) and Fiscus et al. (1981) are based on air-photo analyses.
3. Counts made in different years are not necessarily directly comparable. The present abundance estimate is derived from surveys conducted in different areas of the region between 1975 and 1981, primarily between 1977 and 1979. Although Calkins and Pitcher (1982) have presented evidence that adults, especially females, tend to return to the rookery of their birth, they also have demonstrated that there is considerable movement, by adults and especially by subadults, during the nonbreeding age classes (other than pups) in sequential years.

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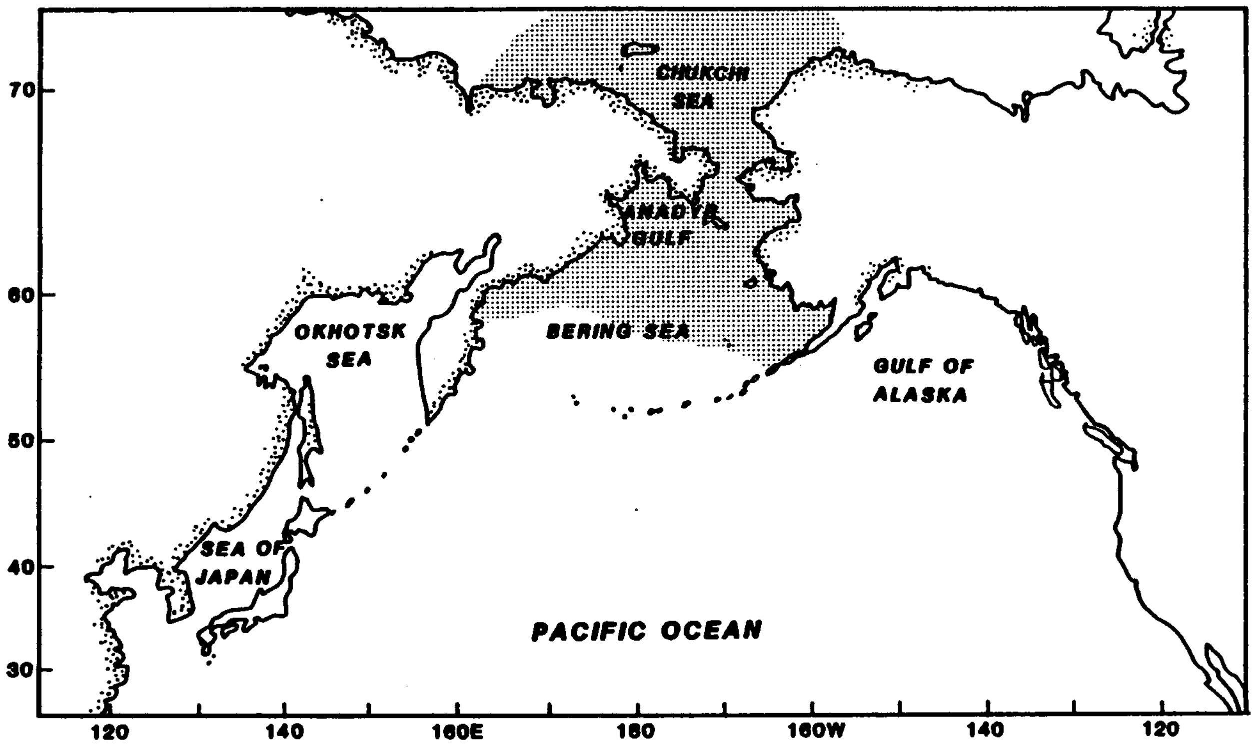
Pacific Walrus Life History



Map 6. Range of Pacific walrus (Fay 1982)

I. NAME
   A. Common Names: Pacific walrus, aivik (Inupiat), asveq (Yupik)
   B. Scientific Name: Odobenus rosmarus divergens

II. RANGE
   A. Statewide
      Walrus range from the eastern and northeastern portions of the Bering Sea north to an area of the Chukchi Sea bounded by 155°W and 165°E longitude (Fay 1982).
   B. Regional
      They occur in Bristol Bay, the north side of the Aleutians, and the east side of the Pribilof Islands.

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

1. Water quality. No published information is available.
2. Water depth. Although walrus have been observed in water as deep as 100 m, feeding is generally restricted to depths between the littoral zone and 80 m; this restriction may be due to physiological limitations but is more likely attributable to the fact that feeding at depths greater than 80 m is inefficient (ibid.).
3. Substrate. Although the fact is not applicable directly to walrus, benthic invertebrates, upon which walrus feed, require marine sediments up to 30 cm deep (ibid.) composed of sand and silt (McDonald et al. 1981).

B. Terrestrial

Terrestrial habitat is used only for haulout areas, predominantly by bulls in Bristol Bay and the Bering Straits (Frost et al. 1982) during late spring, summer, and early fall; and by bulls, cows, calves, and subadults during the southward fall migration in the northern Bering Sea (Fay 1982, Taggert and Zabel 1982).

1. Physical characteristics of terrestrial haulout areas. Characteristics common to all haulouts include the absence of extensive exposed tidal flats (Fay 1982) and proximity to normal distributional and migrational patterns (Lowry 1982). Physical characteristics of haulouts include shoreline areas with one or a combination of the following (ibid.):
   - ° Rocky islands with steep cliffs and boulder beaches (e.g., Round Island)
   - ° Low-lying sand and gravel spits extending from islands on the mainland
   - ° Tundra-covered islands with gently sloping gravel beaches
   - ° Mainland coast with sand/gravel beaches backed by steep bluffs
2. The influence of weather on use of terrestrial haulouts. Walrus abandon terrestrial haulouts during periods of severe storms accompanied by heavy surf (Fay 1982).
3. Functions of terrestrial haulouts:
   a. Escape from predators. Terrestrial haulouts provide escape from pelagic predators such as killer whales (*Orcinus orca*); however, while on terrestrial haulouts walrus are more likely to encounter harassment from terrestrial predators, especially man, than when hauled out on ice (ibid.).
   b. Protection from the elements. Terrestrial haulouts allow opportunity for the thermal advantage of solar insolation, and offer relief from cold water and warmer air temperatures; the thermal advantage is especially important for cows and calves migrating southward ahead of the advancing pack ice, when direct contact between cow and calf can aid the calf in maintaining thermal stability (ibid.).

c. Use as resting platform. Terrestrial haulouts provide a secure surface out of water for grooming, resting, nursing, and social functions (Fay 1981, 1982).

C. Ice

As used for haulout areas, ice not only provides a barrier between water and air but also affords an environment distinct from the aquatic and terrestrial that walrus can exploit.

1. Functions of ice as haulout:
   a. Escape from predators and harassment. The shifting nature of pack ice, as well as its location remote from most human activity, provides a better refuge from man than terrestrial areas (Fay 1982); polar bears (*Ursus maritimus*) are the only major predators common in pack ice (Kelly n.d.).
   b. Protection from natural elements. The dynamic nature of ice creates ridges that provide shelter from wind and sun; ice also moderates the severity of the ocean surface in the immediate proximity (Burns et al. 1981).
   c. Use as resting platform. Grooming, resting, and parturition occur on ice; floating ice serves as a "mobile lek" for courtship display and breeding activities; and moving pack ices serve as continuous transport to new feeding grounds (Fay 1982).
2. Physical characteristics of optimal ice habitat. Floes are needed of sufficient area and thickness (10 to over 100 m in diameter) to accomodate perhaps hundreds of animals; these are usually thick, pressure-ridged floes.

   The presence of sufficient open water or water with ice less than 20 cm thick between floes is required to allow the animals to surface for air; no more than 80% of the sea's surface should be covered by thick ice (ibid.).
3. Seasonal use. Winter ice habitat is old, heavy ice located north of the ice front and in a loose pack; much of this ice probably originated in the Chukchi Sea. Densely consolidated ice farther north provides a barrier to winter walrus distribution (Burns et al. 1977).

   Summer ice habitat is associated with the southern edge of the permanent polar ice pack, characterized by multiyear floes and more open water and generally occurring in the northern Chukchi Sea (ibid.).

IV. NUTRITIONAL REQUIREMENTS

A. Preferred Foods

1. Primary. Bivalve mollusks of the genera *Mya*, *Serripes*, *Spisula*, *Hiatella*, *Astarte*, *Macoma*, *Tellina*, and *Clinocardium* strongly dominate; however, sea cucumber (*Thyonidium commune*) and sea squirt (*Tethyuum aurantium*) may be locally important in the Bering Straits (Fay 1982, Kelly n.d., Lowry et al. 1982).

2. Secondary:
   a. Benthic invertebrates. These are *Nepthys* (Annelida), *Echiurus echiurus* (nonsegmented worm), *Pelonaia* (sea squirt), and lithodid and brachyurid crabs (in the soft-shell stage of molt).
   b. Vertebrates. Walrus occasionally eat seals or fish (Fay and Stoker 1982, Nelson 1981); incidence of predation on fish (sand lance) (Fay and Stoker 1982) and seals (Lowry, pers. comm.) has increased since 1981.
3. Change in prey selection. In the Bering Straits region, prior to the early 1980's, male walrus fed primarily on the larger age classes of the large bivalve genera *Mya* and *Serripes*, and females fed on the smaller genera (e.g., *Tellina*, *Astarte*, *Hiatella*). In the early 1980's (possibly late 1970's), males began feeding on slightly smaller age classes of *Mya* and *Serripes*, and females apparently shifted from the smaller genera to the same age classes of *Mya* and *Serripes* upon which males were feeding. This change in food habits was presumed to be the result of a decrease in availability of the older age classes, probably caused by the increase in the number of walrus feeding on them (Fay and Stoker 1982).

B. Feeding Locations

Most of the Pacific walrus stock use a floating, moving ice platform for most of the year and feed primarily on immobile bivalve mollusks, which are widely distributed in the Bering and Chukchi seas and which are available to the walrus as long as the ice remains in water shallower than the 80 m isobath. Therefore, seasonal differences in feeding locations are due more to abiotic influences (e.g., ocean currents, surface winds) on ice movements than on active selection of feeding areas by the walrus (Fay 1982).

C. Factors Limiting Availability of Food

1. During the southward fall migration, ice is usually too thin to be used for support; animals generally swim ahead of the ice, thus decreasing the amount of time they can feed (ibid.).
2. Because environmental conditions (e.g., salinity, bottom temperature, dissolved oxygen) for the production of benthic invertebrates are relatively stable throughout the Bering Sea, localized differences in diversity and abundance are more related to the density of bottom-feeding fish, commercial fishing activity, and localized differences in sediment type (Stoker 1981).
3. Because sessile bivalve mollusks are susceptible to excessive sedimentation and to pollution (Kelly n.d., Stoker 1981), activities that cause pollution or that alter sedimentation patterns will adversely affect the biomass of the food supply.
4. Use of terrestrial haulout areas limits foraging activities to reasonably accessible distances. Haulout areas presumably are established in the vicinity of appropriate food resources (Lowry, pers. comm.)

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Breeding occurs at the edge of the moving pack ice in late winter (Fay 1982).

B. Reproductive Seasonality (Kelly n.d., Fay 1982)

1. Breeding occurs from December to March. Males are fertile from December to March. Females are in estrus from December to August.
2. There is a delayed implantation of three to four months following conception.
3. Calving occurs from mid April to mid June on the stable ice pack as it moves north in the central Bering Sea/Bering Straits area.

C. Reproductive Behavior

1. Prior to the northward migration in the Bering Sea, estrous females remain at the fringe of the group in the ice front; the dominant males display in water; the female selects the male and dives into the water, where copulation occurs (Fay 1982).
2. Most males return to summer areas in the southeastern portion of the Bering Sea, including northern Bristol Bay and the northern side of the Alaska Peninsula (Fay 1982, Taggert and Zabel 1982).
3. The prepartum female selects a clean floe isolated from the group; parturition occurs on the ice; after a few days, the female and neonate rejoin the "nursery herd" of females and young (Fay 1982).
4. The female forms a strong social bond to her young, actively defending it and leaving it only to feed; occasionally, orphaned calves have been "rescued" by other females (ibid.).

D. Age at Sexual Maturity

1. Males are fertile at 5 to 7 years but are not behaviorally capable until physical maturity at 15 years (Fay 1982).
2. Females are fertile at 5 to 6 years and reach their peak of reproductive performance at 9 to 10 years, declining thereafter (ibid.).

E. Fecundity

1. Because of the 16-month gestation period, only a portion of the female population is in estrus each year. Prior to the 1970's, intrauterine survival was 95%, and birth rates were 32 to 41%/year.
   From 1978-1981, because of increased stillbirths and abortions, birth rates have dropped to 23 to 25%.

F. Frequency of Breeding

1. Prior to the 1970's, females at the peak of their reproductive performance bred in alternate years; older females bred every third or fourth year (Kelly n.d.).
2. During the late 1970's, major disruption of the population's reproductive system caused widespread abortion and subsequent synchronous breeding, resulting in "pulses" of high calf production every two to three years, rather than at a uniform rate (Fay and Stoker 1982).

G. Gestation Period
Including the 4 months of delayed implantation, the gestation period is 16 months.

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

A. Home Range
The concept of "home range" is not applicable to walrus because most of their life history is tied to utilization of ice, the movement of which depends on the seasons, weather conditions, and surface currents (Burns et al. 1981).

B. Timing of Movements and Use of Areas

1. During spring/summer (April to September), the ice retreats from the southern Bering Sea to its most northerly extent in the northern Chukchi Sea (Fay 1982, Burns et al. 1981).
   a. Males. The majority of males after the end of the breeding season in March remain predominantly in the Bering Sea in association with terrestrial haulouts (Fay 1982).
   b. Females. Females and juveniles remain with the southern edge of the stable pack ice as it retreats northward. Parturition occurs in May and June, usually in the central Bering Sea and the Bering Straits. During this period, high winds and storms are infrequent and solar insolation is at its peak, constituting the optimum period for neonatal walrus (ibid.). The Bering Straits area also contains a very high standing stock of benthic invertebrates (Stoker 1981).
2. Fall (October to December) is characterized by the advance of fragmented pack ice southward and the increased consolidation of floes to form a more stable pack (Burns et al. 1981).
   a. Males. Males abandon terrestrial hauling grounds in the northern Bering Sea, although the Walrus Islands are still used. Groups of males move to the advancing ice, primarily in the St. Lawrence Island area (Fay 1982).
   b. Females. Females and young swim south ahead of the advancing ice; during this period more than at any other time, females and subadults use terrestrial haulouts in the St. Lawrence Island/Bering Straits area (ibid.).
3. Winter (January to March) is characterized by the maximum advance and stabilization of the pack ice. Most of the population is concentrated south of the Bering Straits, usually in two areas: south of St. Lawrence Island and between Bristol Bay and Nunivak Island. Courtship and copulation occur during this period (Fay 1982, Kelly n.d.).

VII. FACTORS INFLUENCING POPULATIONS

A. Natural Mortality
This is probably 8 to 13% per year (Fay 1982).

1. Predation. Predation by killer whales and polar bears is relatively insignificant, occurring predominantly on calves and juveniles.

2. Accidents. Mortal accidents to which walrus are liable include rockslides (e.g., on Round Island), spring storms that result in calf hypothermia and drowning, entrapment by heavy ice and subsequent starvation, and physical exhaustion during the fall migration (ibid.).
3. Intraspecific mortal occurences. Tusk strike traumatization is common in adult males, uncommon in females and subadults (ibid.).
   Evidence of trampling of all age classes due to disturbances on haulout areas is common (ibid.); mass trampling in the Punuk Islands has been reported several times (Fay 1982, Kelly n.d.).

B. Limits of Food Supply
Sessile benthic invertebrates are susceptible to pollution, siltation, etc. (Kelly n.d.).
Recent evidence indicates that present population levels of walrus may be adversely affecting standing stocks of bivalve mollusks in some areas (Fay and Stoker 1982).

C. Human-related
A summary of possible impacts from human-related activities includes the following:
- Pollution of water and/or food supply
- Disturbance of walrus on haulouts
- Reduction of food supply
- Destruction of haulout sites

VIII. LEGAL STATUS

Prior to the Marine Mammal Protection Act (1972), walrus were managed as big game by the ADF&G; they are currently managed by the U.S. Department of the Interior.

IX. LIMITATIONS OF INFORMATION

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

B. Long-term effects of the high walrus population on the diversity and abundance of bivalve mollusks are unknown (Fay and Stoker 1982).

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

X. DISTRIBUTION

A. General Distribution

The Pacific walrus is restricted primarily to the Bering, Chukchi, East Siberian, and western Beaufort seas. In the Laptev Sea there exists an isolated population of walrus attributed to either the Pacific (O. r. divergens) or Atlantic (O. r. rosmarus) subspecies by various authors (Lowry 1982, Kelly n.d.). However, Fay (1982) argues that the Laptev Sea population should not be considered part of the North Pacific population.

During winter, the entire North Pacific population is concentrated in two areas of the Bering Sea (Braham et al. 1982). One concentration area is southwest of St. Lawrence Island, and the other is in northern Bristol Bay and outer Kuskokwim Bay. As spring approaches and the pack ice begins to recede, the population becomes divided into two summering groups: a group consisting almost exclusively of males that moves to the Bristol Bay area and northern Alaska Peninsula and a group consisting of mostly females and subadults, with few adult males, that moves north with the receding pack ice and summers along the southern ice fringe (occasionally as far north as 75°N).

In fall, the northern summering group swims southward, usually ahead of the advancing pack ice, and uses terrestrial haulouts in the Bering Straits region. In late fall/early winter, the northern and southern summering groups mix in the Bering Sea pack ice and become concentrated in the two areas mentioned earlier.

B. Factors Affecting Movements

As mentioned in the preceding section, depending on the annual variation in the seasonal extent of the pack ice in the Bering Sea, one of the winter concentrations of walrus is located between outer Bristol Bay and the Pribilof Islands and in general is located north of 56°N (Kelly n.d.). Although in spring the majority of the population moves north and out of the Southwest Region, many mature bulls move to Bristol Bay, where they utilize terrestrial haulouts, especially at Amak Island, Cape Seniavin, Port Moller, Cape Newenham, and the Walrus Islands. Round Island, of the Walrus Islands, is the center of abundance for the Bristol Bay summering group (Lowry, pers. comm.) and is used throughout the summer by 12,000 to 15,000 bulls (Frost et al. 1982). Cape Seniavin and other haulouts in the region appear to be "satellites" of Round Island (Lowry and Frost, pers. comm.), and there is considerable interchange among the haulouts. In 1980-81, surveys were flown concurrently at Cape Seniavin and Round Island for the first time. These surveys indicated that walrus abandoned Cape Seniavin earlier than Round Island (Fay and Lowry 1981). In some years, the walrus appeared to depart earlier from the Cape Seniavin haulout because of frequent disturbances by airplanes and harrassment by individuals landing at the haulout (Lowry, pers. comm.). This may be related to the fact that the brown bear season in the Cape Seniavin area was closed that year. However, in 1983 walrus remained at Cape Seniavin well into June, which is later than they had been observed to remain during recent years (Lowry, pers. comm.).

In recent years, some animals have used the area between Cape Peirce and Security Cove (Frost et al. 1982). In November 1981, 2,500 animals were observed hauled out at Cape Peirce; in the summer of 1983, over 10,000 animals were observed just south of Security Cove, suggesting that this area may be increasing in importance as a summer haulout (Burns, pers. comm.).

C. Special Areas

Two areas, Walrus Islands and Cape Seniavin, have been recognized as sufficiently important to walrus to merit formal protection as state game sanctuaries.

In 1960, the legislature created the Walrus Islands State Game Sanctuary. Round, High, Twin, Crooked, and Summit islands, and Black Rock, are included in the sanctuary. In order to protect these major haulout areas, human access is regulated by permit (ADF&G 1983).

In 1982, the Eskimo Walrus Commission of Nome requested that the legislature designate the Cape Seniavin area a sanctuary (ADF&G files). Bills were introduced into the legislature in 1982; however, the Cape Seniavin sanctuary was included in a statewide marine parks and game sanctuaries bill that failed to pass. As of autumn 1983, there has been no further action.

XI. ABUNDANCE

A. General Abundance

Preliminary analysis of the results of a coordinated United States-Soviet survey in 1980 suggests that the population currently numbers 270,000 to 290,000. Prior to commercial exploitation, the population probably numbered 200,000. During the period from 1860 to 1880, commercial exploitation reduced the population to about 50,000. United States government regulation of the harvest allowed the population to increase somewhat. However, intensive Soviet commercial harvests in the 1930's to 1950's caused a second decline (Fay and Stoker 1982). In 1960, the population was estimated to be 70,000 to 100,000 animals.

B. Regional Abundance

In years in which the pack ice extends far into the southeastern Bering Sea, a significant portion of the North Pacific population could winter in the Southwest Region (Fay 1982, Hood and Calder 1981, Braham et al. 1982).

Fay (1982) estimated that in the spring of 1972 there were approximately 50,000 animals in the Bristol/Kuskokwim bay concentration area, of which 34,000 were definitely in the Southwest Region. The proportion in the Southwest Region represented a minimum of 28% of the total 1972 North Pacific population and possibly up to 41% (Fay 1982) if ice conditions caused the entire concentration area to move into the region. If the same proportion of the 1980 population were in the region as were present in 1972, between 76,000 and 111,000 animals may occur in the region when the ice reaches its maximum extent.

In recent years, 12,000 to 15,000 bulls have hauled out on Round Island in the summer (Frost et al. 1982). In the summer of 1983, however, only one-third of that number used Round Island, and up to 10,000 animals were observed in the Security Cove area (Burns, pers. comm.)

C. Qualification on Data

Estimates of the Pacific walrus population are made by a combination of aerial and ground surveys of haulout areas, extrapolations from direct counts at Round Island in the summer, counts from aerial photos of selected areas, and the use of statistical techniques for survey design and interpretation (Lowry, pers. comm.; Fay 1982; Lowry 1983). Sightability factors (e.g., weather, time of day, season) affect the accuracy of aerial surveys and, to a degree, the utility of aerial photos. In addition, at any point in time, a proportion of the animals will be underwater and out of sight; therefore, the accuracy of any survey is also affected by the proportion of uncounted animals (Lowry 1983, Fay 1982). The latter problem is reduced somewhat by the fact that compared with other pinnipeds walrus spend more time out of water (Fay 1982). Increased knowledge about walrus behavior has allowed researchers to optimize survey information by conducting surveys during seasons when group size is largest or when conditions are such that the maximum number are hauled out (Lowry 1983, Fay 1982).

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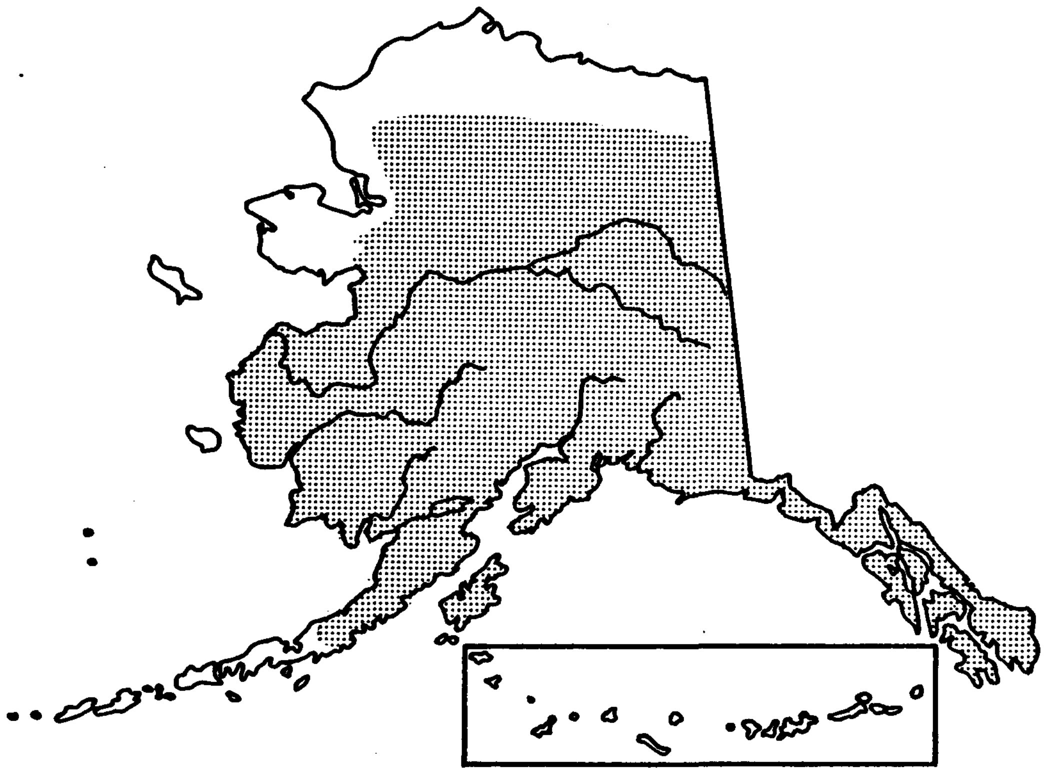
Terrestrial Mammals

Beaver Life History



Map 7. Range of beaver (ADF&G 1978)

I. NAME
   A. Common Name: Beaver
   B. Scientific Name: Castor canadensis

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

III. SELECTION CRITERIA FOR FURBEARER GROUP REPRESENTATIVE

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

IV. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

1. Annual:

a. Water levels. Beavers require seasonably stable water levels (Slough and Sadleir 1977). Gipson (1983) believes that a 3 ft or greater rise in seasonal water levels is detrimental to beaver habitat, whereas Murray (1961) suggested 2 ft or greater. Extreme seasonal fluctuations in water levels can wash away dams, displace lodges or flood them out.

b. Stream sinuosity. A high degree of sinuosity (streambed distance/straight line distance) is preferred because it increases the availability of food within short distances from the water. Sinuosity values greater than 2 are acceptable, but 3 or greater is optimum (Boyce 1974).

c. Stream gradient. Less than 6% is optimal but 6 to 12% is acceptable (Retzer et al. 1956).

d. Flow rates. Flow rates less than 4 mph are preferred; 4 to 7 mph is limiting; and 7 mph or greater is unsuitable for beavers (Gipson 1983).

e. The width factor. Narrow streams and/or lakes with dammable outlets are preferred but not absolutely necessary (Slough and Sadleir 1977).

f. Substrate of stream channel and lake. Beavers prefer a channel bed lined with rocks, gravel, and some large boulders, dikes, or moraines to prevent rapid downcutting of the stream. Lake beds of rock and kettle lakes are preferable (Retzer et al. 1956).

g. Remoteness. Beavers prefer a degree of remoteness from human activities (Slough and Sadleir 1977). However, beavers will occupy suitable aquatic sites in residential areas of Alaska and can be found adjacent to major roads with high traffic levels.

h. Width of valley. Beavers need a valley width greater than the stream channel width, preferably 150 ft or more (Allen 1982, Yeager and Rutherford 1957). Dams constructed across relatively wider valleys can better withstand heavy flood conditions than those in V-shaped valleys, and they are less subject to erosion and soil movement during high-water periods.

2. Summer:

a. Water levels. The minimum depth needed at lodge entrances is 3 ft, to provide protection from predators (ibid.).

b. Food supply. The presence and availability of aquatic vegetation is necessary to beavers for food (Slough and Sadleir 1977).

3. Winter:

a. Water levels. Generally speaking, there must be a minimum depth below the ice of approximately 20-30 inches, to avoid freezeout (Hakala 1952).

B. Terrestrial

1. Spring, summer, fall:

a. Distances to forage. Vegetated land up to 30 m from the water's edge with a supply of food and building materials is preferred (Hall 1960, Jenkins 1980), with areas up to 200 m from water acceptable (Bradt 1938); limited use is made of areas farther than 200 m but less than 0.8 km from water (Murray 1961).

b. Shoreline preference. Shorelines with low banks are most suitable for lodge construction and serve to increase the structure's durability (Slough and Sadleir 1977, Murray 1961).

c. Canopy closure. Forty to sixty percent tree and/or shrub canopy closure is considered optimum (Allen 1982). Extremely dense stands inhibit beavers' mobility and increase the likelihood of their cut trees hanging up in adjacent trees. In areas of the Southwest Region where trees are not prevalent, such as around tundra ponds or streams or above timerline, canopy closure is not an important consideration.

d. Bank suitability. Stable banks along river channels or lakes are necessary for construction of bank burrows (Murray 1961).

e. Shoreline convolution. Heavily convoluted shorelines provide protection from wind, waves, and ice-scouring, increase the amount of food available, reduce the risk of predation, and lessen the amount of energy expended in gathering food (Boyce 1974).

2. Winter. No pertinent published information on winter habitat requirements has been found.

V. NUTRITIONAL REQUIREMENTS

A. Preferred Foods

1. Summer forage includes a) leaves and growing tips of willow (*Salix* spp.), poplar (*Populus balsamifera*), alder (*Alnus* spp.), cottonwood (*Populus* spp.), and birch (*Betula* spp.); and b) aquatic and moist soil plants (Hakala 1952) such as water lily (*Nupha variegatum*) (Aleksiuk 1970), pondweed (*Potamogeton* spp.) (Hakala 1952), duckweed (*Lemna* spp.) (Allen 1982, Banfield 1974), and herbaceous vegetation (Banfield 1974).

2. Winter food includes a) the bark of willow, poplar, and alder (Aleksiuk 1970, Boyce 1974), b) spruce (*Picea* spp.) needles (Hakala 1952), c) water lilies (Taylor, pers. comm.).

B. Feeding Locations

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

C. Factors Limiting Availability of Food

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

° The extent of the total biomass of plant types preferred for their winter's food cache (Boyce 1974)

° Steep topography preventing development of a food transport system on land (Williams 1965, Slough and Sadleir 1977)

° Competition for preferred plants by moose, hares, and porcupine (Boyce 1974)

° Absence of fires, which maintain high quality early seral stage vegetation (Viereck 1973)

VI. REPRODUCTIVE BIOLOGY

A. Reproductive Habitat

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

B. Reproductive Seasonality

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

C. Reproductive Behavior

Beavers are monogamous (Boyce 1974).

D. Age at Sexual Maturity

In exploited populations, beavers reach sexual maturity at three years and in unexploited populations at four years (ibid.).

E. Pregnancy Rate/Litter Size

Females have one litter per year, averaging 2.8 to 3.1 kits in Interior Alaska (Boyce 1974, Hakala 1952). The litter size varies according to the female's age (Gunson 1970), nutritional plane (Pearson 1960), human disturbance (Leege and Williams 1967), and trapper harvest (Boyce 1974). In Boyce's study (1974) in Interior Alaska, approximately 50% of the breeding females were pregnant or had given birth.

F. Gestation Period

Gestation is from 95 to 105 days (Banfield 1974, Hakala 1952).

VII. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

A. Home Range

Beavers range within an 0.8 km radius of their lodges in the Northwest Territories (Aleksiuk 1968). The mean distance between colonies in Interior Alaska was 1.5 km (Boyce 1974).

B. Feeding Range

The average feeding range size in Pennsylvania, excluding water, was 0.56 ha (Brenner 1962); the maximum foraging distance in Alaska was 800 m on upstream forages and 300 m on downstream (Boyce 1974); 90%

of food cutting was done within 30 m of the water (Hall 1960), with distances up to .5 mi reported (Murray 1961).

C. Dispersal

The young leave the parent colonies at one to three years of age (Boyce 1974). Subadult emigration distances have been reported from 8 to 16 stream km (Slough and Sadleir 1977). Hibbard (1958) estimated up to 238 stream km for transplanted beaver populations. Emigration distances depend upon local beaver densities and the availability of suitable habitat, and are generally less than 20 km.

VIII. FACTORS INFLUENCING POPULATIONS

A. Natural

Any or all of the following factors can influence beaver population levels:

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

B. Human-related

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

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

IX. SPECIAL CONSIDERATIONS

A. Primeness

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

B. Overtrapping

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

C. Nonconsumptive Use

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

D. Conflicts

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

X. LEGAL STATUS

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

XI. LIMITATIONS OF INFORMATION

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

XII. Kodiak Island (GMU 8)

A. Distribution

Twenty-four beavers were released on Kodiak Island in 1925 by the Alaska Game Commission; this was Alaska's first recorded beaver transplant (ADF&G 1976a, ADF&G 1976b). Of these 24 beavers, 7 were released at Clark's Lake and 17 in streams entering Kalsin Bay (ADF&G 1973). Another 21 beavers were transplanted in 1929 on Raspberry Island. Since then, beavers have spread over Kodiak Island and Uganik Island, wherever habitat was suitable, and they are also found on Afognak, Shuyak, Long, Spruce, Whale, and Woody islands (ADF&G 1976a).

B. Abundance

Kodiak Island is good beaver habitat (Burris and Ballenger, pers. comm.), and populations are continuing to expand their range. Winters are fairly short and water is open longer on Kodiak than in interior areas (Smith, pers. comm.).

XIII. Alaska Peninsula (GMU 9)

A. Distribution

Beavers are distributed throughout the Alaska Peninsula (ADF&G 1976a). Distribution and abundance is often correlated with habitat availability except in areas where overtrapping has occurred (ADF&G 1978).

B. Abundance

Beavers are abundant and populations are increasing on the Alaska Peninsula southwest of the Kvichak watershed. Trapping, by local residents, is light in most areas, except adjacent to villages in the Kvichak watershed, where the trapping pressure keeps beaver populations low. Trapping in the rest of GMU 9 has little effect on the population (ADF&G 1976a).

XIV. Bristol Bay (GMU 17)

A. Distribution

Beavers are distributed throughout the Bristol Bay region. As a result of overharvest, a general decline in the beaver population near settlements in the Nushagak-Togiak bay watersheds was documented in the 1970's. Under restrictive trapping regulations, most areas have recovered since that time (ADNR/USFWS 1983).

Beaver populations fluctuate naturally in response to the availability of food, the degree of predation, and the mortality caused by other factors such as high-water levels and the freezing of shallow ponds (ibid.). During the period from 1 July 1981 to 30 June 1982, some beaver mortality occurred in GMU 17 when warm weather caused flooding of lodges; and food caches constructed in marginal habitat on shallow ponds may have frozen solid, leading to starvation of the colonies (Taylor 1983).

B. Abundance

Beaver populations are abundant in remote areas where there is lower trapping pressure as a result of changing lifestyles among local residents (ADNR/USFW 1983). On the Alaska Peninsula, populations are high and on the increase, and they are expanding to the southwest as well. Where trapping has occurred, as in the lower Kuskokwim waters, beaver populations are low (ibid.).

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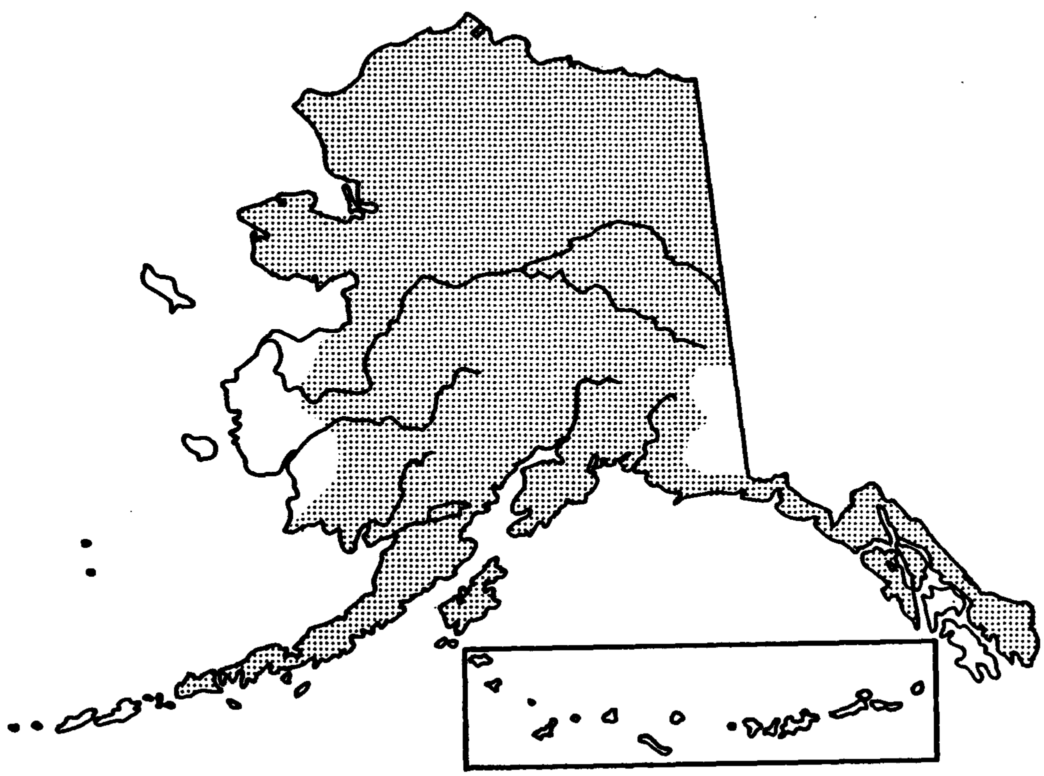
Brown Bear Life History



Map 8. Range of brown bear (ADF&G 1973)

I. NAME

A. Common Names: Brown bear, Kodiak bear, grizzly bear

B. Scientific Name: Ursus arctos

1. Ursus. a. horribilis and U. a. middendorffi are subspecies of Ursus arctos; the latter subspecies occurs only on the Alaska islands of Kodiak, Afognak, and Shuyak (Rausch 1963). All other brown/grizzly bears in North America belong to the first subspecies.

II. RANGE

A. Statewide

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

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

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

B. Terrestrial

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

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

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

   Dens observed by Lentfer et al. were excavated, although these authors stated that denning in natural rock caves had been reported on Kodiak Island and the Alaska Peninsula. Although den re-use may occasionally occur, most bears probably construct new dens each fall because most excavated dens collapse after the spring thaw. Preliminary data from only two years of observations in the Terror Lake study indicate that some bears return to the same general location to den (Smith, pers. comm.).

IV. NUTRITIONAL REQUIREMENTS

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

A. Preferred Foods

1. Spring (mid April to early July). On Kodiak Island, Klinkhart (1976) reported that brown bears "feed primarily on newly emerged plant species such as cow parsnip, red poque, sedges, horsetails, lupine, false hellebore and grasses; they will also be scavenging carion from winter kills of elk, deer, and marine mammals . . ." Moose and/or caribou calves may be important food sources for some bears on the Alaska Peninsula (Glenn 1975).

2. Summer (early July to mid August). On Kodiak Island, Atwell et al. (1980) observed bears in alpine habitat eating sea-coast angelica (*Angelica lucida*), Alaska long-awned sedge and other sedges (*Carex macrochaeta* and *Carex* spp.), common horsetail (*Equisetum arvense*), cow parsnip (*Heracleum lanatum*), nootka lupine (*Lupinus nootkatensis*), and willow. Alaska long-awned sedge was used predominantly. Salmon are used extensively when and where large numbers are available (Glenn 1975, Berns et al. 1980). Red elderberry (*Sambucus racemosa*) and salmonberry (*Rubus spectabilis*) are heavily used on Kodiak. Bears feed heavily on red elderberries well before they ripen.
On Afognak Island, bears feed upon huckleberry (*Vaccinium ovalifolium*) (Smith, pers. comm.). Sellers (pers. comm.) indicated that *Carex lyngbyaei* is an important food source in estuarine areas on the Alaska Peninsula and that bears also use the berries of devil's club (*Oplopanax horridum*) and seeds of cow parsnip.

3. Fall (mid August to mid December). Crowberries (*Empetrum nigrum*), blueberries (*Vaccinium uliginosum*), soapberries (*Shepherdia canadensis*), and lowbush cranberries (*Vaccinium vitis-idaea*) are readily eaten when available (Murie 1944, Erickson 1965, Somerville 1965, Crook 1971, Pearson 1975, Reynolds 1976). Bears will shift back to *Hedysarum* roots if berries are not abundant (Murie 1944, Dean 1957, Crook 1971, Valkenburg 1976, Reynolds 1976). Lupine roots and broomrape roots are also preferred as foods by Kodiak bears. Also, deer and elk gut piles are becoming increasingly important fall foods on both Kodiak and Afognak islands (Smith, pers. comm.). Salmon remain important along coastal areas (Somerville 1965, Erickson 1965, Berns and Hensel 1972). Bears have been observed salmon fishing during December on the Alaska Peninsula (Glenn 1975).

B. Feeding Locations

1. Spring. On the Alaska Peninsula, there was high use of the coastal plain along the beaches where bears searched for dead marine mammals. Grassland areas, especially grass flats, sedge meadows, and saltwater wetlands are also used extensively (ibid.).

2. Summer. Anadromous fish streams along coastal areas (Somerville 1965, Erickson 1965, Berns and Hensel 1972, Glenn 1975, Smith and Van Daele 1982) and lowland areas (Berns et al. 1980) are frequently used. Atwell et al. (1980) reported that bears in the Kodiak NWR made extensive use of alpine habitat during summer. Sedge-forb meadows are used extensively on the Kodiak NWR (Atwell et al. 1980).
3. Fall. On the Alaska Peninsula and Kodiak Island, salmon-feeding areas continue to be used extensively. Use of foothills increases by early October. By mid October, the coastal plain is increasingly used, although less than during spring (Berns and Hensel 1972, Glenn 1975).

C. Factors Limiting Availability of Food
1. During spring, snow cover can limit food availability.
2. The size of the salmon escapement can be influenced both by natural factors and human management.
3. Weather conditions that cause poor berry production can reduce the availability of this important food source during late summer and fall.
4. As winter approaches, snow and progressively cooler weather limit food availability.

D. Activity Patterns
1. At McNeil River Falls, Egbert and Stokes (1976) observed brown bears fishing and found the level of activity lowest during early and mid morning hours and peaking by mid afternoon. Activity dropped sharply by late evening and remained low until mid morning. During their evaluation of brown bear aerial survey results in the Chignik-Black lakes drainages, Erickson and Siniff (1963) found that peak activity on salmon streams occured in early morning and evening.

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat
Breeding does not appear to be habitat-specific. Den characteristics are described in section III. B.1., this report.

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

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

D. Age at Sexual Maturity
The age when successful conception occurs varies from coastal to interior areas. On the Alaska Peninsula and Kodiak Island, it was observed to be between 3.5 and 6.5 years (Hensel et al. 1969, Glenn et al. 1976). In the Nelchina Basin, most brown bears appear to become reproductively mature at 4.5 years. Some females become mature at 3.5 years and others at 5.5 years (Ballard et al. 1982). In the eastern Brooks Range, maturity was attained between 6.5 and 12.5 years. The maximum observed age of reproductive females was

found to be at least 19.5 years on the Alaska Peninsula (Glenn, pers. comm.), 25.5 years in the western Brooks Range (Reynolds 1980), 22.5 years in the eastern Brooks Range (Reynolds 1976), and 21.5 years in the Northern Yukon (Pearson 1976).

E. Fecundity

Litter size ranges from about 1.8 to 2.5 for cubs of the year and yearlings (Sellers, pers. comm.). Litters of five are known (Glenn, pers. comm.). Average litter size varies from one geographic area to another. Coastal Alaska litter size ranged from 2.36 to 2.50 (Troyer and Hensel 1964, Glenn et al. 1976).

F. Frequency of Breeding

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

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

A. Home Range

Home range size varies by age, sex, reproductive status, and the distribution and abundance of food. Smith and Van Daele (1982) reported home range sizes in the Terror Lake study area on Kodiak Island to average 29.9 km² (range = 6 to 132 km²) for females and 141.2 km² (range = 14 to 465 km²) for males. The average home range size reported varied from 12 km² for females to 24 km² for males on Kodiak Island (Berns et al. 1980), from 293 km² to 262 km² on the Alaska Peninsula (Glenn and Miller 1980), from 344 km² to 1,350 km² in northwestern Alaska (Reynolds 1980), and from 408 km² to 769 km² in the Nelchina Basin (Ballard et al. 1982). Individual bear home ranges deviate greatly from the average (e.g., male home range sizes in the Nelchina Basin extended from 281 km² to 1,381 km²). It should also be noted that home ranges may enclose several favored activity areas. Some bears seem to use relatively small home ranges fairly uniformly, while other bears seem to prefer widely separated activity areas with large areas between used only as travel corridors (Smith, pers. comm.).

B. Migration Routes

Within home ranges there are frequently well-defined seasonal ranges. Migration corridors between seasonal ranges have been identified for individual bears (Reynolds et al. 1976), but these corridors are generally not associated with populations. Brown bears, however, are well known for their continued use of distinct trails.

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

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

B. Human-related

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

- Pollution of water and/or food supply
- Reduction in food supply
- Disturbance during denning/abandonment of young
- Illegal hunting/killed in defense of life and property

VIII. LEGAL STATUS

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

IX. LIMITATIONS OF INFORMATION

Accurate information on the relative abundance of brown bears is difficult to obtain. The importance of some food sources, such as berries, in the Southwest Region is not well understood.

X. SPECIAL CONSIDERATIONS

A. Homing

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

B. Nuisance Bears

Brown bears often become "nuisance" bears in the vicinity of villages, remote cabins/lodges, and work camps in the Southwest Region. Factors such as improper garbage disposal and poor siting of camps often encourage the problem. These animals can cause extensive damage and may be dangerous to humans. These problems can often be avoided if proper procedures are followed.

C. Importance of Species

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

XI. DISTRIBUTION

Brown bears are distributed throughout the Southwest Region except for the Aleutian Islands west of Unimak Island and the islands of the Bering Sea. Brown bears may emerge from dens as early as mid March, depending on weather conditions. During spring (mid April-late July), bears found along the coastal areas tend to concentrate on grassland areas, especially grass flats, sedge meadows, and saltwater bogs (Glenn 1975; Smith, pers. comm.). Feeding on salmon begins when the first run of salmon appears, which may begin in early-to-mid May. The most intensive use of salmon occurs during July and August. Use by a few bears may continue into December.

During the fall (September through early November), bears continue to feed on salmon when and where available but use of berries increases substantially during years of good berry production. Denning appears to begin in late October and early November, with most bears denned by mid December. Some bears, however, may remain active all year long (Smith, pers. comm.).

XII. ABUNDANCE

Brown bear populations appear to be high relative to carrying capacity throughout most of the Southwest Region. Kodiak and Afognak islands and the Alaska Peninsula support the highest densities of brown bear in the world. Because of the bear's nature and widespread distribution, abundance estimates are difficult to make with any degree of certainty. Current estimates range from 2,000 to 3,000 brown bears in Game Management Unit (GMU) 8 (Kodiak and Afognak islands) and between 5,000 to 10,000 bears in GMUs 9, 10, and 17 (the Alaska Peninsula, Unimak Island, and the Mulchatna/Togiak area). Until an adequate census technique is developed and used in these areas, broad estimates such as those given above will continue to be used.

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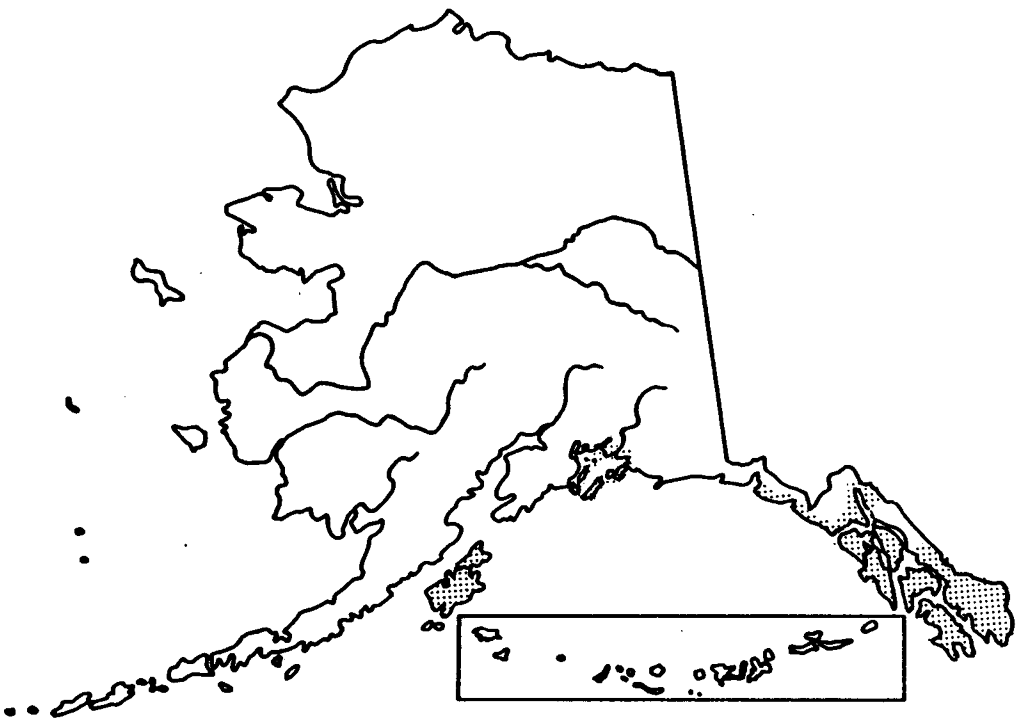
Black-tailed Deer Life History



Map 9. Range of black-tailed deer (ADF&G 1973)

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

II. RANGE
   A. Statewide
      Sitka black-tailed deer are generally 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, and the Yakutat area.
   B. Regional
      Deer have been reported throughout the Kodiak archipelago, with low density deer populations becoming established in the previously unoccupied southwest portion of Kodiak Island.

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

1. Water quality. No pertinent information has been found in the literature.
2. Water quantity. Dietary water is obtained from snow in winter, dew-laden succulent vegetation in rainy periods, and occasional drinking from waterbodies in dry periods (Cowan 1956).

B. Terrestrial

1. Conditions providing security from predators or other disturbances. Smith (1979) described how deer often avoid pursuit by swimming.
2. Conditions providing protection from natural elements. Cottonwood, birch, scattered spruce patches, and dense alder thickets along steep draws are used for cover by deer (Smith 1979). Low elevation coastal spruce stands are used to some extent throughout the year. Deer use the coastal fringe in varying amounts every winter, although these areas become very critical in winters of deep snow. Afognak, Shuyak, Raspberry, and several adjacent islands, including Northeast Kodiak, have extensive coastal spruce forest.

IV. NUTRITIONAL REQUIREMENTS

A. Preferred Foods

1. Winter/early spring (October - April): Forage at this time includes fireweed (*Epilobium angustifolium*), elderberry (*Sambucus racemosa*), fern (*Athyrium felix-femina*) (Smith 1979); willow (*Salix* spp.) (Merriam 1968); Nootka rose (*Rosa nutkana*), highbush cranberry (*Viburnum edule*), cow parsnip (*Heracleum lanatum*) (ADF&G 1973); bearberry (*Arctostaphylos* spp.) (Smith 1979, Alexander 1968); blueberry (*Vaccinium ovalifolium*) (Erikson 1958); hairgrass (*Deschampsia* spp.), salmonberry (*Rubus spectabilis*) (ibid.); reedgrass (*Calamagrostis* spp.), kelp, ground dogwood (*Cornus canadensis*) (ADF&G 1973); and crowberry (*Empetrum nigrum*) (Alexander 1968).
2. Summer (May - September): Forage at this time includes fireweed (*Epilobium angustifolium* L.), hellebore (*Veratrum viride*) (Merriam 1965); elderberry, salmonberry, cow parsnips, reedgrass, hairgrass (ibid.); Nootka rose (Merriam 1966); highbush cranberry, bearberry, crowberry, blueberry (ADF&G 1976).

B. Feeding Locations

1. Summer. Feeding activities occur in willow and alder thickets, grass-brush vegetation type, and alpine areas (greater than 1,000 ft) (Smith 1979).
2. Winter.
   a. Feeding activities occur in grass-brush thickets composed of cottonwood, alder, and willow; spruce forests; windblown capes and bluffs with scattered heath patches; steep, windblown, and southerly exposed hillsides; beach timber fringes during severe winters; and intertidal areas (ibid.).

C. Factors Limiting Availability of Food

1. Winter.
   a. Excessive snowfall can prevent deer from reaching critical food resources.
   b. Low coastal winter ranges may be depleted because of high population densities resulting from a stretch of several years of mild winter weather (ibid.).
   c. An intensive logging program resulting in extensive clearcuts could reduce food accessibility because of resultant higher snow depths in the clearcuts (ibid.).
   d. Competition with cattle and elk can lead to winter range deterioration (Erickson 1958).
2. Summer.
   a. Since rates of phenological development of plant species vary, the degree of physiographic variation (elevation, slope, aspect) can affect the availability, quality, and species diversity of the deer's food plants.
   b. Dense logging slashes and/or coniferous regrowth in clearcuts impede deer movements and access to preferred food plants.

D. Feeding Behavior

1. Deer move up or down elevations according to changing snow conditions and depths. They will paw through 12 to 18 inches of snow to feed on ferns (Smith 1979).
2. During late spring, deer tend to follow the snowline into alpine and subalpine zones, feeding on emergent forbs, flowers, and greens (ADF&G 1976).

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Because deer 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, pers. comm.). The ADF&G (1976) states that fawns are usually born in fringes of trees adjacent to lowland muskegs or beaches.

B. Reproductive Seasonality

The breeding season begins at mid October and peaks in mid November, with fawns born 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 estrous cycle of female deer is 24 to 28 days and may be repeated several times if conception does not occur. 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 yr (their seasonal fall). The quantity and quality of available forage can affect the age at which they first breed.

E. Litter Size/Pregnancy Rate

Data describing litter size are not available for Kodiak, but a mean of 1.8 fawns per doe was determined for Southeast Alaska (Schoen et al. 1982). Forty-five percent of the yearling does and 92% of the adult does between two and six years old in Western Washington were pregnant (Brown 1961). Yearlings produced single fawns, but 49% of two-to-six year-olds and 60% of those seven and older had twins.

F. Gestation Period

The average gestation period is 203 days, with a range of 183 to 212 days (Cowan 1956).

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

A. Home Range

No pertinent data are available for the Kodiak archipelago; however, deer in Southeast Alaska had the following seasonal average home range sizes: fall, 1,248 acres; winter, 301 acres; spring, 3,758 acres; and summer, 576 acres (Schoen et al. 1981).

B. Timing of Movements and Use of Areas

Most deer generally move into alpine areas in late June, depending on snow-melt patterns and plant phenology (Smith 1979), although during the summer deer can be found at all elevations. Deer will remain in the alpine-subalpine ranges until mid September, when freezing weather dessicates herbaceous plants and occasional snowfall begins at the higher elevations. Generally, deer will winter just below the snowline, moving up or down with changing snow depths. During severe winters, deer are forced to congregate on the beaches.

C. Migration Routes

No pertinent information is available.

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

The following naturally occurring circumstances can affect the population levels of deer:

- Predation by dogs and occasionally brown bears
- Accidents
- The quality and quantity of forage
- Overwinter starvation
- Competition for available winter range with elk and goats
- Severe winter weather (temperature, frequency of severe winters, snowfall, and the duration of winter season)

B. Human-related

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

- Pollution of water and/or food supply
- Reduction of food supply
- Alteration of habitat
- Disturbance/displacement
- Barriers to seasonal movements
- Overharvest

VIII. LEGAL STATUS

Sitka black-tailed deer are managed by the Alaska Department of Fish and Game.

IX. LIMITATION OF INFORMATION

Since deer populations have been numerous and are still expanding, the need to gather basic biological data has been difficult to justify. Quantitative data describing deer distribution and abundance, habitat use and requirements, food habits, and reproductive activities are lacking or minimal. Some wintering areas are well known, but in areas where deer have invaded recently, such as Southwest Kodiak, there is little documentation of winter use areas.

X. DISTRIBUTION

In the Southwest Region, Sitka black-tailed deer are distributed only on Kodiak and Afognak islands and on several small nearby islands as the result of transplants in 1924, 1930, and 1934. In 1924, 14 deer were released on Long Island, about 4 mi east of the town of Kodiak (Burris and McKnight 1973). Two more deer were placed there in 1930. A small population became established there; apparently it was intended that deer moving from Long Island would eventually stock Kodiak Island (Smith 1979). In 1931, an Alaska Game Commission report mentioned that three does and two bucks were seen on Kodiak. An additional transplant of nine deer was completed in 1934 (ibid.).

During the 1940's, deer rapidly occupied the northeastern corner of Kodiak Island as the population expanded (ibid.). Since then, deer distribution has expanded, and they occupy suitable habitat throughout most of the Kodiak/Afognak islands area. In late June, deer generally move into alpine ranges, although they are found at all elevations during the summer. The alpine-subalpine range is heavily used until mid September, when freezing weather and occasional snowfall begin at higher elevations (ibid.).

Windblown capes and bluffs at the mouth of bays and along ocean entrances are favored for wintering areas throughout the Kodiak archipelgo (ibid.).

XI. ABUNDANCE

Since the original transplants, the deer population in the Kodiak/Afognak islands has generally continued to increase, although during the 1969 and 1970 winters severe cold and heavy snows caused heavy mortality from starvation (ibid.).

Population estimates for deer are difficult to obtain. Smith (pers. comm.) roughly estimated the 1983 population to be about 60,000 animals.

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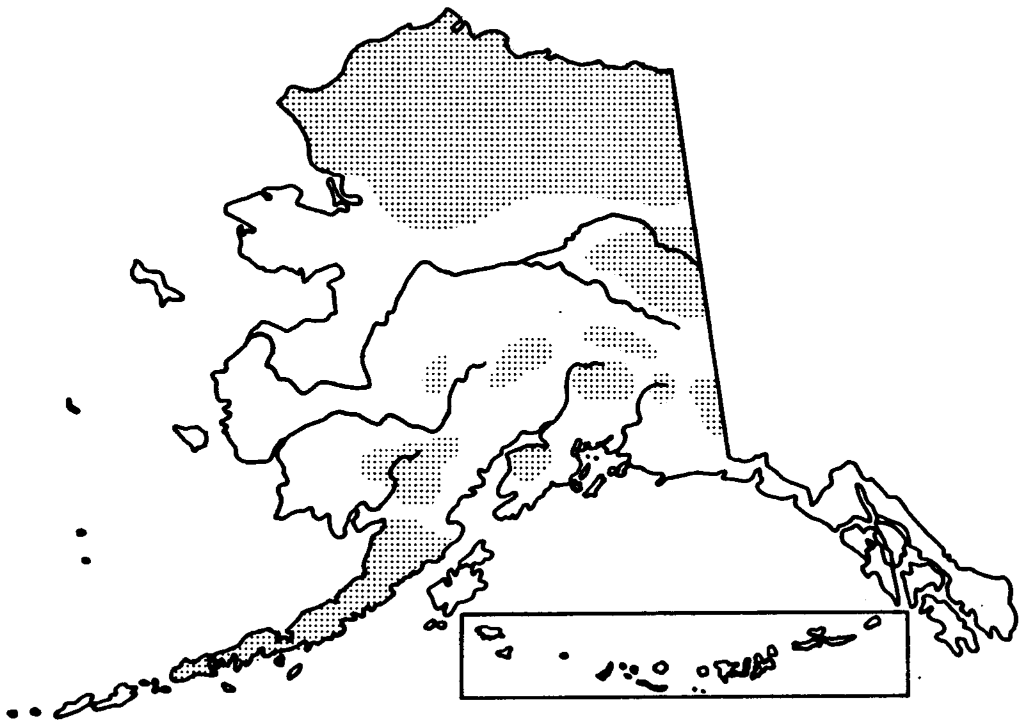
Caribou Life History



Map 10. Range of caribou (ADF&G 1973)

I. NAME
   A. Common Names: Caribou, reindeer, deer
   B. Scientific Name: Rangifer tarandus (Skoog 1968)

II. RANGE
   A. Statewide
      Caribou are distributed throughout Alaska except on the southeastern panhandle and most offshore islands (Hemming 1971).
   B. Regional
      Four distinct herds exist in Southwest Alaska: the Northern Alaska Peninsula (NAP), South Alaska Peninsula (SAP), Mulchatna, and Adak herds. The NAP herd ranges from the Naknek River south to Port Moller. The SAP herd ranges generally from Herendeen Bay south to,

and including, Unimak Island. 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 the Stony River (Taylor, pers. comm.).

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

1. Winter. During winter, aquatic vegetation such as sedges (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).
2. Summer. During summer, caribou tend to concentrate their feeding activity in moist, boggy areas where sedges (Carex spp.) predominate (ibid.).

B. Terrestrial

1. Conditions providing security from predators or other disturbances:
   a. Winter. The use of frozen lakes, frozen bogs, ridge tops, and other open areas for resting is a possible response to caribou/wolf interactions (Miller 1982).
   b. Spring/calving. Use of open terrain with gentle slopes for a wide field of view or dry islands within areas of extensive wet sedge marshes may be related to predator avoidance (ADF&G 1976).
   c. Fall/rutting. No pertinent discussion is found in the literature.
2. Conditions providing relief from insect harassment:
   a. Summer. Caribou make extensive use of windswept ridges, glaciers, lingering snow drifts, gravel bars, elevated terrain, and, on the Alaska Peninsula, cinder patches and beaches. Caribou occupying coastal summer ranges often seek relief from insects by moving out onto the mud flats and standing motionless, head down (Skoog 1968, Kelsall 1968, Hemming 1971, Miller 1982).

IV. NUTRITIONAL REQUIREMENTS

A. Preferred Foods (from Skoog 1968, unless otherwise noted)

1. Winter (mid October to mid April). Fruticose lichens (Cladonia spp. and Cetraria spp.), sedges, and grasses are heavily utilized. Willow (Pegau et al. 1973), horsetails, and dwarf shrubs (e.g., Vaccinium uliginosum) may be used to some extent. Although these plants may be used less by caribou during winter, they may be nutritionally significant.
2. Spring (mid April to mid June). The catkins of willow (especially Salix alaxensis, S. planifolia spp. pulchra, and S. glauca) are among the first of the new-growth vegetation to be eaten. Various grasses and sedges (notably Carex bigelowii, C.

membranacea, C. podocarpa, and Eriphorum vaginatum) are also used extensively. Fruticose lichens continue to be eaten during spring if available and especially if the growing season is late. Resin birch (Betula glandulosa) and dwarf birch (B. nana) become the favored foods as the season progresses, as do horsetails, which are especially attractive.

3. Summer mid June to mid August). Caribou continue to eat the leaves of willow, resin birch, and dwarf birch extensively during June and July. Many species of sedge and grass (especially those of the genera Alopecurus, Arctagrostis, Dupontia, Festuca, Poa, Puccinellia, Calamagrostis, and 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.
4. 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. Feeding Locations

1. Winter. Timbered areas are used, especially spruce-lichen associations north of Becharof Lake (ADF&G 1976). Poorly drained coastal plains where sedges are abundant are frequented by the Alaska Peninsula caribou herd (Hemming 1971).
2. Spring/calving. Open terrain with gentle slopes and shallow U-shaped valleys are preferred (Bos 1974). On the Alaska Peninsula, calving occurs on the coastal plain (Hemming 1971), frequently associated with areas of extensive wet sedge marshes (Faro, pers. comm.). The Mulchatna herd generally calves above timberline in rolling alpine tundra (Hemming 1971).
3. Summer. On the Alaska Peninsula, most cows and calves remain on or near the spring/calving area along the Bering Sea flats. Some sizeable groups (as large as 1,200 and totaling over 3,000) move into mountain valleys from Sandy Lake to Port Moller (Sellers, pers. comm.). Bulls and yearlings scatter widely and are found throughout the Aleutian Range and coast to coast. The Mulchatna herd moves to the west slopes of the Alaska Range (Hemming 1971).

Vegetation consists primarily of treeless upland areas where heath tundra, alpine tundra, and sedge wetland associations dominate.

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. 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, Hemming 1971). A major part of the Northern Peninsula herd begins a northerly migration in late July, but some of these caribou remain south of Port Heiden until late October (Sellers, pers. comm).

C. Factors Limiting Availability of Food

1. Winter. Snow depths of 50 cm are generally considered the upper limit for use of areas by caribou. Ice crust of more than 4 to 6.5 cm on top of snow is considered the upper limit (Pruitt 1960, Skoog 1968, Pegau 1972, LaPerriere and Lent 1977).
2. Spring/calving. Calving area selection by caribou has been attributed in part to early snow melt-off (Lent 1966). Should a late snowmelt 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 snow drifts, where food is unavailable (Skoog 1968, Miller 1982).
4. Fall. Increasing frost in the high country and/or snow decrease the availability and quality of forage, in part triggering fall migration (Skoog 1968).

D. Feeding Behavior

1. Winter and fall. Caribou prefer the finer parts of plants, such as the upper portions of lichens, the leaves and stem-tips of sedges and grasses, and the stem tips and buds of willows. Cursory grazing habits help reduce the possibility of overgrazing the range (ibid.).
2. Spring/calving. Feeding behavior at this time is similar to that occuring in winter, with an increased use of the leaves of willow and dwarf birch (ibid.).
3. Summer. Caribou select plant species according to the phenology 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). (Also see IV.D.1. this report).

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. For the NAP herd, however, major rutting congregations are on the wintering grounds (Sellers, pers. comm.). Breeding usually takes place in areas above timberline for Nelchina and Mulchatna caribou (Skoog 1968). If available, open habitat is preferred (Miller 1982).

2. Parturition areas. See III.B.b. and IV.A.2. this report.

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 (Skoog 1968). The peak of the rut of the NAP herd occurs in the middle two weeks of October (Sellers, pers. comm.).

2. Parturition. Parturition generally occurs from mid May through the first week of June on the Alaska Peninsula (ibid.) and from early May through the first week of June in the Mulchatna area (Taylor, pers. comm.).

C. Reproductive Behavior

1. Breeding. Bulls tend one cow at a time (Miller 1982) and do not gather harems (Skoog 1968). Copulation is brief and generally occurs at dusk or dawn (Espmark 1964).

   Adult bulls restrict their feeding activity during the rut, and a net loss of energy reserves occurs. By the end of the rut adult bulls have depleted their fat reserves and enter winter in lean condition (Skoog 1968).

2. Parturition. Peak calving for the peninsula herds occurs during the first week of June (Sellers, pers. comm.) and the beginning of the third week of May for the Mulchatna herd (Taylor, pers. comm.). Cows do not actively seek isolation to give birth (Lent 1966, Kelsall 1968, Skoog 1968). 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 1960).

D. Age at Sexual Maturity

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

E. Pregnancy Rate/Litter Size

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

F. Gestation Period

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

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTION

A. Home Range

Because caribou frequently are on the move and the distances they travel vary from herd to herd and frequently from year to year, no home range or life function area sizes have been determined.

B. Migration Routes

Terrain features influence movements to a large extent. Open waters of seas, large lakes, and swift rivers will often alter the course of migration. Rivers with floating ice cakes represent barriers. Areas that lack forage, such as the rocky regions of high mountains, volcanic cinder patches, glaciers, and burns, are a barrier to some extent (Banfield 1954, Kelsall and Loughrey 1957, Lent 1966, Skoog 1968, Miller 1982). Certain terrain features, including ridge-tops, eskers, stream-beds, hard-surfaced snow drifts, and frozen lakes and rivers, facilitate movements. Frozen lakes and rivers are particularly important avenues for travel (Skoog 1968).

1. Spring migration. "Instead of displaying the rapid and direct migration to the calving grounds typical of most other Alaskan caribou herds, the Alaska Peninsula herd begins a leisurely drift to the southwest in February or March. This spring drift spans a broad front, at times covering much of the coastal plain, but most cows follow a straight line paralleling the coast between the mouths of the Ugashik and Meshik rivers. Most cows reach the calving grounds by mid May" (Hemming 1971). Significant numbers of caribou, however, are as far south as Cinder River by the first of March and south of Port Heiden by mid April (Sellers, pers. comm.).

   In March and April, the cows of the Mulchatna herd begin to move toward the calving area. "There are no barriers to movement for animals wintering to the west and south of the calving area and they move by the most direct route to the calving grounds" (Hemming 1971). Although there are generally several discrete groups of caribou converging on the calving grounds at the headwaters of the Mulchatna, Chilakadrotna, and Holitna rivers, the majority arrive from the wintering area between Illiamna Lake and the Koktuli and Nushagak rivers (Taylor, pers. comm.).

2. Fall migration. In late July, the NAP caribou begin to shift to the northeast. By mid August, some caribou have reached the area near Becherof Lake. By early November, most animals occupy a common winter range between the Ugashik and Naknek rivers (Sellers, pers. comm.).

   No definite fall migrational pattern has been recorded for the Mulchatna herd, except for a tendency for animals to drift toward the slopes of the Alaska Range during the breeding period (Hemming 1971). In recent years, the majority of the Mulchatna herd has moved to the north side of the Mulchatna River after postcalving aggregations disperse, usually in July or August, and have remained there through the fall (Taylor, pers. comm.).

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

Emigration, which may be density-related, can cause large fluctuations in herd sizes. Weather, primarily snow or ice crusting during winter and spring, can cause dramatic declines in caribou numbers. Wolf predation in some areas may be an important factor in population control. Fire has affected forage abundance over large expanses of winter range in Alaska but in fact may not cause major fluxuations in population numbers. It is possible, however, that fire has caused population shifts (Skoog 1968).

On the Alaska Peninsula, heavy snows followed by freezing rains occurred during several winters in the 1930's. Under these conditions, the tundra is encased in ice, making it impossible for caribou to break through for feed. Reportedly, a large number of caribou died during those winters (Alaska Game Commission 1925-1948, Burdick 1940).

B. Human-related

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

- Pollution of water and/or food supply
- Alteration of habitat
- Disturbance during calving, abandonment of young
- Barriers to seasonal movement
- Overharvest
- Reduction of food supply

VIII. SPECIAL CONSIDERATIONS

Food supply, population density, weather, snow conditions, insects, man, and a variety of other factors can alter the patterns of caribou movement patterns seasonally and perhaps for several years (Skoog 1968).

IX. LEGAL STATUS

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

X. LIMITATION OF INFORMATION

Because of the variety of types of areas occupied by caribou and because of their nomadic behavior, it is difficult to accurately describe caribou habitat requirements. Causes of large population fluxuations in many instances are still unclear.

XI. DISTRIBUTION

A. Southwest Region

Caribou are distributed throughout the mainland in the Southwest Region and are also found on Unimak and Adak islands. As discussed above, there are four recognized caribou herds in the Southwest Region (Sellers, pers. comm.): the Mulchatna, NAP, SAP, and Adak herds. The Mulchatna herd ranges in an area generally north of Iliamna Lake and west of the Alaska Range. Some interchange between the Mulchatna and NAP herds occurred before the turn of the century, when animals seasonally moved on and off the peninsula.

The NAP herd is located between the Naknek River and Port Moller. The SAP herd is composed of two relatively distinct subherds, one that ranges on the mainland between Port Moller and Cold Bay, and the Unimak Island subherd.

In 1958 and 1959, 24 caribou calves from the Nelchina caribou herd were transplanted to Adak Island. Presently, caribou are distributed throughout the southern half of the island (Burris & McKnight 1973).

The Mulchatna caribou herd calving ground is in the Bonanza Hills area. Some scattered calving also occurs along the northwestern shore of Lake Iliamna. Wintering areas have varied in recent years, but normally late winter concentrations occur in the drainages of the Chilikadrotna, Mulchatna, and Hoholitna rivers.

The NAP caribou herd calves primarily between Port Heiden and Sandy River on the Bering Sea flats. Although small groups of caribou calve at scattered locations throughout the herd's range, the Bering Sea flats between Port Heiden and Cinder River, areas near Pinnacle Mountain, Yantarni Creek, and Nakalilok Bay are also considered significant calving areas. During winter, the majority of the NAP herd migrates north up the western half of the Alaska Peninsula and winters near Becharof Lake and between the lake and the Naknek River. Caribou may move throughout that area during the winter, depending on the weather and the behavioral patterns of the animals. As with calving, scattered bands of caribou in winter may be found throughout the herd's range.

The mainland portion of the SAP caribou subherd calves primarily in the area near the Black Hills and Caribou River. During winter, this subherd moves throughout much of its range but remains primarily on the northwestern half between Herendeen Bay and the town of Cold Bay.

The SAP Unimak Island caribou subherd has been observed calving on the southwest coast between Pogromni Volcano and Eickelberg Peak. Because of the island's remoteness, few data have been collected concerning herd movements.

The Adak Island caribou herd is distributed on the southern half of Adak Island.

XII. ABUNDANCE

The number of caribou in the Mulchatna herd has fluctuated in the past, and historical data on the herd are limited. In the mid 1960's, the herd was estimated at 3,000 animals. A 1974 census established a minimum herd size of 14,000 animals. Current (1983) census information indicates a herd size of about 26,000 animals (Taylor, pers. comm.).

The NAP caribou herd currently (1983) numbers about 20,000 animals (Sellers, pers. comm.). Numbers have fluctuated widely in the past; during the late 1940's, the USFWS estimated the herd at about 2,000 animals. Heavy snows followed by freezing rain were reported for the winters of 1930-31, 1933-34, and 1938-39 (Alaska Game Commission 1925-1948, Burdick 1940). These severe conditions apparently caused a substantial decrease in the number of caribou on the Alaska Peninsula. Since then, the herd has experienced a relatively steady growth up to its current level.

The SAP mainland subherd currently (1983) is estimated to number about 10,000 animals (Sellers, pers. comm.). As with the NAP herd, this herd's most recent population low occurred in the late 1940's, when there were an estimated 500 animals present. Since then, the herd has steadily increased to its current population level.

The SAP Unimak Island subherd currently (1983) numbers about 300 animals (ibid.). The number of caribou on the island has fluctuated widely. In 1976, the USFWS estimated the herd to be in excess of 5,000 animals. These wide fluctuations are apparently the result of migration between Unimak Island and the mainland.

The Adak Island caribou herd was established in 1958 and 1959, when 24 caribou calves were released on the island. The herd currently numbers about 175 animals, and as many as 297 caribou have been observed on the island. According to the most recent (unpublished, November 1980) Adak Island Caribou Management Plan, the carrying capacity of the island is approximately 150 adult caribou.

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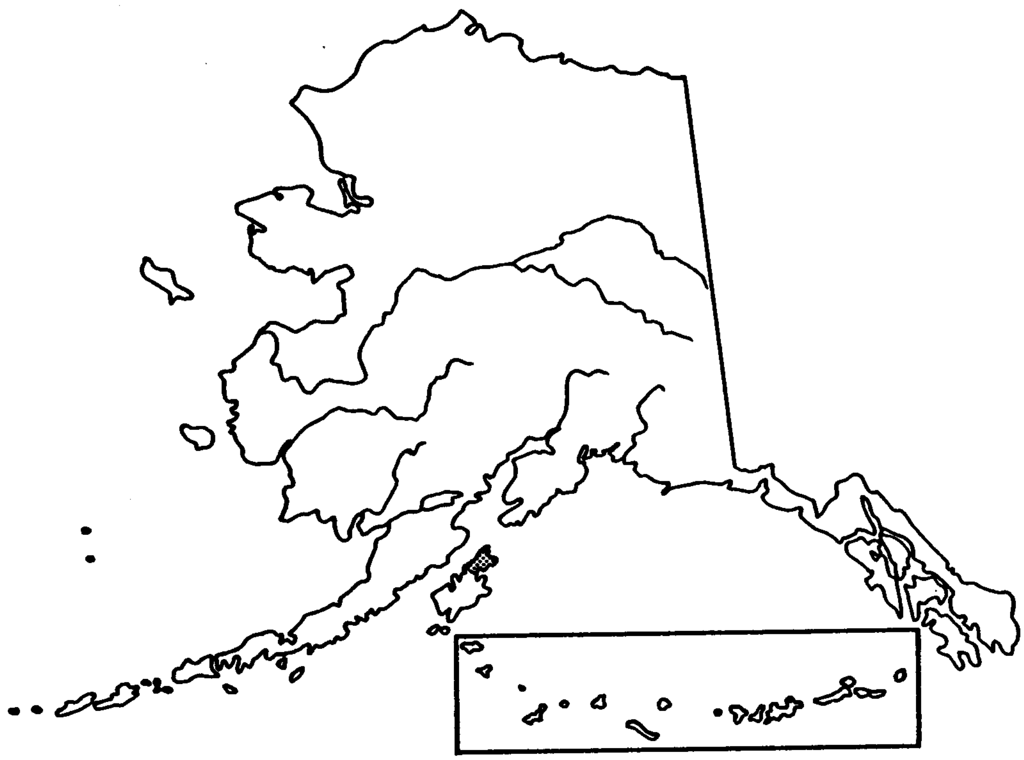
Elk Life History



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

I. NAME
   A. Common Names: Elk, Roosevelt elk, red deer, wapiti
   B. Scientic Name: <u>Cervus elaphus roosevelti</u>

II. RANGE
   A. Statewide
      Elk are found primarily on Afognak and Raspberry islands, although there have been several reports of elk on the northern part of Kodiak Island. Transplants have been attempted in Southeast Alaska but with limited success (Burris and McKnight 1973, Eide 1977).
   B. Regional
      See above.

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

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

B. Terrestrial

1. Conditions providing security from predators or other disturbances. A wide variety of vegetation and terrain can be used by elk as escape cover. Use of escape cover varies seasonally and by sex and reproductive status. Brown bears are the only animal on the islands capable of preying on elk. Although predation of elk by brown bears currently does not appear to be a major mortality factor, Alexander (pers. comm.) has documented the killing of an adult female elk by a brown bear. Smith (pers. comm.) has observed on two occasions brown bears that were apparently stalking elk herds.
2. Conditions providing protection from natural elements. Where available, spruce-timbered areas are used by elk most during December through March, apparently because they provide extra cover and because snow depths are less (Troyer 1960, Alexander 1973).

IV. NUTRITIONAL REQUIREMENTS

A. Preferred Foods

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

During summer feeding observations conducted on southwestern Afognak, Batchelor (1965) found that the following plants are utilized by grazing elk: fireweed (Epilobium angustifolium), lupine (Lupinus nootktensis), burnet (Sanguisorba sitchensis), cow parsnip (Heracleum lanatum), sea lovage (Ligusticum hultenii), hellebroe (Veratrum eschscholtzii), and water chickweed (Montia spp.).

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

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

During spring, the consumption of grasses and grass-like plants and perennial forbs increases with the development of new growth.

Sedges (*Carex* spp.), horsetail (*Equisetum* spp.), Angelica (*Angelica lucida*), bluejoint (*Calamagrostis canadensis*), and cow parsnip are also heavily utilized, as are the buds of fern (*Anthyrum cyclosorum*) and devil's club (*Oplopana horridus*) (ibid.).

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

C. Factors Limiting Availability of Food
Heavy snowfall and overgrazing by elk can sufficiently reduce forage to cause malnutrition, resulting in severe winter mortality.

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat
   1. Calving. Most calving occurs at lower elevations in spruce timber (Troyer 1960).

B. Reproductive Seasonality
   1. Calving. Most calving occurs in early June, although calf tracks have been observed as early as 23 May (ibid.).
   2. Rutting. Bugling begins in early September and continues through early October. Most breeding activity occurs during the last two weeks of September (ibid.).

C. Reproductive Behavior
Currently, little pertinent breeding behavior information exists concerning Afognak elk.

D. Age At Sexual Maturity
   1. Females. Female elk can successfully breed at 1.5 years, although the frequency of successful breeding in yearling cows varies among populations and from year to year in the same population (Flood 1970).
   2. Males. Male elk can successfully breed at 1.5 years (Harper 1971), but because of behavioral patterns larger bulls tend to do most of the breeding. Bulls generally are in their prime at ages 6 to 11.

E. Fecundity
Elk generally produce one calf per year, although twinning is not unknown.

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

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

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

Severe winter weather, as was documented by Alexander (1973), can cause severe losses of elk.

B. Human-related

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

- Pollution of water and/or food supply
- Reduction of food supply
- Alteration of habitat
- Disturbance/displacement
- Barriers to seasonal movement
- Overharvest

VIII. SPECIAL CONSIDERATIONS

1. Elk on Raspberry and Afognak islands are the result of transplants in 1928.
2. Drastic declines in elk numbers as a result of severe winters were documented. The decline was from 1,200-1,500 elk in 1965 to an estimated 500 animals by 1976 (Eide 1977). However, the elk population has since increased to over 1,200 animals (Smith, pers. comm.).
3. Sitka black-tailed deer (Odocoileus hemionus sitkensis) feed on many of the same food plants as elk on Afognak, which could lead to increasing competition as populations increase.
4. Much of the land occupied by elk is privately owned and may be subject to logging. The effect of logging and associated road access on elk habitat on Afognak and Raspberry islands is not clearly understood.
5. State and borough land sales on Raspberry Island may be detrimental to elk where changes in land use result in habitat deterioration or loss.

IX. MANAGERIAL AUTHORITY

The Alaska Department of Fish and Game manages elk.

X. LIMITATION OF INFORMATION

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

XI. DISTRIBUTION

During March of 1929, eight elk (five females and three males) were released on Afognak Island (Batchelor 1965). As the number of elk increased subsequent to the transplant, several relatively distinct herds have been identified. In 1958, Troyer (1960) identified five major herds on Kodiak and Raspberry islands. These herds were 1) the Raspberry Island herd, located from the entrance to Onion Bay on

Raspberry Cape to Windy Point; 2) the Malina herd, located from Cape Nuvilak Peninsula to Malina Cape-Malina Peninsula; 3) the Tonki Cape herd, located on Tonki Peninsula east to Swartz Lake; and 4&5) the upper and lower Raspberry Strait herds, located from Muskomee Bay-Afognak Lake to the Litnik Mountains and Raspberry Strait. Between 1970 and 1972, Alexander (1973) identified nine separate herds. In addition to those herds identified by Troyer (1960), Alexander identified 1) the Paramanof Peninsula herd on the Paramanof Peninsula east to King Lake; 2) the Waterfall herd, found from Waterfall Bay-Waterfall Mountain to Kazakof Peak and Delphin Bay; 3) the Kitoi herd, found from the headwaters of Kitoi Bay to Long Lake; 4) the Duck Mountain herd, found from Cape Kostromitnof to Selezen Bay; and 5) the Duck Mountain and Paramanof Mountain herd, found on Paramanof Mountain and bays west of King Lake. Alexander (1973) combined the upper and lower Raspberry Strait herds into a single Raspberry Strait herd. During his study, Alexander (1973) stated that the last of the Malina herd died off by May 1971 as a result of several winters with high snowfall.

Smith (pers. comm.) identified seven herds in 1983. The Paramanof Peninsula and Paramanof Mountain herds were considered one herd. The Malina herd has yet to firmly reestablish itself.

During winter, elk use spruce (Picea sitchensis) timbered areas on south and southeast-facing slopes adjacent to beach fringes. Much winter feeding also occurs in grass and on health-dominated vegetation types. These vegetation types are sporadically distributed along the entire coast (Smith, pers. comm.).

XI. ABUNDANCE

From the initial release of eight elk on Afognak Island, elk numbers increased to a high of approximately 1,200 to 1,500 animals by 1965. A series of winters with heavy snowfall reduced the population to less than 500 animals by 1976 (Eide 1977). Recent surveys now indicate a population of over 1,200 animals. Current estimates (Smith, pers. comm.) for the seven herds are as follows:

Tohki Cape	50-75	Duck Mountain/Kitoi	100-125
Raspberry Strait	225-250	Waterfall Lake	250-300
Raspberry Island	200-225	Paramanof Peninsula	250-300
Izhut/Seal Bay	100-150		

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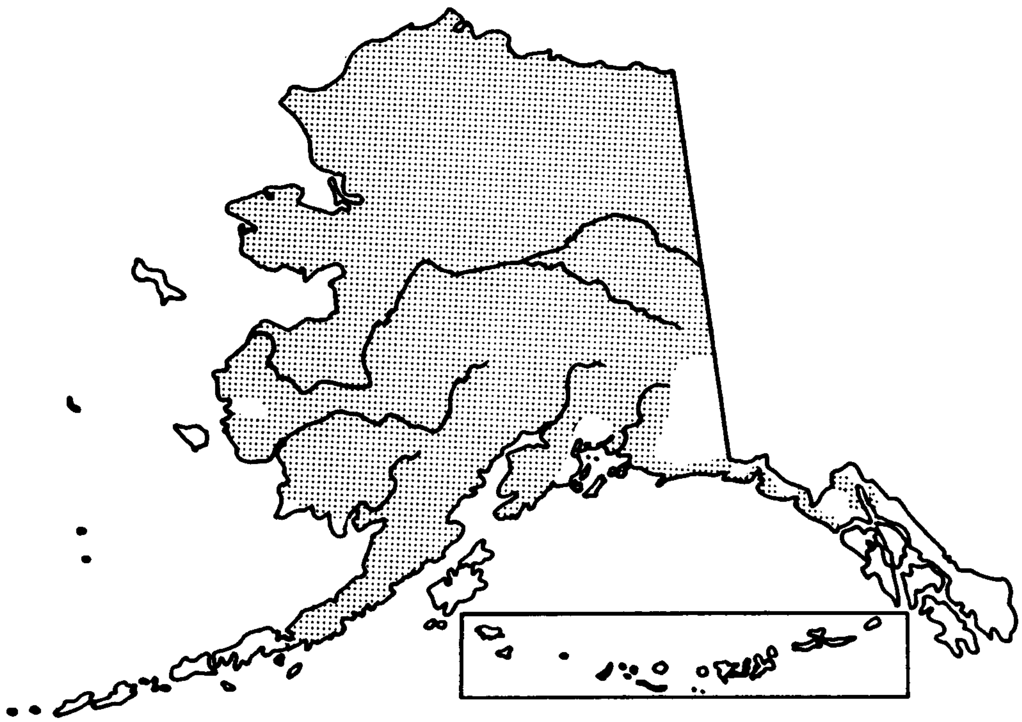
Moose Life History



Map 12. 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. 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. Moose are generally found below 5,500 ft elevations (ADF&G 1976a, 1976b, 1976c).

B. Regional

Moose are present throughout the Southwest Region mainland below elevations of 5,500 ft. Few moose exist south of Port Moller on the Alaska Peninsula (ADF&G 1976a).

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

Moose feed heavily on aquatic vegetation during spring and summer. They may also seek relief from insects in deep water (Flook 1959). (See also I.V. A. below.)

B. Terrestrial Cover Requirements

1. Winter. Shrub communities, such as riparian willow stands, constitute the most important habitat for moose during winter, supplying its preferred winter food (see IV. A. below). Nearby stands of coniferous trees may serve as additional cover, especially for cows with calves, which seek denser cover than do other moose, presumably for greater protection from predators (Peterson 1977). Moose typically use closed-canopy coniferous and deciduous forests during winter because of the reduced snow depth on the ground under them (Coady 1982). In open habitat on the Kenai Peninsula, large groups of moose gather, possibly replacing the role of cover in providing security from predators (Peek et al. 1974).
2. Spring. Moose feed heavily upon the aquatic vegetation of marshy areas (Gasaway, pers. comm.). In extensive wetland areas, cows usually select well-drained, dense islands of trees and shrubs as secluded birth sites and/or as protective cover for their calves (Peterson 1955, Rausch 1967). These calving areas, characterized by dense clumps of interspersed spruce (Picea spp.), 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.
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 and spruce stands. Traveling moose also avoid open areas and move along projecting stands of timber and the edges of spruce and willow islands, which provide concealing cover and the effect of a camouflaged background (LeResche 1966).
4. Fall. Habitat use during fall may be similar to both summer and winter, depending on weather. Early snows may force moose to move to wintering areas and, conversely, warm weather may allow them to remain in summering areas.

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

1. Winter. Shrubs and trees that extend above accumulated snow on the ground and are within reach of moose are the primary food in

winter (Coady 1982). When available, particular willow species are the most preferred browse (Scott et al. 1958, Peek 1974). According to Machida (1979), on the Kenai Peninsula littletree willow (S. arbusculoides) is most preferred, scouler willow (S. Scouleriana), and bebb willow (S. bebbiana) next, and barclay willow (S. barclayi), least preferred. In Interior Alaska, feltleaf willow (S. alaxensis) is most preferred, diamondleaf willow (S. planifolia ssp. pulchra) next, and scouler willow and halbred willow (S. hastata) least. After willow, the most preferred browse is paper birch (Betula papyrifera) (LeResche and Davis 1973). On the Kenai Peninsula, the winter diet of tame moose on normal (versus depleted) winter range was 72% (by number of bites taken) paper birch twigs, 21% lowbush cranberry (Vaccinium vitis - idaea), and 6% willow and green alder (Alnus crispa) (ibid.).

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. Willow is probably the most important food in spring (Gasaway, pers. comm.). 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 comprising almost all other food (LeResche and Davis 1973).

3. Summer. Variety in the diet, especially in summer, may be greater than has been detected by traditional methods of observation (ibid.). In summer, 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 the summer, moose also feed on diamond leaf willow, littletree willow, and feltleaf willow (Murie 1944).

   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 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 riparian willow stands, are the most important winter habitat. 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. During late winter, some moose may remain at higher elevations, where wind action reduces snow depth. Moose may crater through snow up to 40 cm deep (Coady 1982).

   Generally, upland areas of winter habitat are dominated by willow or shrub birch (Betula glandulosa) and lowland areas by stands of old-growth willow 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.).

   In spring and early summer, moose utilize mineral licks, where available (Fraser 1980). In Southwestern and Southcentral Alaska, the importance of mineral licks is unknown at this time; however, in other portions of Alaska and in Canada, moose have been observed using mineral licks (Tankersley and Gasaway 1983, Fraser et al. 1982). Because aquatic vegetation provides minerals for moose, mineral licks take on added importance in areas with limited aquatic vegetation (Best et al. 1977).

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 above.)

   In late summer, moose tend to move away from bog areas with standing water and to use browse in drier areas (Bishop, pers. comm.).

4. Fall. Both lowland and upland climax shrub communities are heavily used during fall (Coady 1982).

C. Factors Limiting Availability of Food

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

The density, height, and distribution of forage plants determine how much a particular area and vegetation type is utilized (Milke 1969). During fall, deterioration of forage quality may be one factor limiting the availability of food (Coady 1982).

D. Feeding Behavior

During winter, spring, and summer, peek feeding activity occurs at dawn and dusk, with the period around sunset the time of greatest activity. During fall, more feeding activity occurs during the day than around dawn or dusk. Fall feeding activity may be influenced by the rut, possibly 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 appears to be influenced by whether particular groups of moose are migratory or nonmigratory (Bailey et al. 1978).

   On the Kenai Peninsula, Bailey et al. (1978) found that most groups of migratory moose were at, or slightly above, timberline during the rut. Nonmigratory lowland moose often remained in the lowlands during the rut.

2. Parturition areas. Wet, marshy lowlands consisting of open boggy areas interspersed with dense stands of shrubs and trees are generally used as calving areas (Rausch 1967). (See III. B. 2.)

B. Reproductive Seasonality

1. Breeding. Breeding occurs during fall, with the peak of rutting activity occurring between late September and early October (Lent 1974). The timing of the rut is remarkably synchronous among moose in different areas and years in North America (ibid.); this synchronism is reflected in the consistency in calving dates observed throughout the range of moose (Coady 1982). If breeding does not occur during an initial estrus, recurrence of estrus (delayed estrus) may occur in some females. Successive estrus cycles may occur at 20 to 30-day intervals (Edwards and Ritcey 1958, Markgren 1969).

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). Bull moose do not form harems (Altman 1959, Geist 1963), but they do congregate into rutting groups ranging 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 yearling females in North America was found to be 0 to 0.47 (Pimlott 1959, Schladwiler and Stevens 1973, Simkin 1974). It was found that on the average 11 to 29% of adult females bore twins in North America (Pimlott 1959, Hosley and Glaser 1952). These percentages, however, are based on fall counts of moose; during spring counts twin rates would be higher. During spring moose counts, Franzmann et al. (1983) found a twinning rate of 70% in the 1969 burn on the Kenai Peninsula. Summer moose calf mortality during two years of study on the Kenai Peninsula was 58% (Franzmann et al. 1980). It is unusual to find three fetuses in cows or triplet calves with adults (Pimlott 1959, Hosley and Glaser 1952).

As indicated by Klein (1970) for deer, spring, summer, and fall diets may have an important influence on production and survival (Peek 1974).

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). The following are some affects of severe winter weather upon moose:
   - Food availability diminished (Peek 1974)
   - Reproductive rates lowered (Pimlott 1959)
   - Susceptibility to predation increased (Peterson and Allen 1974)
   - Calf mortality increased (Bishop and Rausch 1974) (Specific combinations of cold, snow, and wind conditions affect the timing and extent of calf mortality [Sigman 1977].)

- Cow-calf bonds weakened (ibid.)

2. Predation. During severe winters, predation by wolves may contribute further to the decrease in moose populations (Rausch et al. 1974). Studies show that wolf predation is related to snow conditions. Increased snow density and crusting enables wolves to maneuver better (Peterson and Allen 1974) while concomitantly restricting the ability of moose to escape because their greater weight is more likely to break through the crust.

   On the Alaska Peninsula, brown bear predation on newborn moose calves is probably one of the most significant causes of declines in the moose population (ADNR/USFWS 1983). The fact that brown bears can be a significant cause of moose calf mortality has also been demonstrated in the Nelchina Basin (Ballard et al. 1982). Black bears on the Kenai Peninsula are also known to cause significant calf mortality (Franzmann et al. 1980).
3. Disease and parasitism. Moose are subject to a large number of diseases and parasites, including brucellosis, hoof rot, lumpy jaw, leptospirosis, and degenerative arthritis. They are also hosts for liver flukes and several species of tapeworm cysts found in organs and muscle tissue. Direct mortality as a result of these agents is, however, not generally an important factor in population dynamics (Franzmann 1978; Zarnke, pers. comm.).
4. Competition. Competition 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 providing 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 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
- Harassment, active

VII. LEGAL STATUS

The Alaska Department of Fish and Game manages moose. (See the Human Use section for a management summary.)

VIII. SPECIAL CONSIDERATIONS

A. Habitat Protection

To sustain a moose population, good habitat is essential. Habitat protection may consist of the following (Franzmann 1978):

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

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

IX. LIMITATIONS OF INFORMATION

Data are sparse concerning summer and fall habitat use by moose, and area-specific information is needed regarding these seasonal habitat requirements. Also, very little has been reported about the movements and concentration of animals during the post-rut and early winter period.

X. DISTRIBUTION

Moose are distributed within Game Management Units (GMU) 9 and 17 in the Southwest Region. Moose are only occasionally sighted south of Port Moller on the Alaska Peninsula and do not occur on Kodiak and Afognak islands (GMU 8) or the Aleutian Islands (GMU 10).

It is not clear whether moose occupied the Alaska Peninsula in substantial numbers prior to 1900. They may have been periodically eliminated from major portions of the Alaska Peninsula by cataclysmic volcanic eruptions (Klinkhart 1976). During winter, moose tend to congregate in riparian habitats with willow and cottonwood, which occur predominately in lowland areas. Movements to wintering areas reflect forage availability and snow depth and are generally altitudinal in nature. An exception to this is the Cook Inlet drainages in GMU 9, where moose appear to move to the northwest side of the peninsula and return to the Cook Inlet side in May (ibid.).

During spring, some moose congregate in wet marshy lowlands consisting of open areas interspersed with dense stands of shrubs and trees. Although many parturient cows may be associated with these congregations, most calving is secluded. Areas used for calving tend to be isolated marshy lowlands. Within the limits of the tree line, these areas also tend to be forested. During the fall, which includes the rutting period, moose congregate in habitats dominated by willow, cottonwood, and birch.

In many instances spring, fall, and winter concentration areas are coincidental because they provide the biophysical requirements of moose during all three seasons.

XI. ABUNDANCE

Winter moose censuses were conducted in portions of Game Management Subunits 17C and 9B in the Southwest Region during 1983. In an 1,834 sq mi portion of Subunit 17C, the results of the census indicated approximately 1,212 moose with ±23.6% at the 90% CI (Taylor 1983), an overall low-to-moderate density of approximately .7 moose/per mi. Using these estimates as a basis for prediction, Taylor (1983) has tentatively extrapolated densities to other portions of GMU 17. In Subunit 17A he estimates less than 0.1 moose per sq mi, a very low density. In the Nushagak drainage portion of 17B estimates range from 0.6 to 0.9 moose per sq mi, a low-to-moderate density. In the Mulchatra River drainages of Subunit 17B densities are assumed to range between 1.0 and 1.3 moose per sq mi, a moderate density.

A 1,267 sq mi portion of Game Management Subunit 9E was assessed at an estimated 1,148 moose ±16% at the 90% CI (Sellers and McNay, pers. comm.). The overall moose density for this area was approximately 0.9 moose per sq mi, a moderate density. Current estimates of the number of moose in all of GMU 9 range from 5,000 to 6,000 animals (Sellers, pers. comm.).

Although it is uncertain if moose occupied the area south of Lake Iliamna and the Alaska Peninsula in substantial numbers prior to 1900, apparently numbers began to increase in the area at the turn of the century. Moose numbers on the Alaska Peninsula peaked during the late 1960's and have declined by one-third to one-half since. Numbers of moose in the Cook Inlet drainages and the Iliamna lake area north of Katmai National Park have declined from peak levels of the 1940's and 1950's and have stabilized at relatively low densities. Moose were abundant in the Wood River-Tikchick Lakes area in the mid-to-late 1950's, but in other northern Bristol Bay drainages moose have not been abundant, and populations remain static at low levels.

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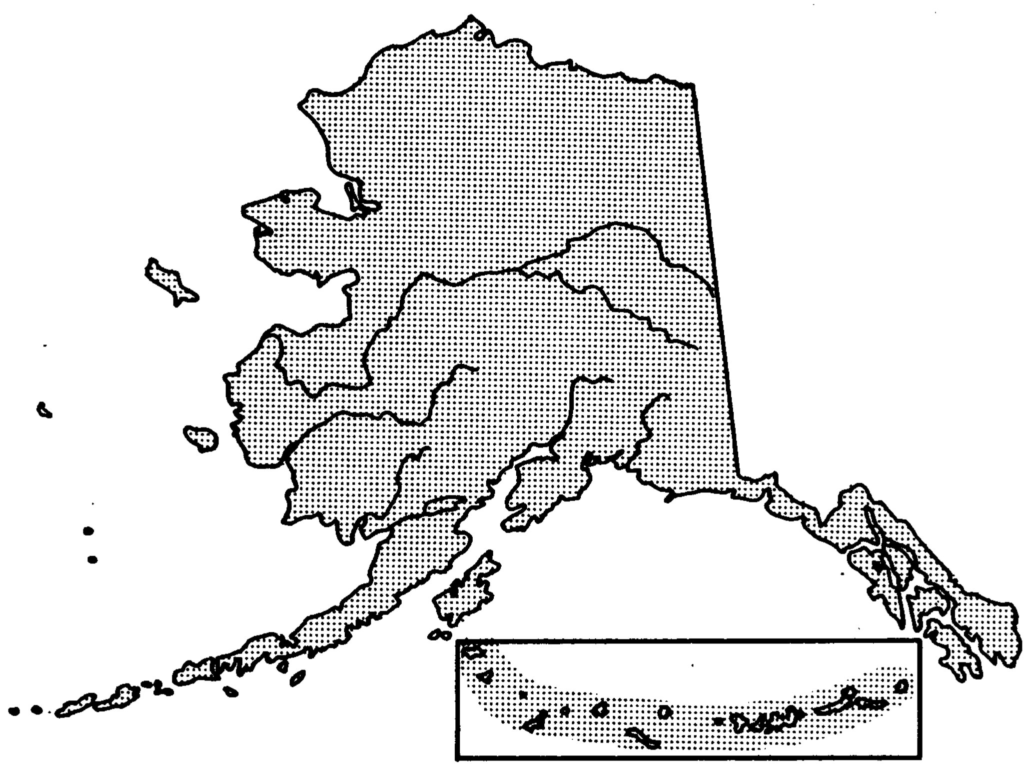
Birds

Dabbling Ducks Life History



Map 13. 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 Known to Occur in the Southwest Region
      In the Southwest Region, the dabbling duck population consists primarily of northern pintails (Anas acuta), mallards (A. platyrhynchos), American wigeon (A. americana), American green-winged teal (A. crecca carolinensis), northern shovelers (A. clypeata), and gadwall (A. strepera) (Conant and King 1981; Trapp, pers. comm.). Lesser numbers of other dabbling duck species use the area as well.

II. RANGE

A. Worldwide

Dabbling ducks occur throughout most of the world.

B. Statewide

Dabbling ducks are abundant and widely distributed throughout the state wherever habitat conditions are favorable.

C. Regional

In general, dabbling ducks are found throughout the Southwest Region at elevations below 1,200 ft (Sellers, pers. comm.). 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.

III. PHYSICAL HABITAT REQUIREMENTS

Dabbling ducks usually live on fresh water but occasionally on salt or brackish waters during migration. Because dabblers are adapted to living on restricted water surfaces, they are frequently found on small ponds or on lakes bordered by trees or aquatic plants such as cattails, reeds, bulrushes, etc., where open water is limited (Terres 1980).

A study of the coastal habitats in Alaska found that dabbling ducks are the most ubiquitous of waterfowl. They are found most abundantly on protected delta water, lagoon water, and salt marshes but are found in measurable quantities on eight other habitats. During the study, only subtle differences in habitat selection were evident. For instance, pintails 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 (Arneson 1980).

IV. NUTRITIONAL REQUIREMENTS

A. Preferred Foods

Dabbling ducks feed primarily upon the seeds of aquatic and marsh plants, masts, or cultivated grains (Bellrose 1976). Most, however, are opportunistic and will eat whatever is most available (e.g., berries, land insects, crustaceans) (Timm 1975).

B. Feeding Location

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 (ibid.).

C. Feeding Behavior

Dabbling ducks feed either at the surface, where they skim the water at the edges of the shores and banks, or by "tipping" tail up in shallow places, reaching down to obtain their sustenance from the bottom (ibid.).

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Dabbling ducks generally require lowland ponded areas for nesting. Such habitat is scattered throughout the Southwest Region. Nest locations vary, but most dabblers build their nests somewhere in heavy cover in association with shallow ponds, sloughs, or streams (ibid.). (See table 4.)

B. Reproductive Seasonality

The span of nest initiation depends on local temperatures and water conditions and varies among species. Incomplete clutches have been found on 25 May and new nests as late as 10 July on the Yukon Delta (Bellrose 1976).

C. Reproductive Behavior

Female dabblers have new mates each season. Courtship takes place in late winter and during early spring. On arrival at their nesting grounds, the females lose little time in searching for a suitable nesting site and then commence nest construction (Timm 1975).

D. Age At Sexual Maturity

All dabblers mature at one year of age (ibid.).

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.).

F. Incubation Period

The incubation period varies by species but usually averages between 21 and 29 days (ibid.). Hatching generally coincides with the longest days of the year and the peak production of aquatic invertebrates in late June.

G. Rearing of Young

As soon as the females are well into incubation, the males withdraw into flocks by themselves and proceed to molt. They take no part in raising young (ibid.).

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

A. Staging

Staging areas in the Southwest Region are usually associated with productive estuaries, river deltas, lagoons, and tidal flats, where a variety of plant and animal material is present. Staging areas provide high-quality feeding habitat where ducks can restock their energy reserves in preparation for breeding (in the spring) and migration/wintering (in the fall).

B. Migration

Dabbling ducks from Alaska utilize all the major flyways. The majority, however, use the Pacific Flyway (Bellrose 1976). The timing of migration varies with the species and annual variations in weather conditions. Pintails are generally the earliest species to arrive (April-May) and the first to leave (August-September), although individuals remain as late as November (ibid.).

Table 4. Breeding Biology of Dabbling Ducks

Species	Nest Location	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: 1 yr
Mallard	Ground, edges 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.

VII. 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. However, flooding in river valleys 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:

- 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

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 retarded to coincide with the development of the young.

IX. LEGAL STATUS

In Alaska, waterfowl are managed under the International Migratory Bird Treaty Act of 1918 as implemented by the U.S. Fish and Wildlife Service and the Alaska Department of Fish and Game.

X. DISTRIBUTION

Dabbling ducks are abundant and widely distributed throughout the state.

A. Timing of Movements

The timing of migration varies with the species and with annual variations in weather conditions. Pintails are generally the earliest species to arrive (April-May) and the first to leave (August-September), although individuals remain as late as November (Bellrose 1976). Most dabbling ducks arrive by mid May and depart by late September or early October.

Staging areas in the Southwest Region are usually associated with productive estuaries, river deltas, lagoons, and tidal flats, where a variety of plant and animal material is present. Major staging areas include Izembek Lagoon, Port Heiden, Cinder River/Hook Lagoon, Egegik, Ugashik, and Naknek, Chagvan, Kvichak, Nanvak, and Kwukak bays (Sellers, pers. comm.; Taylor, pers. comm.).

Dabbling ducks generally require lowland ponded areas for nesting. Such habitat is scattered throughout the Southwest Region. The timing of nest initiation varies by species and with changes in weather conditions. Hatching generally occurs in late June, when there are many hours of daylight and aquatic invertebrate abundance is high. As soon as the females are well into incubation, the males withdraw into flocks by themselves and proceed to molt (Timm 1975). 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 retarded to coincide with the development of the young. Concentrations of molting ducks are found on freshwater habitats such as upriver portions of the Kvichak River and on estuarine areas such as Ugashik, Nushagak, and Chagvan bays.

XI. ABUNDANCE

In the Southwest Region, the breeding population of dabbling ducks consists primarily of northern pintails (Anas acuta), 60%; mallards (A. platyrhynchos), 15%; American wigeon (A. americana), approximately 12%; American green-winged teal (A. crecca carolinensis), 10%; and northern shovelers (Spatula clypeata), less than 1% (Conant and King 1981). Lesser numbers of other dabbling duck species use the area as well. During the winter, the species composition changes. Mallards become the most abundant species, 65%; followed by the green-winged teal, 24%; northern pintail, 8%; gadwall (A. strepera), 2%; and northern shoveler, American wigeon, and European wigeon (A. penelope), all totaling less than 1% (Trapp, pers. comm.). Species composition for the Alaskan population can change dramatically, depending on sport harvest pressure, weather conditions, and water conditions south of Alaska (Bellrose 1976). For example, mallard, American wigeon, green-winged teal, pintail, and northern shoveler populations in Alaska all declined by 45 to 74% between 1981 and 1982 (King and Conant 1982). Population variations within the Alaska-Yukon survey area (see map 14) are shown in table 5. The breeding population index for dabbling ducks in Bristol Bay was 108,100 (less than half that of diving ducks) and represents nearly 5% of the Alaskan dabbling duck breeding population and 2.2% of the total Alaskan breeding duck population. The dabbling duck species found in Bristol Bay averaged 10.9 ducks per sq mi over 9,900 sq mi of habitat (King and Conant 1982). The population index for the Bristol Bay survey area is given in table 6.

A. Species Accounts

1. Pintail. Pintails are one of the most abundant species of dabbling duck in the Southwest Region. Although some pintails nest within the area, the largest concentrations are seen during spring and fall migrations. In the spring, according to survey data for the Togiak NWR (1983), pintails utilize the northern Bristol Bay area, particularly the Nushagak Peninsula and Chagvan Bay, in relatively large concentrations (1,000 to 5,000 birds). During the fall, the largest concentration of pintails, approximately 75,000, gather on the Izembek NWR, and another 15,000 concentrate in other areas on the Alaska Peninsula and Aleutian Islands in preparation for their migration south (Bellrose 1976). In addition, smaller concentrations are found on the Togiak refuge, where a majority of the birds are found on the Nushagak Peninsula (1,500) and at Chagvan and Nanvak bays (1,800 and 6,800 birds, respectively). Small numbers of pintails winter along the Aleutian Islands (Gabrielson and Lincoln 1959); and an estimated 650 birds winter in Kodiak (Forsell and Gould 1981).
2. Mallard. During the breeding season, mallard densities average 1.2 birds per sq mi in the Bristol Bay area. Mallards are the most abundant dabbler in the region during the winter. Mallards winter as far north as the Alaska Peninsula and westward along the Aleutian chain (Bellrose 1976). Approximately 10,100 mallards are thought to winter around Kodiak (Forsell and Gould 1981).
3. American wigeon. Small numbers of wigeon have been seen in the Izembek Bay area, and although this species is not common to the Aleutians, it is regularly reported (Gabrielson and Lincoln 1959). During the winter, an estimated 250 birds inhabit the Kodiak area (Forsell and Gould 1981).
4. American green-winged teal. The American green-winged teal breeds as far west as the Aleutian Islands, and a Eurasian subspecies breeds throughout the Aleutian chain (Zeillemaker, pers. comm.). Important breeding areas include the Bristol Bay marshes, where the population numbers about 7,400, or 0.75 per sq mi (Bellrose 1976). Teal are the third most abundant puddle duck in the Kodiak area during the winter, with an estimated

Table 5. Alaska-Yukon: 10-Year Trend in Adjusted Dabbling Duck Breeding Population Estimates by Species, 1973-82 (in Thousands)

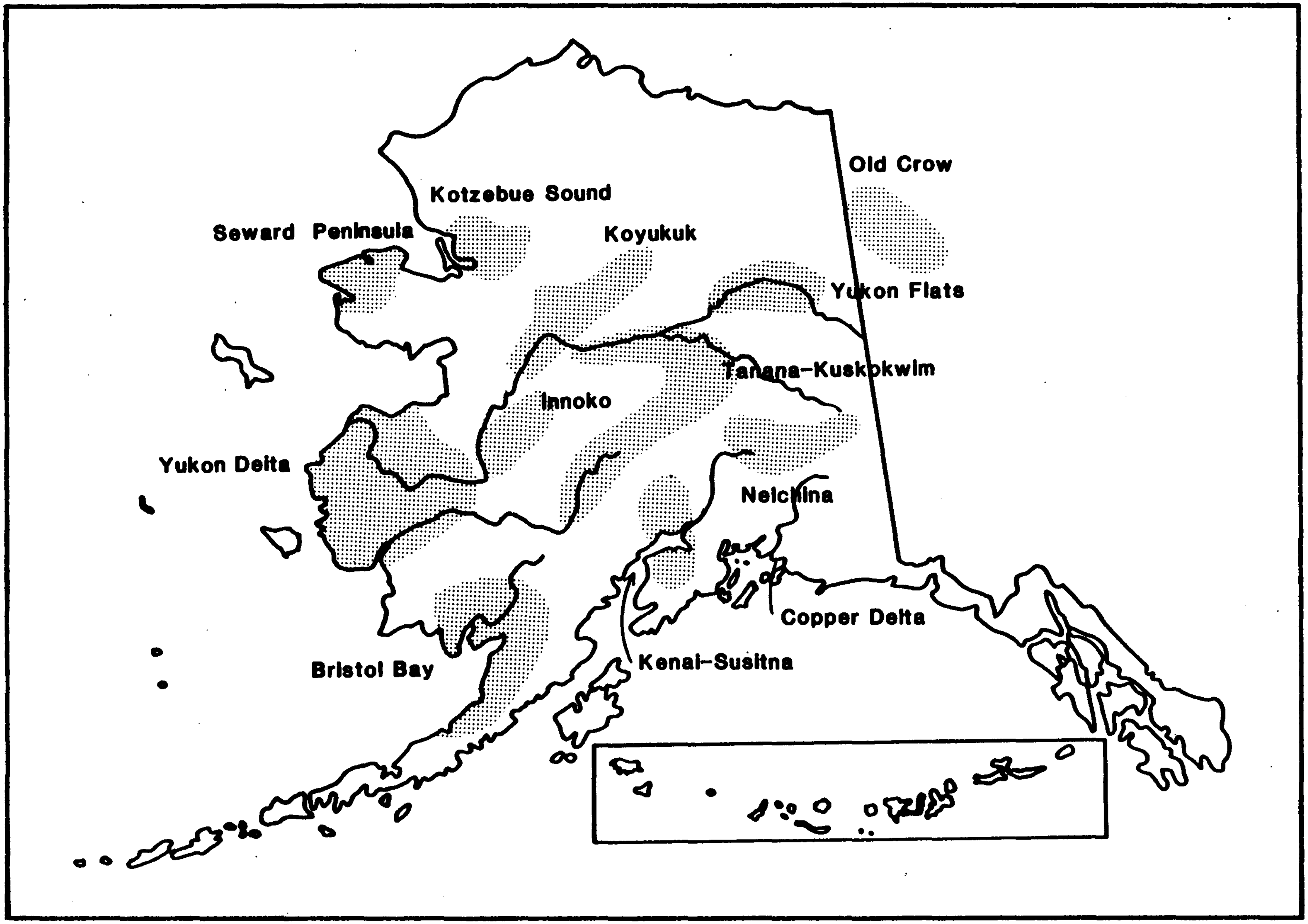
Species	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
Mallard	207.3	237.3	111.1	153.6	392.0	269.7	234.5	339.9	410.6	215.7
Gadwall	0.9	8.4	1.5	0.9	0.2	3.3	1.2	1.2	3.9	3.3
Am. wigeon	466.6	645.5	313.5	344.3	686.4	890.9	755.9	1,028.1	1,198.6	649.0
Green-winged teal	240.6	446.8	116.8	205.0	227.6	304.2	278.0	344.4	568.9	228.6
N. shoveler	78.8	151.0	43.4	92.2	217.6	239.8	119.0	430.7	676.2	177.1
Pintail	1,522.7	1,270.8	899.8	1,153.7	2,657.4	1,385.8	1,020.4	2,539.7	2,034.1	1,100.8
Total	2,516.9	2,759.8	1,486.1	1,949.7	4,181.2	3,093.7	2,409.0	4,684.0	4,892.3	2,374.5

Source: King and Conant 1982.

Table 6. Dabbling Duck Population Index for the Bristol Bay Survey Area

Species	1978	1979	1980	1981	1982
Mallard	18,377	8,848	10,209	21,099	15,654
Gadwall	3,084	1,028	----	1,028	----
Am. wigeon	32,534	15,105	25,562	44,734	22,076
Green-winged teal	8,200	6,150	6,150	47,151	10,250
N. shoveler	10,737	826	4,956	14,041	2,478
Pintail	73,386	60,043	114,248	70,884	47,534
Total	146,318	92,000	161,125	198,937	97,992

Source: Conant and King 1981; King and Conant 1978, 1979, 1980, 1982.



Map 14. Alaska-Yukon waterfowl breeding-pair survey, 18 May to 13 June 1982 (James G. King and Bruce Conant, USFWS, Juneau, AK.)

population of between 400 and 500 birds (Forsell and Gould 1981).

5. Northern shovelers. These birds may be seen throughout the region in small numbers.

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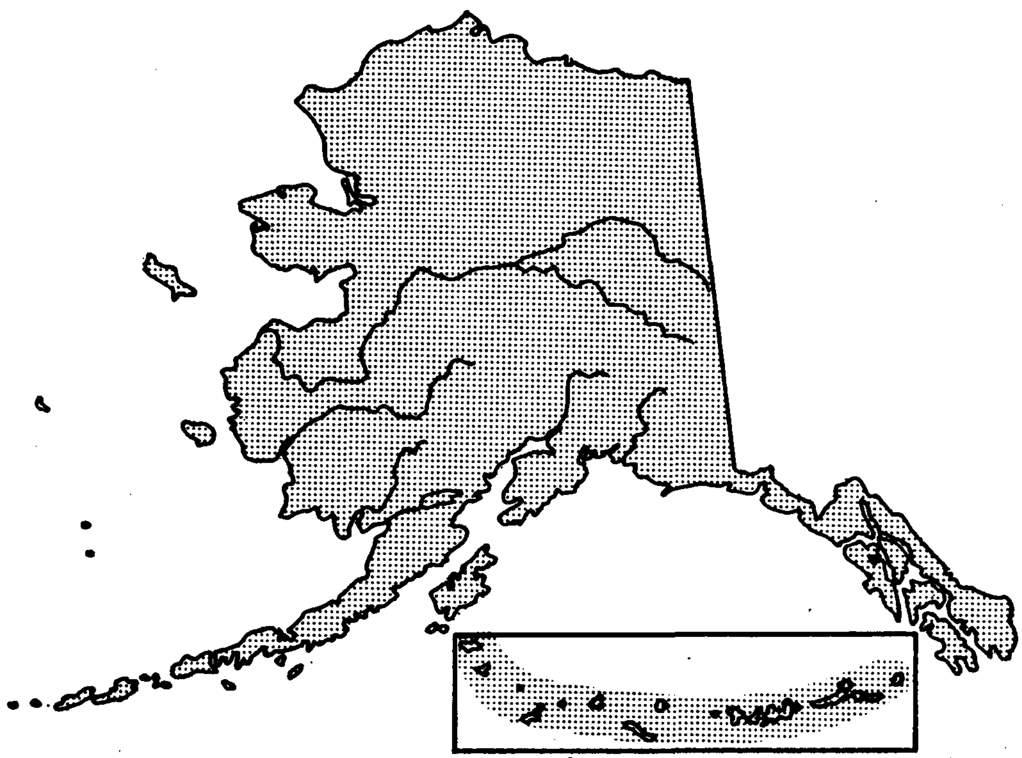
Diving Ducks Life History



Map 15. 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. Anythyini.
         b. Sea Ducks. Mergini.
   C. Species Commonly Known to Occur 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*).

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

In general, diving ducks are distributed throughout the Southwest Region at elevations below 1,200 ft (Sellers, pers. comm.). 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.

III. PHYSICAL HABITAT REQUIREMENTS

Jim 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).

IV. NUTRITIONAL REQUIREMENTS

A. Preferred Foods

An inland diver, the greater scaup eats a mixed diet of about one-half vegetation (e.g., pond weeds, muskgrass, sedges, and other grasses and aquatics) and one-half animal matter. Other diving ducks (i.e., common and Barrow's goldeneyes, buffleheads, mergansers, and eiders) are primarily animal feeders. Mollusks, crustaceans, and insects form the bulk of their diet, although they do consume small amounts of plant materials (Timm 1975).

B. Feeding Locations

Diving ducks generally frequent the larger and deeper inland bodies of water and protected estuarine habitats.

C. 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. Some may feed at greater depths, however; oldsquaws, for example, have been recorded at depths of over 200 ft (ibid.).

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Most diving ducks require lowland pond habitats for nesting. Nest locations vary according to species (see table 7). The majority of

Table 7. Reproductive Characteristics of Diving Ducks

				Clutch Size		
Species	Nest Location	Mating	Incubation	Range	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 2 yr of age
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 2 yr of age
Surf scooter	Ground: carefully concealed, lined with a small amount of grass; will breed inland	Usually June	----	5-9	7	----
White-winged scooter	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

(continued)

Table 7 (continued.

Species	Nest Location	Mating	Incubation	Clutch Size Range	Clutch Size Average	Sexual Maturity*
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 2 yr 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	

(continued)

Table 7 (continued).

Species	Nest Location	Mating	Incubation	Clutch Size Range	Clutch Size Average	Sexual Maturity*
Steller's eider	Apparently nest in restricted areas near the coast, on slight rise on a peninsula or along the margin or a tundra pond	May	3 weeks but probably longer	6-10	7-8	Many are assumed to begin breeding late in their second year
Pacific common eider*	Close to the sea, usually on small islands or islets but sometimes on tundra ponds distant from the coast	May-June	1-8 days	1-14	4-5	Do not breed until at least 3 yr old
King eider*	May nest on small islets along the coast or near tundra ponds and lakes inland from the coast	May-June	23-24 days	2-6	4-5	Probably breed at 2 yr of age

Source: Refuge file data Yukon Delta NWR, Timm 1975.

* Information taken from Bellrose 1976.

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 (ibid.). 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
Female diving ducks have new mates each season. Those 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.).

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. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS
Timing of arrival and departure for those species that do not winter in Bristol Bay varies by species and changes according to annual weather patterns. Arrival for greater scaup and goldeneye is generally earlier than for scoter and oldsquaw. Arrival dates begin in May. Fall departure also varies by species, extending from late August until freeze-up. Diving ducks, particularly scoter and oldsquaw, are found wintering along the coast of Bristol Bay.

VII. FACTORS INFLUENCING POPULATIONS

A. Natural
Species composition and numbers for the Alaska population of diving 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).

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 estuarine and/or lagoonal habitat
- Alteration of shoreline habitat
- Alteration of nesting habitat
- Dredging/filling/draining of wetlands
- Disturbance during nesting/abandonment of ducklings
- Oiling of feathers
- Mortality from fishing gear
- Disturbance of fall/spring staging areas
- In-flight hazards (e.g., transmission lines, towers)

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).

IX. LEGAL STATUS

In Alaska, waterfowl are managed under the International Migratory Bird Treaty Act of 1918 as implemented by the U.S. Fish and Wildlife Service and the Alaska Department of Fish and Game.

X. DISTRIBUTION

Diving ducks occur throughout the state, generally near the larger and deeper inland bodies of water and along the sea coast (Timm 1975). King (pers. comm.) indicated that any coastal waters of the state 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).

A. Timing of Movements

Timing of arrival and departure for those species that do not winter in the Southwest Region varies by species and changes according to annual weather patterns. Arrival for greater scaup and goldeneye is generally earlier than for scoter and oldsquaw. Arrival dates begin in mid-to-late April for the earliest species and extend through mid May for later species (BBCMP 1983).

Nest initiation extends from early-to-late June, depending on the species and weather conditions, with scoters generally being the last nesters (ibid). Diving ducks generally require lowland pond habitats for nesting, although the American and Barrow's goldeneye and the bufflehead are habitually tree nesters (Timm 1975). Brood-rearing occurs throughout July and August (BBCMP 1983).

Requirements of molting adults vary with the 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 traditional molting areas. The timing of the molt extends from mid July to the end of August (Bellrose 1976). Important staging and molting habitats are usually associated with river deltas, major lagoon systems, and estuaries. The Ugashik, Egegik, and Nushagak rivers and bays are heavily utilized areas (BBCMP 1983).

The fall departure of diving ducks also varies by species, extending from late August until freeze-up. Some divers, particularly scoters, eiders, and oldsquaw, winter along the coast of Bristol Bay and the Aleutian Islands (ibid).

XI. ABUNDANCE

A number of waterfowl species, including some of the sea ducks, comprise the diving duck group. The greater scaup (Aythya marila) has been the most numerous species encountered on surveys of spring breeding pairs conducted by the USFWS (table 8). The 1982 Bristol Bay diving duck population index was 267,000, of which greater scaup comprised 35%; oldsquaw (Clangula hyemalis), 22%; surf scoter (Melanitta perspicillata), white-winged scoter (M. fusca deglandi), and a black scoter (M. nigra), 41%; Barrow's goldeneye (Bucephala islandica) and common goldeneye (B. clangula), 2%; and red-breasted merganser (Mergus serrator) and common merganser (M. merganser americanus), 1% (King and Conant 1982). The adjusted population estimate for Alaska is 1,483,700, of which the Bristol Bay diving ducks comprise about 18% (267,000 birds) (ibid). (See table 9.)

The diving duck group is distributed throughout the Bristol Bay lowlands. Approximately 9,200 sq mi of breeding habitat produce a fall flight (after nesting) of 572,000 ducks (King and Lensink 1971). Fall duck numbers on Bristol Bay estuaries exceed 1 million birds, the majority of which are divers (ibid). (See map 14.)

A. Species Account

1. Greater scaup. According to King and Conant (1982), an average (1972-1981) of 1,461,700 scaup breed in the Alaska-Yukon survey area. Whereas the greatest density of breeding lesser scaup occurs in the interior of Alaska, the greater scaup is a common nesting species in habitats bordering the eastern Bering Sea (King and Dau 1981). The largest breeding ground for greater scaup is the Yukon Delta, with a 1982 population index of 268,424 birds, followed by the Bristol Bay area, with 92,857 birds (King and Conant 1982). Gabrielson and Lincoln (1959) reported concentrations of greater scaup breeding in the vicinity of the Chulitna and Kvichak rivers. Greater scaup winter as far north as the Alaska Peninsula, and surveys on Kodiak Island estimate a wintering population of between 3,500 and 4,000 birds (Forsell and Gould 1981).

2. Oldsquaw. The breeding range of the oldsquaw includes the Bristol Bay area, with an estimated 57,356 birds (King and Conant 1982). Although oldsquaws have been known to nest on the islands of the Bering Sea, current information indicates that breeding in the Aleutians does not occur (Trapp, pers. comm.). Oldsquaws winter along the Aleutian Islands and the coast of

Table 8. Alaska-Yukon: 10-Year Trend in Adjusted Diving Duck Breeding Population Estimates by Species, 1973-1982 (Estimates in Thousands)

Species	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
Scaups	1,196.1	1,131.6	1,175.4	1,494.8	1,748.0	1,315.3	1,203.2	1,771.3	1,461.7	1,196.2
Goldeneye	142.1	128.2	147.0	133.7	142.5	103.8	158.5	172.7	94.8	115.8
Bufflehead	58.0	93.4	63.1	117.3	72.7	100.4	113.2	86.3	57.2	69.1
Oldsquaw	419.0	742.4	543.0	497.8	990.0	906.3	677.2	1,147.3	597.3	609.2
Eiders	34.9	23.2	20.4	17.8	22.6	13.7	23.6	16.6	21.5	21.7
Scoters	296.6	430.1	321.0	376.2	434.7	465.5	472.6	545.0	430.0	513.7
Mergansers	5.7	4.8	7.6	3.1	11.9	17.6	8.2	7.6	9.9	12.9
Total	2,152.4	2,553.4	2,277.5	2,640.7	3,422.4	2,922.6	2,656.5	3,746.8	2,672.4	2,538.6

Source: King and Conant 1982.

Table 9. Diving Duck Population Index for the Bristol Bay Survey Area

Species	1978	1979	1980	1981	1982
Scaups	151,001	91,121	113,396	93,436	92,857
Goldeneyes	10,653	10,653	2,367	2,367	5,918
Bufflehead	1,162	581	--	--	--
Oldsquaw	163,673	75,542	106,318	81,837	57,356
Eiders	--	--	--	775	--
Scoters	125,203	95,826	130,799	87,432	108,556
Mergansers	7,317	861	2,152	3,013	2,152
Total	459,009	274,584	355,032	268,860	266,839

Sources: Conant and King 1981; King and Conant 1978, 1979, 1980, 1982.

Southeast Alaska. Refuge reports estimate the number of oldsquaws wintering along the Aleutian Chain at 700,000 to 1 million and at 20,000 to 35,000 for the Izembek NWR on the Alaska Peninsula (Bellrose 1976). In addition, survey information suggests that approximately 65,000 oldsquaws winter in Kodiak bay and nearshore areas and that additional birds occur over the nearby continental shelf (Forsell and Gould 1981).

3. Surf scoter. Flocks of surf scoters are sometimes seen in the summer at various points along the south shore of the Alaska Peninsula and in the Aleutians (e.g., Stepovak Bay, Unalaska Island, Akun Island). Approximately 5,000 birds winter around Kodiak (ibid.). Surf scoters have also been found wintering in limited numbers along the southwest coast of the Alaska Peninsula and (to some extent) in the Aleutians (Gabrielson and Lincoln 1959).
4. White-winged scoter. Approximately 250,000 white-winged scoters winter in the Aleutian Islands as far west as Amchitka (Bellrose 1976). At Dutch Harbor, Cahn (1947) recorded white-winged scoters as common residents from December to February. Density indices from a February cruise indicated that 29,000 scoters winter in Kodiak bays, and it is believed that 35,000 birds would be a conservative estimate were birds along the outer coasts enumerated. It is also suspected that many additional thousands of white-winged scoters winter over the shallow shelf surrounding Northern Afognak and the Trinity Islands (Forsell and Gould 1981).
5. Black scoter. The largest number (157,000) of breeding black scoters occurs on the Yukon Delta, followed by 75,000 on the

breeding grounds adjacent to Bristol Bay (King and Lensink 1971). In addition, Edgar Bailey reported that black scoters nest at the Izembek NWR near the tip of the Alaska Peninsula and probably at nearby Unimak Island. From there west in the Aleutians they are rare summer residents, probably nonbreeding yearlings. In July, molting occurs in large flocks in the nearshore waters from Cape Romanzof south to Cape Pierce. During September and October these assemblages begin departing from this area and are found then along the south side of Bristol Bay and in coastal lagoons (King and Dau 1981). King and McKnight (1969) reported some 180,000 scoters, mostly black scoters, in the nearshore waters of Bristol Bay in October 1969. Wintering black scoters have been observed along the Alaska Peninsula, and an estimated 250,000 birds winter in the Aleutian Islands (Bellrose 1976). In addition, an estimated 30,000 black scoters winter in bay and nearshore habitats of Kodiak Island (Forsell and Gould 1981).

6. Barrow's goldeneye. The breeding range of Barrow's goldeneye in Alaska extends from the Yukon flats southwestward to Bristol Bay and the triangular area lying between there and the coast. Recoveries within Alaska reveal a migration southwestward from interior breeding grounds to the coast east of the Alaska Peninsula. Most of the recoveries centered around the Kenai Peninsula and Kodiak Island. A majority of Barrow's goldeneye winter along the Pacific Coast from between Cold Bay and Kodiak Island south to San Francisco Bay (Trapp, pers. comm.). They appear to winter in concentrations on Kodiak and Afognak islands from November through April (Gabrielson and Lincoln 1959). Approximately 7,036 goldeneye, including *B. clangula*, were observed in the nearshore waters of the Kodiak archipelago during November and February surveys (Forsell and Gould 1981).
7. Common goldeneye. The common goldeneye winters along the Aleutian chain to its western tip and south through the bays and inlets of the Gulf of Alaska to California. Reports from the national refuges in Alaska on waterfowl populations for September-December 1967-1969 listed 2,000 to 6,000 goldeneyes (species not given) on Kodiak Island, 25,000 common goldeneyes in the Izembek area, and 20,000 common goldeneyes on the Aleutian Islands (Bellrose 1976).
8. Bufflehead. On the Pacific coast, buffleheads winter from Adak, Alaska, to Washington. Reports from Alaskan refuges indicate that winter populations on the Aleutian Islands NWR average about 8,500, 2,000 at Izembek, and 4,500 to 5,000 at Kodiak (Bellrose 1976, Forsell and Gould 1981). According to Gabrielson and Lincoln (1959), early dates of arrival on Alaskan wintering areas are October 1 on Unalaska and October 17 in Cold Bay.
9. Red-breasted merganser. Although red-breasted mergansers breed over most of Alaska, including the Aleutian Islands, they are most abundant in areas adjacent to the Bering Sea (Gabrielson and Lincoln 1959). Aerial surveys by the USFWS show that of the

3,000 mergansers north of the Alaska Peninsula, 840 occur around Bristol Bay (Bellrose 1976). Approximately 1,000 red-breasted mergansers winter around Kodiak Island (Forsell and Gould 1981), while smaller numbers appear as far west as the islands of Adak and Amchitka in the Aleutians (Gabrielson and Lincoln 1959).

10. Common merganser. This large merganser is a common, year-long resident of Alaska from Kodiak south and east and is found less commonly as a summer resident on the Alaska Peninsula and in the interior valleys (ibid.). An estimated 500 common mergansers winter in Kodiak, with the largest numbers found in nearshore areas of Chiniak Bay (Forsell and Gould 1981).

11. Steller's eider. Steller's eiders breed predominately north of the Bering Strait along the coastal plains of the eastern Soviet Arctic and Alaska (King and Dau 1981), although population reports for May to August 1967-1969 at the Izembek NWR averaged 27,000 birds (Bellrose 1976). Steller's are found in spring and fall in enormous flocks in the lagoons of Bristol Bay and the Alaska Peninsula. A molt migration into this area from northerly nesting and/or staging areas in the Soviet Arctic and probably Alaska occurs in the late summer (King and Dau 1981). Subadult Steller's eiders usually move during June and July to Nelson Lagoon, Port Heiden Bay, Seal Islands Lagoon, and Izembek Lagoon, whereas adults arrive in August. More than 60,000 birds have been reported at Nelson Lagoon, and tens of thousands of birds have been observed in the other lagoons during the mid-July-to-mid-October molting period (BBCMP 1983). In the winter, Steller's eiders are common in the vicinity of Kodiak Island, the south side of the Alaska Peninsula, and the eastern Aleutian Islands (King and Dau 1981). Wintering populations of Steller's around Kodiak appear to vary, depending on the weather patterns in other areas. For instance, approximately 1,500 to 2,000 birds wintered in the Kodiak area during the winter of 1976-1977, whereas 320 birds were counted on a coastal survey during the winter of 1979-1980 (Forsell and Gould 1981). Population estimates (Jones 1965) place about 200,000 Steller's eiders during the winter along the west half of the Alaska Peninsula in Nelson Lagoon and in Izembek and Bechevin bays.

12. Pacific common eider. Pacific common eiders are found in the Southwest Region throughout the year. They commonly nest in localized areas along the northside of the Alaska Peninsula and the Yukon Delta (King and Dau 1981). Birds nest on fox-and bear-free barrier islands near major lagoons on the north side of the peninsula and on islands along the south side of the peninsula (BBCMP 1983). Approximately 1,700 common eiders nest in the Bristol Bay region. In addition, although the numbers of eiders breeding in the Aleutian Islands are unknown, they do occur from Unalaska to Attu (Bellrose 1976). During the winter, the common eider inhabits the nearshore waters of the Alaska Peninsula and Aleutian Islands. Nearshore waters of the Pribilof Islands remain ice-free and support wintering birds also (King and Dau 1981). A winter population of 400-500 common

eiders is thought to inhabit the Kodiak area (Forsell and Gould 1981).

13. King eider. The King eider does not nest in onshore areas of the eastern Bering Sea, but during spring migration they are seen in flocks of tens of thousands in shallow waters of Bristol Bay and its lagoons. In the winter, king eiders utilize the nearshore waters of the Alaska Peninsula and the Aleutian and Bering Sea islands (King and Dau 1981). Refuge reports indicate that a population of 190,000 to 220,000 winter adjacent to the Aleutian Islands and that another 3,000 winter at the Izembek NWR (Bellrose 1976). Wintering birds have also been reported in the vicinity of St. Paul and St. George islands in the Pribilofs (Gabrielson and Lincoln 1959). Estimates from winter surveys indicate a maximum of about 13,000 eiders in Kodiak bays during the 1979-1980 winter season. Many thousands also may occur over the shallow continental shelf around the Trinity Islands and northern Afognak Island (Forsell and Gould 1981).
14. Harlequin duck. The harlequin duck nests by the fast-running clear streams associated with trout and grayling and is never seen in the freshwater habitat associated with most ducks. Since for this reason it does not appear in normal breeding-ground surveys, population figures are speculative (King and Dau 1981). Federal refuge reports, however, indicate a summer population of 100,000 to 150,000 birds on the Aleutian Islands Unit, Alaska Maritime NWR (Bellrose 1976).

    Harlequins are never seen in migration, but after nesting they are found at the margin of the sea, where they remain most of the year. They are well camouflaged and hence difficult to see from any distance. In general, harlequin ducks are recorded throughout the Bering Sea, often far from land, and around all the islands (King and Dau 1981).

    On the west coast of North America, harlequins winter in greatest numbers in the Aleutian Islands. Refuge reports imply that the entire spring-fall population of 600,000 to 1 million birds winter there (Bellrose 1976), although the records are unclear because few of the islands have been surveyed through the winter months (Zeillemaker, pers. comm.). On the Izembek NWR, the winter population is only about 500 to 1,500 birds (Dau, pers. comm.).

    In the Kodiak area, harlequin ducks are inconspicuous inhabitants of rocky coastal habitats. Of an estimated 9,600 birds, many are permanent residents nesting in freshwater habitats. In the winter, the largest concentrations of ducks are found in the Sitkalidak Narrows-Midway Bay area and between Ugak Island and Narrow Cape (Forsell and Gould 1981).

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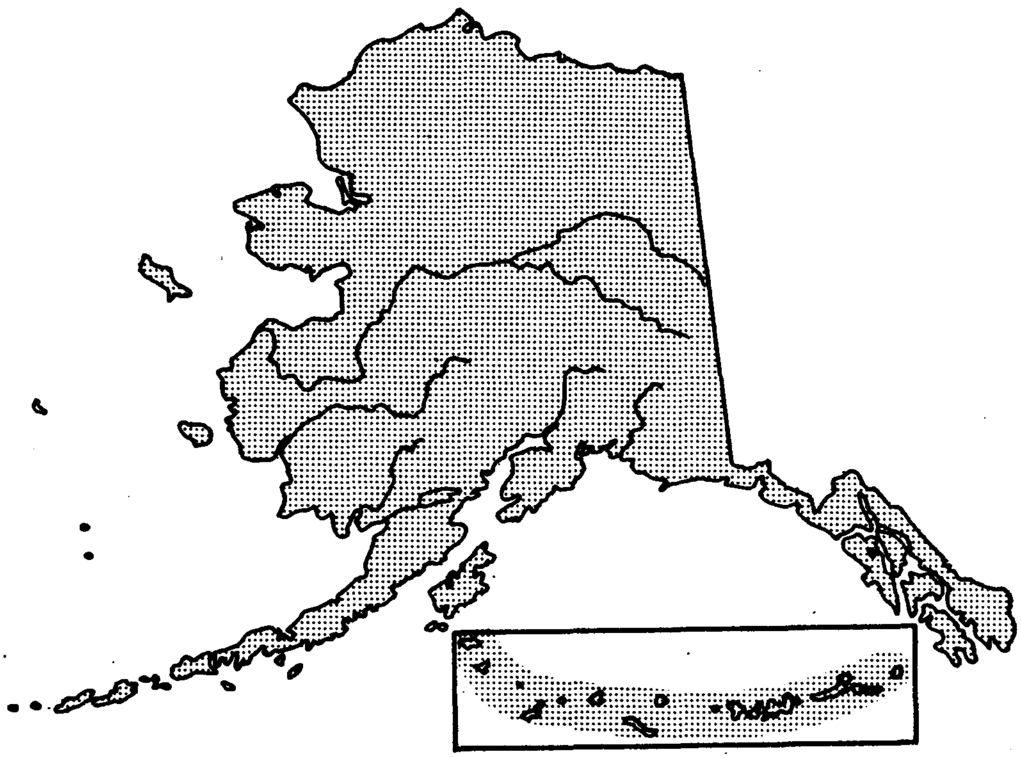
Geese Life History



Map 16. Range of geese (Bellrose 1976)

I. NAME

A. Common Names: Geese and brant

B. Scientific Classification

1. Family. Anatidae.
2. Subfamily. Anserinae.
3. Tribe. Anserini.

C. Species Commonly Known to Occur in the Southwest Region

In the Southwest Region, goose populations are comprised primarily of the greater white-fronted goose (*Anser albifrons*); the lesser snow goose (*Chen caerulescens*); 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*).

II. RANGE

A. Worldwide

Geese are found in nearly all north temperate and arctic zones.

B. Statewide

Geese are found throughout the state where suitable habitat is available.

C. Regional

In general, geese are distributed throughout the Southwest Region at elevations below 500 ft (Sellers, pers. comm). Estuaries, lagoons, river deltas, marshes, and tidelands, however, support the largest concentrations of geese. Similarly to ducks, the largest concentrations of geese occur in the Bristol Bay area during spring and fall migrations; Kodiak and the Aleutian Islands remain important wintering areas.

III. PHYSICAL HABITAT REQUIREMENTS

Geese are usually found where lagoon water and embayment habitat is plentiful. Brant are primarily restricted to lagoon water where eelgrass is found. Canada and snow geese use alluvial floodplains, whereas emperors use lagoonal island sand and protected delta mud (Arneson 1980).

IV. NUTRITIONAL REQUIREMENTS (table 10)

A. Preferred Foods

Geese are predominantly vegetable and berry eaters, although some species do consume small quantities of mollusks, crustaceans, and other animal material. Whereas brant forage exclusively on aquatic life, other geese rely largely on terrestrial herbaceous plants (Johnsgard 1975).

B. Feeding Location

Geese are mainly grazers and forage both in water and on land.

C. Feeding Behavior

Geese are essentially grazers, and they crop vegetation with their bills. 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 (Terres 1980).

V. REPRODUCTIVE CHARACTERISTICS (table 11)

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 for the incubating bird.

B. Reproductive Seasonality

The span of nest initiation varies among species and is sometimes dependent on snow conditions. In years when snow cover persists later into the season, nesting efforts may be delayed.

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

Table 10. Preferred Foods and Breeding Habitat of Geese in the Southwest Region

Species	Preferred Food	Breeding Habitat
Pacific white-fronted goose	Plants used include vegetative parts of various native grasses and sedges (Johnsgard 1975)	Nests on both tidal flats and upland areas, typically in tall grass bordering tidal sloughs or in sedge marshes and less often in grass-covered pingos or the margins of tundra hummocks. Infrequently, they nest on heath tundra, sometimes as far as 50 to 100 yds from water (Bellrose 1976)
Lesser snow goose	Diet consists primarily salt marsh vegetation; berries and grasses are often important diet in upland areas (Bellrose 1976)	Usually locate nesting colonies on low grassy tundra plains within a few miles of the sea, along broad shallow rivers near coast, and on islands in shallow lakes 10 - 80 mi inland (Bellrose 1976)
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 (Barry 1976)	Tend to nest slightly inland on coastal fringe from black brant; almost all nest within several hundred yd of tidal waters that may extend up to 30 or 40 mi inland tidal grasslands, low pingo tundra, and sedge marshes (Bellrose 1976)
Pacific black brant	Eelgrass most important food; when scarce or unavailable, brant use rockgrass and sea lettuce (Bellrose 1976)	Nesting on Yukon Delta confined either to extreme coastal rim or to areas along major estuaries flanked by tidal meadows; nests on delta 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 1976)

(continued)

Table 10 (continued).

Species	Preferred Food	Breeding Habitat
Canada goose	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	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; cackling geese use pond-studded tundra of coastal Yukon coastal Yukon Delta, select islets for 81% of nest sites, islets average 5 - 11 ft in size and 8 inches in height; 16% nested on small peninsulas extending into tundra ponds, but only 3% placed nests on mainland shore (Mickelson 1973)

Table 11. Breeding, Rearing, and Molting Biology of Geese in the 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	2-10	4.75	First breed at 3 yr; favorable nest conditions may induce some 2-yr-olds to breed (Barry 1966)	55-65 days	Adult molt begins when goslings about 3 weeks old (Bellrose 1976)	4 weeks (Mickelson 1973)
Lesser snow goose	Nest may require several years to reach final form (Cooch 1958); beginning nests little more than scrapes in moss or gravel, enlarged by females as eggs are laid; moss, willow, and grass added to old nests to form fairly substantial raised structures (Bellrose 1976)	Mating apparently occurs during northward migration, particularly at rest stops immediately preceding their last passage to nesting grounds (Bellrose 1976)	23 days (Cooch 1958)	2-10 (Bellrose 1976)	3.9	Reach sexual maturity at 2 yr; majority do not breed until 3rd yr and in some seasons not until 4th yr (Bellrose 1976)	45 days (Cooch 1958)	Adults molt about 2.5 weeks after young hatched (Barry 1966)	About 24 days (Cooch 1958)
Emperor goose	Prefer to nest on an elevated site near tidal pond; nest 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. comm.)	23-27 days (Eisenhauer & Frazer 1972)	1-12	4.83	The age at breeding is 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)	3rd 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)	40-46 days (Barry 1966)	Adults molt 2 weeks after eggs hatched (Barry 1966)	3 weeks, controlled by day length (Barry 1966)
Canada goose	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	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 (Hall and McGilvrey, Mickelson 1973); some 2-yr and probably all 3-yr-olds nest	40-46 days (Mickelson 1973)	Adults molt when goslings are 1 to 2 weeks old (Mickelson 1973)	3-4 weeks (Mickelson 1973)

colonies each year, where they establish a territory prior to nesting. The size of the territory varies by species and within a species, according to the demands made upon the available space. White-fronted geese are an exception, as they do not nest in colonies, nor are they militant territorialists (Bellrose 1976).

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.

E. Fecundity

The number of eggs per clutch varies among species but ranges between 1 and 12 eggs, the average size being between 3 and 5 eggs.

F. Incubation Period

The incubation period varies by species but usually averages between 23 and 30 days.

G. Rearing of Young

Both parents are solicitous of their young, the male principally assuming the role of guarding them from predators (ibid.).

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

A. Staging

Staging areas in the Southwest Region are usually associated with productive estuaries, river deltas, lagoons, marshes, and tidelands, where a variety of plant and animal material is present. Staging areas provide high-quality feeding habitat where geese can restock their energy reserves in preparation for breeding (in the spring) and migration/wintering (in the fall).

B. Migration

The majority of the geese that migrate to and from Alaska utilize the Pacific Flyway. The timing of migration varies with the species and the annual variations in weather conditions.

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

Species composition and numbers for the Alaska population of geese 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).

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 estuarine and/or lagoonal habitat
- Alteration of nesting habitat
- Dredging/filling/draining of wetlands
- Disturbance on fall/spring staging areas

- Disturbance during nesting/abandonment of goslings
- Oiling of feathers
- In-flight hazards (e.g., transmission lines, towers)
- Harvest

VIII. SPECIAL CONSIDERATIONS

A. Molting

The first geese to molt are usually the subadults, followed by mature breeders that failed to nest successfully, and then by successful breeders. For breeding birds, the molt is initiated when the goslings are between one and three weeks old, varying by species. Geese are flightless for approximately three to four weeks.

IX. LEGAL STATUS

In Alaska, waterfowl are managed under the International Migratory Bird Treaty Act of 1918 as implemented by the U.S. Fish and Wildlife Service and the Alaska Department of Fish and Game.

X. DISTRIBUTION

Several varieties of geese inhabit the Southwest Region on either a year-round or seasonal basis. As is true of ducks, the largest concentrations of geese occur in the area during the spring and fall migrations. Most of the geese migrating to and from Alaska utilize the Pacific Flyway. The timing of migration varies with the species and with annual variations in weather conditions.

A. Timing of Movements

Staging areas in the Southwest Region are usually associated with productive estuaries, river deltas, lagoons, marshes, and tidelands, where a variety of plant and animal material is present. Geese generally congregate in spring staging areas during April and May. The greatest fall concentrations of geese typically occur during September and October. Particularly important staging habitats include 1) the Naknek River delta, 2) Egegik Bay, 3) Ugashik Bay, 4) the Cinder River delta, 5) Pilot Point, 6) Nelson Lagoon, 7) Port Heiden, and 8) the Izembek Lagoon complex.

A majority of the geese move northward to nest, although some remain in the region to raise their young. The most prevalent nesting species is considered to be the white-fronted goose. The timing of nest initiation varies among species and is sometimes dependent on snow conditions.

XI. ABUNDANCE

In the Southwest Region, geese populations are comprised primarily of the greater white-fronted goose (*Anser albifrons*); the lesser snow goose (*Chen caerulescens caerulescens*); the emperor goose (*Philacte 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*) (ADNR/USFWS 1983, Bellrose 1976).

A. Species Accounts

1. Greater white-fronted goose. The Nushagak and Naknek rivers, Egegik Bay, and other tidelands and marshes along northern Bristol Bay are all spring staging areas where over 25,000 white-fronted geese may gather during April and early May. Based on spring aerial surveys, it is estimated that 4,000 breeding white-fronted geese inhabit the Bristol Bay lowlands like those found along the Nushagak drainages (ADNR/USFWS 1983). Areas in the Southwest Region used during the fall migration and as fall staging areas (September-October) include Pilot Point, Egegik, Cinder River, and the Nushagak River delta.
2. Lesser snow goose. The snow geese that use the Southwest Region primarily belong to the Wrangell Island, Siberia, breeding population. Concentrations of snow geese in the region are greatest during the fall (Bellrose 1976). In the past, on any given day during late September and early October, up to 15,000 snow geese might stage in the combined areas of Egegik, Cinder River, and Pilot Point (Timm, pers. comm.). However, over the past four years fewer than 150 birds, total, were counted at these three areas (Sellers, pers. comm.). In upper Bristol Bay, snow geese stage at Chagvan and Nanvak bays (Dau, pers. comm.). Relatively few birds stop over in the region during the spring migration. Those that do are generally found in marshes along the Nushagak and Kvichak river drainages during the first three weeks of May (Timm, pers. comm.).
3. Emperor goose. Although few emperor geese, if any, nest within the Southwest Region, the lagoons and estuaries of Bristol Bay are used extensively as spring and fall staging areas. Izembek Lagoon, Nelson Lagoon, Seal Island Lagoon, Port Heiden, and the Cinder River delta are the most important spring and fall staging areas on the north side of the Alaska Peninsula. Ugashik and Egegik bays are also used by a few emperors in the spring. Key fall staging areas on the south side of the Alaska Peninsula include Stepovak, Chignik, and Wide bays (ADNR/USFWS 1983).

   Numbers of emperor geese using the Alaska Peninsula have been estimated from USFWS spring and fall aerial surveys. Counts made in the fall of 1981 revealed 63,156 emperors on the peninsula; however, it should be recognized that some birds had probably migrated west into the Aleutians before the surveys were completed. Spring 1982 accounts revealed approximately 100,000 emperors along the peninsula (ibid.).

   Most emperors winter in bays and estuaries from Port Moller west along the Aleutian Islands to Kamchatka Peninsula in the USSR. The Cold Bay/Izembek area generally is the northernmost wintering area for emperors, but during mild winters birds may initiate their winter season as far north as Port Moller. In addition, some birds, approximately 2,000 to 3,000, cross the

Alaska Peninsula and winter along the coast of Kodiak Island (Bellrose 1976).

4. Pacific black brant. Black brant do not nest in the Southwest Region, but the area is critical to brant during spring and fall migrations. Virtually the entire world population of the species (150,000 birds in 1983) stages at Izembek and adjacent lagoons near the tip of the Alaska Peninsula from September through early November. Lesser numbers of brant also use Izembek Lagoon and adjacent lagoons and bays during the spring (Timm, pers. comm.). During years when weather conditions are mild, up to 10,000 brant may winter in the Izembek National Wildlife Range (Dau, pers. comm.).

5. Canada geese:

   a. Cackling Canada goose. Use of the Southwest Region by cackling geese is limited to the migration periods. Although cacklers generally stage during the spring in the interior areas of Alaska, they are occasionally observed along the northern coast of the Alaska Peninsula. During the fall migration, a large percentage of the cacklers (estimated 1982 population, 75,000 to 100,000 birds) stage in the bays and estuaries that surround Bristol Bay (ADNR/USFWS 1983). The most heavily used areas are Ugashik Bay, Cinder River/Hook Lagoon, and Port Heiden; other key use areas include Nanvak Bay, Osviak Bay, Ilnik Lagoon, and other small estuaries of the Alaska Peninsula (Sellers, pers. comm.; Timm, pers. comm.).

   b. Aleutian Canada goose. The Aleutian Canada goose once nested in the outer two-thirds of the Aleutian Islands (Bellrose 1976). In recent years, however, since the introduction of the arctic fox to most of the Aleutian Islands, the main breeding population is found on Buldir Island, near the tip of the Aleutian chain. In June 1982, a new or remnant breeding population of unknown size was discovered on Chagulak Island in the Island of Four Mountains (Aleutian Canada Goose Recovery Team 1982). And, finally, a population of geese that appears to be taxonomically intermediate between the Aleutian Canada goose and Taverner's Canada goose breeds on Kaliktagik Island in the Semidi Island group (ibid). Upon leaving Buldir Island in the fall, some Aleutian geese may migrate eastward along the Aleutian chain for almost 1,000 mi before heading to their wintering grounds in California (Dau, pers. comm.).

   c. Taverner's Canada goose. The Taverner's goose stages in Bristol Bay coastal lagoons prior to fall migration. Key fall staging areas include Izembek Lagoon, Nanvak Bay, Port Moller lagoons, Morzhovoi Bay; and Kinzarof, Nurse, and Mortensen lagoons in Cold Bay (ADNR/USFWS 1983). Between 75,000 and 100,000 birds are believed to stage in the Izembek Lagoon complex generally during September and October. A peak count of 74,500 birds was recorded in

1974, but annual counts do not cover the entire migration period (Timm, pers. comm.).

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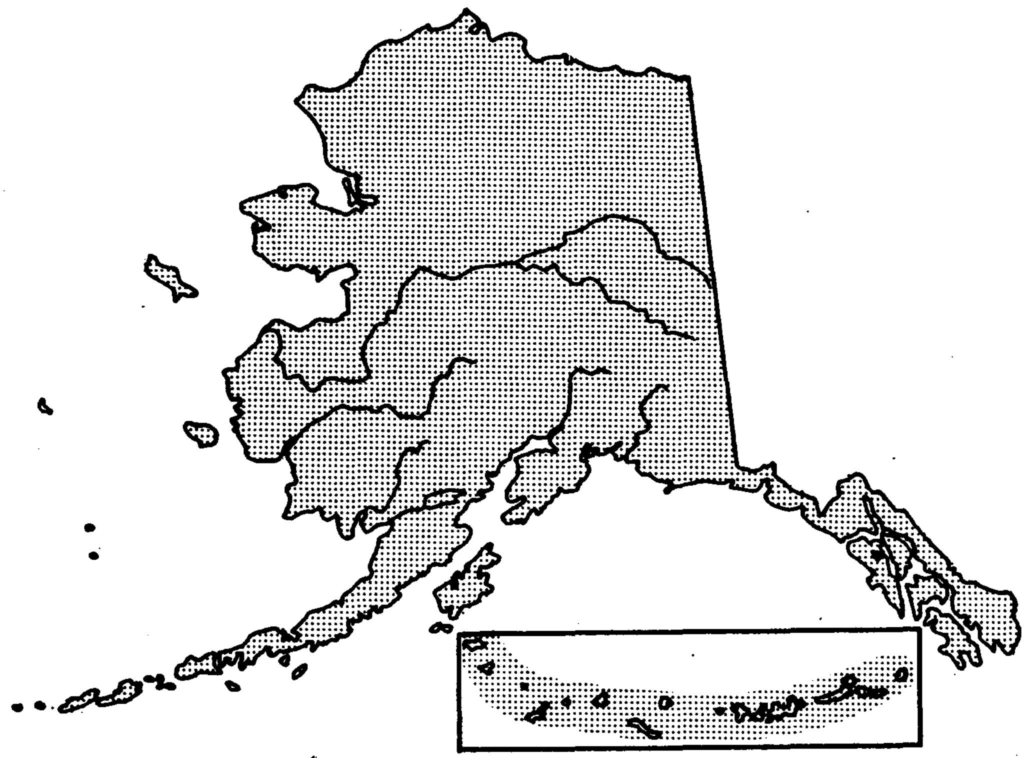
Tundra Swan Life History



Map 17. Range of tundra swan (Bellrose 1976)

I. NAME
   A. Common Names: Tundra swan, whistling swan
   B. Scientific Name: Olor columbianus

II. RANGE
   A. Worldwide
      1. Breeding range. Tundra swans nest in arctic North America, with the greatest density along the arctic coastal strip from the west side of Mackenzie Delta to the east side of Anderson Delta. Swans also nest on islets off the shores of shallow lakes or flooded tundra from north Alaska south to the Alaska Peninsula (Terres 1980).
      2. Wintering areas. Tundra swans winter from the Aleutians south along the Pacific Coast to extreme northern Baja California; and on the Atlantic coast rarely from Massachusetts, New

Jersey, and Long Island, N.Y., but mainly Chesapeake Bay, Md., south to Currituk Sound, North Carolina; rarely to Florida and the coasts of Louisiana and Texas (ibid.).

B. Statewide

1. General distribution. Tundra swans are found throughout the state where conditions are suitable. Records extend from Attu Island on the west to Demarcation Point on the east (Gabrielson and Lincoln 1959).

2. Breeding range. The breeding range is from Unimak Island, Kodiak Island, and the northern part of the Alaska Peninsula to Cape Prince of Wales, Meade River, the Colville Delta, and Camden Bay (ibid.).

C. Regional

In general, tundra swans are distributed throughout the Southwest Region east of Unimak Pass at elevations below 1,200 ft (Sellers, pers. comm.). Major concentrations, however, are found in coastal and riverine habitats. Two populations of tundra swans utilize the area, one migratory, the other nonmigratory. When a majority of the swans have migrated to warmer climes, usually by mid September, a population of approximately 400 to 700 birds remains in the region wintering primarily at Peterson Lagoon in Urilia Bay, Unimak Island (Sarvis, pers. comm.).

III. PHYSICAL HABITAT REQUIREMENTS

In the summer, tundra swans occur primarily on coastal tundra areas dotted with small lakes (Timm 1975). During spring and fall migrations, swans utilize river deltas and outlets as well as lagoons and estuaries. Recent studies on coastal migratory bird habitats showed that of the available habitat types swans preferred protected delta water and salt marshes (Arneson 1980).

IV. NUTRITIONAL REQUIREMENTS

A. Preferred Food

Tundra swans feed largely on the leaves, stems, and tubers of aquatic and marsh plants (Bellrose 1976). Berries, particularly lowbush cranberry and blueberry, are also important (Sellers, pers. comm.).

B. Feeding Locations

Swans usually feed in shallow water where immersion of the head and neck is sufficient to enable them to obtain the desired food items (Bellrose 1976). They also graze along the margins of lakes and ponds (Scott 1972); during the spring and fall, tundra areas near lakes are used for foraging on berries (Sellers, pers. comm.).

C. Feeding Behavior

When feeding, large flocks of swans will usually break up into family units of three to six individuals (Bellrose 1976).

V. REPRODUCTIVE CHARACTERISTICS

A. Breeding Habitat

Hummocks located on peninsulas and islands are preferred nesting areas. Most swan nests are in heath tundra, which not only dominates the nesting grounds but also provides most of the elevated sites used by swans. The nest is an elaborate platform, 12 to 18 inches high, composed of moss, grass, and sedges, and resembling a muskrat house surrounded by a moat (Lensink, pers. comm.).

B. Breeding Seasonality

According to Lensink (pers. comm.), the first swans reach their breeding grounds on the Yukon Delta in late April, and almost all have arrived by mid June. During warm years, when the snow melts early, nesting begins soon after the arrival of the flocks on the outer delta, usually by mid-to-late May (Bellrose 1976). Tundra swans, however, frequently arrive on breeding grounds before the snow has melted (Scott 1972), and in those years the date of nesting is delayed, perhaps until early June. Inland from the coast, where the snow melts earlier, nesting occurs earlier (Bellrose 1976).

C. Breeding Behavior

1. Swans are territorial in their nesting behavior. In Alaska, tundra swans nest at densities varying between 0.4 and 1.0 pairs/km^2 (King and Dau 1981).
2. Sexually mature adults normally pair for life, sharing the responsibilities of nest care, incubation, and rearing of the young.
3. Traditional ponds and lakes are used for nesting, with birds often returning to the same nest sites. In making the nest, swans pluck the vegetation from around the nest site, creating a circle of open water or disturbed ground up to 15 ft in diameter (Bellrose 1976; Sarvis, pers. comm.).

D. Age At Sexual Maturity

Although swans mature in their third year, most do not establish a territory and breed before their fifth or sixth summer (Scott 1972; Sarvis, pers. comm.).

E. Fecundity

The average number of eggs per clutch is three to five, with a hatch success of approximately 75%. Differences in clutch size appear attributable to the timing of the snowmelt. The later the birds commence nesting, the smaller the clutch (Bellrose 1976). In the Izembek area, clutch size is from three to nine eggs, with hatching success varying from 36% to 50% (Sarvis, pers. comm.).

F. Incubation Period

The incubation period is approximately 30 to 33 days; peak hatching occurs about mid June (Bellrose 1976; Sellers, pers. comm.; Sarvis, pers. comm.).

G. Rearing of Young

Both parents guard the welfare of their young. On the Yukon Delta, broods stay within 100 to 400 yd of their nests for a considerable length of time after hatching (Bellrose 1976). In the Izembek area, some broods travel up to 2 mi from the nest lake to the brood rearing lake, whereas others raise broods on the same lake where they hatched (Sarvis, pers. comm.).

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

A. Staging

In late August, when the birds have regained their flight capabilities, they congregate along the coast or near large inland lakes in preparation for the move to wintering areas. River outlets and deltas such as the Naknek River, as well as the lagoons and estuaries in Bristol Bay, are used by spring and fall migrants. In the fall in the Izembek area, the nonmigratory swans gather into flocks and begin a gradual shift to Peterson Lagoon on Unimak Island (ibid.).

B. Migration Behavior

Tundra swans migrate as family units, with several families and probably some nonbreeding birds combining into a single flock (Bellrose 1976).

C. Migration Routes

1. Fall migration. The migrating population of tundra swans leaves the Southwest Region from September through October (Sellers, pers. comm.). The peak fall migration occurs in mid October (ibid.). They move south along the coast to Vancouver Island and the small bays along the coasts of Washington and Oregon. Tundra swans begin arriving at their wintering grounds about mid-to-late November (Bellrose 1976).
2. Spring migration. Swans begin leaving their central California winter grounds in mid February. By mid March they are leaving the Klamath Basin, and by late March, the higher Malheur and Great Salt Lake basins. The western population of tundra swans migrates earlier and more swiftly than its eastern counterpart. The Naknek River near King Salmon supports 1,000 or more swans in early spring (King, pers. comm.). According to Lensink (pers. comm.), the first swans reach their breeding grounds on the Yukon Delta in late April, and almost all have arrived by mid May (Bellrose 1976).

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

Survival of young to the flight stage (60 to 70 days) is greatly affected by severe weather, predator populations, and possibly diseases (Sarvis, pers. comm.).

B. Human-related

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

- ° Pollution of water and/or food
- ° Reduction of food supply
- ° Alteration of freshwater habitat
- ° Alteration of nesting habitat
- ° Dredging/filling/draining of wetlands
- ° Disturbance of fall/spring staging areas
- ° Oiling of feathers
- ° In-flight hazards (e.g., transmission lines, towers)

VIII. SPECIAL CONSIDERATIONS

A. Molting

Molting is a once-a-year phenomenon that occurs in the mid-to-late summer, following the nesting period. The birds are flightless for a period of 20 to 25 days (ibid.).

IX. LEGAL STATUS

In Alaska, waterfowl are managed under the International Migratory Bird Treaty Act of 1918 as implemented by the U.S. Fish and Wildlife Service and the Department of Fish and Game.

X. DISTRIBUTION

Tundra swans are distributed throughout Alaska primarily on coastal tundra areas dotted with small lakes (Timm 1976). Distribution records exist for the area extending from Attu Island on the west to Demarcation Point on the east (Gabrielson and Lincoln 1959). River deltas and outlets, as well as lagoons and estuaries, are the most intensively used habitats within the region.

A. Timing of Movements

Migrating tundra swans begin to arrive on the Alaska Peninsula in early spring, generally from April to May. Swans that winter on the Aleutian Islands begin arriving at Izembek Refuge in mid March (Sarvis, pers. comm.). The first swans reach their breeding grounds on the Yukon Delta in late April, and almost all have arrived by mid May (Bellrose 1976).

Initiation of nesting appears to be closely related to the timing of the snowmelt. During warm years, swans may begin nesting around mid May. In years when snow cover persists later into the season, nesting efforts may be delayed until early June. The Izembek Refuge, Mortensen's Marsh, and Cathedral River Valley are heavily utilized nesting areas at the end of the Alaska Peninsula. In upper Bristol Bay, the Ugashik and Pilot Point areas are prime nesting areas (Sarvis, pers. comm.). Nesting concentrations also occur on Kodiak Island.

In late August, following the nesting period and annual molt, tundra swans again congregate in coastal and riverine habitats to stage. Wetlands, such as those along the Naknek River, that supported staging swans during the spring are again used during the fall, although possibly to a lesser degree. Migratory swans generally leave the region from mid September through October.

XI. ABUNDANCE

The Bristol Bay area supports the second largest tundra swan breeding population in Alaska. Between 1972 and 1981 an average of 11,200 swans summered in this area, with a 10-yr high of approximately 20,400 swans in 1981 (Conant and King 1981). Smaller numbers of swans nest on Kodiak Island. An average of 20 to 25 nesting pairs have been seen on the island since 1980 (Zwiefelhofer, pers. comm.).

As a staging area, the Naknek River near King Salmon supports particularly high densities of swans. As many as 1,000 to 5,000 swans have been estimated in this area during the spring (ADNR/USFWS 1983; Sellers and Russell, pers. comm.). In the fall, approximately 80 to 100 swans are known to stage on Kodiak Island (Vivion, pers. comm.).

In addition to the migratory swans, there are approximately 600 birds that winter in the region. Overwintering occurs primarily at Peterson Lagoon in Urilia Bay, Unimak Island (Sarvis 1981); however, another group consisting of approximately 50 pairs winter in the vicinity of Mother Goose Lake (Sellers and Russell, pers. comm.).

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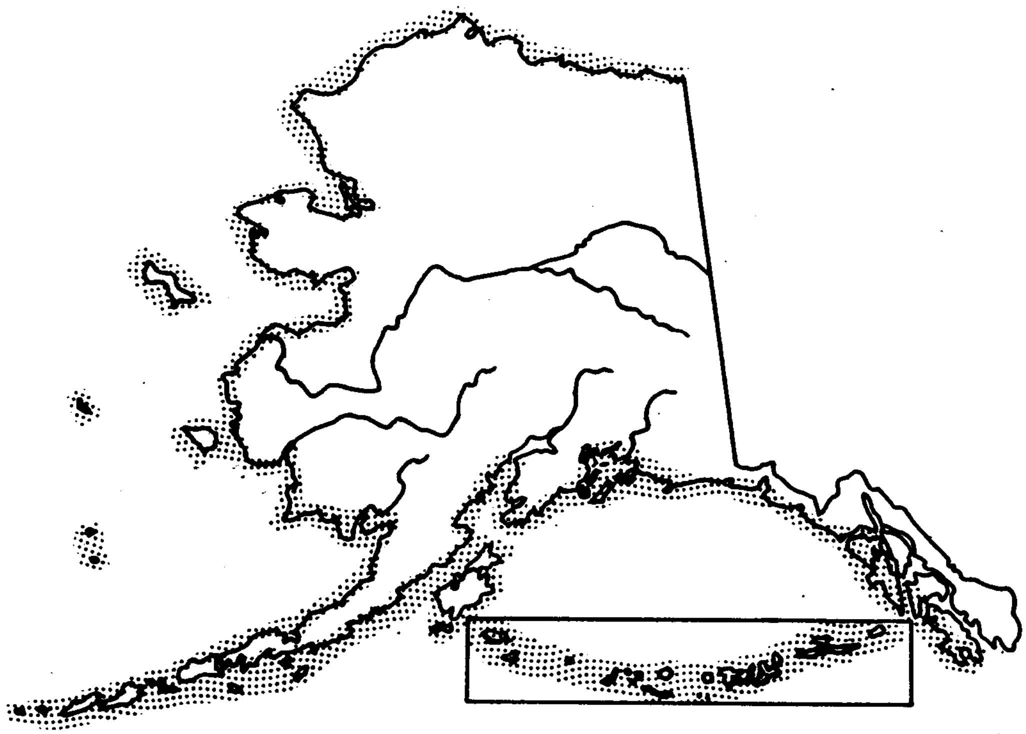
Seabirds Life History



Map 18. 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: tubenosed birds, including albatrosses, shearwaters, fulmars, storm-petrels; cormorants; gulls and terns; and alcids, which include murres, guillemots, murrelets, auklets, and puffins (Quinlan, pers. comm.).

II. RANGE

A. Statewide

1. At least 65 species of seabirds migrate, breed, or visit along Alaska's coastline and adjacent waters (Trapp, pers. comm.). For specific range information, see the Distribution and Abundance section.
2. 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. In the Bering Sea and Chukchi Sea region, fewer colonies are found; however, all are very large, many containing breeding populations exceeding a million birds (King and Lensink 1971).

3. In late fall, most seabirds migrate south, and populations in Alaskan waters become much reduced from those of summer (ADF&G 1978).

B. Regional
  1. 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.).
  2. In Southwest Alaska, over 98 colonies, or colony complexes, including 23 species of seabirds, have been recorded (Sowls et al. 1978). Of these, 34 colonies are located in the Gulf of Alaska. Fewer colonies occur on the south side of the Alaska Peninsula (ADNR/USFWS 1983).
    a. In Southwest Alaska, the common murre is one of the most important species, exceeding half the total population of colonial birds (ibid.).
    b. Black-legged kittiwakes are second in abundance to murres and are found primarily in colonies on the Walrus Islands, Cape Pierce, and Cape Newenham (ibid.).
    c. Tufted puffins are the third most abundant species in this area (ibid.).
    d. Cormorants are known to breed in at least 69 locations in the Bristol Bay area, although colony populations are rather small. The pelagic cormorant is the most abundant species in this area (ibid.).
    e. The widely distributed glaucous-winged gull is present in substantial abundance. They compose nearly 16% of the state's total gull population (ibid.).

III. PHYSICAL HABITAT REQUIREMENTS

See table 12.

IV. NUTRITIONAL REQUIREMENTS

A. Preferred Foods
   See table 12.

B. Feeding Locations
   See table 12.

C. Feeding Behavior
   See table 12.

V. REPRODUCTIVE CHARACTERISTICS

A. Breeding 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 (e.g., 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, herring gull, mew gull, and arctic tern are widely distributed throughout the interior along lakes, streams, and in moist tundra (ibid.). (See table 12.)

B. Nonbreeding Habitat

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).

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

Seasonal seabird movements vary considerably among species, ranging from strictly nocturnal to diurnal. Most seabird movements during the nesting season are related to food-gathering activities. Individual species must travel to areas where these food sources are available, and some range up to 20 mi or more in their searches. The nearshore waters of the Alaskan continental shelf provide substantial quantities of food species for most seabirds during the breeding season. After the breeding season, the adults and young of the year begin to disperse and spend time at sea following their food sources.

Winter forces most species to begin migrational movements south along the coast, or away from the coast for the pelagic species.

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

1. Disease and parasites have the potential to kill many birds, although study of this phenomenon is in its infancy in Alaska (ibid.).
2. Increasing gull populations could cause substantial damage (food-robbing and egg and young predation) to specific colonial species (such as terns and puffins), as they have on the Atlantic coast (Trapp, pers. comm.).

B. Human-related

1. Predators introduced in the late 1800's and early 1900's have had a devastating and long-lasting impact on Alaska seabird colonies throughout Southcentral and Southwest Alaska (ibid.).
2. Oil and gas developmental activities and the related possibility of marine oil pollution can pose a threat to seabirds. If properly regulated, however, offshore oil and gas development may not severely impact seabirds (Trapp, pers. comm.).
3. 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 (Trapp, pers. comm.).
4. Toxic chemical contamination of seabirds is a serious threat. The widespread distribution of a variety of pollutants in marine ecosystems is well documented (ibid.).
5. In Alaska, human disturbance in the form of tourism has not yet been a problem (ibid.). Properly organized and regulated

Table 12. Seabird Life Histories

Species	Preferred Foods	Feeding Location	Feeding Behavior	Incubation	Clutch Size	Nest Location	Sexual Maturity
Albatross, black-footed	Fishes, sea urchins, amphipods, and squids	Pelagic ocean surface	Feeds at night from the ocean surface	63-68 days; incubation by both sexes	1	Shallow scrape in the sand; when sharing location with the Laysan Albatross, b. footed nests on the outer edge of the colony	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	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	No data
Shearwater, slender-billed	Fishes	Ocean surface	Shallow dives from surface or catches fish near surface	52-55 days	1	In colonies, in burrows on coastal islands near Australia (does not breed in Alaska)	No data
Gulls, glaucous	Barnacles, mollusks, and sea urchins; they are scavengers, feeding on carrion fishes and garbage on docks, dumps, shores, or from ships	See Preferred Foods	See Preferred Foods	28-29 days	2-3, usually 3	Nests usually built of grasses, mosses, seaweed, on narrow ledges of steep cliffs facing the sea, usually near colonies of murres; also nests in lakes of the tundra or on coastal dunes	Approximately 4 yr

(continued)

Table 12 (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	Approximately 3 yr
Kittiwake, black-legged & red-legged	Small fish, crustaceans, or other invertebrates	Feeding occurs at or near the pelagic ocean surface; far from land both during and outside the breeding season	Hovers briefly before landing on ocean surface; or dives shallowly; assembles in large flocks to forage on scraps from ships	Avg. 27 days by both sexes	Black-leg: usually 2; red-leg: usually 1	Nests in large colonies on cliffs; some are found in fjords, often near glaciers	Approximately 2-3 yr
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 and catches prey; attracted to schools of fishes by actions of gulls; also dives into rough seas and surf near boulders to catch food	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	3-4 yr
Double-crested cormorant	Salt water: fishes, crustaceans, mollusks, seaworms. Freshwater: fishes, salamanders, reptiles, crustaceans	Surface of salt, brackish waters 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 brooded, but may re-lay if nest is destroyed	Nests in colonies on rocky islands, cliffs facing water, or stands of trees near water; ground nest material is seaweeds & trash; tree nest material is twigs, grass	3-4 yr

(continued)

Table 12 (continued).

Species	Preferred Foods	Feeding Location	Feeding Behavior	Incubation	Clutch Size	Nest Location	Sexual Maturity
Red-faced cormorant	Small fishes, crabs, shrimps	Rarely observed far away from land; dives in inshore waters	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	3-4 yr
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 or in the face of 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 on feeding waters and dives from surface; best diver among alcids, up to 240 ft	28-34 days; egg incubated in turn 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; nest site is in crevices, caves, or talus slopes of cliffs, abandoned burrows of puffins or rabbits	No data
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	No data

(continued)

Table 12 (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 or in natural rock crevices or abandoned burrows of other alcids	No data
Parakeet auklet	Amphipods or other small crustaceans	Ocean surface or rocky bottom at moderate depths	Flies out to sea in morning and returns 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	No data
Crested auklet	Amphipod crustaceans	Nearshore waters	Surface dives or can dive as deep as 200 ft	34-47 days; parents carry food to young in pouch under the tongue	1	Nests in colonies in crevices in cliffs, talus slopes, or under beach boulders	No data
Whiskered auklet	Amphipods, snails and crabs	Nearshore waters and passes in breeding season, 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	No data
Rhinocerous auklet	Small fish and crustaceans	Nearshore waters during breeding season	Nocturnal; at nest site dives from surface and uses wings to "fly" underwater	By both sexes 31-33 days	1	Nests in burrows from near shoreline to 400-500 ft up banks with sticks, grasses, for material; same mates and burrows are maintained from year to year	No data

visits to seabird colonies by tour groups can actually benefit seabirds by promoting public support for managerial efforts (ibid.).

VIII. LEGAL STATUS

All seabirds are protected year-round by United States federal laws.

IX. DISTRIBUTION AND ABUNDANCE

A. Least Auklet

1. Distribution. The least auklet breeding range is along the islands of the Bering Sea, the Aleutian Islands, and the southern coast of the Alaska Peninsula. The Semidi Islands mark the eastern border of their breeding range in the Gulf of Alaska (Sowls et al. 1978).

2. Abundance. The least auklet is perhaps the most abundant species of seabird breeding in Alaska. Sowls et al. (1978) listed 31 sites, with an estimated 3.4 million birds, and they believed the actual population of least auklets in Alaska to be about 6 million birds. Populations of least auklets are difficult to assess because of their overwhelming numbers, type of nesting habitat, and marked fluctuations in colony attendance.

The largest colonies of least auklets are those at Little Diomede Island (111 009), St. Lawrence Island (093 001 and 093 005), St. George Island (038 001), Gareloi Island (016 015), and Sirius Point (014 002), containing from 250,000 to nearly 1 million birds each (ibid.).

a. Aleutian Islands. There are nine known breeding colonies of least auklets in the Aleutians, with a minimum population of 906,000. The three largest colonies occur on the following islands: Gareloi (016 015) 402,000; Sirius Point, Kiska (014 002) 250,000; and Buldir (014 001) 100,000 birds (ibid.).

b. Alaska Peninsula area. This area has two known sites, only one of which has a population estimate. Least auklets are known to be present at Castle Rock (027 014) in the Shumagin Islands, but no population estimates have been attempted. Chowiet Island (031 003) in the Semidi Islands has a few least auklets present (ibid.).

No least auklet breeding sites are known to occur in the Kodiak area (Hatch and Hatch 1983). Small numbers may breed at Round Island (040 001) in northern Bristol Bay (Sowls, pers. comm.).

B. Whiskered Auklet

1. Distribution. Whiskered auklets nest in the Aleutian Islands, on Komandorskie Island in the Bering Sea, and the southern Kuriles north of Japan (Terres 1980). They have declined or disappeared in the Near Islands (Murie 1959) and historically have bred in the Kurile and Commander islands, as well as throughout the Aleutians (ibid.).

Whiskered auklets are the rarest of the auk family in Alaska and are known or suspected to breed in small or moderate numbers on islands of the Aleutian chain from Buldir Island (014 001) east to Unimak Pass.

2. Abundance. Population estimates for whiskered auklets in Alaska are suspected to be low because undiscovered breeding populations undoubtedly exist (Trapp, pers. comm.). The total population of whiskered auklets breeding in Alaska is estimated to be about 50,000 birds (Nysewander, pers. comm.). All known colonies occur in the Aleutian Islands. At least 33 islands are known breeding sites (Nysewander et al. 1982). The paucity of data on this species is probably due to its breeding habit; it is highly nocturnal at the nest site (Trapp, pers. comm.). Trapp (pers. comm.) suspects that whiskered auklets will eventually be found nesting on every island in the Aleutians where suitable habitat exists. More recent surveys in the eastern Aleutians have found an estimated 10,000-15,000 breeding auklets in the Fox Islands (025 028) (Byrd and Gibson 1980, Nysewander et al. 1982). The most important concentration occured in the Avatanak Strait area, in which several thousand auklets were regularly seen in flocks. Other concentration areas noted occurred in the Baby Islands (023 003) and at Ship Rock (Nysewander et al. 1982).

   The largest known southwestern colony is at Buldir Island (014 001), where an estimated 3,000 whiskered auklets occur (Sowls et al. 1978).

C. Cormorants

1. Distribution. Four species of comorants occur in Alaska: red-faced, pelagic, brandt's, and double-crested (Sowls et al. 1978). The two most important species in Southwest Alaska are the red-faced and pelagic cormorant. Only those two will be discussed here.

   Red-faced comorants nest from the arctic coast of northeastern Siberia and Komandorskie Island (formerly on Kamchatka and Kurile islands) east through the Pribilof Islands, the Aleutian Islands to Amak, Shumagin, and Simidi Island (ibid.).

   The red-faced comorant is endemic to Alaska except for some breeding colonies in the Commander Islands (USSR) (ibid.). They are sedentary, nonmigratory, and resident (Trapp, pers. comm.).

   Pelagic cormorants nest on ledges of precipitous, rocky, inaccessible cliffs. Their breeding range is from northeastern Siberia south to Los Coronados Island, Baja California, on the west side of the Pacific, and to Japan on the eastern side (Terres 1980).

   Cormorant colony locations may change from year to year, which is common among the colonial species of cormorants and terns (Sowls et al. 1978).

2. Abundance. According to Sowls and his co-workers, the Alaskan population of cormorants is approximately 250,000. There are 489 known sites.

There are estimates of 130,000 red-faced cormorants from 179 sites and 90,000 pelagic cormorants from 285 recorded sites in Alaska (ibid.). The two most notable pelagic cormorant sites in Alaska are Middleton Island (048 001), 47,000 birds, and the Walrus Islands (maps 039 and 040), 11,000 birds.

The majority of red-faced cormorant colonies occur in the western Gulf of Alaska, Alaska Peninsula, and the Aleutian Islands. The Near Islands (Attu) have the most notable colony of cormorants (88,000, mostly red-faced) (ibid.).

The pelagic cormorant distribution includes Southeast Alaska, the western Gulf of Alaska, and the eastern Aleutian Islands, and extends north into the Bering Sea, Norton Sound, and the Chukchi Sea. One large colony in the Walrus Islands (Bristol Bay) has 11,000 pelagic cormorants (ibid.).

a. Aleutian Islands. The Aleutian chain contains 21 known colonies of pelagic cormorants, with a minimum population of 4,000 birds. The red-faced cormorant has 42 known colonies and a minimum population of 23,000 birds. The Near Islands group appears to be a concentration area for the red-faced cormorant. No notable concentration area appears to occur here for the pelagic cormorant (ibid.).

b. Alaska Peninsula area. This area supports 44 known colonies of pelagic cormorants, with a population of at least 3,000 birds. Forty-seven colonies of red-faced cormorants occur, with a minimum of 15,000 birds. The largest population consists of a single species colony of 5,000 red-faced cormorants on Bay Point (028 030). Another concentration area occurs on Amagat Island (025 014), which contains 3,000 birds evenly divided between the two species (ibid.).

c. Kodiak area. There are 54 known colonies of pelagic cormorants and 48 known colonies of red-faced cormorants in this area. Their populations are estimated to be at least 4,000 and 3,300 individuals, respectively. No high concentration areas occur here.

d. Bristol Bay area. This area contains 19 known colonies of pelagic and four known colonies of red-faced cormorants. Minimum populations are 16,000 pelagic and 36 red-faced cormorants, respectively. Two concentrations of pelagic cormorants occur here: 5,740 on High Island (039 024) and 3,150 on Crooked Island (039 032). Both occur in the Walrus Islands. No concentrations of red-faced cormorants are known here (ibid.).

e. Pribilof Islands. Pelagic cormorants are not known to occur here. The Pribilof Islands are estimated to have 7,700 breeding red-faced cormorants. St. George Island (038 001) supports approximately 5,000 and St. Paul's Island (038 002) about 2,500 cormorants.

D. Northern Fulmar

1. Distribution. The northern fulmar breeds throughout the temperate and far northern Atlantic. Its Pacific range

includes the Kurile, Commander, and Aleutian islands as well as islands in the Bering Sea and Gulf of Alaska (ibid.).

2. Abundance. Sowls et al. (1978) listed approximately 1,500,000 northern fulmars at 30 breeding sites. Unlike other seabirds, almost the entire population (more than 99%) of northern fulmars is concentrated at four major breeding grounds; these are the Semidi Islands (map 031), St. Matthew and Hall islands (map 056), Chagulak Island (020 002), and the Pribilof Islands (map 038). Smaller colonies are located in the Aleutians and the Gulf of Alaska. A large population of prebreeders remain at sea during the breeding season. Therefore, Sowls and co-workers believe the entire Alaskan population to be about 2 million birds.
   a. Aleutians. There are five known colonies in the Aleutian Islands, which contain approximately 457,000 northern fulmars. Almost all of these occur on one island, Chagulak (020 002), which has about 450,000 birds (ibid.).
   b. Alaska Peninsula area. There are nine known colonies here, which contain about 440,000 birds (Hatch and Hatch 1983). All occur within the group of islands south of the Alaska Peninsula known as the Semidi Islands (map 031) (ibid.).
   c. Kodiak Island area. Only one small colony of 20 birds is known to occur in the Kodiak Island area. This colony is located within the Barren Islands (map 043) on East Amatuli Island (043 010) (ibid.).
   d. Bristol Bay area. Northern fulmars are not known to breed in this area.
   e. Pribilof Islands. There are roughly 71,000 northern fulmars in the Pribilof Islands (map 038). Almost all occur on St. George Island (038 001) (ibid.).

E. Glaucous-Winged Gull

1. Distribution. Glaucous-winged gulls nest in a variety of habitats, including rocky cliffs, sandbar islands, rocky beaches, and the vegetated tops of islands among seabird colonies of the northern Pacific coast, from Alaska and the island of St. Lawrence, the Pribilofs and the Aleutians, south to northwestern Washington. They winter from the Aleutian Islands south along the Pacific coast to southern Baja California (Terres 1980; Gabrielson and Lincoln 1959; Trapp, pers. comm.).
2. Abundance. Sowls et al. (1978) lists some 229,022 glaucous-winged gulls at 547 sites with an estimated population of 500,000 birds. Gulls generally comprise only a small fraction (a fews tenths of 1%) of large, multispecies seabird colonies. Glaucous-winged gull colony sizes in Alaska are roughly as follows: 8% are of unknown size, 40% have fewer than 100 birds, 40% are estimated at over 100 but under 1,000 birds, 11% are between 1,000 and 10,000, and only two of 547 sites have more than 10,000 birds. Nelson Lagoon (028 042) is one of

the larger colonies, containing approximately 13,000 gulls nesting on several sandbar islands.

a. Aleutian Islands. There are 69 known colonies of glaucous-winged gulls, containing at least 40,000 birds. The two largest colonies in this area occur on Bird Island (025 023) and Buldir Island (014 001), which have populations of 7,000 and 5,000 birds, respectively (Sowls et al. 1978).

b. Alaskan Peninsula. The glaucous-winged gull is an abundant nesting species along the Alaska Peninsula. At least 86,000 glaucous-winged gulls are estimated to reside there. According to Sowls et al. (1978), the largest concentrations occur on the following islands: Kudobin Island (028 042), 13,500; Amagat Island (025 014), 8,000; Chistiakof Island (030 036), 5,500; and Karpa Island (028 039), 5,000.

c. Kodiak area. There are 174 known glaucous-winged gull colonies within this area, with a population of at least 40,000 birds. The southern island of the two Noisy Islands (034 038 and 034 039) off the northwestern coast of Kodiak Island contains by far the largest known population in this area: approximately 7,400 gulls (ibid.).

d. Bristol Bay area. There are 23 known colonies of glaucous-winged gulls within the Bristol Bay area. These colonies have a population of about 9,500 birds. The largest concentration here occurs on Shaiak Island (039 011), which has a population of 5,000 birds (ibid.).

e. Pribilof Islands. Glaucous-winged gulls are known to nest here in small numbers (ibid.).

F. Black-Legged Kittiwake

1. Distribution. The black-legged kittiwake nests on sea cliffs along the southern coast of Alaska to Prince William Sound to the tip of the Alaska Peninsula and in the southern Bering Sea (ibid.). In the Aleutians, they breed locally in every major island group (Sekora et al. 1975).

Being the most pelagic of gulls, black-legged kittiwakes range far from land, both during and outside the breeding season (Sowls et al. 1978).

2. Abundance. Sowls et al. (1978) estimated the Alaskan population of black-legged kittiwakes to be approximately 2.5 million birds at 263 sites. The majority of black-legged kittiwakes breed along the southern coast from Prince William Sound to the tip of the Alaska Peninsula and in the southern Bering Sea. More than 100,000 birds occur at Middleton Island (048 001), Aghiyuk Island (031 008), and Cape Peirce (039 010). At an additional 36 sites, populations exceed 10,000 kittiwakes, and another 88 have fewer than 500 birds.

a. Aleutian Islands. In this area, 21 known colonies of black-legged kittiwakes occur, with an estimated population of at least 83,000 birds. The two largest colonies in the area occur on Chagulak (020 002) and Buldir islands (014 001), which contain 28,500 and 21,600 kittiwakes, respectively (ibid.).

b. Alaska Peninsula area. There are 49 known colonies here, with a minimum population of 533,000 birds. The five largest concentration areas here occur on the following islands: Aghiyuk (031 008), 154,000; Unga (southeastern foot) (028 012), 55,000; Anowik (031 007), 52,000; Bird (026 001), 43,000; and Aghik (031 001), 42,000 (ibid.). Aghiyuk, Anovik, and Aghik islands are all part of the Semidi Islands, which contain a total population of approximately 300,000 black-legged kittiwakes (ibid.).

c. Kodiak area. Sixty-eight black-legged kittiwake colonies are known to occur in the Kodiak area. The minimum population here is estimated at 141,000 birds. The two largest concentration areas occur in the western area of Boulder Bay on Kodiak Island (034 008) and on Nord Island (043 011) in the Barren Islands; these contain 40,000 and 20,000 black-legged kittiwakes, respectively (ibid.).

d. Bristol Bay area. At least 19 colonies of black-legged kittiwakes, consisting of a minimum of 380,000 birds, occur here. The largest concentration occurs in the vicinity of Cape Peirce (039 010) and consists of 200,000 kittiwakes. Other lesser concentrations occur on Round Island (040 001), in an area west of Jagged Mountain (039 006), on High Island (039 024), and on Shaiak Island (039 011). These areas contain populations of 43,000, 24,500, 22,000, and 20,000, respectively (ibid.).

e. Pribilof Islands. The Pribilof Islands contain at least 108,000 birds. St. George Island (038 001) has an estimated 72,000 kittiwakes and St. Paul Island (038 002) an estimated 31,000 kittiwakes (ibid.).

G. Red-Legged Kittiwake

1. Distribution. All known red-legged kittiwake nesting colonies are in Alaska (except for a small number on Copper Island in the Commander Islands, USSR), and its entire breeding range is limited to the Bering Sea. This species, like the black-legged kittiwake, is highly pelagic and may be seen far from land throughout most of the year (ibid.).

Red-legged kittiwakes nest on ledges of sea cliffs on the Komandorskie, Aleutian, and Pribilof islands in the Bering Sea and winter on adjacent seas (Terres 1980; Sowls, pers. comm.). They share all of their known breeding grounds with black-legged kittiwakes (ibid.).

2. Abundance. Census data for red-legged kittiwakes are good. Sowls et al. (1978) listed a total of 226,802 birds at a total of six sites in Alaska.

Nearly all (97%) of Alaska's population of red-legged kittiwakes breed at colonies on St. George Island (038 001)

(Lensink 1983). There are other known colonies of red-legged kittiwakes on St. Paul Island (038 002), Buldir Island (014 001), Bogoslof Island (022 003), Fire Island (022 044), and Otter Island (038 004) (Sowls et al. 1978). The red-legged kittiwake nests only within the Southwest Region and is limited here to the Pribilof and Aleutian islands.

a. Aleutian Islands. The locations of red-legged kittiwake colonies in the Aleutians and their numbers are as follows: Buldir Island (014 001), 4,400; Bogoslof Island (022 003), 162; and Fire Island (022 004), 40 (ibid.).

b. Pribilof Islands. By far the largest colony in Alaska and in the world occurs on St. George Island (038 001), where an estimated 220,000 individuals occur. St. Paul Island (038 002) has an estimated population of 2,200 birds, and on Otter Island (038 004) the population is unknown (ibid.).

H. Murres

1. Distribution. Common murres nest in the Pacific from Komandorskie Island, St. Lawrence, and St. Matthew Island in the Bering Sea and northwest Alaska, south through the Aleutians and Pribilofs and along the Pacific coast as far south as southern California and south to the Kuriles, eastern Korea, and Japan (Terres 1980).

The thick-billed murre is associated with arctic and subarctic regions, and although the common murre also frequents those regions its range is more southerly and extends into temperate latitudes as well. Where their ranges overlap, common and thick-billed murres may breed in close association (Sowls et al. 1978).

Since the two species of murres can be distinguished only by close examination, most of the census data for murres in Alaska does not distinguish between species; therefore, their status should be discussed jointly (ibid.).

2. Abundance. In combination, these two species are probably the most numerous of all seabirds breeding in Alaska, both in absolute numbers and in biomass. Sowls et al. (1978) listed more than 7 million birds at 183 colonies of one or both species. Large aggregations of murres are difficult to estimate, and, since not all nonbreeding birds nor both members of breeding pairs are ever present at one time, the combined population of murres in Alaska is estimated to be closer to 10 million (ibid.). In the Gulf of Alaska, thick-billed murres represent 15 to 20% of the population. The two species are approximately evenly distributed in the Aleutian Islands. Thick-billed murres tend to predominate in areas north of the Aleutians, but very few are present in Bristol Bay or Norton Sound (ibid.). Overall, the populations of common and thick-billed murres in Alaska appear to be similar, with approximately 5 million birds each.

The Pribilof Islands (map 038) contain the largest breeding aggregation of murres in Alaska, with 1.7 million thick-billed and 150,000 common murres (ibid.). Populations of common murres at mainland colonies at Cape Newenham (map 039) and Cape Peirce (039 010) in Bristol Bay are estimated at 300,00 and 500,000 birds, respectively. Throughout coastal Alaska other colonies are scattered, with large populations of over 300,000 occurring at Capes Newenham (map 039) and Peirce (039 010) in Bristol Bay, Hall Island (056 009), and Cape Thompson (map 129). Six other locations along the western coast and Aleutian Islands have populations of over 200,000 murres (ibid.). The Semidi Islands (map 031) in the Gulf of Alaska has a notable complex of colonies containing 1,133,300 murres, 90% of which are common murres (Hatch and Hatch 1983).

Large colonies of murres are relatively conspicuous. It is unlikely that any major breeding colonies have been missed (Sowls et al. 1978).

a. Aleutian Islands. The Aleutian Islands contain 18 colonies of common murres, consisting of at least 26,000 individuals. This same area supports 12 colonies of thick-billed murres, with a minimum population of 36,000 individuals. The two largest colonies of common murres occur on Bird Island (025 023), which contains at least 15,000 birds, and Fire Island (022 004), which has at least 5,000. Only one large thick-billed murre colony occurs here, on Fire Island (022 004), and contains a population of at least 34,300 birds (ibid.). Nysewander et al. (1982) noted two other high concentration areas for common murres, one at Aiktak Island (map 024) and the other on Bogoslof Island (022 003) adjacent to Fire Island (022 004).

b. Alaska Peninsula area. Both thick-billed and common murres have a total of 19 colonies in this area. The thick-billed murre has an estimated minimum population of 1,340 birds and the common murre, 7,940 birds. No large colonies of thick-billed murres occur in this area, but a moderately large colony of common murres occurs on Castle Rock (027 014) (ibid.).

c. Kodiak area. Two colonies of thick-billed murres occur in the Kodiak area and contain a minimum of 300 birds. Eight colonies of common murres occur here, with a minimum population of 93,000 birds. Larger colonies of common murres occur on East Amatuli Island (043 010), 61,000, and Nord Island (043 011), 30,000, in the Barren Islands group (ibid.).

d. Bristol Bay area. There are 15 colonies of common murres in the Bristol Bay area, with a population of over 1 million birds. The two largest known colonies occur at Cape Pierce (039 010), which has 500,000 birds, and on the northern part of Twin Islands (039 026) (in the Walrus Islands), which has 228,000 birds. No known colonies of thick-billed murres occur here (ibid.).

e. Pribilof Islands. This area contains the largest breeding population of murres in Alaska. Three colonies of each species of murre occur here. The population of thick-billed murres consists of at least 1.6 million birds and that of the common murre of at least 141,000. On St. George Island (038 001), at least 1.5 million thick-billed and 19,000 common murres are present. St. Paul Island (038 002) contains at least 110,000 thick-billed and 39,000 common murres (ibid.).

I. Horned Puffin

1. Distribution. The horned puffin nests on shores and offshore islands from Kotzebue Sound, northwestern Alaska, throughout the Bering Sea and the Aleutian Islands to Kodiak Island and the Kenai Peninsula, southeastern Alaska (Glacier Bay and Forrester Island) to northern British Columbia. In Asia, the horned puffin nests from Kolyuchin Island, East Cape, and Diomede Island in the Bering Strait south to Kamchatka and Komandorskie Island to the northern Kurile Islands and Japan. They winter on open water and have been seen as far south as Baja California (Terres 1980, Gabrielson and Lincoln 1959).

   Horned puffin prefer nesting under beach boulders, in talus, or in crevices of cliffs. This probably reduces competition with tufted puffins, which nest almost exclusively in burrows, and may explain the almost complete overlap in breeding distribution of the two species in Alaska (Sowls et al. 1978).

2. Abundance. In Alaska, horned puffins are most abundant in the islands off the southern coast of the Alaska Peninsula from about 156° west to False Pass. Many breeding sites are reported to the east, particularly in the Kodiak archipelago, the northcentral Gulf of Alaska, and Prince William Sound, but the average colony size declines markedly. New data will probably show a much larger population of horned puffins, particularly in the Aleutian Islands (ibid.).

   In the southern Bering Sea, St. George Island (038 001) has most of the horned puffin population (ibid.). The principal breeding areas in the northern Bering Sea are at St. Matthew and Hall Islands (map 56), Nunivak Island (map 57), and Little Diomede Island (111 002). Other outstanding colonies of horned puffins in the western Gulf of Alaska are those at the Semidi Islands (map 31), totaling several hundred thousand birds. Another large colony at Amagat Island (025 014) has an estimated 140,000 birds (ibid.).

   Sowls et al. (1978) estimated a statewide population of 1,500,000 birds at 435 sites; at that time there were only 15 breeding sites, with estimated populations of more than 10,000 birds. No estimates were available for 54 of the 435 known breeding sites.

   a. Aleutian Islands There are 51 known colonies of horned puffins here. The population is estimated at approximately 65,000 birds. The largest single colony consists of 20,000 horned puffins on Buldir Island (014 001) (ibid.).

b. Alaska Peninsula area. The Alaska Peninsula contains 72 known colonies of horned puffins. The population is estimated at about 576,000 birds. The following areas contain colonies consisting of more than 50,000 birds: Amagat Island (025 014), 140,000; Suklik (031 004) and Aghik (031 009) islands in the Semidi Islands, 250,000 and 60,000, respectively; and Castle Rock (027 014) in the Shumagin Islands, 60,000 (Sowls et al. 1978, Hatch and Hatch 1983).

c. Kodiak area. The Kodiak area contains 107 known horned puffin colonies and an estimated population of at least 15,500 birds. The single largest population consists of about 10,100 birds on East Amatuli Island (043 010) in the Barren Islands. Most colonies are widely scattered and very small (ibid.).

d. Bristol Bay area. Sixteen known colonies occur, with an estimated population of at least 4,000 birds. The largest colony consists of only 1,750 birds, on Round Island (040 001). Most colonies are much smaller (ibid.).

e. Pribilof Islands. The Pribilof Islands have an estimated population of 32,000. The largest population (28,000) occurs on St. George Island (038 001) (ibid.).

J. Tufted Puffin

1. Distribution. Tufted puffins in North America nest on shores and offshore islands from Kotzebue Sound, northwest Alaska, to the Aleutian Islands, Kodiak Island, the Kenai Peninsula, and Southeast Alaska, to British Columbia, Washington, Oregon, and southern California. In Asia, they nest from Kolyuchin Island, East Cape, and Diomede Island in the Bering Strait south to Kamchatka and Komandorskie Island to the Kurile Islands and Japan. They winter on open waters often far from land.

2. Abundance. Tufted puffins are the fourth most abundant member of the auk family and the most widely distributed Alaskan seabird (Lensink 1983). In Alaska, the population is estimated to be approximately 4 million individuals (Sowls et al. 1978). The smallest Alaskan populations occur in the Bering Sea north of Bristol Bay and in Southeast Alaska, where adjacent colonies on Petrel (001 001) and Forrester (001 002) islands contain most of the population. There are over 500 known breeding sites in Alaska, and there are at least 11 islands with populations exceeding 50,000 puffins. The largest Alaskan colony probably occurs on Egg Island, which has an estimated population of 163,000 birds (Nysewander et al. 1982). Most colonies, however, contain fewer than 10,000 birds (Sowls et al. 1978).

a. Aleutian Islands. Sowls et al. (1978) estimated that at least 785,000 tufted puffins and 71 known breeding colonies are in the Aleutian chain. There are seven known island areas in the Aleutian chain that contain populations of over 100,000; the Baby Islands (023 003), Egg Island (025 015), Avatanak Island-Anuk Islands (024 002), Kaligagan Island (024 012), Aiktak Island (map 024), and the Vsevidof-Kigul Island (map 022) area; all six of these occur within the Fox Island group (Nysewander et al. 1982). Nysewander et al. (1982) has recently estimated at least 1 million breeding tufted puffins occur in the Fox Islands (025 028); this population comprises 40% of all known breeding tufted puffins in Alaska and 26% of the estimated total population.

b. Alaska Peninsula area (including islands along the coast). The Alaska Peninsula and its coastal islands contain at least 620,000 tufted puffins (Sowls et al. 1978). There are three island areas there that contain populations of over 100,000: Amagat Island (025 014), the Semidi Islands (map 31), and the Shumagin Islands (map 027) (ibid.).

c. Kodiak area (including islands in the south, north to the Barren Islands). The Kodiak area contains a population of at least 412,000 tufted puffins (ibid.). Only the Barren Islands (map 043) contain populations known to exceed 100,000. At least 205,000 birds occur here, the vast majority of which are found on East Amatuli (043 010) and West Amatuli (043 009) islands (ibid.).

d. Bristol Bay area. Fifteen known colonies, consisting of at least 87,000 birds, occur here. The largest known populations consists of 80,000 birds occurring at Shaiak Island (039 011) (ibid.).

e. Pribilof Islands. The Pribilof Islands have a population of at least 7,000 tufted puffins (ibid.).

K. Short-Tailed and Sooty Shearwaters

1. Distribution. The short-tailed and sooty shearwaters do not nest in Alaska but in the South Pacific; they cross the equator to spend their nonbreeding season in northern waters. They appear in Alaska in June and remain until October. From October to January, generally, they range in Alaska from the Aleutian Islands along the Alaska coast through the Bering Sea to the Arctic Ocean (Gabrielson and Lincoln 1959, Terres 1980).

2. Abundance. Short-tailed and sooty shearwaters are true oceanic birds, seldom seen in sheltered waters such as in Southeast Alaska. They are most abundant from June to September, sometimes appearing in great swarms during these months. They are most abundant in the Aleutians, particularly in the eastern islands, and the Bering Sea (Gabrielson and Lincoln 1959).

a. Sooty and short-tailed shearwaters are difficult to differentiate in the field except under good observing conditions; therefore, we are discussing them as a single group. There is, however, reliable data from the gulf that identifies shearwaters as to species (Gould et al. 1982). In the Gulf of Alaska, sooty shearwaters outnumbered short-tailed shearwaters by almost 9:1 in the northeast, but from Kodiak westward short-tails outnumbered sooties by about 1.2:1 (ibid.).

b. Short-tailed shearwaters comprise about 3.9 million (32%) of the 12.4 million shearwaters in the Gulf of Alaska, plus an unknown number south of the Aleutian Islands, for a total of more than 16 million. The Alaska population of sooty shearwaters is estimated to be greater than 8.8. million. The number of shearwaters fluctuate in these areas, however, as birds move back and forth through Aleutian passes and the Bering Strait (ibid.).

L. Fork-Tailed Storm-Petrel

1. Distribution. Fork-tailed storm-petrels breed from the Kurile Islands through the Aleutians, the Gulf of Alaska, and south to northern California (Sowls et al. 1978, Terres 1980).

2. Abundance. In Alaska, the abundance of storm-petrels is not well known because the birds are nocturnal and their nests difficult to detect in the talus. Sowls et al. (1978) documented 60 known nesting colonies of fork-tailed storm-petrels, but population estimates are available for only 11. These 11 colonies contain an estimated 1,148,500 birds. Sowls et al. (1978) estimates the Alaska population of fork-tailed storm-petrels to be 5 million. Many colonies are known to be "large" but whose numbers are not yet estimated, and many colonies may still be undiscovered (Sowls et al. 1978).

Buldir Island (014 001) has the largest known colony, with an estimated 540,000 breeding birds. Nonbreeding birds are not considered in this estimate; therefore, the population may be much larger. East Amatuli Island (043 010) has a crudely estimated population of 300,000, and Amagat Island (025 014), 200,000 birds. Petrel Island has an estimated population of 88,700 birds. There are many smaller known colonies, such as one of 300 birds at Hall Island (027 004) (ibid.).

New colonies should be found in the Aleutian Islands and on islands along the south side of the Alaska Peninsula and some on islands in Southeast Alaska. According to Sowls et al. (1978) there is no evidence of nesting in the Bering Sea north of the Aleutians, although fork-tailed storm-petrels are quite common around the Pribilof Islands.

The introduction of foxes to many Alaskan islands undoubtably greatly depleted populations of petrels. Fork-tailed storm-petrels are known to have been extirpated from islands in the Sanak group (map 25), Salt Island (018 009), and Ilak Island (016 014). Fork-tailed storm-petrels may now be recolonizing former breeding grounds since introduced foxes have died or been removed by trapping from some of these islands (ibid.).

a. Aleutian Islands. There are 21 known colonies of fork-tailed storm-petrels in the Aleutian chain, with a minimum population of 541,500 birds. The largest colony occurs here on Buldir Island (014 001), where there are an estimated 540,000 breeding birds (ibid.). More recently, Nysewander et al. (1982) found other large populations of fork-tailed storm-petrels in the Aleutians: Egg Island (025 015), 200,000; and large concentrations on Vsevidof (map 022), Aiktak (map 024), Kaligagan (024 012), and the Baby islands (023 033).

b. Alaska Peninsula area. Twenty-two known colonies of fork-tailed storm-petrels, with an estimated population of at least 209,000 occur here. The largest known colony occurs on Amagat Island (025 014), where 200,000 birds reside (ibid.).

c. Kodiak area. There are five known colonies of fork-tailed storm-petrels in this area, which contains a minimum of 300,000 birds. Only one of these, the largest, has a known population count. This count was on East Amatuli Island (043 010), with a population of 300,000, and is the second largest known colony of fork-tailed storm-petrels in Alaska (ibid.).

No known colonies occur in the remainder of the Southwest Region.

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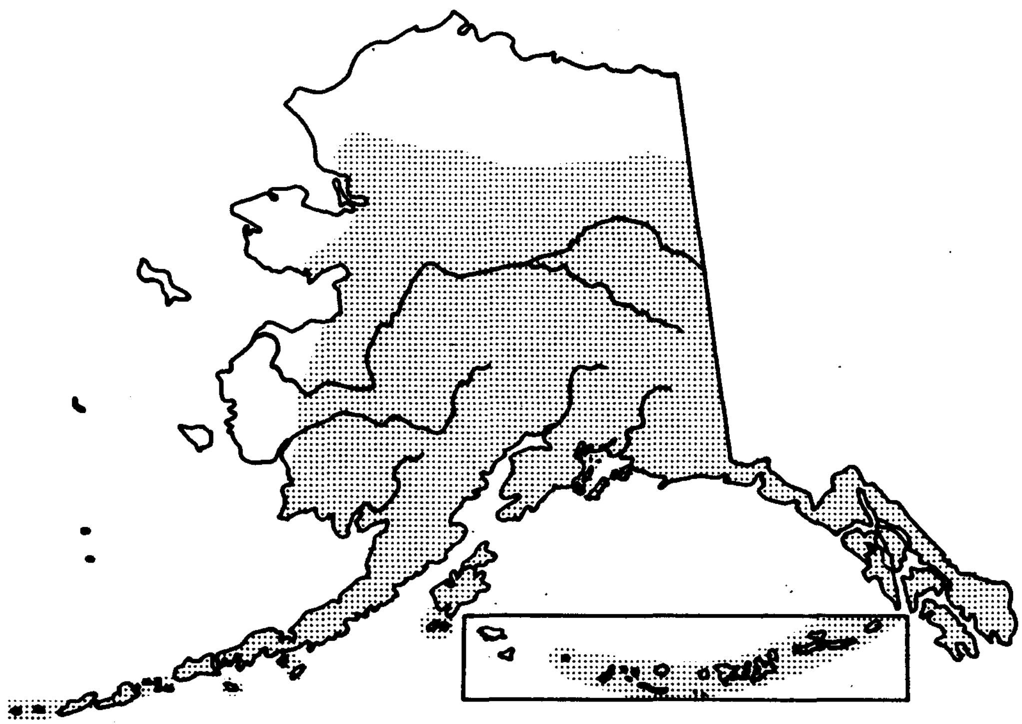
Bald Eagle Life History



Map 19. Range of Bald Eagle (ADF&G 1978)

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

II. RANGE
   A. Statewide
   The largest populations 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 found along major river drainages of Western, Interior, and Southcentral Alaska (Gabrielson and Lincoln 1959).
   B. Breeding Range
   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, pers. comm.).

C. Winter Range

Bald Eagles normally winter along the southern coasts of Alaska, with some movement of birds, especially immature birds, into British Columbia and the conterminous United States (Gabrielson and Lincoln 1959).

III. PHYSICAL HABITAT REQUIREMENTS

Over its entire range, the Bald Eagle is typically associated with land/water interfaces: coastal areas, riverine areas, and lake front areas. Bald Eagles are also associated with prominences, which are used for perches and nests; typically, these are the largest trees occurring near land/water interfaces, although cliffs and sea stacks may also be utilized (White et al. 1971). Preferred habitat in Southwest Alaska lies within several hundred meters of coastlines or along rivers (ADNR/USFWS 1983).

IV. FORAGING STRATEGY

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. Eagles often congregate in large numbers along salmon-spawning streams to feed on spawned-out fish. In coastal areas, shorelines are often searched for stranded or dead fish. Crabs, octopi, and other tidepool animals are often prey (Beebe 1974). Occasionally, Bald Eagles take live fish from lakes and streams. High prey visibility is important for foraging success. Fishing success is reduced on lakes with turbid water (Grubb 1977), and the effect of wind on water also lowers the bird's fish-capture rates (ibid.). Lakes bordered with strips of mature timber and small knolls are probably very attractive to foraging eagles (Bangs et al. 1982). Fish appear to be the preferred food item of Bald Eagles (Wright 1953).

A. Southwest Region

In the Aleutians, Murie (1940) found 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). White et al. (1971) found on Amchitka Island that the Bald Eagle's diet consisted of 26% birds, 28% fish, and 46% mammals (55% of which was sea otter). Increased mammalian consumption appears to be due in large part to the increase and expansion of the sea otter population (Early 1982).

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

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 typically situated within a few hundred meters from water and afford both height and isolation (Sherrod et al. 1976). The nest is usually a huge structure consisting of masses of sticks, and the center is filled with seaweed, vines, grass, and plant stalks; dirt is added along with the sod. The center of the nest is lined with leaves, mosses, straw, and feathers and is usually four inches deep in the center (Gabrielson and Lincoln 1959). Kalmbach (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 the same, although the preferred species of nesting tree varies with location (Lehman 1978). Nest trees are usually close to water, have a clear view to 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, Robards and King 1966, Lehman 1978, and Bangs et al. 1982). Bald Eagles almost always use live nest trees, although the tops of trees 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, 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 (Populus balsamifera) stands and cliffs (Troyer and Hensel 1965).

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 (Hensl and Troyer 1974, 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. 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 fledge by the first week of July (Early 1982).

C. 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. Four-year-old birds, which do not have a pure white head, are often classified as mature birds regardless of whether they frequently breed or function as adults.

D. Clutch Size

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 1.60 young per active nest.

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).

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

Bald Eagles along the coast generally remain near their nesting area throughout the year, but some may migrate several hundred miles to either food concentrations or milder, more southerly areas; eagles in the interior migrate to the coast (Gabrielson and Lincoln 1959, ADF&G 1978, ADNR/USFWS 1983).

A. Southwest Region

Adult birds along the coast normally remain near their nesting areas throughout the year, but some range several hundred miles to seasonally abundant food sources such as salmon-spawning runs. After freeze-up, adults that nest in inland areas probably move to coastal habitats. Immature eagles may travel long distances to find optimal habitats with abundant food or a more suitable climate (ADNR/USFWS 1983).

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

1. Habitat. Nesting habitat may be potentially limiting. Bald Eagles, as noted, prefer large trees near water. Over 500 nest trees have been recorded in Southeast Alaska, and not one was located in a young stand of timber (USDA et al. 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 Forest Service 1974).

   Forest fires also can destroy nesting habitat and could have a major impact. Bangs et al. (1982), for instance, 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 (Roseneau, pers. comm., cited by 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). They report 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. Severe weather may affect the productivity of eagles in a given year (Broley 1947). 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 or the percentage of active nests that are successful (Bangs et al. 1982).

c. Intermittent breeding. Intermittent breeding is common among large eagles and has been observed in both races of 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; Lockie and Ratcliffe 1964, cited by Chrest 1964). Evidence indicates that the response of golden eagles to reduced prey availability is nonbreeding of adults (White 1974).

d. Accidents. Young eagles may sometimes fall from their nests to the ground below. Birds younger than seven to eight weeks probably will not survive if they land in dense growth where adults cannot reach them (Dunston 1978). The first flights of fledglings are also hazardous (Sherrod et al. 1976).

e. Infertility. A proportion of all eggs laid are infertile, and the incidence is higher in larger raptors (Brown and Amadon 1968).

f. Smoke. Smoke from fires is also a potential hazard to nesting eagles (Ritchie 1982).

4. Disease and parasites. A variety of diseases and parasites are reported to infect eagles. These include avian cholera (Locke et al. 1972, Rosen 1972), asperillosis (Coon and Locke 1968), and enteric bacterial pathogen. Edwardsiella tarda (White et al. 1973), infestations of helminth parasite (Kocan and Locke 1974) and others (Coon and Locke 1968) also occur. None occur frequently or are considered limiting factors.

5. Predation. Occasionally, racoons, bobcats, ravens, crows, magpies, and, under unusual circumstances, gulls prey on eggs and small young (Chrest 1964, Hensel and Troyer 1964, Sprunt and Ligas 1964, and 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:

° Pollution of water and/or food
° Reduction of food supply
° Disturbance during resting/abandonment of young

- Destruction of nesting habitat
- Electrocution on transmission wires
- Illegal shooting

VIII. DISTRIBUTION

Bald Eagles are typically distributed along land and water interfaces such as lakes, rivers, and coastlines (Hensel and Troyer 1964, Robards and King 1966, King et al. 1972). Both feeding and nesting are associated with these areas. The mean distance of Bald Eagle nests from water was found to be 329 m in Alaska (Corr 1969). Hunting typically occurs from perches adjacent to water, though they may also hunt in flight.

IX. ABUNDANCE

Alaska supports the largest known population, an estimated 30,000 to 55,000 birds (USDI 1974). Densities are highest in the coastal regions.

A. Population Counts or Estimates

Accurate census data on the Bald eagle, however, is sparse and fragmentary throughout much of its northern range (U.S. Army Corps of Engineers 1979).

1. Aleutian Islands. An estimated 500 breeding pairs of Bald Eagles inhabit the Aleutian chain, and an estimated 564 birds are fledged each year (Early 1982). The Rat Islands contained the highest density, with a pair found every 5 km; the western Andreanof Islands, every 9.5 km; and no Bald Eagles were found to nest in the Near Islands.
   No census information appears to be available for the Islands of Four Mountains or the Fox Islands. In the Aleutian Islands, where there are few trees, nests are typically about 5 m horizontal distance from the water and seldom are further than 30 m.
2. Alaska Peninsula. In this area, Bald Eagles are most numerous along the southern coast of the Alaska Peninsula, with fewer occurring along the northern coast (ADNR/USFWS 1983). Little census information appears to be available, however. Approximately 1,000 adult eagles are estimated to inhabit the Bristol Bay area (ibid).
3. Kodiak Island. Little current information appears to be available on populations in the Kodiak Island area. What little is available comes from the Kodiak NWR, which occupies the southern two-thirds of Kodiak Island. In this area, there were an estimated 190 active nests in 1963, which produced an estimated 200 eaglets (Troyer and Hensel 1965).

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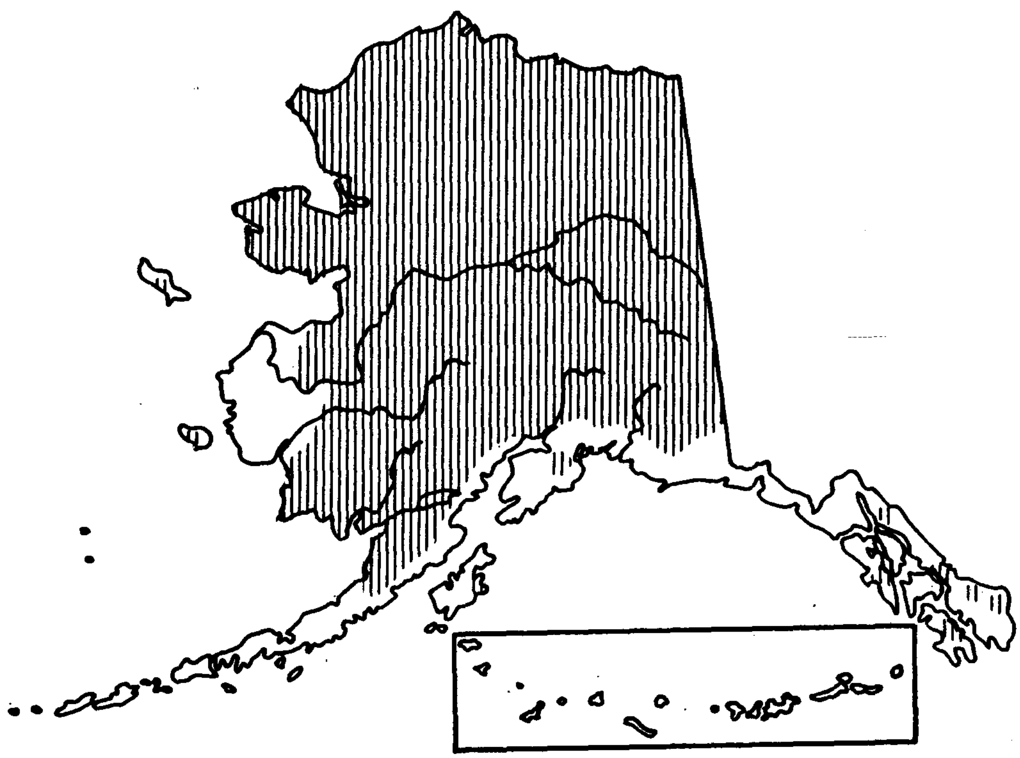
Freshwater/Anadromous Fish

Arctic Grayling Life History



Map 20. Range of arctic grayling (ADF&G 1978)

I. NAME
Common Name: Arctic grayling
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
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.).

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). Grayling migrate to spawning sites as soon as spring-flow conditions permit passage (Warner 1955, Tack 1973). 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 displayed signs of discomfort and experienced unusually high mortality when taken in waters with a temperature of 17.2°C (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, La Perriere 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). Juveniles in both Poplar Grove and Wier Creek migrated at lower velocities (Krueger 1981).

   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 backwaters 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 (Krueger 1981).

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 mainstem Colville River (Bendock 1979)
   - Gravel 0.5 to 7.6 cm in diameter (Kratt and Smith 1977)
   - Relativly 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).

B. Terrestrial

Newly emerged fry have limited swimming abilities and 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).

IV. NUTRITIONAL REQUIREMENTS

A. Preferred Foods

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 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. 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, Wojcik 1954). 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 (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. Feeding Locations

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). 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., 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, grayling in the Susitna River drainage spawned during late May and early June (ADF&G 1983). 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).

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). 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 22 years (deBruyan and McCart 1974, Craig and Poulin 1975, Craig and Wells 1975).

E. Fecundity

Fecundity varies, apparently depending on the size of the fish and the stock. 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 fish up to 12,350 for a 400 mm fish. An average fecundity of 8,968 was found for 20 grayling from the Yukon Territory (deBruyan and McCart 1974) with no significant correlation between fecundity and fish length.

F. Frequency of Breeding

Grayling spawn annually upon maturation (deBruyan and McCart 1974, Craig and Wells 1975, Engel 1973, Tack 1980, Williams 1969).

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 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 migration patterns and require unresricted 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. 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 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).

C. Migration Routes

A river or stream's source of water affects the migration 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 and 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 (Salmo gairdneri [Richardson]), arctic char (Salvelinus alpinus[(Linnaeus]), round whitefish (Prosopium cylindraceum [Pallus]), northern pike (Esox lucius [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 (see Land and Water Uses). A summary of possible impacts from human-related activities include 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

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 exploitation dynamics, 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 almost no studies on the effects of environmental changes on Arctic grayling in Alaska (Armstrong 1982, Grabacki 1981).

X. DISTRIBUTION AND ABUNDANCE

A. Kodiak-Afognak Islands Area

1. Distribution. Arctic grayling are not native to the Kodiak-Afognak islands area. All populations are the result of experimental stocking programs (ADF&G 1977a; Murray, pers. comm.). Table 13 lists all Kodiak area lakes stocked with grayling. Freshwater fish distribution reference maps designate approximate locations of the lakes.

Table 13. Kodiak Area Lakes Stocked With Arctic Grayling, 1977-83

		Number of Fish in Thousands						
Lake	Location	1977	1978	1979	1980	1981	1982	1983
Abercrombie	Kodiak	10.0	10.0	0	0	20.3	0	20.0
Aurel	Women's Bay	0	0	0	0	0	0	20.0
Cascade	Anton Larson Bay	0	0	0	0	10.3	0	0
Cicely	Women's Bay	10.0	10.0	0	0	0	0	10.0
Heitman	Women's Bay	0	0	0	0	0	0	36.0
Long	Woody Is.	10.0	10.0	0	0	10.2	0	20.0
Total		30.0	30.0	0	0	40.8	0	106.0

Source: Murray, pers. comm.

2. Abundance. Grayling stocking has had limited success. Survival has been poor, and in at least one lake (Long Lake) the high rate of mortality is attributed to predation on sac fry by threespine stickleback (Van Hulle and Murray 1980, 1981). Naturally reproducing grayling populations have been established in a few stocked lakes in the Kodiak area; however, most systems require supplemental stocking. Cascade Lake has some natural production that appears sufficient to maintain the population (ADF&G 1977a; Murray, pers. comm.).

B. Bristol Bay, Alaska Peninsula, and Aleutian Island Areas

1. Distribution. The freshwater fish distribution reference maps display the general distribution by quadrangle for arctic grayling in the Bristol Bay and Alaska Peninsula areas.

   Populations of grayling are found widespread in Bristol Bay drainages from Cape Newenham to Port Heiden. There are unsubstantiated reports of grayling down the Alaska Peninsula near Bear Lake (ADF&G 1977b); however, available documentation indicates that the Mother Goose Lake-King Salmon River drainage is the southern limit of their distribution. The eastern boundary of the Bristol Bay watershed appears to be marginal habitat, supporting few grayling. There are no arctic grayling on the Pacific side of the Alaska Peninsula or in the Aleutian Islands (ADF&G 1977b, ADF&G 1978).

   Southwest Alaska grayling are spring-spawning fish. In the Iliamna and Ugashik watersheds, they have been observed utilizing the tributary streams as spawning grounds. These fish re-enter the lakes after spawning. Grayling fry also rear in the tributary streams (ADF&G 1977b). These known areas are documented on the freshwater fish distribution reference maps.

   In the Bristol Bay area, grayling are generally found in all systems sometime during the year, with the exception of shallow land-locked ponds subject to oxygen depletion or freezing solid (ADF&G 1977a). All life-phases usually take place within the semiconfined environment of one drainage or watershed system. Usually, different locations within a drainage are better suited to meet the seasonal needs of life functions, and grayling therefore often exhibit complex migratory patterns and require undisturbed movement within a system (Armstrong 1982).

2. Abundance. The arctic grayling is an important sport species and is abundant in the Bristol Bay area. Populations are believed to be healthy and stable; however, few population estimates are available. With the exception of the Ugashik Lake drainage system, which has been fished for many years, research activities on grayling in the Bristol Bay area have been designed to inventory and catalog general characteristics of spawning populations and have not been extensive enough to determine population parameters (Gwartney 1978).

   Tagging and length-frequency data collected in 1969, 1971, and 1978 through 1982 indicate that the arctic grayling population structure of lower Ugashik Lake outlet is stable and probably not very different from an unfished population (Gwartney 1979, 1980, 1981, and 1983). The 1979 population point estimate of 2,053 fish is higher than estimates made in either 1969 or 1971: 1,952 and 1,180 fish, respectively (Gwartney 1980, Paddock 1970, Siedelman 1972).

XI. REFERENCES

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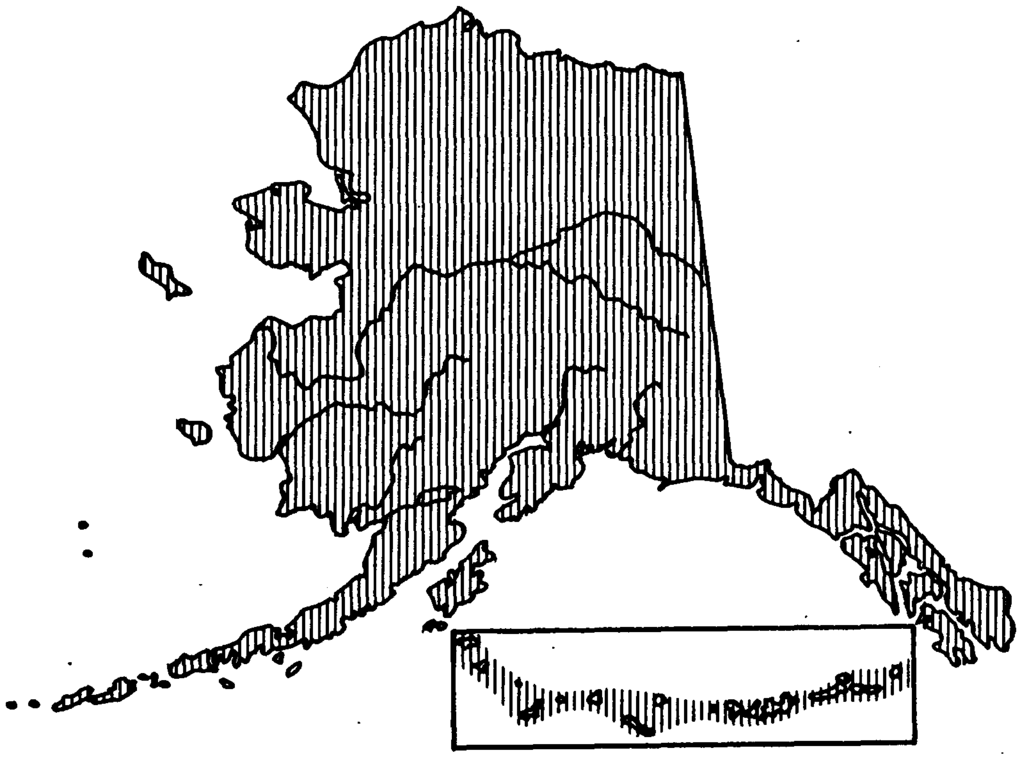
Char Life History



Map 21. Range of 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 Salmonidae. Because of their similarities and common distribution 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

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 1977a and 1977b).

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 form 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 char eggs began hatching after 129 days in water with a mean temperature of 8.5°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 various substrates 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 1977a).

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 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 (Krueger 1981, ADF&G 1977c) 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 1977c). 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 overlow areas provide cover for young-of-the-year (yoy) fish. Char seldom swim near the water surface, preferring to remain near the bottom (Krueger 1981, ADF&G

1977a and 1977c). 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 amphipods, cladocerans, and copepods (small crustaceans).

In the Wood River Lakes system, char feed on sockeye salmon smolt during the smolt's summer migration to Nushagak Bay (Rogers 1972, Buklis et al. 1979). ADF&G 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, sculpins, flounder larvae, and cod are major food components. Amphidpods, decapods, mysids, euphausids, brachiopods, polychaetes, and isopods are also included in their diet (Armstrong and Morrow 1980, Johnson 1980). Townsend (1941) 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 and 1977c). Adult anadromous char appear to be equally capable of taking food from mid water or from the bottom (Johnson 1980). Resident char in a lake 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 fresh water, 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 .3 m deep or in gravel-bottomed lakes (Krueger 1981, ADF&G 1977c).

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 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).

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 (Farbricus 1953, Fabricus and Gustafson 1954, Krueger 1981, ADF&G 1977c).

D. Age at Sexual Maturity

Char are an especially slow-growing fish and attain sexual maturity at different ages and sizes, varying with their life history and local environmental conditions. Three life forms of char occur in Alaska: resident lake char, resident stream char, and anadromous char. In general, resident stream char do not grow as large as resident lake or anadromous stream char. Resident stream char commonly occur in dwarf form (sexually mature and fully grown but only six to eight inches in length) (ADF&G 1977c, 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 postspawning mortality rate, a number live to spawn again in subsequent years. Armstrong (1974) found that in a Southeast Alaska population of char, 73% spawned once, 26% twice, and 1% three times. Up to 50% of the females spawning for the first time survived to spawn again. 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 (ADF&G 1977c, 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 1977c).

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).

Juvenile anadromous char rear in streams and lakes for two to seven years before outmigrating as smolt (ADF&G 1977b and 1977c). Most immature and mature char emigrate from overwintering areas to marine summer feeding areas following ice breakup from April to June. Systems without lakes may support an additional autumn smolt outmigration (Armstrong 1965 and 1970, Armstrong and Kissner 1969, Elliott 1975 and 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 1977b and 1977c). 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, 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 freshwater through the winter months to avoid the cooler water temperatures of the marine environment (ADF&G 1977c). 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 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

VIII. LEGAL STATUS

A. Managerial Authority

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

X. DISTRIBUTION AND ABUNDANCE

Because of the difficulty in distinguishing between these two char species and their overlap in distribution within the Southwest Region, they will be discussed together and all referred to as char.

A. Kodiak-Afognak Islands Area

1. Distribution. Char occur as both anadromous and resident races and are the most widely distributed freshwater or anadromous fish species in the Kodiak-Afognak islands area. Nearly all anadromous stream and lake systems seasonally contain a small number of char, and many landlocked lakes also contain char (ADF&G 1977a; Murray, pers. comm.). Anadromous fish stream reference maps show char to be distributed throughout the Kodiak archipelago. Known critical overwintering sites are designated in the ADF&G's Atlas to the Catalog of Waters Important for Spawning, Rearing, or Migration of Anadromous Fishes. Most resident fish inhabit landlocked lakes or reaches of flowing waters above barriers to anadromous stocks (ADF&G 1977c).

   Char spawn in smaller streams and lake tributaries throughout the Kodiak area from September through December (Murray, pers. comm.).

   After spawning, anadromous char seek out a lake-river system in which to overwinter. Kodiak Island lakes known to be important overwintering sites for anadromous char include Buskin, Barabara, Saltery, Uganik, Little River, Fraser, Red, Karluk, Akalura, Upper Station, and Lake Rose Tead. Afognak, Malina, Portage, and Marka are among the important overwintering sites on Afognak Island (ADF&G 1977c).

   Outmigration to estuarine and nearshore feeding areas begins in mid April and extends through the month of May. Anadromous char remain in the ocean to feed for approximately six to eight weeks, then begin reentering fresh water around July 1. The inmigration continues into the fall (ibid.).

   Juvenile rearing takes place primarily in smaller tributary streams. Kodiak char rear three to four years before entering salt water for the first time (Marriot 1967).

2. Abundance. Relatively large numbers of char are present in the Kodiak-Afognak islands area, and most populations are believed to be healthy and stable; however, few recent population estimates are available (ADF&G 1977a).

The ADF&G, Sport Fish Division, has inventoried and cataloged 29 unnamed lakes on northern Afognak Island and determined that 21 of the lakes contained natural char populations of sufficient size to support recreational fisheries (Van Hulle and Murray 1979, 1980).

The Buskin River near Kodiak is the major sport fishing system in the Kodiak-Afognak islands area and supports a large, intensive char fishery. Though it has a large overwintering population of char and has annually produced the largest char catch, there is concern that the population may be overharvested. Because of increased fishing pressure, a reduction in char mean size and catch per hour, and lack of population data, the bag limit was reduced from 15 to 10 fish in 1981 to help protect the Buskin River char (Murray 1982).

B. Bristol Bay, Alaska Peninsula, and Aleutian Islands Area

1. Distribution. Char occur in nearly every watershed within Bristol Bay and throughout the Alaska Peninsula and Aleutian Islands. Their distribution is shown on the anadromous fish stream reference maps, and known critical overwintering sites are designated in the ADF&G's Atlas to the Catalog of Waters Important for Spawning, Rearing or Migration of Anadromous Fishes. Their habitat includes not only clear freshwater lakes and river systems but also glacial streams and brackish deltas and lagoons (ADF&G 1977b). It is also important to note that natural phenomena such as high or low water and stream channelization may extend or decrease the range of char from one year to the next (ibid.).

   Both anadromous and nonanadromous races of char exist, and there appears to be a tendency for nonanadromous char to differentiate into resident lake char and resident stream char (ADF&G 1978).

   Nonanadromous char found in Bristol Bay systems that support substantial sockeye salmon runs are the largest, commonly exceeding 10 lb. Dwarf char exist discontinuously throughout much of the mountainous interior north of Bristol Bay (ADF&G 1977b).

   Char in Bristol Bay spawn in the fall, primarily in lakes (ibid.). Alluvial bars off the mouths of intermediate-to-small-size creeks are also believed to be preferred spawning sites (Meacham, pers. comm.). Some spawning may also occur in the lower reaches of creeks (ADF&G 1977b). Char move seasonally from the lakes to the rivers and back, overwintering in the lakes (ibid.). Char concentrate near river mouths in the spring to feed on outmigrating sockeye salmon fry and smolt. McBride (1979) concluded through analysis of tagging experiments that char in the Wood River Lakes system, present at a given feeding site, represent subpopulations or stocks. There was very little migration of char between feeding sites, and for those feeding sites that were studied at least 75% of the char present (at a given feeding site) homed back to that same feeding site in future years.

2. Abundance. Char are considered relatively abundant in the Bristol Bay, Alaska Peninsula, and Aleutian Islands areas. Comprehensive studies of predation upon juvenile sockeye salmon by arctic char were conducted in 1975-1978 in the Wood River system, the major salmon-producing system of the Nushagak portion of Bristol Bay (Buklis et al. 1979, Meacham 1977 and 1980). Char were captured, tagged, and released throughout the Wood River Lakes system to document major feeding sites. The average number of char residing at each feeding site was estimated, using both Peterson and Schnabel estimators. The average annual population point estimate for all feeding sites combined in the Wood River Lakes system from 1975 to 1978 was 64,728 (McBride 1979).

   In April and May of 1977 and 1979, the ADF&G, Sport Fish Division, conducted a char-tagging study in the Naknek River (Bristol Bay) to determine distribution and degree of exploitation of the char population within that system. Length frequencies (average lengths) of fish tagged in both years were similar, indicating a healthy population; however, the study was inconclusive because no tags were recovered. It was concluded that either the population was very large with respect to the number of fish tagged or that outmigration took place at a rapid rate, resulting in fish passing quickly through the sport fishery, or that fishermen simply were not returning tags (Gwartney 1978, 1980).

   With the recreational angling effort on char increasing in this area, additional biological data are needed to ensure maintenance of the char population at a high level.

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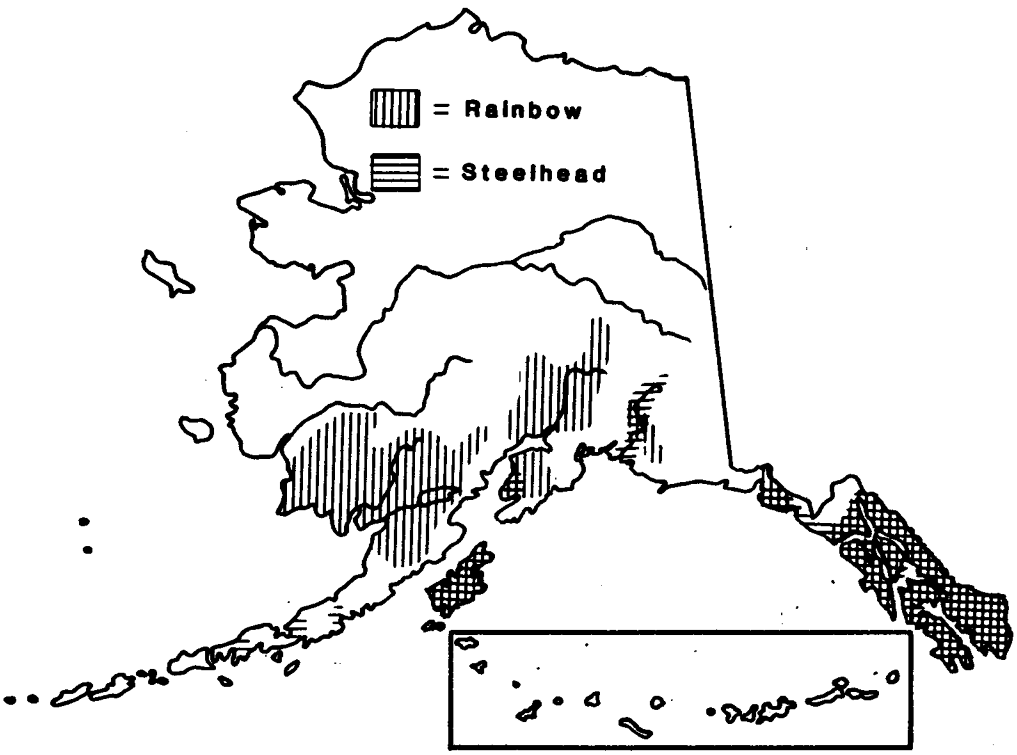
Rainbow Trout/Steelhead Life History



Map 22. Range of rainbow trout and steelhead trout (ADF&G 1978)

I. NAME
   A. Common Names: Rainbow trout and steelhead trout
   B. Scientific Names: 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
      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 (Red) 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).

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, cited in Carlander 1969).

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, cited by Raleigh and Hickman 1982) 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 adult steelhead spawning migrations 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 9.5 (McAfee 1966, cited in Carlander 1969).

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.

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 raise thermal barriers to migration (Reiser and Bjornn 1979). 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 hr 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. 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). 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). Smith (1973) gave depth and velocity requirements for spawning steelhead in Oregon as at least .24 m deep and 40 to 91 cm/sec. Rainbow trout values were at least .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 .2 to .35 m deep but that they were also found spawning on shallow riffles

not exceeding .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 .15 to .60 m deep, with moderate-to-fast flow (no actual velocity measurements were taken).

3. Substrate. 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 (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). 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. Preferred Foods

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 (Morrow 1980). 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).

Russell (1980) reported that rainbows from the Chilikadrotna and Mulchatna rivers in Southwest Alaska frequently consumed small rodent. One Chilikadrotna rainbow stomach contained a total of five shrews.

B. Feeding Locations

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) fast water invertebrate production areas. 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.

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) 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 Southwest Alaska (Gwartney 1983b). The availability of large numbers of salmon eggs in the summer may enhance the rainbow's 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. 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 Habitat Requirements section of this account.

B. Reproductive Seasonality

Generally, rainbow trout spawn during May and June (ADF&G 1978). Steelhead generally spawn between March and May (ibid.). Russell (1977) found that rainbow trout in Lower Talarik Creek in Southwest Alaska spawned from late April through mid June, with the spawning peak occuring between early May and early June, depending upon water temperature.

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). 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).

E. 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). Rainbow from Talarik Creek in Southwest Alaska averaged 3,431 eggs per female (Russell 1977). Rainbow from Cottonwood Creek in Southcentral Alaska averaged 489 to 2,042 eggs per female, depending on size (Allin and Baxter 1957). Morrow (1980) gives a general fecundity value of 3,250 eggs.

F. 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). Wallis and Balland (1981) found that 15 to 20% of steelhead in Anchor River on the Kenai Peninsula survive spawning and would thus have the potential to spawn again. 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).

G. Incubation Period

Eggs usually develop to hatching in a period of four to seven weeks (ibid.), though 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 1,100 heat units (based on 11 A.M. daily temperatures [Fahrenheit] and presumably calculated by summing the difference of these temperatures from 32°F) were required for eggs to develop to fry with absorbed yolk sacs.

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

A. Natural

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. Ocean steelhead 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).

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 Ballard (1981) reported spawning mortalities of 80 to 85% in steelhead from the Anchor River. (For more information on spawning mortality, see V. F. above.)

B. Human-related

A summary of possible impacts from human-related activities inlcudes 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

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 stock found in a different area.

X. DISTRIBUTION AND ABUNDANCE

A. Kodiak-Afognak Islands Area

1. Distribution. Rainbow trout and steelhead are native to specific systems in the Kodiak-Afognak islands area. They are typically found in lake-river systems characterized by inlets/outlets capable of rearing fish (Van Hulle and Murray 1974). Their distribution is closely associated with the presence of sockeye salmon populations, and all steelhead systems also contain populations of resident rainbow trout (ADF&G 1977a).

   Important native rainbow trout waters include the Portage, Afognak, Upper and Lower Malina, Uganik, Karluk, Frazer, and Ayakulik (Red) lake-river systems. Steelhead trout are distributed in a number of lake-river systems in the Kodiak Island area but are relatively abundant in only the Karluk and Ayakulik (Red) rivers (Van Hulle and Murray 1979, 1980, 1981; Murray 1982, 1983). (See the section on Abundance.)

A series of 1:250,000-scale reference maps cartographically depict known distribution and critical habitat sites of native rainbow trout by quadrangle (available at ADF&G area offices). Anadromous fish stream reference maps show the known distribution of steelhead trout; however, for critical habitat designations the reader is referred to the ADF&G Atlas to the Catalog of Waters Important for Spawning, Rearing, or Migration of Anadromous Fishes.

In addition to native stocks, enhancement of rainbow trout by stocking and lake rehabilitation has been done on many roadside lakes with easy access from Kodiak. These lakes are listed in table 14, and their approximate location is shown on the accompanying freshwater fish distribution reference maps.

Resident rainbow trout spawn during the spring of the year, beginning in late April and extending into early June. Spawning occurs primarily in lake inlet streams (Morrow 1980, Van Hulle and Murray 1974). (See the Life History narrative.)

Juvenile rainbow rear in the lake inlet streams for one to three years until they attain a length of 8 to 10 inches. Then the young lake-dwelling rainbows move back into the lake to feed and mature (ADF&G 1977a and 1977b). Inlet streams suitable for rearing of juvenile rainbow trout must contain sections of swift-flowing water where stickleback (<u>Gasterosteus aculeatus</u> [Linnaeus]) have more difficulty competing with them (ADF&G 1977a). Competition from stickleback is an important limiting factor for rearing rainbow trout (Van Hulle and Murray 1981, Murray 1982). (See the Life History narrative for other natural factors influencing rainbow trout and steelhead populations.)

Kodiak area steelhead are fall-run fish that enter the freshwater systems in early September and continue into late fall, peaking some time in October (ADF&G 1977a). Steelhead overwinter in deep river holes or lakes and then spawn in the rivers beginning in April and extending through early June (ibid.). Following spawning, steelhead outmigrate to sea. (See the Life History narrative.)

The distribution of rearing steelhead and resident rainbow trout is believed to be similar within a lake-river system. The majority of steelhead juveniles rear two years in freshwater, primarily in outlet streams, and then migrate out to spend one to three years at sea (ADF&G 1977b, Van Hulle and Murray 1973). Most steelhead return as mature spawners after one year (ADF&G 1977a). Repeat spawners on the Karluk River have varied from 8 to 50% (Van Hulle and Murray 1979, 1980, 1981; Murray 1983).

2. <u>Abundance</u>. Few population counts or estimates of native rainbow trout abundance are available for any Kodiak area system. Traditionally, the primary goal of the ADF&G, Sport Fish Div-

Table 14. Kodiak Area Lakes Stocked with Rainbow Trout, 1977-83

Lake	Location	Number of Fish in Thousands						
		1977	1978	1979	1980	1981	1982	1983
Abercrombie	Kodiak	2.4	4.1	1.9	3.7	0	3.7	3.7
Aurel	Womens Bay	1.1	0	0	3.0	0	3.0	3.0
Big	Kodiak	0	0	0	3.6	0	3.6	3.6
Beaver Ponds	Womens Bay	0.3	0	0	0.6	0	0	0
Bull	Pasagshak	3.0	0	1.0	2.9	0	2.0	0
Caroline	Womens Bay	1.0	0	0	1.4	0	1.4	1.4
Cascade	Anton Larson Bay	0	0	0	1.6	0	3.3	3.3
Cicely	Womens Bay	0	0	0	1.2	0	1.1	0
Dark	Kodiak	0	0	0	0	0	3.0	0
Delphin	Afognak	0	0	3.7	0	0	0	0
Dolgoi	Long Island	3.6	0	5.2	3.6	0	5.1	5.1
Dragonfly	Cliff Point	1.6	0	0.8	1.6	0	1.6	0
Heitman	Womens Bay	0	0	0	3.0	0	3.2	3.2
Horseshoe	Cliff Point	1.2	0	0	1.0	0	1.0	0
Island	Kodiak	0	0	0	0	0	9.0	0
Jack	Womens Bay	0.9	0	0	1.0	0	1.0	0
Jupiter	Chiniak	0	0	0	0	0	2.1	0
Lee	Womens Bay	2.8	0	1.4	2.8	0	2.8	1.8
Lilly Pond	Kodiak	0	0	2.1	1.0	0	1.6	1.6
Long	Woody Island	2.7	5.2	3.6	5.4	0	3.6	4.1
Lupine	Pasagshak	1.5	0	0.8	1.6	0	1.6	0
Mayflower	Kalsin Bay	0	0	0	2.4	0	0	0
Tanignak	Woody Island	0.7	0	3.0	5.5	0	6.0	10.6
Total		22.8	9.3	23.5	46.9	0	59.7	41.4

Source: J.B. Murray, pers. comm.

ision, projects in the Kodiak region has been to optimize the survival and growth of resident and stocked game fish and to maintain the natural runs of anadromous fish (Van Hulle and Murray 1981). Past investigations of native rainbow populations, however, have indicated only general characteristics of spawning populations and have not been extensive enough to determine population parameters (Van Hulle and Murray 1980). Data collected in 1979 and 1980 indicate that Big Kitoi Lake and Afognak River have "sizeable" naturally reproducing rainbow trout populations (Van Hulle and Murray 1981). Murray (1983) noted recent substantial increases in sport fishing effort and recommended that studies be intensified to determine rainbow trout population parameters in Portage Creek, Gretchen Creek, Laura Creek, and Afognak River.

Surveys of Shuyak Island streams conducted in 1975 and 1980 indicate that there are at least 10 streams on North Shuyak Island that contain steelhead/rainbow trout (Van Hulle and Murray 1981). Steelhead appear to be most abundant, however, in the larger lake-river systems on the south end of Kodiak Island (ADF&G 1977a). Steelhead escapement counts through weirs on Kodiak and Afognak islands from 1977 to 1982 are presented in table 15.

The Ayakulik (Red) River and Karluk River systems are the most important steelhead systems in the Kodiak-Afognak islands area. Steelhead runs were quite depressed in the mid 1960's, amounting to only several hundred spawners a year in the Karluk River (Marriott 1966-1968). The latter population appears to have recovered in recent years, increasing to a couple thousand spawners annually (table 15). Multiple age classes and repeat spawners sampled in 1975, 1977, 1978, and 1979 suggest that the Karluk River steelhead run is currently in excellent condition (Van Hulle and Murray 1980). In 1981, 28 adult steelhead were observed in the Buskin River. This is the largest spawning escapement observed since the river was closed to steelhead fishing in 1970 (Murray 1982). Small populations of steelhead occur in various other Kodiak area streams, including Akalura River, Olga Creek, Dog Salmon Creek, Uganik River, Afognak River, and Portage River (ADF&G 1978).

Rainbow trout stocking has been quite successful on Kodiak. Kodiak area lakes stocked with fingerling rainbow trout from 1977 to 1983 and the respective number of fish planted are listed in table 14. A few naturally reproducing populations have been established but most stocked lakes lack adequate spawning habitats (ADF&G 1977a) and require occasional restocking or rehabilitation to eliminate competitors (primarily stickleback). Oxygen depletion in small, shallow ponds during

Table 15. Steelhead Trout Escapement Counts Through Weirs on Kodiak and Afognak Islands, 1977-82

Year	Escapement Counts[a] by River							
	Afognak		Upper Station (Olga)		Ayakulik (Red)		Karluk Lagoon	
	Kelts[b]	Up[c]	Kelts	Up	Kelts	Up	Kelts	Up
1977	*	*	*	*	*	*	1,163	1,265
1978	*	*	*	*	*	*	1,052	1,008
1979	*	*	*	18	473	57	2,980	965
1980	*	*	*	24	*	29	902	50
1981	3	1	*	15	*	*	2,195	164
1982	106	0	*	0	54	4	1,136	27

Sources: Van Hulle and Murray 1978, 1979, 1980, 1981; Murray 1982, 1983.

a Escapement counts are relative indexes only; total escapements were not counted, as all weirs were removed in August, September, or October.

b Kelts are adults that have already spawned and are returning to sea.

c "Up" denotes upmigrants or inmigrant adults.

* Indicates that no escapement count is available.

severe winters has also influenced populations of stocked rainbows (ADF&G 1976b). Growth and survival of stocked rainbow trout is generally good through age two, and most stocked fish are normally harvested by the sport fishery by age three (ibid.).

B. Bristol Bay, Alaska Peninsula and Aleutian Islands Area

1. Distribution. The freshwater fish distribution reference maps display the general distribution by quadrangle for rainbow trout in the Bristol Bay, Alaska Peninsula, and Aleutian Islands areas. Data gaps in the knowledge of their distribution remain, and the maps should not be interpreted as a final representation. With additional studies, particularly in the Alaska Peninsula area, rainbow trout may be found in waters not presently documented. The overwhelming majority of rainbow trout in Southwest Alaska, however, do exist within the present known distribution (ADF&G 1977a).

   Rainbow trout are native to the Bristol Bay area and inhabit all major drainages north of Becharof Lake-Egegik River (ADF&G 1978). The cold, clear, gravel-bottomed streams and deep, oligotrophic lakes of Bristol Bay provide near ideal habitat (ibid.). Rainbow trout are primarily found in the Kvichak watershed below Six-Mile Lake and in the Naknek watershed. They also occur in the Wood and Nushagak rivers systems but are not present in the Egegik or Ugashik rivers. Isolated populations of rainbow trout have been documented as far down the Alaska Peninsula as the Port Moller area (Bear Lake, Sapsuk Lake). Rainbow trout are not present on the Pacific side of the Alaska Peninsula and do not naturally occur in the Aleutian Islands; however, rainbows have been stocked at Adak Island to provide a recreational fishery for military personnel stationed there (ADF&G 1977a).

   The anadromous fish stream reference maps show the known distribution of steelhead trout; however, for critical habitat designations the reader is referred to the ADF&G Atlas to the Catalog of Waters Important for Spawning, Rearing or Migration of Anadromous Fishes.

   Steelhead trout are rare in Southwest Alaska, being present in only a small number of Alaska Peninsula systems south of Port Heiden (ADF&G 1978). Steelhead are 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 Pacific side of the peninsula, steelhead have been documented in the Chignik River and a stream draining into Ivanof Bay (ADF&G 1984).

   The rainbow trout's life history in Bristol Bay has been the subject of continuing, intensive studies conducted by the ADF&G.

(See the Life History component of this report for detailed life history information.)

Bristol Bay resident rainbow trout populations exhibit two basic life history patterns. Some rainbow trout spend their entire life in a stream. These rainbows overwinter in deep holes within the river. Spawning occurs in the spring over stretches of gravel-bottomed riffles. Juveniles may make short ascents up the mainstream to the headwaters and other small tributaries to rear and feed, but they do not undertake any long migrations (ADF&G 1977a). Other rainbow trout populations inhabit both rivers and lakes during their life cycle. These fish spend their early years in the stream, then migrate into lakes. They occasionally move into and out of the lakes throughout the year, but most lake-dwelling rainbow trout return to gravel-bottomed riffles of tributaries and lake outlets in the spring to spawn (ibid.).

What little information there is available on Alaska Peninsula steelhead indicates that they are a fall-run fish that prefers lake-river systems (ADF&G 1978).

2. Abundance. The present populations of rainbow trout in Bristol Bay do not appear to be overexploited; however, concern by all individuals involved with rainbow trout has influenced the Board of Fisheries and the federal government to adopt very restrictive angling methods and fishing seasons to ensure the continued survival of the wild rainbow trout populations (Gwartney 1983b). Rainbow trout remain abundant throughout the area, and large rainbows exist in great numbers throughout all of the lake-river systems, indicating relatively stable populations (ADF&G 1977a). Because of the remoteness and inaccessibility of most of the habitat, sportfishing effort has been kept low and widely distributed in comparison to more accessible fishing areas. A catch-and-release philosophy is also encouraged in the area, and it is noteworthy that anglers do follow the traditional pattern of releasing most of their catch (Gwartney 1978, 1981).

A major fishery for rainbow trout occurs within the Naknek Lake and Lake Iliamna drainages. The ADF&G conducts annual rainbow trout spawning surveys on selected index streams in both the Naknek and Kvichak drainages (table 16). These surveys, continuous since 1972, provide an annual comparison of the numbers of large rainbows available to spawn and subsequently available to the angling public (Gwartney 1980). Surveys conducted in the spring are the only time visual observation of the rainbow's abundance is possible, since most large rainbow trout spend their summers in a lake environment (ibid.). Rainbow trout spawning survey estimates conducted in 1982 (table 16) are equal to or higher than other estimates for the past 11 years (Gwartney 1983a).

Table 16. A Summary of Rainbow Trout Spawning Surveys of Select Index Streams in the Naknek and Kvichak Drainages, 1972-82

	Naknek		Kvichak		
Year	Naknek River	Brooks River	Cooper River	Lower Talarik	Dream Creek
1972	260[a]	---[b]	630	600	---[b]
1973	130[a]	150	102	1,000	218
1974	---[b]	169	91	1,100	43
1975	500[a]	88	85	1,100	46
1976	300-500[a]	100	---[c]	1,100	200-250
1977	300-500[a]	125-175	400-500	800	138
1978	---[b]	125-150	250-350[a]	1,100-1,200a	175-225a
1979	---[b]	250-300	200-250[a]	1,900-2,100[a]	---[c]
1980	---[b]	200	---[b]	1,250-1,300a	---[b]
1981	2,000[d]	100-200[b]	650-750[a]	1,200-1,300a	125-150[a]
1982	2,000[d]	---[b]	1,000-1,200[a]	1,800-2,000a	200-250[a]

Sources: Gwartney 1978, 1979, 1980, 1981, 1982, 1983.

a Aerial survey estimate.

b No peak count made.

c No count possible due to turbid waters.

d Estimate based on aerial surveys and daily ground observations.

The ADF&G, Sport Fish Division, conducted an extensive study of rainbow trout between 1971 and 1976 at Lower Talarik Creek, located on the north shore of Lake Iliamna (Russell 1977). For five years following the completion of that report, research on the effects of angling pressure and the general condition of the stocks was very limited (Gwartney 1982). Beginning in 1981, the ADF&G, Sport Fish Division, initiated a comprehensive study to define population parameters, fish movement, and sport angling effort in the Naknek River drainage (ibid.). During 1981 and 1982, rainbow trout were tagged in the Naknek River at Lake Camp and Brooks River. Low recoveries from these releases indicated a low catch rate and apparently large rainbow populations available to the angling public (Gwartney 1983a). Gwartney (1982 and 1983a) examined all available size and age composition data from sporadic creel census studies conducted on selected streams back to the mid 1950's and did not find any evidence that the average size of rainbow trout is affected by present angling pressure.

No information on the abundance of steelhead was found in the literature. The few steelhead systems known to exist in Southwest Alaska are remote and not easily accessible.

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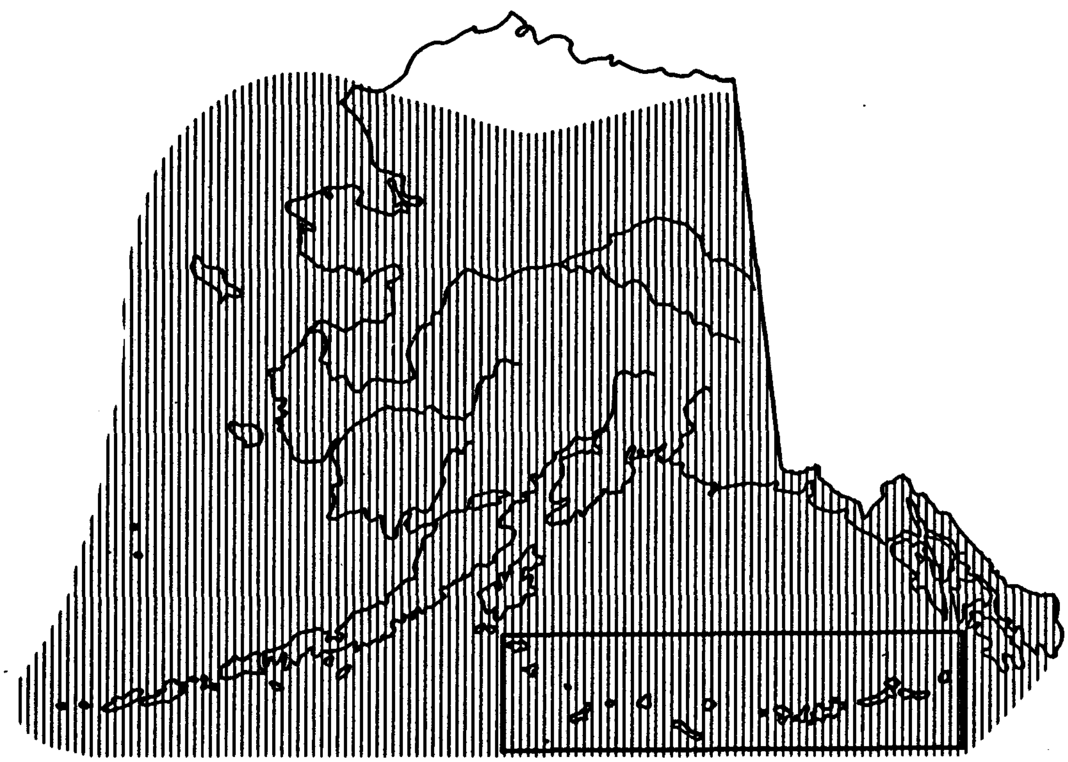
Sockeye Salmon Life History



Map 23. Range of sockeye salmon (ADF&G 1978)

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

II. RANGE
   A. Worldwide
   In North America, the sockeye salmon ranges from the Klamath River, California, north to Point Hope, Alaska. In Asia, they are found from northern Hokkaido, Japan, to the Anadyr River in northeastern Siberia (Scott and Crossman 1973).
   B. Statewide
   The sockeye is found in stream and river drainages from Southeast Alaska to Point Hope, Alaska. Spawning rivers are almost invariably those with lakes in their systems (Hart 1973).

C. Regional

In the Kodiak area, major sockeye 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 1977c).

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-producing waters include the Togiak, Igushik, Snake, Wood, Nushagak, Kvichak, Alagnak (or Branch), Naknek, Egegik, Ugashik, and Bear river systems. Other important runs are also located at Nelson Lagoon, Sandy River, Ilnik, and Urilla Bay (ADF&G 1977b).

In the waters draining the south side of the Alaska Peninsula and the Aleutian Islands are found numerous small runs of sockeye salmon. On the south peninsula, Thin Point and Orzinski lakes are important producers of sockeye salmon (Shaul, pers. comm.). The most significant Aleutian Island run is at Kashega on Unalaska Island. In the Chignik area, almost all are found in the Chignik River system (ADF&G 1977b), although there are several other minor systems in the area (Shaul, pers. comm.). To supplement the distribution information presented in the text a series of 1:250,000-scale reference maps has been produced that depict anadromous fish streams and anadromous fish stream watersheds within the Southwest Region. In addition, a set of 1:1,000,000-scale maps of anadromous fish streams and anadromous fish stream watersheds may be found in the Atlas that accompanies this narrative.

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 (ADF&G 1977a, 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, cited in Foerster 1968) 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, in the way 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 longitude 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 almost exclusively in streams that connect with lakes, although some populations spawn in lakes and a few in streams with no lakes. It is estimated that in the Copper River, Alaska, about 20% of the run spawns in the delta (Morrow 1980). Factors determining the selection of spawning sites are variable and include stream gradient, water depth and velocity, and the size of the streambed materials (substrate). Spawning sites are usually selected where there is a good waterflow through the gravel (ADF&G 1977a). These areas may be 1) in the streams flowing into the lake, 2) in the upper sections of the outlet river, or 3) along the shores of the lake where "springs" or seepage outflows occur (Foerster 1968).

In summarizing Alaskan spawning waters, Foerster (1968) states: ". . . a review of available evidence indicates that in general, while stream spawning is still the most important, lake-beach spawning increases in extent and significance (when compared to Canadian waters). At Karluk Lake on Kodiak Island, it is reported that about 75 percent of the spawning occurs in the streams, the remaining 25 percent on the lake beaches. For Bristol Bay and its highly productive sockeye salmon areas there appears to be a transition in importance of specific types of spawning ground. In the eastern part, stream spawning ranks as the most important. The Naknek and Kvichak River systems each have a number of smaller lakes auxiliary to the main lake. Salmon spawn in streams tributary to these lakes as well as in streams connecting them to the main lake. . .the spawning in both systems is confined to stream bed areas rather than beaches. Further west, however, in the Nushagak River system which comprises 10 major lakes, the sockeye spawn principally in the rivers between lakes and along lake shore beaches, although there are also a few important tributary streams."

B. Reproductive Seasonality

In Alaska, adult sockeye salmon ascend their natal streams from July to October, depending on the geographic location (Morrow 1980, ADF&G 1977a). Fish breeding in lakes or their outlets spawn later than those in streams because the lake waters generally cool off more slowly in late summer than do runoff waters in lake tributaries (ADF&G 1977a). This breeding characteristic, however, is by no means universal (Morrow 1980) and is not true for Bear Lake on the north side of the Alaska Peninsula or for Chignik Lake in the Chignik Management Area 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 to spawn (some may spawn in lakes). 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 (1977a) 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 managed to average 3.7 m^2 as spawning territory. When competition for space was eliminated each female occupied an average area of 6.97 m^2. The ADF&G (1977a) 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). In a few streams of the Copper River drainage, young sockeye stay in the stream rather than migrate (Morrow 1980). 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.

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 counterclockwise 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

See Impacts of Land and Water Development, Freshwater Fish, in another volume of this publication for the early life history and the spawning stages of the life cycle; and see also Marine Fish for the ocean residence period of the life cycle.

VIII. LEGAL STATUS

A. Managerial Authority

1. The Alaska Department of Fish and Game manages the fresh waters of the state and marine waters to the 3-mi limit.
2. The North Pacific Fishery Management Council is composed of 15 members, 11 voting and 4 nonvoting members. The 11 are divided as follows: 5 from Alaska, 3 from Washington, 3 from state fishery agencies (Alaska, Washington, Oregon). The four nonvoting members include the director of the Pacific Marine Fisheries Commission, the director of the U.S. Fish and Wildlife Service, the commander of the 17th Coast Guard District, and a representative from the U.S. Department of State. The council

prepares fishery management plans, which become federal law and apply to marine areas between the 3-mi limit and the 200-mi limit. With regard to salmon the only plan prepared to date is the Salmon Power Troll Fishery Management Plan.

3. The International North Pacific Fisheries Commission (INPFC), a convention comprised of Canada, Japan, and the United States, has been established to provide for scientific studies and for coordinating the collection, exchange, and analysis of scientific data regarding anadromous species.
   With regard to salmon, the INPFC has also prepared conservation measures that limit the location, time, and number of fishing days that designated high seas (beyond the 200-mi limit) areas may be fished by Japanese nationals and fishing vessels.

IX. LIMITATIONS OF INFORMATION

The physical habitat requirements for sockeye salmon are less well documented than other aspects (timing and movement patterns, e.g.) of this species' freshwater residency in Alaska.

X. SPECIAL CONSIDERATIONS

A freshwater form of this species exists and is known as the kokanee. The kokanee is generally very similar to the anadromous sockeye salmon except 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.

XI. DISTRIBUTION AND ABUNDANCE

The distribution and abundance account for the salmon species has been aggregated and follows the coho salmon life history.

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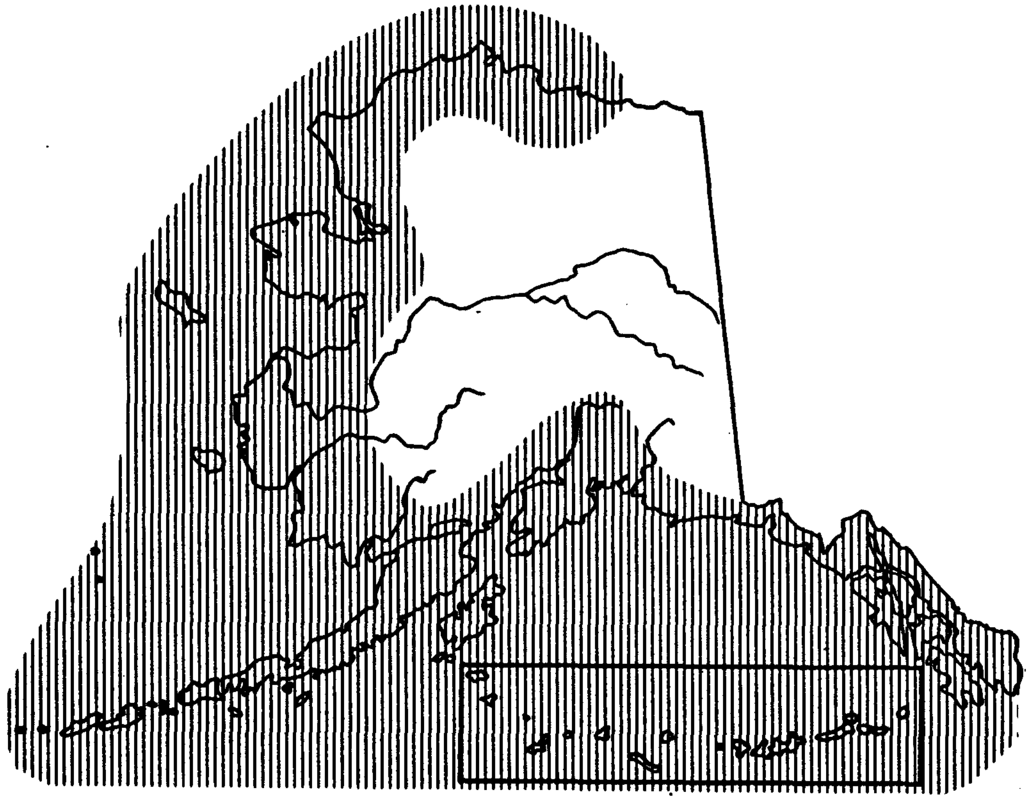
Pink Salmon Life History



Map 24. Range of pink salmon (ADF&G 1978)

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 1966, cited in Takagi et al. 1981).

B. Statewide

Pink salmon are widely distributed along coastal Alaska. 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). Recent studies on the Susitna River in Southcentral Alaska have found spawning pink salmon at least 223 km upstream (ADF&G 1981).

C. Regional

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 northside 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 (Shaul, pers. comm.; ADF&G 1977).

To supplement the distribution information presented in text a series of 1:250,000-scale reference maps has been produced that depict anadromous fish streams and anadromous fish stream watersheds within the Southwest Region. In addition, a set of 1:1,000,000-scale maps of anadromous fish streams and anadromous fish stream watersheds may be found in the Atlas that accompanies this narrative.

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 18.4°C (Sheridan 1962, cited in Krueger 1981). 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 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" (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, 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 adults' 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 since increased amounts of small material (fines) can reduce intragravel water flow. McNeil and Ahnell (1964, cited in Krueger 1981), 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. Migrating juveniles generally do not feed; if the distance to the sea is great, however, they may feed on nymphal and larval insects (Scott and Crossman 1973). 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, no data are available on freshwater feeding locations. Juvenile pink salmon school in estuarine waters and frequent the water's edge along mainland and inland shores (ibid.). 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

Since 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 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 (1969) 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. 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 (south side of the Alaska Peninsula) Alaska 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 (south of the Alaska Peninsula) Alaska 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 (northside of Alaska Peninsula). Very little information is available concerning pink salmon marine migrations from stocks in Western and Southwestern (north of the Alaska Peninsula) stocks. 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

(See Land and Water Uses, Freshwater Fish, in this publication for the early life history and spawning stages of the life cycle, and see also Marine Fish for the ocean residence stage of the life cycle.)

VIII. LEGAL STATUS

A. Managerial Authority

1. The Alaska Department of Fish and Game manages fresh waters of the state and marine waters to the 3-mi limit.
2. The North Pacific Fishery Management Council is composed of 15 members, 11 voting and 4 non-voting members. The 11 are divided as follows: 5 from Alaska, 3 from Washington, and 3 from state fishery agencies (Alaska, Washington, Oregon). The four non-voting members include the director of the Pacific Marine Fisheries Commission, the director of the United States Fish and Wildlife Service, the commander of the 17th Coast Guard District, and a representative from the United States Department of State.

   The council prepares fishery management plans, which become federal law and apply to marine areas between the 3-mi limit and the 200-mi limit. With regard to salmon, the only plan prepared to date is the Salmon Power Troll Fishery Management Plan.
3. The International North Pacific Fisheries Commission (INPFC) a convention comprised of Canada, Japan, and the United States, has been established to provide for scientific studies and for coordinating the collection, exchange, and analysis of scientific data regarding anadromous species.

   With regard to salmon, the INPFC has also prepared conservation measures that limit the location, time, and number of fishing days that designated high seas areas (beyond the 200-mi limit) may be fished by Japanese nationals and fishing vessels.

IX. LIMITATIONS OF INFORMATION

Very little 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 and laboratory studies.

X. SPECIAL CONSIDERATIONS

Neave (1966) states: "Schools of adult pink salmon often frequent bays and estuaries for days and even weeks before entering the streams. Fish tagged at this stage still show movements away from, as well as towards, the nearest spawning grounds. It appears, therefore, that spawning populations are not necessarily well segregated until actual entrance into the spawning streams."

Because of the two-year life cycle, returns of spawning adults are predictable by highly segregated even-numbered year and odd-numbered year runs. Both types of runs, or races, may use the same stream, or one or the other may predominate in a particular river (Scott and Crossman 1973). Some streams with a dominant run of one type have a very much smaller off-year run of the other race; they often utilize different tributaries as spawning grounds. There may be a significant difference in the date of return and in the length and weight of individuals of the two races or of the same race in different spawning rivers (ibid.).

In addition, caution must be used when extending information from one stock of pink salmon to another stock. Environmental conditions for one area must not be treated as absolute; the stocks (races) have acclimated/evolved over time and space to habitat conditions that can vary greatly.

XI. DISTRIBUTION AND ABUNDANCE

The distribution and abundance account for the salmon species has been aggregated and follows the coho salmon life history.

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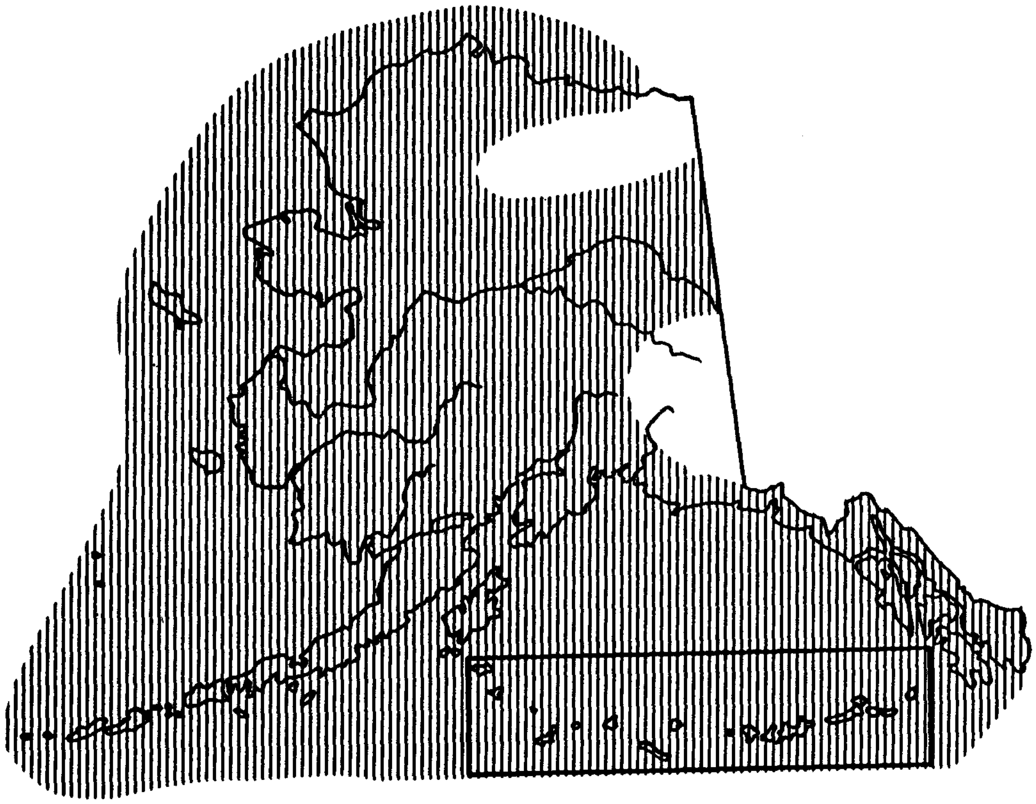
Chum Salmon Life History



Map 25. Range of chum salmon (ADF&G 1978)

I. NAME
   A. Common Names: Chum salmon, dog salmon, keta salmon
   B. Scientific Name: <u>Oncorhynchus</u> <u>keta</u>

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 and in the eastern Brooks Range. Relatively few streams north of the Kotzebue Sound drainage support runs of chum salmon (Hale 1981).

C. Regional

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 1977c).

In the Bristol Bay area (for waters from Cape Newenham to Cape Menshikof and northside 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 southside Alaska Peninsula streams, chum salmon are found at Canoe Bay and in every other major bay east of False Pass (ADF&G 1977b). 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 (ibid.). Small runs of chum salmon occur sporadically throughout the Aleutian Islands chain, but few of these are expected to be of commercial importance (Holmes 1984).

To supplement the distribution information presented in the text, a series of 1:250,000-scale reference maps has been produced that depict anadromous fish streams and anadromous fish stream watersheds within the Southwest Region. In addition, a set of 1:1,000,000-scale maps of anadromous fish streams and anadromous fish stream watersheds may be found in the Atlas that accompanies this narrative.

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

1. Water quality:

a. Temperature. Egg hatching and alevin development have occurred in Alaska at temperatures ranging from 0.2 to 6.7°C during the winter months (Hale 1981). Optimal incubation temperatures, however, appear to range between 4.4 and 13.3°C (Bell 1973).

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 Alaska 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. 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 (1977a) 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 the characteristics of chum salmon redd sites as follows: "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 (1977a) states 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). However, those that must spend several days to weeks on their journey 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), thereby decreasing the food supply.

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 between 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 1970).

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Chum salmon spawn in streams 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 consist of suitable substrate as well as suitable stream conditions. Many stocks of chum salmon (particularly fall chum) select areas with springwater or groundwater emergence. These areas tend to maintain water flows and temperatures warm enough to keep from freezing during the winter months (Morrow 1980, Hale 1981).

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 the peak 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).

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 Bjorrn 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 (1977a) states that the optimum size is considered 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 USSR 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 spent in the gravel by the eggs and alevin is a time of heavy mortality. Straty (1981) states that the greatest natural mortality (to Pacific salmon) occurs in fresh water during the early life stages and is greatly influenced by environment. The survival rate from eggs to fry for chum salmon 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 on 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

See Impacts of Land and Water Development, Freshwater Fish (in another volume of this publication), for the early life history and the spawning stages of the life cycle; and see also Marine Fish for the ocean residence period of the life cycle.

VIII. LEGAL STATUS

A. Managerial Authority

1. The Alaska Department of Fish and Game manages fresh waters of the state and marine waters to the 3-mi limit.
2. The North Pacific Fishery Management Council is composed of 15 members, 11 voting and 4 non-voting 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.
3. The International North Pacific Fisheries Commission is a convention comprised of Canada, Japan, and the United States established to provide for scientific studies and for coordinating the collection, exchange, and analysis of scientific data regarding anadromous species.
   With regard to salmon, the INPFC has also prepared conservation measures that limit the location, time, and number of fishing days that designated high seas (beyond the 200-mi limit) areas may be fished by Japanese nationals and fishing vessels.

IX. LIMITATIONS OF INFORMATION

Very little life history and habitat requirements information concerning Alaskan chum salmon has been collected/published. Most of the available information has been doucmented 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.

XI. DISTRIBUTION AND ABUNDANCE

The distribution and abundance account for the salmon species has been aggregated and follows the coho salmon life history.

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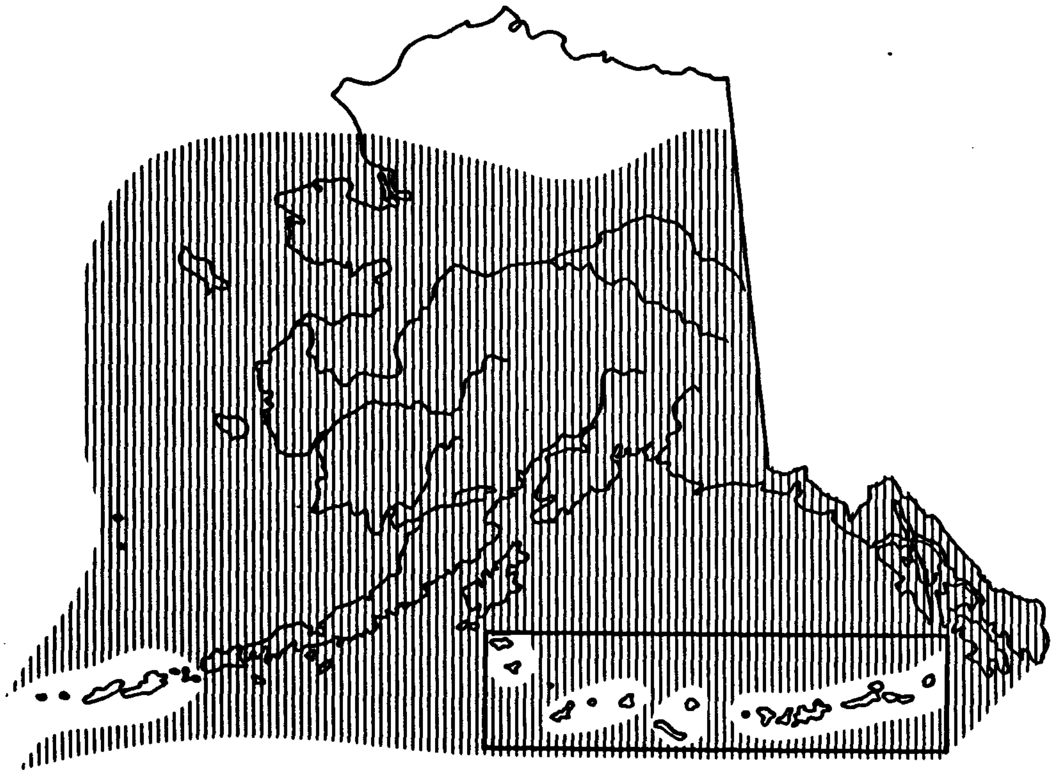
Chinook Salmon Life History



Map 26. 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

In the Kodiak area, major chinook salmon spawning and rearing drainages include the Karluk and Red river systems (ADF&G 1977c).

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, Nushagak, 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 1977b).

Streams on the Alaska Peninsula (south and west of Moffet Bay) and the Aleutian Islands appear to be unsuitable for supporting chinook salmon. Chinook salmon are found in one drainage on the southside of the Alaska Peninsula: the Chignik River system (ibid.).

To supplement the distribution information presented in the text a series of 1:250,000-scale reference maps has been produced that depict anadromous fish streams and anadromous fish stream watersheds within the Southwest Region. In addition, a set of 1:1,000,000-scale maps of anadromous fish streams and anadromous fish stream watersheds may be found in the Atlas that accompanies this narrative.

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

1. Water quality:

a. Temperature. 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 established a temperature range of 5.8° to 14.2°C for normal development if the temperatures remained constant throughout incubation, a situation not likely to occur under natural conditions. In later experiments, Combs (1965) found that 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 (ibid.). Prolonged exposure to turbid water causes gill irritation in juveniles that can result in fungal and pathogenic bacterial infection. Excess turbidity from organic materials in the process of oxidation may reduce oxygen below safe levels, and sedimentation may smother food organisms and reduce primary productivity (ibid.). Turbid water will absorb more solar radiation than clear water and may thus indirectly raise thermal barriers to migration (Reiser and Bjornn 1979).

2. Water quantity:

a. Instream flow. Sufficient water velocity and depth are needed to allow proper intragravel water movement (apparent velocity) so that dissolved oxygen is transported to eggs and alevin and, in turn, metabolic wastes are removed

(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 substrate 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, ADF&G 1977a). 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 et al. 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 et al. (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 et al. 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 et al. 1978), although juvenile chinook salmon in fresh water do not seem to utilize fish as food (Scott and Crossman 1973, Morrow 1980). Upon returning to fresh water, adult salmon no longer feed but live off the fat stored up in the ocean (Netboy 1974).

V. REPRODUCTIVE CHARACTERISTICS

A. Breeding Habitat

The general nature of the spawning ground, which may be located from just above tidal limits to great distances upstream (over 3,200 km in the Yukon River) varies considerably (Major et al. 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 et al. (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 et al. 1978).

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 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 et al. 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 1977a, Morrow 1980).

D. Age at Sexual Maturity

The age at which chinook salmon reach sexual maturity ranges from two to eight years (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 et al. 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 et al. 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 spring. 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 day time.

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 et al. 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 et al. 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 Impacts of Land and Water Development, Freshwater Fish, in another volume of this publication for the early life history and the spawning stages of the life cycle; and see also Marine Fish for the ocean residence period of the life cycle.

VIII. LEGAL STATUS

A. Managerial Authority

1. The Alaska Department of Fish and Game manages the fresh waters of the state and the marine waters to the 3 mi limit.
2. The North Pacific Fishery Management Council is composed of 15 members, 11 voting and 4 nonvoting members. The 11 are divided as follows: 5 from Alaska, 3 from Washington, 3 from state fishery agencies (Alaska, Washington, Oregon). The four nonvoting members include the director of the Pacific Marine Fisheries Commission; the director of the U.S. Fish and Wildlife Service; the commander, 17th Coast Guard District; and a representative from the U.S. Department of State.

   The council prepares fishery management plans, which become federal law and apply to marine areas between the 3-mi limit and the 200-mi limit. With regard to salmon, the only plan prepared to date is the Salmon Power Troll Fishery Management Plan.
3. The International North Pacific Fisheries Commission (INPFC), a convention comprised of Canada, Japan, and the United States, has been established to provide for scientific studies and for coordinating the collection, exchanges, and analysis of scientific data regarding anadromous species.

   With regard to salmon, the INPFC has also prepared conservation measures that limit the location, time, and number of fishing days that designated high seas (beyond the 200-mi limit) areas may be fished by Japanese nationals and fishing vessels.

IX. 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.

X. 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.

XI. DISTRIBUTION AND ABUNDANCE

The distribution and abundance account for the salmon species has been aggregated and follows the coho salmon life history.

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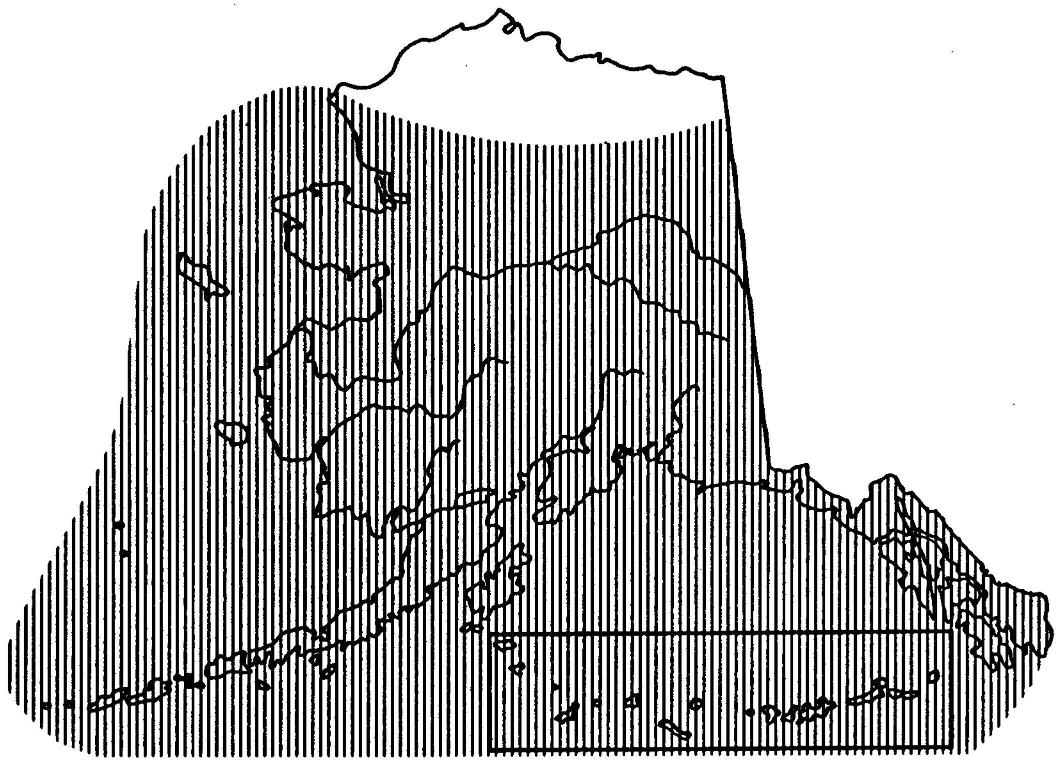
Coho Salmon Life History



Map 27. Range of coho salmon (ADF&G 1978)

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 1977a).

C. Regional

In the Kodiak area, many streams have runs of coho salmon; however, the runs are late in the season, and escapement figures are incomplete (ADF&G 1977c).

In the Bristol Bay area (for waters from Cape Newenham to Cape Menshikof and north-side Alaska Peninsula streams south to Cape Sarichef), major coho-producing drainages include the Togiak and Nushagak systems, with smaller runs found in the Kulukak, Naknek, Kvichak, Egegik, and Ugashik systems (Middleton 1983). Further south on the Alaska Peninsula important north-side coho salmon-producing systems are found at Nelson Lagoon, Port Heiden, and Cinder River. Smaller fisheries also exist at Swanson Lagoon and Ilnik (Shaul, pers. comm.).

For south-side Alaska Peninsula streams and the Aleutian Islands, data are scarce concerning coho salmon production. The best-known runs on the South Peninsula occur in Russel Creek, Mortensen Lagoon, and Thin Point Cove at Cold Bay (ADF&G 1977b). 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 1977b).

To supplement the distribution information presented in the text a series of 1:250,000-scale reference maps has been produced that depict anadromous fish streams and anadromous fish stream watersheds within the Southwest Region. In addition, a set of 1:1,000,000-scale maps of anadromous fish streams and anadromous fish stream watersheds may be found in the Atlas that accompanies this narrative.

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.O. concentrations below air saturation level. Bell (1973) states that it is desirable that D.O. concentrations be at or near saturation and that it is especially important in spawning areas, where D.O. levels must not be below 7 ppm at any time. State of Alaska water quality criteria for growth and propagation of fish state that "D.O. shall be greater than 7 mg/l in waters used by anadromous and resident fish. Further, in no case shall D.O. be less than 5 mg/l to a depth of 20 cm in the interstitial waters of gravel utilized by anadromous or resident fish for spawning. . . In no case shall D.O. above 17 mg/l be permitted. The concentration of total dissolved gas shall not exceed 110 percent of saturation at any point of sample collection."

d. Turbidity. Sedimentation causes high mortality to eggs and alevin by reducing water interchange in the redd. If 15 to 20% of the intragravel spaces become filled with sediment, salmonid eggs have suffered significant (upwards of 85%) mortality (Bell 1973). Prolonged exposure to turbid water causes gill irritation in juveniles, which can result in fungal and pathogenic bacterial infection. Excess turbidity from organic materials in the process of oxidation may reduce oxygen below safe levels, and sedimentation may smother food organisms and reduce primary productivity (ibid.). From investigation of the Susitna River in Southcentral Alaska during 1982, turbid water was found to be a strong factor that influenced juvenile fish distributions. This study indicates that rearing coho salmon apparently avoid turbid water (ADF&G 1983). Turbid water will absorb more solar radiation than clear water and may thus indirectly cause thermal barriers to adult upstream spawning migration (Reiser and Bjornn 1979).

2. Water quantity:

   a. Instream flow. Sufficient water velocity and depth are needed to allow proper intragravel water movement (apparent velocity) so that dissolved oxygen is transported to eggs and alevins and in turn metabolic wastes are removed (ibid.).

   Juveniles after emerging from the gravel stay almost entirely in pools, avoiding riffle areas (Morrow 1980). Burger et al. (1983), during studies on the Kenai River, Alaska, and its tributaries, found that recently emerged juveniles (less than 50 mm long) in the mainstem 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 mainstem spawned coho salmon into tributaries, canals, and basins. He also suggests that since the mainstem 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 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 (1977a) 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 mainstem 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 Alaska 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

The preferred streams are usually short coastal streams, 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 1977a).

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 1977a). As a rule, fish in the northern part of the range enter freshwater earlier in the season, with later 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 cohos 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 and Bjorrn 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 1977c, 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 mainstem, one in a tributary stream) and listed their sizes. Mainstem 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. The downstream movement of juveniles bound for the sea is usually at night (Meehan and Siniff 1962), and the trip is completed by spring or early summer of the year. Burger et al. (1983) suggest, however, 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 southeasterly 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 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 Impacts of Land and Water Development, Freshwater Fish, for the early life history and the spawning stages of the life cycle; and see also Marine Fish for the ocean residence period of the life cycle.

VIII. LEGAL STATUS

A. Managerial Authority

1. The Alaska Department of Fish and Game manages the fresh waters of the state and marine waters to the 3-mi limit.
2. The North Pacific Fishery Management Council is composed of 15 members, 11 voting and 4 nonvoting members. The 11 are divided as follows: 5 from Alaska, 3 from Washington, and 3 from state fishery agencies (Alaska, Washington, Oregon). The four non-voting 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.
3. The International North Pacific Fisheries Commission (INPFC), a convention comprised of Canada, Japan, and the United States, has been established to provide for scientific studies and for coordinating the collection, exchange, and analysis of scientific data regarding anadromous species.
   With regard to salmon, the INPFC has also prepared conservation measures that limit the location, time, and number of fishing days that designated high seas (beyond the 200-mi limit) areas may be fished by Japanese nationals and fishing vessels.

IX. LIMITATIONS OF INFORMATION

Very little life history and habitat requirements 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.

XI. DISTRIBUTION AND ABUNDANCE

The distribution and abundance account for the salmon species has been aggregated and follows the coho salmon life histories.

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Salmon Distribution and Abundance

I. BACKGROUND

Five species of North American Pacific salmon are found in the marine and fresh waters of the Southwest Region. The discussion of individual species' distribution and abundance will be presented by ADF&G commercial fisheries management area. There are five such management areas within the region: Kodiak, Chignik, Alaska Peninsula, Aleutian Islands, and Bristol Bay. Each area is divided into districts that in turn may be separated into subdistricts and/or sections for fishery management purposes such as regulating seasons and weekly fishing periods. Salmon commercial harvest area maps included in the Southwest Region Atlas show the location and boundary lines of the five management areas and their districts.

Within each management area, selected salmon species are managed to achieve and maintain populations at a level of sustained yield. Therefore, the distribution, timing, and abundance information needed to manage a given species may be well documented in one area (where it is of particular commercial value), but little data may be available for the same species in another area (where it has yet to be fully exploited commercially).

Salmon abundance, or run-strength, for an individual stream system is derived, where possible, by combining catch numbers (commercial harvest) and escapement (number of fish entering fresh water). The resultant population estimate, however, should be treated as an approximation or estimate of run-size because many factors can influence the harvesting and the escapement enumeration of the fish. Such factors as weather, current, and type of gear can affect the catch. Turbidity and/or glacial silt, weather and light conditions, and stream flow can affect escapement counts and aerial surveys.

In some cases, run-strength calculations for an individual stream system are a problem because the fisheries are harvesting mixed stocks of fish. It is therefore difficult to define what proportion of the catch should be allotted to which stream system. A few tagging studies and some analyses of growth patterns or age-class composition have clarified questions raised by mixed stock harvests in some areas; however, much more research is needed.

In the narratives and tables that follow, care has been taken to document locations and methods used to gather escapement data so that the approximate level of detail may be deduced (e.g., aerial surveys are generally less precise than weir counts). The data are taken in large part from the annual finfish reports prepared by area commercial fishery biologists, who stress that in the majority of cases run-strength assessments are estimates that should not be treated as absolute figures.

To supplement the distribution information presented in the text, a series of 1:250,000-scale reference maps has been produced that depicts anadromous fish streams and anadromous fish stream watersheds within the Southwest Region.

II. KODIAK MANAGEMENT AREA

The Kodiak Management Area includes all waters of Alaska south of a line extending east from Cape Douglas (58°52'N), west of 150°W, north of 55°30'N, and east of a line extending south from the southern entrance of Imuya Bay near Kilokak Rocks (156°20'13"W) (ADF&G 1983). The area is divided into nine districts, with the Afognak, Alitak, Red River, General, and Mainland districts divided into sections.

Adult salmon are found in the Kodiak area marine waters from mid March to late September or early October, and in fresh waters from mid May to mid December. Listed below in table 17 are general run-timing information on the different species (variations from these times occur in some systems).

Table 17. General Salmon Run-Timing Information, Kodiak Area

Species	Adults Present in Bays and Estuaries	Adults Present In Fresh Water	Peak of Spawning
Chinook	Mid Mar.-early July	Mid June-early Sept.	Early Aug.-early Sept.
Sockeye	Early May-mid Sept.	Mid May-mid Nov.	Early Aug.-early Oct.
Coho	Early July-early Oct.	Mid Aug.-mid Dec.	Mid Oct.-mid Nov.
Pink	Early June-early Sept.	Mid June-early Oct.	Early Aug.-mid Sept.
Chum	Mid June-early Sept.	Mid Aug.-early Oct.	Mid Aug.-early Oct.

Source: ADF&G 1977a.

Note: Early = 1st to 10th of month, mid = 11th to 20th of month, late = 21st to 30th/31st of month.

A. Sockeye Salmon

1. Distribution. There are more than 30 sockeye salmon systems in the Kodiak area, but only the Karluk, Red River (Ayakulik River), Upper Station, and Fraser systems, located in the southwest corner of Kodiak Island, are today considered of major economic importance (ADF&G 1982a). Minor systems include the Afognak River and Paul's Lake in the Afognak District, Kaflia in the Kukak section of the Mainland District, Uganik Lake in the east arm of Uganik Bay, Little River south of Cape Ugat, both in the Uganik Bay District, and Saltery in Ugak Bay of the General District.
2. Abundance. During the past 10 years (1973-1982) the sockeye salmon indexed escapements for the Kodiak area have averaged 1,182,660 fish. When compared to the 20-year average (1963-1982) of 886,868, it is apparent that more sockeye are being allowed to return to fresh water.

   By combining annual catch with the indexed escapement figures, a clearer picture of actual run-size begins to take shape. Since 1973, when the run was about 710,000 fish, the population steadily increased until in 1978 it was over 2,072,000 fish.

Although the major sockeye salmon runs will probably never reach the high level of production that occurred in the early years (around the turn of the century), it is the goal of the ADF&G to gradually rebuild these stocks to a higher level of production than is now the case, while still allowing some harvest during the building years. The department has partially realized this goal as recent runs have approached or exceeded historic highs in several systems, including Red River, Fraser, Upper Station, Afognak, Kaflia, Paul's Bay, Uganik, and Saltery (ADF&G 1982a). Detailed figures for sockeye escapement by major and minor river systems are shown in tables 18 and 19, respectively. Table 20 gives total run figures for the entire management area.

B. Pink Salmon

1. Distribution. Approximately 300 streams produce pink salmon in the Kodiak Management Area. Of these, however, 60 to 85% of the total pink salmon escapement is usually contained in 35 of the major river systems for odd-year returns and 47 of the major systems during even-year returns (Prokopowich, pers. comm; ADF&G 1982a). Following is a summary of these streams:

District	Year	Stream
Afognak	Odd	Portage, Paramanof, Afognak, Danger
	Even	Portage, Paramanof, Afognak, Danger, Malina, Marka
Uganik	Odd	Baumans, Terror, Uganik
	Even	Baumans, Terror, Uganik, Little
Uyak	Odd	Zachar, Uyak
	Even	Zachar, Uyak, Browns
Karluk	Odd	None
	Even	Karluk
Sturgeon R.	Odd	None
	Even	Sturgeon
Red River	Odd	None
	Even	Red River
Alitak	Odd	Dog Salmon, Narrows, Humpy, Deadman
	Even	Dog Salmon, Narrows, Humpy, Deadman
General	Odd	Seven Rivers, Kauignak, Barling, Kiliuda, Saltery, Hurst, Sid Olds, American, Buskin, Sheratin
	Even	Those above plus Miam
Mainland	Odd	Missak, Kinak, Geographic, Dakavak, Kashvik, Alinchak, Portage, Oil Creek, Jute Creek, Kanatak, Big Creek, Kukak
	Even	Those above plus Big River, Village Creek, Cape Chiniak, Hallo Bay.

Table 18. Weir Escapements of Sockeye Salmon for Major River Systems of the Kodiak Management Area (in Thousands of Fish)

	Districts						
	Karluk	Red River	Alitak Bay			Afognak	
Year	Karluk[a] System	Red River[b] System	Fraser System	Upper Station System	Akulara Lake System	Afognak Weir[e] System	Paul's Lake System
1973	252.7	120.0	56.3	87.6	5.8		
1974	340.6	181.6	82.6	285.7	34.8		
1975	378.8	94.5	64.2	82.0	5.1		
1976	523.5	219.9	119.3	62.9	10.7		
1977	552.2	307.0	139.5	77.6	6.8		
1978	360.9	132.9	142.3	115.9	1.0[c]	50.9	18.0
1979	513.1	223.1	126.8	174.6	8.1[d]	82.7	
1980	146.6	773.6	405.5	110.0	5.1[d]	93.8	48.1
1981	222.7	279.2	377.7	181.6	5.2[d]	57.3	21.8
1982	164.4	169.6	437.5	407.7	5.0[d]	123.1	18.6

Source: ADF&G 1982a. (These escapements are considered complete as compared to indexed or estimated escapements from aerial surveys [Manthey, pers. comm.]).

a Karluk Weir Location: 1946-1975 Karluk Lake; 1976 to present Karluk Lagoon.

b Red River Weir Location: 1970 to present Ayakulik Lagoon.

c Weir removed before September-October portion of run.

d No weir after 1978. Counts from foot and aerial surveys.

e Weir counts only. No escapement data shown for years when only aerial surveys or foot surveys were done.

Table 19. Escapement Estimate of Sockeye Salmon to Minor Systems in the Kodiak Management Area (Aerial and Foot Surveys)

Stream Name	Stream Number	1982 Escapement	Average[a] Escapement	Historical Escapement Range	District
Akalura	257-302	5,000	43,930	1,828 - 252,193	Alitak
Afognak River	252-342	123,055	27,876	100 - 93,861	Afognak
Barabara Cove	252-363	1,200	768	100 - 3,200	Afognak
Buskin Lake	259-211	3,600	3,377	65 - 7,846	General
Horse Marine	257-402	7,500	5,546	15 - 23,000	Alitak Bay
Kaflia	262-301	43,000	11,530	100 - 51,000	Mainland
Little Afognak	252-321	-	300	300 - 300	Afognak
Little Kitoi	252-313	200	1,603	60 - 3,760	Afognak
Little River	253-115	11,500	12,693	300 - 38,500	Uganik
Malina	251-105	7,000	5,883	300 - 20,000	Afognak
Miam	259-412	200	1,289	5 - 4,600	General
Ocean Beach	258-401	100	3,732	100 - 18,000	General
Paramanof	251-301	-	1,501	60 - 5,800	Afognak
Pasagshak	259-411	5,400	3,762	150 - 12,000	General
Paul's Lake	251-828	18,654	14,523	150 - 50,993	Afognak
Perenosa	251-825	8,963	4,458	141 - 12,474	Afognak
Russian Harbor	258-801	-	100	100 - 100	General
Saltry Lake	259-415	28,000	15,252	1,000 - 43,300	General
Selief Bay	251-101	350	923	400 - 2,800	Afognak
Silver Salmon	257-303	-	1,202	15 - 3,045	Alitak Bay
Swikshak	262-151	43,000	9,640	1,500 - 43,000	Mainland
Thorsheim Creek	251-302	166	653	100 - 1,200	Afognak
Uganik Lake	253-122	50,000	30,472	1,500 - 77,000	Uganik
Total	23	356,888	147,962		

Source: ADF&G 1982a; Manthey, pers. comm.

a Averages computed by using only those years when fish were observed in the stream. Many years, no surveys were flown or surveys were flown at the wrong time for observation of sockeye salmon escapements.

Table 20. Kodiak Management Area Salmon Total Run Estimates 1977 to 1982 (in Thousands of Fish)

Year		Species					Total
		Chinook	Sockeye	Coho	Pink	Chum	
	Catch	0.6	623.5	27.9	6,252.4	1,072.3	7,976.7
1977	Escapement	13.8	1,270.0	59.1	2,212.4	742.4	4,297.7
	Total run	14.4	1,893.5	87.0	8,464.9	1,814.7	12,274.4
	Catch	3.2	1,071.8	48.8	15,004.1	814.3	16,942.2
1978	Escapement	14.7	1,000.4	37.5	5,006.3	483.0	6,541.8
	Total run	17.9	2,072.1	86.3	20,010.3	1,297.3	23,484.0
	Catch	1.9	631.7	140.6	11,287.6	358.4	12,420.3
1979	Escapement	14.4	1,410.8	94.0	3,100.0	607.0	5,226.2
	Total run	16.4	2,042.5	243.6	14,387.6	965.4	17,646.5
	Catch	0.5	651.4	139.2	17,290.6	10,075.6	19,157.2
1980	Escapement	5.9	1,831.7	28.0	6,500.0	830.0	9,195.6
	Total run	6.4	2,483.1	167.2	23,790.6	1,905.6	28,352.9
	Catch	1.4	1,288.9	121.5	10,299.7	1,345.3	13,056.9
1981	Escapement	15.7	1,400.0	59.0	3,200.0	742.0	5,416.7
	Total run	17.1	2,688.9	180.5	13,446.3	2,087.3	18,986.8
	Catch	1.2	1,204.8	343.5	8,076.2	1,266.2	10,892.0
1982	Escapement	10.8	1,603.7	86.4	5,370.0	1,023.9	8,094.8
	Total run	12.0	2,808.5	429.9	13,446.3	2,290.1	18,986.8
Average catch		1.5	912.0	136.9	11,368.4[a]	988.7	13,407.5
Average run		13.5	2,331.4	197.6	15,599.9[b]	1,726.7	18,869.2

Source: ADF&G 1982a.

a Pink odd-year average catch = 9,279.9; pink even-year average catch = 13,457.0.

b Pink odd-year average run = 12,117.4; pink even-year average run = 19,082.4.

2. Abundance. Pink salmon are the most abundant species of salmon found within the Kodiak Management Area. Following poor returns in the early 1970's, a more cautious approach to the management of the fishery in 1974 and 1975 was implemented. This approach allowed for good escapement in both years and resulted in excellent returns that compared favorably with the best historical returns. The population continued to increase and culminated in 1980 with the largest catch ever recorded, 17.3 million, and with an escapement of about 6 million. Since then, catches for both even and odd-year returns have been above historical averages (ADF&G 1982a). In 1983, however, the catch dropped to about 600,000 below average (Manthey, pers. comm.). Pink salmon escapement figures for index streams are provided in table 21, and table 20 gives total run figures for the entire management area.

C. Chum Salmon

1. Distribution. Chum salmon are found in most of the streams of the Kodiak Management Area. They utilize many of the same streams as pink salmon for spawning. The main run of chums occurs on the east side of Kodiak Island in the General District and in the Kukak section (northern portion) of the Mainland District (ADF&G 1982a).

The major chum salmon systems are primarily late runs that often allow the ADF&G to manage them separately from the earlier-running pink salmon. It is difficult to rank individual systems in terms of importance because collectively they all contribute to the commercial harvest for the bay and cape fisheries. A few, however, may be mentioned since they are found near areas of significant chum harvests (Prokopowich, pers. comm). These systems are listed below:

District	System
General	Kiliuda Bay index streams #258-204 (Dog Bay Cr.) and #258-205 (Coxcomb Bay)(NE of Coxcomb Pt.), index stream #259-426b (Gull Cape Cr.) near Gull Cape Lagoon, Kaguyak Creek, Sitkinak Bay tributaries
Mainland	Big River in vicinity of Wide Bay; Hallo Bay index streams #262-201, 202, 203, and 204; Dakovak; Bear Bay tributaries; Puale Bay tributaries; and Dry Bay tributaries
Uganik Bay	Uganik River
Uyak	Zachar River
Alitak	Deadman, Sukhoi Lagoon tributaries, Frazer (Dog Salmon) River, Portage Creek
Sturgeon R.	Sturgeon River

Table 21. Escapement Estimates of Pink Salmon for Index Streams in the Kodiak Management Area (in Thousands of Fish)

District	Stream	1973	1974	1975	1976	1977	1978	1979	1980	1981
Afognak	Portage	11.0	6.0	21.0	20.2	21.6	31.0	71.0	55.0	56.0
	Paramanof	3.0	7.0	0.2	11.0	1.3	2.0	13.0	30.0	26.0
	Malina	---	8.3	---	20.6	---	38.0	---	152.9	---
	Afognak	9.5	15.8	0.7	60.8	21.0	48.2	4.8	21.0	4.4
	Marka	---	38.0	---	51.0	---	62.0	---	76.0	---
	Danger	3.0	15.7	2.1	33.5	21.0	17.0	24.0	11.0	43.0
Uganik	Baumans	3.0	4.0	0.6	2.1	5.9	6.3	18.1	18.5	44.5
	Terror	22.0	69.0	42.0	46.0	56.0	34.5	80.0	108.0	92.0
	Uganik	53.0	118.0	77.5	87.0	44.0	67.5	99.0	127.0	75.0
	Little	---	---	---	26.0	---	33.0	---	122.0	---
Uyak	Zachar	110	92.0	35.5	84.4	35.5	57.0	53.0	135.0	50.0
	Browns	---	7.5	---	41.0	---	161.0	---	29.0	---
	Uyak #202	50.0	13.2	66.0	31.2	111.0	66.0	147.0	80.5	136.0
Karluk	Karluk	---	212.0	---	373.4	---	1,380.8	---	2,359.1	---
Sturgeon	Sturgeon	---	13.0	---	31.0	---	100.0	---	60.0	---
Red River	Red River (Ayakulik)	---	612.7	---	708.6	---	1,000.0	---	900.0	---
Alitak	Dog Salmon	22.0	43.0	38.0	189.0	98.0	217.5	85.2	167.0	157.0
	Narrows	1.0	3.3	0.2	7.5	2.5	---	3.8	12.0	16.0
	Deadman	40.0	43.0	76.7	86.0	141.0	7.3	97.5	52.0	180.0
	Humpy	45.0	72.0	71.0	240.0	92.0	290.0	306.0	260.0	240.0
General	Seven R.	24.0	27.5	86.0	71.0	53.0	104.0	100.7	117.5	128.0
	Kaiugnak	1.0	2.0	1.6	35.4	13.0	14.0	17.0	21.0	22.0
	Barling	23.0	33.6	39.4	36.7	48.5	49.0	67.5	55.0	52.0
	Kiliuda	1.5	24.4	3.7	26.0	2.7	22.8	22.2	39.0	47.0
	Saltery	25.0	17.0	46.0	38.0	144.0	30.0	68.0	50.0	57.0
	Miam	---	55.0	---	19.0	---	18.2	---	16.0	---
	Hurst	8.3	53.0	7.7	61.0	33.0	29.0	17.0	10.0	6.1
	Sid Olds	13.0	36.0	16.0	32.2	41.0	65.0	80.0	67.7	73.0
	American	11.3	30.0	24.4	33.0	51.9	28.9	45.3	50.0	54.0
	Buskin	26.4	45.8	22.0	52.0	54.0	81.0	61.0	95.0	88.0
	Sheratin	3.3	17.0	12.0	23.5	18.0	26.0	38.0	---	20.5

(continued)

Table 21 (continued).

District	Stream	1973	1974	1975	1976	1977	1978	1979	1980	1981
Mainland	Kukak	0.1	3.0	15.0	---	5.0	---	3.0	2.0	2.6
	Missak	0.4	---	4.2	---	10.5	4.0	5.0	9.0	14.0
	Kinak	0.5	0.5	34.0	---	55.0	47.5	55.0	85.0	89.2
	Geographic	1.0	0.2	0	7.5	15.0	2.4	21.0	11.0	57.0
	Dakavak	3.0	9.0	29.0	2.1	76.0	21.3	77.0	80.4	31.0
	Kashvik	9.5	7.5	16.0	---	60.0	11.0	38.7	36.0	37.0
	Alinchak	6.0	4.5	5.2	5.0	28.0	11.0	17.0	21.0	11.0
	Portage	3.0	2.4	3.0	3.5	7.0	1.4	12.0	75.0	14.0
	Kanatak	2.0	2.0	3.0	2.0	10.5	20.0	40.0	2.0	50.0
	Jute Creek	0.3	0.01	0.1	0.2	1.5	0.3	1.2	7.5	0.5
	Oil Creek	5.0	0.6	2.2	0.6	0	---	5.7	48.0	15.0
	Big Creek	5.0	21.0	13.0	60.0	112.0	40.0	184.0	32.0	65.0
	Big River	---	8.0	---	4.0	---	5.0	---	8.3	---
	Village Creek	---	1.8	---	3.5	---	15.0	---	20.5	---
	C. Chiniak	---	0.4	---	0.5	---	0.2	---	---	---
	Hallo Bay	---	0.6	---	0.2	---	2.5	---	---	---

Sources: ADF&G 1981b, ADF&G 1982a.

2. Abundance. Although areawide chum-run estimates are available (see table 20), very little escapement information for specific stream systems has been published that summarizes the magnitude of runs in each stream. In-season escapement estimates from aerial and foot surveys as well as weir counts are documented in the Kodiak area annual finfish reports.

D. Chinook Salmon
   1. Distribution. The Karluk and Red (Ayakulik) rivers on the southwest corner of Kodiak Island have the only natural chinook salmon runs in the Kodiak Management Area. Chinook have been introduced to the Dog Salmon River, which flows from Fraser Lake in the Alitak Bay District, and to the Pasagshak River on the northeast corner of Kodiak Island in the Ugak section of the General District.
   2. Abundance. Table 22 lists escapement figures for the chinook salmon in the Kodiak Management Area, and table 20 provides an estimate of the total run within the management area.

E. Coho
   1. Distribution. Coho salmon are found in many streams on Kodiak Island and in a few systems of the Mainland District.
   2. Abundance. Because of the lateness of the runs, escapement figures are incomplete for coho salmon. Available information for a few streams is presented in table 23 for Kodiak Island and

Table 22. Escapement Estimates of Chinook Salmon for Streams in the Kodiak Management Area (in Number of Fish)

Year	Karluk River	Ayakulik (Red River)	Frazer	Pasagshak	Total
1968	700+	N.C.[b]	3	0	703+
1969	1,750+	N.C.[b]	2	0	7,752+
1970	3,900+	N.C.[b]	0	0	3,900+
1971	4,500+	N.C.[b]	24	0	4,524+
1972	1,290+	1,644	113	0	3,047+
1973	3,500+	1,262	0	0	4,762+
1974	771+	851	0	0	1,622+
1975	2,000+	1,053	6	0	3,059+
1976	6,897	1,493	21	0	8,411
1977	8,456	5,163	205	0	13,824
1978	9,795	4,739	143	0	14,677
1979	9,555	4,833	53	0	14,441
1980	4,810	974[a]	66	0	5,850+
1981	7,575	8,018	85	42	15,720
1982	7,490	3,230[a]	47	41	10,773+
Average[b]	7,947	3,023	64	42	11,243

Source: ADF&G 1982a.

a After 1976, chinook salmon counts on the Karluk are weir counts and are more accurate than the indexed escapements made prior to 1977. The Ayakulik counts are accurate except for 1980 and 1982, when severe flooding caused the weir to wash out for an extended period during the peak of the chinook run. The Frazer and Pasagshak systems support new runs of chinook.

b The average was computed by using only the years when escapement data are considered complete.

Table 23. Escapement Estimates of Coho Salmon in the Kodiak Management Area (in Number of Fish)

Location	Year								
	1975	1976	1977	1978	1979	1980	1981	1982	Average[b]
Karluk	1,478+	13,513	18,537	12,089	45,262	5,729	24,792	14,902	19,261
Ayakulik (Red R.)	1,709+	112+	N.C.	1,705+	2,047+	2,500+	392+	5,011+	1,925
Upper Station	7,169	5,792	4,885	4,000	11,555	2,200	7,733	4,839	6,022
Afognak	N.C.	N.C.	20,000	5,631	4,920	800+	4,350	1,178+	6,147
Road system [a]	5,812	3,157	2,397	5,799	11,204	7,413	6,756	10,602	6,159
Remainder [b]	13,466	13,509	13,276	8,255	18,952	8,648	14,706	49,890	17,588
Total	29,634	36,083	59,095	37,479	93,940	27,290+	58,729	86,402	57,102

Source: ADF&G 1982a.

a Each stream on the Kodiak road system that received coho has been included in table 24.

b All total coho escapement counts for each year should be considered incomplete, but more effort has been expended in recent years to obtain more complete coho escapement counts. This has resulted in higher counts, especially for streams on the road system and the "Remainder" of Kodiak Island.

Table 24. Escapement Estimates of Coho Salmon for Systems on the Kodiak Island Road System (in Number of Fish)

Stream or River	Year										Avg.[b]
	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	
American	31	250	350	146	113	705	740	903	627	266	362.6
Buskin	930	250	500	851	1,070	886	1,010	1,021	919	1,176	849.6
Chiniak	?[a]	115	150	44	115	51	202	32	170	155	114.9
Hurst	?	?	?	?	34	183	?	218	?	644	234.8
Kalsin	23	50	67	60	292	84	240	237	133	181	124.8
Monashka	?	3	15	17	18	13	75	72	57	31	33.2
Olds	147	7	350	104	309	1,090	1,355	780	439	1,375	460.5
Pasagshak	1,829	210	3.500	1,505	?	1,441	1,103	2,664	2,621	3,432	1,901.2
Pillar	?	11	20	13	23	74	33	68	33	36	30.8
Roslyn	17	76	160	131	183	406	1,825	628	314	525	282.5
Russian	?	39	50	4	15	22	24	30	47	87	35.3
Salonie	69	291	350	273	200	261	597	741	393	388	334.8
Saltery	?	462	?	?	?	543	4,000	?	959	2,176	1,322.6
Sargent	?	24	300	9	25	35	?	18	44	130	68.9
Twin	?	?	?	?	?	5	?	1	?	?	3.0
Total	3,046	1,788	5,812	3,157	2,397	5,799	11,204	7,413	6,756	10,602	6,159.3

Source: ADF&G 1982a.

a Coho escapement counts are made by aerial survey and on foot and are often incomplete because of weather and budget restrictions in the fall. When counts were not obtained, a ? is used for that year.

b The average is computed only from those years in which escapement counts were obtained and for the American, Buskin, Pasagshak, Roslyn, and Salonie systems includes estimates from 1965 through 1972. Many counts are low because they were made under adverse weather conditions and often before most of the coho had reached spawning grounds.

in table 24 for the road system streams on the northeast corner of Kodiak Island. Table 20 provides an estimate of the total run.

III. CHIGNIK MANAGEMENT AREA

The Chignik Management Area includes all waters of Alaska on the south side of the Alaska Peninsula enclosed by 156°20'13" west longitude (the longitude of the southern entrance to Imuya Bay near Kilokak Rocks) and a line extending 135° southeast from Kupreanof Point (ADF&G 1983). The area is divided into five districts. All but the Chignik Bay District are further divided into sections. There are approximately 75 salmon streams within the area (ADF&G 1982d).

Adult salmon are found in the Chignik area marine waters from May through November and in fresh waters from mid June through early November. Listed below in table 25 are general run-timings of the different species (variations from these times occur in some systems).

A. Sockeye Salmon

1. Distribution. The Chignik River system is the only major sockeye producer in the area. Within this system, two major sockeye runs occur. The early run enters the Chignik Lagoon in early June, peaks toward the end of June, and migrates upstream to Black Lake tributaries to spawn. The late run enters the lagoon late in June, peaks about the middle of July, and moves upstream to spawn in Chignik Lake and its tributaries (Probasco, pers. comm). In addition to the major sockeye run in the Chignik River system, minor runs exist in the Aniakchak River system, Agripina, Port Wrangell, Ocean Beach, and Yantarni (ADF&G 1977b).

Table 25. General Salmon Run-Timing and Early Life History Information, Chignik Area

	Adults		Juveniles	
Species	Present in Fresh Water	Spawning	Emerge from Gravel	Outmigration
Chinook	Mid June-mid Aug.	Mid Aug.-mid Sept.	Early Apr.-early May	No data
Sockeye	Early June-mid Oct.	Mid July-mid Jan.	Early Apr.-end May	Early May-early Aug.
Black L (system peak)		1 Aug.-16 Aug.	10 Apr.-20 May	(peak 1 June)
Chignik L (system peak)		5 Sept.-1 Oct.	20 Apr.-1 Oct. (peak 20 May)	
Coho	Mid Aug.-early Nov.	Early Oct.-mid Jan.	No data	No data
Pink	Early July-early Sept.	Late July-late Sept.	Mid Mar.-mid May	Mid Mar.-mid May
Chum	Mid July-mid Sept.	Late July-late Sept.	Early Mar.-early May	No data

Source: ADF&G 1977b.

Note: Early = 1st to 10th of month, mid = 11th to 20th of month, late = 21st to 30th/31st of month.

2. <u>Abundance</u>. Total sockeye run-strength for the Chignik area is derived from escapement estimates within the Chignik Management Area and catch information from the Chignik area, the Cape Igvak section of the Kodiak Management Area, and the Balboa Bay and East and West Stepovak sections of the Southeastern District in the Alaska Peninsula Management Area. Eighty percent of the Cape Igvak and Stepovak catches are added to Chignik catches because past tagging studies have indicated that 80% of the sockeye salmon intercepted at Cape Igvak, Aniakchak, Hook Bay, and Stepovak are Chignik-bound (ADF&G 1982d). Table 26 presents sockeye run-strength estimates for the Chignik Management Area.

Table 26. Total Run Estimate of Sockeye Salmon for the Chignik Management Area (in Thousands of Fish)

Year	Chignik Area Escapement	Chignik Area Catch	Balboa-Cape Igvak Catch(%)[a]	Stepovak Catch(%)[a]	Total Catch	Total Run
1973	780	871 (90)[b]	53 (6)	39 (4)	963	1,743
1974	664	659 (77)	127 (15)	69 (8)	855	1,519
1975	577	400 (94)	24 (5)	3 (1)	427	1,004
1976	821	1,136 (87)	118 (9)	47 (4)	1,301	2,122
1977	734	1,972 (92)	129 (6)	38 (2)	2,138	2,873
1978	681	1,576 (86)	227 (13)	25 (1)	1,828	2,509
1979[c]	738	1,047 (93)	15 (1.3)	64 (5.7)	1,126	1,864
1980[c]	664	848 (90.4)	1 (.1)	89 (9.5)	938	1,602
1981[c]	831	1,839 (82.1)	284 (12.6)	118 (5.3)	2,241	3,072
1982[c]	838	1,251 (83.9)	172 (11.6)	68 (4.5)	1,491	2,329

Source: ADF&G 1982d.

a Impact of Cape Igvak (Kodiak Mgmt. Area) and Balboa-Stepovak (Ak. Peninsula Mgmt. Area) catches on Chignik-bound sockeye: 80% of the Cape Igvak and Stepovak catches are added to Chignik catches to determine total run-strength for Chignik because past tagging studies have indicated that 80% of the sockeye salmon intercepted at Cape Igvak, Aniakchak, Hook Bay, and Stepovak are Chignik-bound.

b Figures in parentheses represent the percentage of the total catch of sockeye destined for the Chignik River system.

c Sockeye taken after July 25 in the Cape Igvak section are not to be considered when computing the "impact," according to the Cape Igvak Management Plan adopted by the State Board of Fisheries in 1978.

B. Pink Salmon

1. Distribution. Pink salmon are found in most of the stream systems of the Chignik Management Area. A few of the more productive pink salmon systems include the Ivan River, Coal Cape Creek, Humpback Bay Creek, Ivanof River, Kupreanof Creek, Chiginagak River, Portage Bay Creek, Cape Kumliun Creek, Hook Bay Creek, Yantarni River, stream #272-905, Main Creek, and Agripina River (ADF&G 1981a, ADF&G 1980).
2. Abundance. Pink salmon stocks within the Chignik Management Area are beginning to recover from the severe winters of 1970-1971 and 1971-1972, which are thought to have caused sharp declines in the population. Since 1978, returns have approached historical highs.

   Within the area, pink salmon exhibit the normal even-odd-year cycle but with some local variation. The Eastern District has produced larger runs during even years, whereas the Central, Chignik Bay, Western, and Perryville districts, at times, have produced larger runs during odd years (ADF&G 1981a). Table 27 presents pink salmon run-strength estimates for the Chignik Management Area.

C. Chum Salmon

1. Distribution. Chum salmon are found throughout the Chignik Management Area. They utilize many of the same streams as pink salmon for spawning.
2. Abundance. Chum salmon are harvested primarily incidentally to pink salmon harvest in the Chignik area. For this reason, it is impossible, in most cases, to manage them separately from the pink salmon runs. Thus, chum salmon escapements may suffer during years of large pink salmon runs when more fishing time is allowed. Conversely, weak pink salmon runs sometimes contribute to large chum salmon escapements due to reduced fisheries (ADF&G 1977b). Table 28 presents the population estimation for Chignik Management Area chum salmon.

D. Chinook Salmon

1. Distribution. Chinook salmon are found in the Chignik River system of the Chignik Management Area.
2. Abundance. The population estimate for Chignik area chinook salmon is derived by combining Chignik River escapement estimates with area catch reports. Table 29 presents the Chignik Management Area chinook salmon run estimates.

E. Coho Salmon

1. Distribution. The Chignik River system presently produces most of the coho utilized by the commercial fishery. Other streams in the Central, Eastern, Western, and Perryville districts also produce coho, but virtually nothing is known about the magnitude of the runs.
2. Abundance. Due to the lateness of the runs, no data are available for preparing an estimate of run-size.

Table 27. Chignik Management Area Pink Salmon Run Estimates (in Thousands of Fish)

Year		Districts					
		Eastern	Central	Chignik Bay	Western	Perryville	Total
1973	Catch	0	2.8	22.7	0	0	25.5
	Escapement	12.8	50.2	2.2	62.4	31.5	159.1
	Total run	12.8	53.0	24.9	62.4	31.5	184.6
1974	Catch	1.1	21.7	33.8	13.3	0	69.9
	Escapement	76.2	9.8	4.0	77.4	60.2	227.6
	Total run	77.3	31.5	37.8	90.7	60.2	297.5
1975	Catch	0	31.4	27.4	7.4	0	66.2
	Escapement	23.5	26.4	1.2	141.7	45.3	238.1
	Total run	23.5	57.8	28.6	149.1	45.3	304.3
1976	Catch	28.8	16.4	104.3	134.8	104.7	389.0
	Escapement	228.8	66.0	12.3	114.2	89.3	510.6
	Total run	257.6	82.4	116.6	249.0	194.0	899.6
1977	Catch	0.2	120.0	60.9	379.0	44.6	604.7
	Escapement	76.0	199.9	3.0	355.5	115.4	749.8
	Total run	76.2	319.9	63.9	734.5	160.0	1,354.5
1978	Catch	86.7	61.3	137.1	419.3	280.7	985.1
	Escapement	309.3	101.2	10.7	333.4	157.5	912.1
	Total run	396.0	162.5	147.8	752.7	438.2	1,897.2
1979	Catch	271.3	277.3	312.6	746.0	269.4	1,876.6
	Escapement	194.3	297.0	1.2	185.0	181.3	858.8
	Total run	415.6	574.3	313.8	931.0	450.7	2,735.4
1980	Catch	514.8	96.9	180.6	215.6	107.9	1,125.5
	Escapement	425.5	99.4	3.0	139.5	74.8	742.2
	Total run	940.3	196.3	183.6	355.1	182.7	1,867.7
1981	Catch	128.2	255.1	121.4	433.6	224.3	1,162.6
	Escapement	154.7	76.5	1.4	249.3	116.0	598.0
	Total run	282.9	331.6	122.8	682.9	340.3	1,760.6
1982	Catch	89.1	80.6	83.0	602.4	18.3	873.4
	Escapement	301.5	26.1	2.4	45.9	13.4	389.4
	Total run	390.6	106.7	85.4	648.3	31.7	1,262.8

Source: ADF&G 1982d.

Table 28. Chignik Management Area Chum Salmon Run Estimates (in Thousands of Fish)

Year		Districts					
		Eastern	Central	Chignik Bay	Western	Perryville	Total
1973	Catch	0	1.4	7.3	0	0	8.7
	Escapement	59.1	12.2	0.7	35.6	9.3	116.9
	Total run	59.1	13.6	8.0	35.6	9.3	116.6
1974	Catch	0.4	13.9	17.5	3.2	0	35.0
	Escapement	76.3	18.1	2.1	39.4	12.5	148.4
	Total run	76.7	32.0	19.6	42.6	12.5	183.4
1975	Catch	0	3.2	21.2	0.8	0	25.2
	Escapement	41.3	18.8	2.1	43.4	20.5	126.1
	Total run	41.3	22.0	23.3	44.2	20.5	151.3
1976	Catch	10.0	3.4	18.2	33.0	15.6	80.2
	Escapement	122.3	17.8	2.4	55.0	8.9	206.4
	Total run	132.3	21.2	20.6	88.0	24.5	286.6
1977	Catch	1.5	8.9	8.6	88.0	3.4	110.4
	Escapement	54.5	9.3	2.0	70.4	15.4	151.6
	Total run	56.0	18.2	10.6	158.4	18.8	262.0
1978	Catch	17.4	10.3	15.0	45.9	32.1	120.7
	Escapement	55.8	13.8	2.1	27.3	5.3	104.3
	Total run	73.2	24.1	17.1	73.2	37.4	225.0
1979	Catch	32.6	11.2	31.3	83.2	26.1	184.4
	Escapement	79.5	44.8	1.6	42.5	12.8	181.2
	Total run	112.1	56.0	32.9	125.7	38.9	365.6
1980	Catch	56.8	94.1	27.2	92.0	41.3	312.6
	Escapement	107.0	34.2	.3	56.5	29.1	227.1
	Total run	163.8	128.3	27.5	148.5	70.4	539.7
1981	Catch	94.4	175.0	38.1	221.6	51.3	580.3
	Escapement	126.0	26.1	.5	70.3	19.3	242.1
	Total run	220.4	201.1	38.6	291.9	70.6	822.4
1982	Catch	64.5	33.7	16.0	253.3	22.6	390.1
	Escapement	145.4	49.4	1.4	35.4	23.6	255.1
	Total run	209.9	83.1	17.4	288.7	46.2	645.2

Source: ADF&G 1982d.

Table 29. Chignik Management Area Chinook Salmon Total Run Estimates (in Numbers of Fish)

Year	Catch	Chignik River Escapement[a]	Total Run
1973	525	822	1,347
1974	255	672	927
1975	549	877	1,426
1976	763	700	1,463
1977	711	798	1,509
1978	1,603	1,197	2,800
1979	1,266	1,050	2,316
1980	2,325	876	3,201
1981	2,694	1,603	4,297
1982	5,236	2,412	7,648

Source: ADF&G 1982d.

a Only large chinook salmon are recorded because of the difficulty in distinguishing small chinooks from sockeyes as they pass through the Chignik weir.

IV. ALASKA PENINSULA MANAGEMENT AREA

The Alaska Peninsula Management Area includes all waters of Alaska from Cape Menshikof south to Unimak Pass, then easterly to Kupreanof Point (ADF&G 1983). The area is divided into six districts, with all but the Unimak District being further separated into sections. For management purposes the area is subdivided into the North Peninsula (made up of the North and Northwest districts) and the South Peninsula (made up of the Unimak, Southwestern, Southcentral, and Southeastern districts). In the narratives that follow, information for the North and South Peninsula is presented separately to highlight differences in the data collected. The South Peninsula is managed primarily for pink and chum salmon and, during June, for sockeye intercept fisheries, whereas the emphasis on the North Peninsula is on coho, sockeye, chinook, and chum salmon. For this reason, population estimates, run-timing, and life history events (spawning times, emergence from gravel, and outmigration to the sea) for a given species are well documented in some areas and scarcely observed in others.

Adult salmon are found in the Alaska Peninsula marine waters from late April through October and in fresh waters from mid May through January. General run-timing for the different species is presented in tables 30 and 31 to reflect differences in South and North Peninsula run-timing (variations from these times occur in some systems).

A. Sockeye Salmon

1. South Peninsula:

   a. Distribution. Sockeye salmon runs on the South Peninsula are numerous but small.

   b. Abundance. Sockeye salmon escapement estimates for the South Peninsula are made by surveying selected streams in the Southwestern, Southcentral, and Southeastern districts. Included in this survey are waters in the Ikatan Bay, Morzhovoi Bay, Thin Point, Cold Bay, Pavlof Bay, Canoe Bay, Mino Creek-Little Coal Bay, Shumagin Island, and West Stepovak sections. Table 32 presents, by section, annual escapement estimates, and table 33 gives the total South Peninsula sockeye run-strength estimate.

2. North Peninsula:

   a. Distribution. Sockeye salmon are found in nearly every drainage of the North Peninsula. The major run is to the Bear River north of Port Moller in the Northern District. Other important runs in the Northern District include the Nelson River, Sandy River, and Ilnik. In the Northwestern District Urilia Bay supports an important sockeye run (ADF&G 1977b).

   b. Abundance. Sockeye salmon run-strength estimates for the Northwestern and Northern districts are provided in table 34. Total North Peninsula sockeye salmon run estimates are given in table 35 and show their size in comparison to the other species of salmon in the North Peninsula.

B. Pink Salmon

1. South Peninsula:

   a. Distribution. Pink salmon are the major species on the South Peninsula. Mino Creek, Settlement Point, and Southern Creek on Deer Island occasionally produce one-half the total pink salmon run. Apollo Creek and Middle Creek have the combined potential of producing another 500,000 to 2,000,000 pink salmon in a good year were fish ladders installed on these streams (Shaul, pers. comm.).

   b. Abundance. Pink salmon populations on the South Peninsula have increased greatly during the past 20 years and for the five years, 1979 to 1982, have ranged between 7.3 to 10.5 million fish. Table 36 presents, by district, the pink salmon population estimate for the South Peninsula, and table 33 gives the total South Peninsula pink salmon run-strength estimate in comparison with the other species of salmon.

Table 30. General Run-Timing and Early Life History Information: Alaska Peninsula Area, South Peninsula

	Adults		Juveniles	
Species	Enter Fresh Water[a]	Spawning[b]	Emerge From Gravel[b]	Outmigration[b]
Chinook	------------ Chinook salmon are not found in fresh waters of the South Peninsula ------------			
Sockeye	Early June-mid Aug.	Mid July-late Sept.	Early Apr.-early June	Early May-early Aug.
Coho	Late Aug.-early Oct.	Early Oct.-late Dec.	No data	No data
Pink	Early July-late Aug.[c]	Late July-mid Sept.	Mid Mar.-mid May	Mid Mar.-mid May
Chum	Early July-late Aug.	Late July-late Sept.	Early Mar.-early May	No data

Note: Early = 1st to 10th of month, mid = 11th to 20th of month, late = 21st to 30th/31st of month.

a Shaul, pers. comm.

b ADF&G 1977b

c The pink salmon even-year run starts the first week of July and goes till mid Aug. The odd-year runs begin in mid July and early Aug.

Table 31. General Run-Timing and Early Life History Information: Alaska Peninsula Area, North Peninsula

	Adults		Juveniles	
Species	Enter Fresh Water[a]	Spawning[b]	Emerge From Gravel[b]	Outmigration[b]
Chinook	Late May-late July	Mid July-mid Aug.	Probably Apr.-June	Probably June
Sockeye	Late June-early Aug.[c]	Mid July-mid Jan.	Probably mid Mar.-mid May	Probably late May-mid July
Coho	Mid Aug.-mid Sept.	Early Oct.-late Nov.	Probably Apr.-June	Probably June
Pink	Mid July-mid Aug. (for the few that do arrive)		No data	No data
Chum	Early June-mid Aug.	Late July-late Aug.	Probably late Apr.-May	Probably early June

Note: Early = 1st to 10th of month, mid = 11th to 20th of month, late = 21st to 30th/31st of month.

a Shaul, pers. comm.

b ADF&G 1977b.

c Nelson River sockeye run: mid June-early Aug. Peak of run: late June-mid July. Spawning occurs until late Nov. The Bear River has two runs: early run from mid June to mid Sept.; late run starts early Aug. Late-run fish have smaller eggs and may stay in Bear Lake up to four months before spawning.

Table 32. South Peninsula Escapement Estimates of Sockeye Salmon (in Thousands of Fish)

Year	Southeastern District		Southcentral District			Southestern District			
	West Stepovak Section	Shumagin Islands Section	Mino Creek - Little Coal Bay Section	Pavlof Bay Section	Canoe Bay Section	Cold Bay Section	Thin Point Section	Morzhovoi Bay Section	Ikatan Bay Section
1973	1.2	1.0	0	0.5	0	1.5	0.7	0.4	1.0
1974	61.5	7.9	0	0.2	0.2	3.5	16.0	5.3	1.0
1975	22.3	11.6	0.5	1.6	1.6	5.0	6.1	2.2	0.8
1976	29.7	7.5	1.0	2.8	0.3	4.9	20.5	1.7	1.3
1977	17.0	9.2	2.0	4.5	0.5	7.6	17.7	3.8	2.6
1978	22.2	9.0	2.7	2.1	1.5	14.7	7.4	2.6	(2.6)[a]
1979	20.0	13.0	0.2	1.1	1.5	7.8	6.9	0.7	2.1
1980	12.0	6.3	1.1	1.9	5.5	4.8	12.0	1.3	1.0
1981	18.0	4.0	0.5	5.5	2.0	5.6	7.5	1.2	1.4
1982	9.1	10.0	0.8	1.0	1.0	2.6	8.8	4.2	1.7

Source: ADF&G 1982b. Data are derived from aerial surveys.

a Figures in parenthesis are approximations based on seasonal and historical performance.

Table 33. South Peninsula Salmon Run Estimates, 1973 to 1982, for All Species of Salmon (in Thousands of Fish)

Year		Chinook*	Sockeye	Coho*	Pink	Chum
1973	Catch	0.4	330.2	6.6	58.3	293.0
	Escapement	---	7.3	---	110.8	212.5
	Total run	---	337.5	---	169.1	505.5
1974	Catch	0.5	204.7	9.4	100.2	71.5
	Escapement	---	95.6	---	284.4	257.3
	Total run	---	300.3	---	384.6	328.8
1975	Catch	0.1	268.4	0	61.7	132.9
	Escapement	---	51.7	---	552.1	193.3
	Total run	---	320.1	---	613.8	326.2
1976	Catch	2.1	375.0	0.2	2,367.0	532.5
	Escapement	---	69.7	---	1,456.4	327.2
	Total run	---	444.7	---	3,823.4	859.7
1977	Catch	0.5	311.7	2.1	1,448.6	243.2
	Escapement	---	64.9	---	2,677.8	774.9
	Total run	---	376.6	---	4,126.4	1,018.1
1978	Catch	0.8	579.5	60.7	5,490.0	547.0
	Escapement	---	64.8	---	2,858.7	600.5
	Total run	---	644.3	---	8,348.7	1,147.5
1979	Catch	2.1	1,149.7	356.5	6,570.6	483.0
	Escapement	---	53.3	---	2,629.5	411.1
	Total run	---	1,203.0	---	9,200.1	894.1
1980	Catch	4.8	3,613.0	274.2	7,861.5	1,351.2
	Escapement	---	45.9	---	2,641.6	362.4
	Total run	---	3,658.9	---	10,503.1	1,713.6
1981	Catch	12.2	2,255.2	162.2	5,035.9	1,770.3
	Escapement	---	45.7	---	2,307.5	381.3
	Total run	---	2,300.9	---	7,343.4	2,151.6
1982	Catch	9.8	2,346.0	256.0	6,734.9	2,272.5
	Escapement	---	39.2	---	2,293.0	386.9
	Total run	---	2,385.2	---	9,027.9	2,659.4

Source: ADF&G 1982b.

* Figures for chinook and coho salmon represent only catch data. No escapement information is available for the South Peninsula for coho. The chinook and many of the coho are migrants taken incidentally to other species along the capes (Shaul, pers. comm.).

Table North Peninsula Sockeye Salmon Run Estimates (in Thousands Fish)

Year		Northern District								Northwestern District		
		Cinder River Section	Port Heiden Section	Three Hills & Ilnik Sections	Bear River Section	Herendeen-Moller Bay Section	Nelson Lagoon Section	Caribou Flats & Black Hills Sections	Northern District Totals	Izembek-Moffet Bay Section	Bechevin & Urilia Bays Sections	North-western District Totals
1973	Catch	0	1.5	21.5	117.3	4.2	23.9	0	168.4	1.2	2.6	3.8
	Escapement	1.2	7.2	16.0	130.1	0	18.7	0	173.2	2.0	5.0	7.0
	Total run	1.2	8.7	37.5	247.4	4.2	42.6	0	341.6	3.2	7.6	10.8
1974	Catch	0	2.5	47.0	140.9	7.7	25.2	0	223.3	4.7	3.6	8.3
	Escapement	1.3	1.4	14.6	266.5	0	39.9	1.8	325.5	4.0	3.3	7.3
	Total run	1.3	3.9	61.6	407.4	7.7	65.1	1.8	548.8	8.7	6.9	15.6
1975	Catch	0	0.6	8.7	166.0	3.7	51.5	0	230.5	1.5	1.5	3.0
	Escapement	0.9	5.1	40.8	310.0	0.1	138.6	2.0	497.5	7.0	12.3	19.3
	Total run	0.9	5.7	49.5	476.0	3.8	190.1	2.0	728.0	8.5	13.8	22.3
1976	Catch	0	5.0	219.7	310.9	9.9	74.9	0	620.4	19.0	1.7	20.7
	Escapement	6.3	30.3	15.7	328.0	0.5	108.9	7.4	497.1	14.0	21.5	35.5
	Total run	6.3	35.3	235.4	638.9	10.4	183.8	7.4	1,117.5	33.0	23.2	56.2
1977	Catch	0	3.4	97.0	268.7	11.0	56.4	0	436.5	3.1	31.5	34.6
	Escapement	3.9	23.6	20.7	265.2	13.5	155.0	4.1	486.0	26.5	28.6	55.1
	Total run	3.9	27.0	117.7	533.9	24.5	211.4	4.1	922.5	29.6	60.1	89.7
1978	Catch	0	0.8	32.2	556.4	53.7	213.4	0	856.5	15.6	24.5	40.1
	Escapement	3.8	18.8	21.2	814.0	4.9	304.3	1.5	1,168.5	17.0	28.0	45.0
	Total run	3.8	19.6	53.4	1,370.4	58.6	517.7	1.5	2,025.0	32.6	52.5	85.1
1979	Catch	0.1	36.9	194.4	1,320.9	32.1	320.9	0	1,905.3	10.8	63.1	73.9
	Escapement	6.0	(46.7)[a]	97.5	1,013.0	5.0	360.1	3.0	1,531.3	9.0	33.7	42.7
	Total run	6.1	(83.6)	291.9	2,333.9	37.1	681.0	3.0	3,436.6	19.8	96.8	116.6

(continued)

Table 34 (continued).

Year		Northern District								Northwestern District		
		Cinder River Section	Port Heiden Section	Three Hills & Ilnik Sections	Bear River Section	Herendeen-Moller Bay Section	Nelson Lagoon Section	Caribou Flats & Black Hills Sections	Northern District Totals	Izembek-Moffet Bay Section	Bechevin & Urilia Bays Sections	North-western District Totals
1980	Catch	0	24.6	252.2	741.9	10.5	318.5	0	1,347.7	34.2	15.2	49.4
	Escapement	30.0	(47.0)[a]	(100.0)	751.0	1.5	352.6	3.9	1,286.0	11.5	90.1	101.6
	Total run	30.0	(71.6)	(352.2)	1,492.9	12.0	671.1	3.9	2,633.7	45.7	105.3	151.0
1981	Catch	0	3.8	68.9	1,327.8	18.6	374.7	0	1,793.8	30.9	20.1	51.0
	Escapement	100.0	(26.6)	(151.0)	741.5	0.6	251.0	(4.0)	1,274.7	12.0	60.7	72.7
	Total run	100.0	(30.4)	(219.9)	2,069.3	19.2	625.7	(4.0)	3,068.5	42.9	80.8	123.7
1982	Catch	0	8.8	142.5	1,009.3	11.3	229.2	0.4	1,401.5	24.5	9.3	33.8
	Escapement	(13.0)	(62.0)	(43.0)	361.3	0.5	179.6	6.0	665.4	21.5	29.3	50.8
	Total run	(13.0)	(70.8)	(185.5)	1,370.6	11.8	408.8	6.4	2,066.9	46.0	38.6	84.6

Source: ADF&G 1982b.

a Figures in parentheses are approximations based on seasonal and historical performance.

Table 35. North Peninsula Salmon Run Estimates for All Species of Salmon (in Thousands of Fish)

Year		Chinook	Sockeye	Coho[a]	Pink	Chum
1973	Catch	4.4	171.8	6.6	0.3	155.7
	Escapement	4.3	180.2	---	(0.2)[b]	122.4
	Total run	8.7	352.0	---	(0.5)	278.1
1974	Catch	5.1	247.9	24.0	10.5	35.3
	Escapement	3.0	332.8	---	(23.0)	105.1
	Total run	8.1	580.7	---	(33.5)	140.4
1975	Catch	2.1	233.5	28.2	0.3	8.7
	Escapement	4.6	516.8	---	0.6	109.2
	Total run	6.7	750.3	---	0.9	117.9
1976	Catch	4.9	641.1	26.0	0.6	73.6
	Escapement	6.0	532.6	---	37.3	293.4
	Total run	10.9	1,173.7	---	37.9	367.0
1977	Catch	5.5	471.1	34.1	0.9	129.1
	Escapement	7.1	541.1	---	8.5	681.2
	Total run	12.6	1,012.2	---	9.4	810.3
1978	Catch	14.2	896.2	63.3	466.6	163.2
	Escapement	13.7	1,213.5	---	96.8	310.5
	Total run	27.9	2,109.7	---	563.4	473.7
1979	Catch	17.1	1,979.5	112.3	5.0	65.7
	Escapement	15.8	1,574.0	---	9.3	305.3
	Total run	32.9	3,553.5	---	14.3	371.0
1980	Catch	16.8	1,397.1	127.9	301.7	700.2
	Escapement	11.0	1,387.6	---	103.6	769.5
	Total run	27.8	2,784.7	---	405.3	1,469.7
1981	Catch	18.3	1,844.9	155.4	11.2	706.8
	Escapement	12.4	1,347.9	---	6.1	535.2
	Total run	30.7	3,192.8	-	17.3	1,242.0
1982	Catch	30.1	1,435.3	238.0	12.3	331.1
	Escapement	20.0	718.4	---	51.7	457.6
	Total run	50.1	2,153.7	---	64.0	788.7

Source: ADF&G 1982b.

a Figures for coho salmon represent only catch data; no escapement.

b Figures in parentheses are approximations based on seasonal and historical performance.

Table 36. South Peninsula Pink Salmon Run Estimates (in Thousands of Fish)

Year		Southeastern and Southcentral Districts	Southwestern and Unimak Districts	South Peninsula Totals
1973	Catch	45.1	13.2	58.3
	Escapement	85.7	25.1	110.8
	Total run	130.8	38.3	169.1
1974	Catch	95.5	4.7	100.2
	Escapement	238.6	45.8	284.4
	Total run	334.1	50.5	384.6
1975	Catch	32.4	29.3	61.7
	Escapement	357.8	194.3	552.1
	Total run	390.2	223.6	613.8
1976	Catch	2,041.9	325.1	2,367.0
	Escapement	1,084.0	372.4	1,456.4
	Total run	3,125.9	697.5	3,823.4
1977	Catch	1,165.4	283.2	1,448.6
	Escapement	2,168.5	509.3	2,677.8
	Total run	3,333.9	792.5	4,126.4
1978	Catch	4,110.3	1,379.7	5,490.0
	Escapement	1,966.3	892.4	2,858.7
	Total run	6,076.6	2,272.1	8,348.7
1979	Catch	4,951.0	1,619.6	6,570.6
	Escapement	2,125.1	504.4	2,629.5
	Total run	7,076.1	2,124.0	9,200.1
1980	Catch	2,439.6	3,815.6	6,255.2[a]
	Escapement	1,410.4	1,231.2	2,641.6
	Total run	3,850.0	5,046.8	8,896.8
1981	Catch	4,325.4	710.5	5,035.9
	Escapement	1,875.0	431.8	2,306.8
	Total run	6,200.4	1,142.3	7,342.7
1982	Catch	4,104.9	906.1	5,011.0[b]
	Escapement	1,533.2	759.8	2,293.0
	Total run	5,638.1	1,665.9	7,304.0

Source: ADF&G 1982b.

a Does not include approximately 1.6 million pinks taken during June.

b Does not include approximately 1.7 million pinks taken during June.

2. North Peninsula:
   a. Distribution. Pink salmon are not abundant on the North Peninsula. The existing stocks are characterized by even-year productivity. There are several pink salmon-producing systems in the Bechevin Bay section (west of False Pass) in the Northwestern District (Shaul, pers. comm.).
   b. Abundance. Table 37 presents pink salmon run estimates for the Northwestern District of the North Peninsula, and table 35 gives the entire North Peninsula run estimate.

C. Chum Salmon

1. South Peninsula:
   a. Distribution. On the South Peninsula, runs of chum salmon are found in every bay east of False Pass. The major fisheries for local South Peninsula chum salmon stocks take place at Canoe, Stepovak, Balboa, Volcano, and Belkofski bays. It is anticipated that Cold Bay will be a major area after the Russel Creek hatchery receives returns. Many local chums are intercepted in cape fisheries (Shaul, pers. comm.).
   b. Abundance. Local stocks of chum salmon have been increasing since 1972. During the three-year period, 1980-1982, the runs averaged 1.4 million fish. Table 38 presents district population estimates, and table 33 shows chum salmon stock estimates in comparison to the other salmon species in the South Peninsula.
2. North Peninsula:
   a. Distribution. Major chum salmon systems on the North Peninsula are located in Izembek-Moffet Bay and Bechevin Bay in the Northwestern District, the Sapsuck River (Nelson Lagoon), Herendeen-Moller Bay, and during recent years Frank's Lagoon (just north of Port Moller) in the Northern District (ADF&G 1977b; Shaul, pers. comm.).
   b. Abundance. During the 10 years, 1973-1982, run-strengths in the Northwestern District have fluctuated greatly. During the same period, Northern District run-strengths fluctuated to a lesser degree and appear to be increasing. Table 39 presents district run-strength estimates for the North Peninsula, and table 35 shows chum salmon run strength estimates in comparison to the other salmon species on the North Peninsula.

D. Chinook Salmon

1. South Peninsula:
   a. Distribution. Although some streams on the South Peninsula appear to be as suitable as North Peninsula chinook-producing streams, none are found on the South Peninsula. Chinooks harvested in South Peninsula waters are probably strays or are migrating to other areas (Shaul, pers. comm.).

b. Abundance. No escapement figures are available for chinook salmon on the South Peninsula. Only catch figures are presented in table 33.

2. North Peninsula:

a. Distribution. Chinook salmon are found throughout the North Peninsula. The Sapsuck River system (Nelson Lagoon) in the Northern District supports about one-half of the North Peninsula chinook salmon run. Major spawning has been observed in the Meshik River system (Port Heiden) and in the Cinder River, both in the Northern District. Small runs are scattered as far west as Right Hand Valley in Moffet Bay (ADF&G 1977b) at the eastern end of the Northwestern District.

b. Abundance. Run strength estimates for the Northern District of the North Peninsula are presented in table 40 and table 35 compares these figures with other salmon-strength estimates.

E. Coho Salmon

1. South Peninsula:

a. Distribution. Little is known of coho salmon on the South Peninsula. Runs are scattered and small. The best-known runs occur in Russel Creek, Mortensen Lagoon, and Thin Point Cove at Cold Bay (ADF&G 1977b). Other runs occur at Pavlof Bay, Long John Lagoon, Grub Gulch, Lefthand Bay, Beaver River, and Stepovak River.

b. Abundance. No escapement figures are available for coho salmon on the South Peninsula. Only catch figures are reported in table 33.

2. North Peninsula:

a. Distribution. On the North Peninsula, coho salmon are harvested principally at Nelson Lagoon, with smaller fisheries at Swanson Lagoon, Ilnik, Port Heiden, and Cinder River.

b. Abundance. No escapement figures are available for coho salmon on the North Peninsula. Only catch figures are reported in table 35.

V. ALEUTIAN ISLANDS MANAGEMENT AREA

The Aleutian Islands Management Area includes all waters of Alaska in the Aleutian Islands west of, and including, Unimak Pass (ADF&G 1983). The area is divided into four districts, which include, from east to west, Akutan, Unalaska, Umnak, and Adak. To date, only the Unalaska District is subdivided into sections for managerial purposes.

Within the area, practically all of the commercial salmon harvest occurs in the Unalaska District. Therefore, management effort and stream survey activities have been directed toward Unalaska Island waters. During 1982, however, the first extensive survey of salmon streams west of Unalaska Islands to Attu Island was completed. It is from this survey that the majority of the salmon distribution and abundance information contained in the following narratives was derived. Although salmon were found on most

Table 37. North Peninsula Pink Salmon Run Estimates (in Thousands of Fish)

Year		Northwestern District[a] Izembek-Moffet Bay Section	Bechevin & Urilia Bays Sections	Northwestern District Totals
1973	Catch	0	0	0
	Escapement	0	(0.2)[b]	(0.2)
	Total run	0	(0.2)[b]	(0.2)
1974	Catch	0	10.3	10.3
	Escapement	0	(23.0)	(23.0)
	Total run	0	(33.3)	(33.3)
1975	Catch	0	0	0
	Escapement	0.1	0.5	0.6
	Total run	0.1	0.5	0.6
1976	Catch	0	0	0
	Escapement	0.1	37.2	37.3
	Total run	0.1	37.2	37.3
1977	Catch	0	0	0
	Escapement	0.2	6.2	6.4
	Total run	0.2	6.2	6.4
1978	Catch	2.2	465.6	467.8
	Escapement	0	90.4	90.4
	Total run	2.2	556.0	558.2
1979	Catch	0	1.6	1.6
	Escapement	0	9.3	9.3
	Total run	0	10.9	10.9
1980	Catch	0	297.9	297.9
	Escapement	0	94.0	94.0
	Total run	0	391.9	391.9
1981	Catch	0	9.1	9.1
	Escapement	0	5.7	5.7
	Total run	0	14.8	14.8
1982	Catch	0	5.1	5.1
	Escapement	0.2	51.5	51.7
	Total run	0.2	56.6	56.8

Source: ADF&G 1982b.

a No run estimates for the Northern District of the North Peninsula are available because of the scarcity of pink salmon in the area.

b Figures in parentheses are approximations based on seasonal and historical performance.

Table 38. South Peninsula Chum Salmon Run Estimates (in Thousands of Fish)

Year		(Not Including June Migrants)			(June Migrants)[a]		
		Southeastern and Southcentral Districts	Southwestern and Unimak Districts	Total	South Unimak	Shumagins	Migrants Totals
1973	Catch	67.1	12.1	79.2	178	36	214
	Escapement	130.9	81.6	212.5			
	Total run	198.0	93.7	291.7			
1974	Catch	56.6	15.3	71.9	0	0	0
	Escapement	169.8	87.5	257.3			
	Total run	226.4	102.8	329.2			
1975	Catch	29.9	4.0	33.9	64	35	99
	Escapement	160.2	33.1	193.3			
	Total run	190.1	37.1	227.2			
1976	Catch	109.4	25.1	134.5	326	72	398
	Escapement	225.3	101.9	327.2			
	Total run	334.7	127.0	461.7			
1977	Catch	109.4	18.8	128.4	93	22	115
	Escapement	500.9	274.0	774.9			
	Total run	610.3	292.8	903.1			
1978	Catch	341.6	139.8	481.4	47	18	65
	Escapement	386.2	214.3	600.5			
	Total run	727.8	254.1	1,081.9			
1979	Catch	280.4	97.6	378.0	64	41	105
	Escapement	302.7	108.4	411.1			
	Total run	583.1	206.0	789.1			
1980	Catch	654.2	169.1	823.3	457	71	528
	Escapement	241.6	120.8	362.4			
	Total run	895.8	289.9	1,185.7			
1981	Catch	966.1	229.2	1,195.3	521	54	575
	Escapement	234.5	146.8	381.3			
	Total run	1,200.6	376.0	1,576.6			
1982	Catch	922.9	253.8	1,176.7	935	160	1,095
	Escapement	203.0	183.9	386.9			
	Total run	1,125.9	437.7	1,563.6			

Source: ADF&G 1982b.

a June chum salmon harvests represent in large part intercepted fish bound for Western Alaska waters (e.g., Bristol Bay, Yukon River, Kuskokwim River, North Peninsula) and possibly Asian waters.

Table North Peninsula Chum Salmon Run Estimated (in Thousands o sh)

Year		Cinder River Section	Port Heiden Section	Three Hills & Ilnik Sections	Bear River Section	Herendeen-Moller Bay Section	Nelson Lagoon Section	Caribou Flats & Black Hills Sections	Northern District Totals	Izembek-Moffet Bay Section	Bechevin Bay & Urilia Bay Sections	North-western District Totals
		Northern District								Northwestern District		
1973	Catch	0	2.5	0.9	34.2	13.2	1.8	0	52.6	96.6	6.5	103.1
	Escapement	0.6	22.8	0.8	0.8	3.7	12.7	0	46.8	68.1	(7.5)[a]	75.6
	Total run	0.6	25.3	1.7	35.0	16.9	14.5	0	99.4	164.7	(14.0)	178.7
1974	Catch	0	1.0	1.3	11.4	3.2	0.5	0	17.4	11.2	3.0	14.2
	Escapement	4.6	4.5	0	1.5	3.7	8.3	0.4	23.0	76.0	(6.1)	82.1
	Total run	4.6	5.5	1.3	12.9	6.9	8.8	0.4	40.4	87.2	(9.1)	96.3
1975	Catch	0	0	0.1	3.8	0.2	0.7	0	4.8	3.4	0.5	3.9
	Escapement	0.3	1.5	2.0	2.0	7.3	4.5	0	17.6	74.3	17.3	91.6
	Total run	0.3	1.5	2.1	5.8	7.5	5.2	0	22.4	77.7	17.8	95.5
1976	Catch	0	1.1	2.9	12.3	5.5	5.8	0	27.6	38.1	7.9	46.0
	Escapement	1.9	30.7	5.7	18.0	28.5	42.5	0.1	127.4	127.7	38.3	166.0
	Total run	1.9	31.8	8.6	30.3	34.0	48.3	0.1	155.0	165.8	46.2	212.0
1977	Catch	0	0	7.1	32.3	34.8	10.7	0	84.9	20.3	22.6	42.9
	Escapement	(1.7)	32.0	(1.5)	17.0	108.5	83.3	1.5	245.5	381.4	54.3	435.7
	Total run	(1.7)	32.0	(8.6)	49.3	143.3	94.0	1.5	330.4	401.7	76.9	478.6
1978	Catch	0	0	1.2	14.6	6.6	10.3	0	32.7	82.3	48.4	130.7
	Escapement	7.4	22.0	(1.5)	(15.5)	89.3	10.2	(1.0)	146.9	134.1	29.5	163.6
	Total run	7.4	22.0	(2.7)	(30.1)	95.9	20.5	(1.0)	179.6	216.4	77.9	294.3
1979	Catch	0	0.8	0.7	17.4	10.9	5.7	0	35.5	17.8	12.5	30.3
	Escapement	(3.6)	(32.7)	0	7.0	30.6	37.0	4.0	114.9	178.0	12.4	190.4
	Total run	(3.6)	(33.5)	0.7	24.4	41.5	42.7	4.0	150.4	195.8	24.9	220.7

(continued)

Table 39 (continued).

Year		Cinder River Section	Port Heiden Section	Three Hills & Ilnik Sections	Bear River Section	Herendeen-Moller Bay Section	Nelson Lagoon Section	Caribou Flats & Black Hills Sections	Northern District Totals	Izembek-Moffet Bay Section	Bechevin & Urilia Bays Sections	North-western District Totals
		Northern District								Northwestern District		
1980	Catch	0	2.6	29.7	161.7	59.6	80.1	0	333.7	282.5	85.0	367.5
	Escapement	(10.0)	(33.7)	(10.0)	20.0	116.1	164.0	10.4	364.2	364.2	41.1	405.3
	Total run	(10.0)	(36.3)	(39.7)	181.7	175.7	244.1	10.4	697.9	646.7	126.1	772.8
1981	Catch	0	0.2	7.1	155.0	126.2	62.8	0	351.3	296.4	59.1	355.5
	Escapement	(11.8)	(73.4)	(11.0)	27.2	85.0	57.0	(11.0)	276.4	235.0	29.6	264.6
	Total run	(11.8)	(73.6)	(18.1)	182.2	211.2	119.8	(11.0)	627.7	531.4	88.7	620.1
1982	Catch	0	0.7	21.2	142.4	50.2	21.4	0.1	236.0	57.5	37.7	95.2
	Escapement	(5.5)	(35.5)	1.0	42.4	152.0	29.1	(2.0)	267.5	166.4	23.8	190.2
	Total run	(5.5)	(36.2)	22.2	184.8	202.2	50.5	(2.1)	503.5	223.9	61.5	285.4

Source: ADF&G 1982b.

a Figures in parentheses are approximations based on seasonal and historical performance.

Table 40. North Peninsula Chinook Salmon Run Estimates (in Thousands of Fish)

Year		Northern District[a]							
		Cinder River Section	Port Heiden Section	Three Hills & Ilnik Sections	Bear River Section	Herendeen-Moller Bay Section	Nelson Lagoon Section	Caribou Flats & Black Hills Sections	Northern District Total
1973	Catch	0	1.6	0	0.7	0.3	1.5	0	4.1
	Escapement	0.6	0.6	0	0.1	0	1.5	0.8	3.6
	Total run	0.6	2.2	0	0.8	0.3	3.0	0.8	7.7
1974	Catch	0	2.5	0	0.2	0.2	2.1	0	5.0
	Escapement	0.5	0.7	0	0.3	0	1.1	0.4	3.0
	Total run	0.5	3.2	0	0.5	0.2	3.2	0.4	3.0
1975	Catch	0	0.4	0	0.3	0.2	1.2	0	2.1
	Escapement	0.1	0.9	0	0.7	0	2.5	0.4	4.6
	Total run	0.1	1.3	0	1.0	0.2	3.7	0.4	6.7
1976	Catch	0	1.5	0.1	0.5	0.6	2.2	0	4.9
	Escapement	1.6	0.2	0	0	0	3.3	0.4	6.0
	Total run	1.6	1.7	0.1	1.0	0.6	5.5	0.4	6.0
1977	Catch	0	2.5	0.1	0.7	0.5	1.7	0	5.5
	Escapement	0.1	0.7	0	0	0	5.6	0.7	7.1
	Total run	0.1	3.2	0.1	0.7	0.5	7.3	0.7	12.6
1978	Catch	0	9.5	0	0.6	0.7	3.4	0	14.2
	Escapement	1.1	4.2	0	(0.2)[b]	0	4.2	4.0	13.7
	Total run	1.1	13.7	0	(0.8)	0.7	7.6	4.0	27.9
1979	Catch	0	9.7	0	1.4	0.5	5.4	0	17.0
	Escapement	0.3	(3.2)	0	0.0	0	11.0	1.5	15.8
	Total run	0.3	(12.9)	0	1.4	0.5	16.4	1.5	32.8

(continued)

Table 40 (continued).

Year		Northern District[a]							
		Cinder River Section	Port Heiden Section	Three Hills & Ilnik Sections	Bear River Section	Herendeen-Moller Bay Section	Nelson Lagoon Section	Caribou Flats & Black Hills Sections	Northern District Total
1980	Catch	0	5.4	0.1	1.7	0.9	8.7	0	16.8
	Escapement	(3.0)	(1.6)	0	0.1	0	5.5	0.8	(11.0)
	Total run	(3.0)	(7.0)	0.1	1.8	0.9	14.2	0.8	(27.8)
1981	Catch	0	6.1	0	1.1	0.1	11.0	0	18.3
	Escapement	(3.0)	(1.0)	0	2.3	0	5.2	0.9	(12.4)
	Total run	(3.0)	(7.1)	0	3.4	0.1	16.2	0.9	(30.7)
1982	Catch	0	11.0	0.9	2.9	0.6	13.5	1.2	30.1
	Escapement	(2.5)	(7.5)	0	0.9	0	7.0	2.1	20.0
	Total run	(2.5)	(18.5)	0.9	3.8	0.6	20.5	3.3	50.1

Source: ADF&G 1982b.

a No run estimates for the Northwestern District of the North Peninsula are available because of the scarcity of chinook salmon in the area.

b Figures in parentheses are approximations based on seasonal and historical performance.

of the islands inventoried, this survey revealed that the only islands in the Aleutian Islands Management Area with commercial salmon potential at this time are Unalaska, Umnak, Atka, Adak, and Attu (ADF&G 1982b). Umnak, Atka, Adak, and Attu, however, probably would not be productive for pink salmon during odd-numbered years (Holmes, pers. comm.).

As regards distribution and abundance of salmon in the Aleutian Islands, it must be noted that the mouths of streams are blocked by debris or changes in beach contour as a result of storms and wave action. Conversely, the streams may be open periodically. For this reason, the abundance of salmon in these systems could vary with time, particularly in streams with a low velocity (ibid.).

Adult salmon are found in the Aleutian Islands marine and fresh waters at about the same time they are found in South Peninsula waters: late May to October and June through November, respectively (ADF&G 1977b). General run-timing estimates for the different species are presented in table 41 for the Aleutian Islands area.

Table 41. General Run-Timing and Early Life History Information, Aleutian Islands Area

	Adults		Juveniles	
Species	Enter Fresh Water	Spawning	Emerge from Gravel	Outmigration
Chinook	--------- The Aleutian Islands appear to be unsuitable for chinook production.[a] ----------			
Sockeye	Early June-mid Aug.	Mid July-late Sept.	Early Apr.-early June	Early May-early Aug.
Coho	Late Aug.-early Oct.	Early Oct.-late Dec.	No data	No data
Pink	Early July-late Aug.	Late July-mid Sept.	Mid Mar.-early May	Mid Mar.-mid May
Chum	Early July-late Aug.	Late July-late Sept.	Early Mar.-early May	No data

Source: ADF&G 1977b.

Note: early = 1st to 10th of month, mid = 11th to 20th of month, late = 21st to 30th/31st of month.

a Chinook adults are reported to be present in some of the passes (areas between islands) in the spring (possibly as early as April and in May and June). They are probably migrating fish bound for Western Alaska (North Peninsula, Bristol Bay, Kuskokwim R., Yukon R.) waters (Holmes, pers. comm.).

A. Sockeye Salmon

1. Distribution. Sockeye salmon were found on 8 of 18 islands surveyed during 1982 (Holmes 1982). These islands include (from east to west) Unalaska, Umnak, Amlia, Atka, Kagalaska, Adak, Kiska, and Attu. The timing of the study was such that it may have been too late in the season to accurately assess early runs of sockeye, if they exist in the area. Reported runs of sockeye in major Aleutian passes are probably migrating fish from other areas (Holmes, pers. comm.).

A good run of sockeye salmon occurs at Kashega Lakes on Unalaska Island and is the only sockeye system of any commercial consequence in the Aleutian chain (Holmes 1982). It is located in the Unalaska District.

Within the Umnak District, sockeye salmon were located on Umnak Island in Nikolski Bay and Sandy Beach, but the runs were relatively small. A few streams on the north side of Amlia Island produced small sockeye runs. Atka Island produced the largest sockeye salmon run west of Unalaska. The run was located in the west arm of Deep Bay on the northcentral coast of the island. Northeast of Deep Bay is found the Korovin Lake system, which is an important sockeye-producing system. Other Atka sockeye are scattered along the north and south coasts of the island.

Within the Adak District, Kagalaska was found to have small sockeye runs at Quail Bay and Galas Point. North Hidden Bay on Adak supports the only run of sockeye of consequence on the island. Kiska was found to have a few sockeye in Salmon Lagoon (on the east side of the island). Attu sockeye salmon systems include Lake Nicholas and the Cories Lake/Canirco Lake drainage.

2. Abundance. No run-strength estimates for the Aleutian Islands sockeye stocks have been made; however, table 42 provides a rough estimate of Aleutian Island area sockeye stocks during August and September of 1982. Since these data were compiled from one survey and in most cases one observation of each system, they are by no means complete.

B. Pink Salmon

1. Distribution. Within the Akutan District, the Akutan Island harbor stream contains pink salmon. Other streams in the district, specifically on Akutan Island, may have small runs; however, they have never been surveyed (Holmes, pers. comm.).

Within the Unalaska District, numerous pink salmon systems are found on Unalaska Island. Unalaska Bay has the major runs on the island and is the only area that produces many pink salmon during odd-numbered years (ibid.). Most streams draining into the north side of Makushin Bay produce pinks. Holmes (1982) observed several excellent runs on the southwestern panhandle of the island from McIver Bight (on the Bering side) to Surveyor Bay (near the southeast tip on the Pacific side). Excellent runs were also observed at Final Bay and Tanaskan Bay in Beaver Inlet at the northeast corner of the island. Riding Cove (northeast of Surveyor Bay) appeared to support a good run of pink salmon.

Within the Umnak District, pink salmon streams were found on Umnak, Amila, and Atka islands (Holmes 1982). On Umnak Island, most of the salmon streams are located in the southern half of the island in Russian Bay, Amos Bay, Driftwood Bay, Okee Bay, Nikolski Bay, and Inanudak Bay. On Amila Island, the only reasonably productive salmon runs are on the northwest side and extend about 20 mi east from the vicinity of Hungry Bay. Atka

Table 42. Aleutian Islands Management Area, Summary of Maximum Salmon Counts by Species, by Island, in 1982

District	Island	Pinks	Sockeye	Chums	Coho
Akutan	Akutan	10,500 [a]	-	-	-
Unalaska	Unalaska	1,541,317	44,995	100	300
Umnak	Umnak	295,385	805 [b]	-	143
	Amlia	138,258	453	772	0
	Atka	578,086	3,971	1,484	825
Adak	Igitkin	0	0	0	0
	Great Sitkin	7,720	0	0	0
	Umak	230	0	0	0
	Little Tanaga	1,550	0	0	0
	Kagalaska	3,310	975	0	0
	Adak	362,438	993	0	2
	Kanaga	18,448	0	0	0
	Tanaga	68,585	0	0	0
	Semisophochnoi	400	0	0	0
	Amchitka	1,248	0	0	0
	Rat Island	0	0	0	0
	Kiska	43,393	8	1	20
	Agattu	15,000 [c]	0	0	-
	Attu	133,589 [d]	220	1	14

Source: Holmes 1982. (The timing of this study was focused on obtaining the best data on pink salmon. Out of necessity, assessment of all runs of each species of salmon could not be made equally well. Counts of other species are acknowledged underestimates. The study may have been too late to accurately assess early runs of red and chum salmon. It probably was too short in duration, because coho were just beginning to enter fresh water at the end of the field work. High winds and water turbulence made it nearly impossible to make any counts of coho schooling in saltwater.) Most streams were surveyed between Aug. 12 and Sept. 17.

a Harbor Creek was the only stream surveyed.

b Includes the estimated abundance of sockeyes in Village Lake at 670 based on the number of spawning redds; there was poor visibility at the time of the survey.

c The island was not surveyed; the figure is based on stream morphology observations made by ADF&G staff and USFWS ornitholgists staff observations. Estimated escapement is of 10,000-20,000 pink salmon, possibly a few hundred coho.

d This was a partial survey: approximately .4 of island's potential.

Island has several moderate-to-good pink salmon runs located on the south side from Explorer Bay to Cape Utalug and on the northcentral portion of the island from Blue Fox Bay to Korovinski Lagoon.

Within the Adak District, pink salmon are found in the Eastern Anderanof Islands, Adak, Kanaga, Tanaga, Amchitaka, Semisopochnoi, Kiska, and Attu islands. For the Eastern Anderanof Island group (Igitkin, Tagulak, Chugul, Umak, Little Tanaga, Great Sitkin, and Kagalaska) only Great Sitkin and Kagalaska have small runs that exceed a thousand fish (Holmes 1982). On Adak Island, the major streams are located on the north end of the island. Included in these systems are drainages of Shagak Bay (on the northwest coast), Gannet Cove (at east end of Expedition Harbor), and Finger Bay and Little Thumb (on the northeast coast). The Finger Bay system is the major producer on the island (Holmes, pers. comm.). On the southside of Adak Island, the Hidden Bay system produces the largest run of pink salmon (Holmes 1982). On Kanaga Island, only three systems have any appreciable number of pink salmon: the systems into Kanaga Bay (on the south side of the island) and stream #307-12-160 (south of Lakeside Point on the northcentral shore of the island). On Tanaga Island, nearly 85% of the pink salmon were located in two streams. These were streams #307-23-70 and #307-23-90, both tributaries of Tanaga Bay. On Semisopochoi Island, only Fenner Creek was found to have pink salmon. On Kiska Island, the major pink salmon run appears at Gertrude Cove. Four other streams, #308-17-70 and 308-17-90 (south of Gertrude Cove), 308-11-60 (on the west coast near Bluff Cove), and #308-12-70 (in the Kiska Harbor on the east coast), support small runs of pink salmon. On Attu Island, major documented pink salmon runs occur at the Henderson and Peaceful rivers. Good runs are also found in the Cories Lake, Canirco Lake, and Lake Nicholas systems. The systems on the north coast of Attu Island west of Holtz Bay and the Etienne Lake, Chuniksak Creek, Nevidiskov Creek and River systems on the south side of the island remain unsurveyed (ibid.).

2. Abundance. With the exception of Unalaska Island, no pink salmon run-strength estimates have been made for the Aleutian Islands area. In 1982, Holmes, using data from the research project and the area management biologists' survey, determined that Unalaska Island pink salmon escapements were about 1.54 million fish (ibid.). The pink salmon catch for 1982 (all reported from Unalaska Bay, Makushin Bay, and Kashega Bay) was 1.45 million fish (ADF&G 1982b). Total run-strength was about 3 million pink salmon for Unalaska Island in 1982.

Table 42 provides a glimpse of the pink salmon stocks as they were found during August and September of 1982. Since these data were compiled from one survey and in most cases one observation of each system, they are by no means complete. A spot check of pink salmon streams on Unalaska, Adak, Attu, and

Atka islands during 1983 showed low returns and indicates that the Aleutian Island chain seems to be far more productive for pink salmon during even-numbered years (Holmes 1984).

C. Chum Salmon

1. Distribution. Chum salmon were found on 5 of 18 islands surveyed during 1982 (Holmes 1982). These islands include (from east to west) Unalaska, Amlia, Atka, Kiska, and Attu. The timing of the study was such that it may have been too late in the season to assess early runs of chum salmon, if they exist in the area.

   Within the Unalaska District, a few chums (about 100) were observed at Kalekta Bay on Unalaska Island.

   Within the Umnak District, chum salmon were found in small numbers on Amlia Island along both the northwest shore and the south shore. On Atka Island, chum salmon were located at Korovinski Lagoon (in the northwest portion of island), in a small stream just north of Cape Shaw (in the northeast corner of the island), and in stream #305-32-270 (west of Cape Utalus).

   Within the Adak District, one chum salmon was observed on Kiska in Gertrude Cove. On Attu Island, chum salmon were found in the Henderson River (located on the southeast corner of the island near Massacre Bay).

2. Abundance. No run-strength estimates for the Aleutian Island chum salmon stocks have been made. Table 42 provides a glimpse of the stocks as they were found during August and September of 1982. Since these data were compiled from one survey and in most cases one observation of each system, they are by no means complete.

D. Chinook Salmon

1. Distribution. There are no systems that would provide for spawning and rearing chinook salmon in the Aleutian Islands area. Chinook salmon landed in the Aleutians are most likely "feeder kings" intercepted while migrating through the Aleutians (ibid.).

2. Abundance. Chinook salmon are not found in the drainages of the Aleutian Islands area.

E. Coho Salmon

1. Distribution. Coho salmon were found on 8 of 18 islands surveyed during 1982 (ibid.). These islands include (from east to west) Unalaska, Umnak, Atka, Little Tanaga, Adak, Tanaga, Kiska, and Attu. The timing of the study was such that it may have ended too soon to fully assess coho salmon, since they were just beginning to enter fresh water when field work was terminated. Weather conditions were generally too poor to assess coho in salt water. Coho have been reported to occur in many more streams than those in which they were actually observed (Holmes, pers. comm.).

   On Unalaska Island in the Unalaska District, coho salmon were found in McIver Bight (on the Bering Sea side of the southwest panhandle) and in the southeast tributary of Pumicestone Bay

(Holmes 1982). Other coho-producing systems on the island are found in the Captains Bay and Iliuliuk Bay vicinity (on the northcentral coast) and in the Surveyor Bay vicinity (on the Gulf of Alaska side of the panhandle).

Within the Umnak District, coho were found on Umak Island in streams of Nikolski Bay and Sandy Beach. They have also been documented in a stream east of Kshaliuk Point (on the northcentral coast), in a stream near Hot Springs Cove (in Inanudak Bay), in a tributary to the Otter Bight (on the northeast corner of the island), and in a stream/lake system south of Thumb Point (on the southcentral coast). On Atka Island, coho salmon were found in fresh waters in the vicinity of Banner Bay, Bechevin Bay, Portage Lagoon, Crescent Bay, and Beaver Bay. They were also found in streams northwest of Cape Utalus and in the Koronvinski Lagoon drainage. Coho have been reported to occur in the steams on the southeast end of Atka Island from Vasilief Bay east to stream #305-32-290 and in streams on the eastern part of Amlia Island, although none were documented during the 1982 survey (Holmes, pers. comm.).

Within the Adak District, coho salmon were found on Little Tanaga Island in Scripps Bay. On Adak Island, coho were found in NavFac Creek (west of Zeto Point) and have been reported to occur in several additional streams (ibid.). On Tanaga Island, coho were observed in Hot Springs Bay and in a stream southwest of Hazard Point. They have also been reported in the major tributary system of Twin Bays. On Kiska Island, coho salmon were found in stream #308-12-70 in Kiska Harbor. They have also been reported at Model Cove (north of Kiska Harbor) and in the vicinity of Gertrude Cove (on the southcentral coast of the island). On Attu Island, coho salmon were found in the Henderson River, Peaceful River, and Lake Nicholas systems. They were also in Addison Creek, O'Donnel Creek, Lake Corries, Navy Town Creek, Temnak River, and Kaufman Creek.

2. Abundance. No run-strength estimates for the Aleutian Islands' coho salmon stocks have been made. Table 42 provides a glimpse of the stocks as they were found during August and September of 1982. Since these data were compiled from one survey and in most cases one observation of each system, they are by no means complete.

VI. BRISTOL BAY MANAGEMENT AREA

The Bristol Bay Management Area includes all waters of Alaska in Bristol Bay east of a line from Cape Newenham to Cape Menshikoff (ADF&G 1983). The area is normally divided into five districts, with all but the Egegik and Ugashik districts being further separated into sections. At times, a sixth district, the General District, is used to control the harvest of exceptionally large runs of sockeye salmon. Since 1970, the General District has been utilized twice: once in 1970 and again in 1980. For control purposes, the Bristol Bay area is divided into the West Side and the East Side. West-Side Bristol Bay includes the Togiak and Nushagak districts. East-Side Bristol Bay includes the Naknek-Kvichak, Egegik, and Ugashik districts. The General District, when used, is found within the East Side.

Adult salmon are found in Bristol Bay marine waters from early May through September and in fresh water from late May through December (Russell, pers. comm.). The seasonality of the fishery is typical for salmon in this latitude. Chinook salmon are the earliest to arrive in the fishing districts, in late May/ early June, and they peak in mid June but are still taken in numbers in early July. The sockeye and chum salmon arrive coincidentally, entering in late June and peaking in early July. Pink salmon follow closely, entering in mid July and peaking in late July. Coho salmon enter the fishery about mid July and peak in August (Middleton 1983). General run-timing for the different species of salmon is presented in table 43 (variations from these times occur in some systems).

Table 43. General Run-Timing and Early Life History Information, Bristol Bay Area

	Adults		Juveniles	
Species	Enter Fresh Water	Spawning	Emerge from Gravel	Outmigration
Chinook	Late May-mid July	Late July-early Sept.	No data (probably Apr.-June)	No data (probably May & June)
Sockeye	Mid June-mid Aug.	Late July-late Oct.	Mid Mar.-mid May	Late May-mid July
Coho	Mid July-mid Sept.	Early Sept.-late Nov.	No data (probably Apr.-June)	No data (probably May & June)
Pink	Mid July-mid Aug.	Mid Aug.-mid Sept.	No data (probably late Apr.-May)	Early June
Chum	Mid June-mid Aug.	Late July-late Aug.	No data (probably late Apr.-May)	Probably June

Source: ADF&G 1977b; Russell, pers. comm.

Note: Early = 1st to 10th of month, mid = 11th to 20th of month, late = 21st to 30th/31st of month.

A. Sockeye Salmon

1. Distribution. Sockeye salmon are found in the drainages of each district in the Bristol Bay area. Within the Ugashik District, important sockeye systems include the Ugashik River and Upper and Lower Ugashik Lake, the Dog Salmon River, and the King Salmon/Mother Goose system.

   Within the Egegik District, sockeye salmon are found in the Becharof Lake system and its outlet stream, the Egegik River, as well as in another King Salmon River.

   The Naknek-Kvichak District contains the Naknek system, which includes Naknek River, Naknek Lake, Lake Brooks, Lake Grosvenor, Lake Coville, Hammersly Lake, and their associated stream systems. The major sockeye component in the district is the

Kvichak River, which drains Iliamna Lake and Lake Clark and its outlet stream, the Newhalen River, and includes the Alagnak (Branch) River, which is formed by the outlet streams of Kukaklek and Nonvianuk lakes.

Within the Nushagak District, important sockeye runs are found in the Nushagak River system, which includes the large Nushagak River proper, the Wood River and Wood River Lakes, the Mulchatna River, and the Nuyakuk River, which drains the Tikchik Lakes system. Also found in the Nushagak District are the Snake and Igushik river systems.

Within the Togiak District, the Togiak, Matogak, Osviak, and Slug river systems support sockeye runs.

2. Abundance. Bristol Bay produces more sockeye salmon than any other single area in the world. The runs to Bristol Bay are characterized by a distinctive five-year pattern of peak abundance. Presently, the cycle peak occurs bi-decadally, 1965, 1970, 1975, e.g., interspersed by years of decreased production. Historically, this pattern prevailed, with three relatively high years and two low years in a five-year period. From the early 1940's through the 1950's, the cycle changed drastically to a four-year pattern, with one to two years of relatively good production followed by two to three years of greatly reduced production. The major production system, the Kvichak River system, is the key to the cycle pattern, and it returned to a five-year cycle pattern as a result of the large 1960 brood, or parent, year. This pattern has been maintained since then, and the objective of maintaining this five-year cycle is basic to the managerial strategy for this important sockeye salmon-producing system (Middleton 1983).

The extremely cold winters of 1970 and 1971 apparently caused increased mortality for the salmon produced by the 1969 and 1970 sockeye escapements. Consequently, fishing time was severely restricted in both 1974 and 1975 in order to secure escapement goals for these two critical brood years. Sockeye catches during the 1972 to 1977 rebuilding period dropped to an all-time low, averaging only 3.3 million fish per year (ibid.).

The restraints imposed on the fishery during 1974 and 1975 began to pay off handsomely in 1978 and are expected to continue. Unusually good survival rates also aided in boosting production throughout Bristol Bay. The 1980 sockeye salmon catch could easily have broken the historical record of 24.7 million set in 1938 had there not been a price dispute. Escapement totals in 1980 were the highest on record. The strong sockeye salmon run in 1981, which was not burdened by a price dispute, saw a new record harvest of 25.6 million sockeye salmon (ibid.). Middleton (1983) states that "the most significant factors, however, have been the 1978 to 1982 production, plus the outlook for 1983-1985. The overlapping production from these adjacent strong years is and will be highly significant to future production. If the 1983 projected run and harvest materializes as expected, the average production in terms of catch for the five-year period, 1978-1983, will be 19.6 million sockeye salmon per year, or as high as any six-year period in the history of the fishery."

Preliminary data (ADF&G 1984) for the 1983 commercial salmon fishery in Bristol Bay indicate that 37.3 million sockeye salmon were harvested, breaking the previous high catch of 25.6 million set in 1981, and raising the six-year average catch to 21.9 million. Escapement figures show that 8.5 million sockeye salmon reached the spawning grounds. When combined, these figures produce a sockeye salmon run of 45.8 million fish, an all-time off-peak-year record. The exceptional sockeye return in 1983 is the third largest ever recorded for Bristol Bay, with only peak-year total returns in 1965 (51.3 million) and 1980 (62.5 million) exhibiting larger runs (ADF&G 1984).

Sockeye salmon run-strength figures are presented by district in table 44.

B. Pink Salmon

1. Distribution. The primary pink salmon system in Bristol Bay is the Nuyakuk River, tributary to the Nushagak River of the Nushagak District. In most years, the bulk of the spawners concentrate in a 30 mi stretch of the river from the ADF&G counting towers upstream to the rapids at the outlet of Tikchik Lake. Smaller populations also exist in the Wood, Igushik, Nushagak, and Mulchatna rivers (Middleton 1983) and in some years in the Naknek and Kvichak rivers (Russell, pers. comm.).

2. Abundance. Pink Salmon are the second most abundant salmon species in Bristol Bay, considering only even years, since odd-year production is almost nonexistent. Within the area, the vast majority of pink salmon are produced from river systems entering the Nushagak District, and the bulk of this production comes from the Nuyakuk River, tributary to the Nushagak River. The Nushagak District has accounted for 86% of the Bristol Bay pink salmon catches since 1958. Pink salmon runs to other districts tend to be small, and most catches are taken incidentally in sockeye salmon gill net gear (Middleton 1983).

   Because tower and aerial enumeration on the primary Nuyakuk River has been operational only since 1958, total run data for the Nushagak District is limited, and total run comparisons can be made only for the past 13 even years. Since 1958, the catch plus escapement, or total run, of pink salmon to the Nushagak District has averaged 3.2 million fish. This includes one very depressed cycle year (1972), which produced a total run of only 126,000 pink salmon. Presumably, this was a result of the severe winters of 1970-1971, which also affected sockeye salmon production during this same period. However, the 1976 cycle year escapement of 863,000 to the Nushagak District produced the enormous run of 13.7 million in 1978, for a 16-to-1 return per spawner (ibid.). Table 45 presents the Nughagak District pink

Table 44. Bristol Bay Sockeye Salmon Run Estimates (in Thousands of Fish)

Year		Districts					
		Naknek-Kvichak[a]	Egegik	Ugashik[b]	Nushagak[c]	Togiak[d]	Total
1973	Catch	168.2	221.3	3.9	272.1	95.7	761.3
	Escapement	618.5	328.8	39.0	581.3	114.9	1,682.6
	Total run	786.8	550.2	42.9	853.4	210.7	2,443.9
1974	Catch	538.2	172.3	2.2	510.6	139.3	1,362.5
	Escapement	5,889.8	1,275.6	61.9	2,267.5	108.5	9,603.2
	Total run	6,427.9	1,447.9	64.0	2,778.0	247.8	10,965.7
1975	Catch	3,085.4	964.0	14.6	645.9	188.9	4,898.8
	Escapement	15,267.6	1,173.8	429.3	2,273.0	189.2	19,333.0
	Total run	18,353.0	2,137.9	443.9	2,918.9	378.1	24,231.8
1976	Catch	2,547.3	1,329.8	174.9	1,265.4	301.9	5,619.3
	Escapement	3,367.9	509.2	356.3	1,486.3	200.6	5,920.2
	Total run	5,915.1	1,838.9	531.2	2,751.7	502.5	11,539.5
1977	Catch	2,167.2	1,780.6	92.6	619.0	218.5	4,877.9
	Escapement	2,527.0	692.5	201.5	1,220.1	202.6	4,843.7
	Total run	4,694.2	2,473.1	294.1	1,839.1	421.1	9,721.6
1978	Catch	5,123.7	1,207.3	8.0	3,137.2	452.0	9,928.1
	Escapement	5,192.1	895.7	82.4	3,485.5	340.1	9,995.8
	Total run	10,315.7	2,103.0	90.4	6,622.7	792.1	19,923.9
1979	Catch	14,991.8	2,257.3	391.1	3,327.3	461.0	21,428.6
	Escapement	12,438.0	1,032.0	1,706.9	3,073.6	224.8	18,475.3
	Total run	27,429.8	3,289.4	2,098.0	6,400.9	685.8	39,904.0
1980	Catch	15,120.5	2,623.1	885.9	4,497.8	634.6	23,761.7
	Escapement	25,447.9	1,060.9	3,335.3	8,310.4	572.5	38,726.9
	Total run	40,568.3	3,683.9	4,221.2	12,808.2	1,207.0	62,488.6
1981	Catch	10,948.7	4,480.7	1,949.5	7,713.4	620.8	25,713.2
	Escapement	3,632.8	647.7	1,327.7	2,850.6	365.9	8,871.7
	Total run	14,581.5	5,175.4	3,277.2	10,564.1	986.7	34,584.9
1982	Catch[e]	4,987.9	2,413.9	1,161.1	5,998.8	583.7	15,145.5
	Escapement	2,529.7	1,034.6	1,185.6	2,012.7	341.4	7,104.0
	Total run	7,517.6	3,448.6	2,346.7	8,011.6	925.1	22,249.5

Source: ADF&G 1982c. (Note: Catch and escapement figures may not add to total run due to rounding.)

a Escapement figures include the Kvichak, Alagnak (Branch), and Naknek rivers.

b Escapement figures include the Mother Goose system, 1976-82.

c Escapement figures include the Wood, Igushik, Nuyakuk, Snake, and Nushagak-Mulchatna rivers.

d Escapement figures include Togiak River, Togiak tributaries, the Kulukak system, and other miscellaneous systems.

e Catch figures are from preliminary reports.

Table 45. Nushagak District of Bristol Bay Management Area Pink Salmon Run Estimates (in Numbers of Fish)

		Escapement by River System						
Year[a]	Catch	Wood[b]	Igushik[c]	Nuyakuk[d]	Nushagak/ Mulchatna[e]	Snake[f]	Total	Total Run
1958	1,113,794			4,000,000			4,000,000	5,113,794
1960	289,781			146,359			146,359	436,140
1962	880,424	25,000	12,000	493,914	6,100	6,000	543,014	1,423,438
1964	1,497,817	1,560	450	883,500	25,000	50	910,560	2,408,377
1966	2,337,066			1,442,424			1,442,424	3,779,490
1968	1,705,150			2,161,116			2,161,116	3,866,266
1970	417,834			152,580			152,580	570,414
1972	67,953			58,536			58,536	126,489
1974	413,613	44,800	7,500	529,216	3,100	900	585,516	999,129
1976	739,580	21,986	5,070	794,478	41,800	100	863,434	1,603,024
1978	4,348,336	205,000	16,210	8,390,184	771,600	3,483	9,386,477	13,734,813
1980	2,202,545	31,150	3,500	2,626,746	123,000	800	2,785,196	4,987,741
1982	1,285,947[h]	36,100	8,430	1,592,096	19,130	900	1,656,656	2,942,603
13-year total	17,299,850	365,596	53,160	23,271,149	989,730	12,233	24,691,868	41,991,718
13-year average	1,330,758	52,228	7,594	1,790,088	141,390	1,748	1,899,374	3,230,132

Source: ADF&G 1982c.

a Includes even-year only.

b Aerial survey estimate, 1962 and 1974-82; tower count, 1964.

c Aerial survey estimate, 1962-80; aerial survey estimate and tower count, 1976 and 1982.

d Tower count, 1960-82; aerial survey estimate, 1958, and below counting tower, 1962-64 and 1974-82.

e Aerial survey estimate.

f Aerial survey estimate, 1962-64, 1974-76 and 1980-82, and weir count, 1978.

g Only years and systems with escapement data were included in calculating averages.

h Preliminary.

salmon run-strength estimates, and table 46 gives by district catch information and areawide run estimates.

C. Chum Salmon

1. Distribution. Chum salmon in Bristol Bay are produced largely in the Nushagak District, which has accounted for 52% of the total production since 1960. The Togiak and Naknek-Kvichak districts rank second, producing 20%. The remaining 8% are somewhat evenly divided between the Egegik and Ugashik districts (ibid.).

Table 46. Bristol Bay Pink Salmon Run Estimates 1964 to 1982, Even-Year Only (in Thousands of Fish)

	Catch by District[a]							
Year	Naknek-Kvichak	Egegik	Ugashik	Nushagak	Togiak	Area Total Catch[b]	Escapement Estimates[b,c]	Area Total Run Estimate[b]
1964	49.1	0.6	0.02	1,497.8	2.0	1,550	911.0	2,461.0
1966	142.2	0.0+[d]	0.01	2,337.1	13.5	2,493	1,442.0	3,935.0
1968	218.7	0.2	---	1,705.2	11.7	1,936	2,161.0	4,097.0
1970	28.3	0.04	---	417.8	10.7	457	153.0	610.0
1972	57.1	0.01	---	68.0	2.0	127	59.0	186.0
1974	508.5	4.4	0.3	413.6	13.1	940	986.0	1,926.0
1976	264.6	4.1	0.1	739.6	28.1	1,037	1,040.0	2,077.0
1978	734.9	11.4	0.5	4,348.3	57.5	5,153	11,492.0	16,645.0
1980	288.4	2.5	0.05	2,202.5	70.0	2,563	3,317.0	5,880.0
1982[e]	125.9	2.0	0.1	1,285.9	23.7	1,437	1,806.0	3,243.0

a ADF&G 1982c.

b Middleton 1983.

c 1964-72: Nushagak District estimates only. 1974: Nushagak and Naknek-Kvichak district estimates combined. 1976-78: Nushagak, Naknek-Kvichak, and Togiak district estimates combined. 1980: Nushagak, Naknek-Kvichak, Togiak, and Ugashik district estimates combined. 1982: Nushagak, Naknek-Kvichak, Togiak, Ugashik, and Egegik district estimates combined.

d Less than 10 fish harvested.

e 1982 catch information are preliminary data.

2. Abundance. Chum salmon is the third most abundant salmon species in Bristol Bay. Although chum salmon occur simultaneously with the sockeye salmon, their pattern of catches is quite stable throughout the history of the fishery, far more so than that of any other species (ibid.).

   Efforts to determine chum salmon escapements have been centered in the Nushagak and Togiak districts of Bristol Bay, where 73% of the commercial catch has been produced since 1960. A comprehensive aerial survey data base has been established for chum salmon escapement estimates in the Togiak District since 1967. Nushagak District escapements were extensively monitored between 1977 and 1980. After three years of aerial surveying of the Nushagak-Mulchatna rivers, it was determined that counting chum salmon in these drainages was not feasible because of the unfavorable counting conditions (muddy, turbid waters associated with chum salmon spawning habitat in the area), the inability to determine the peak spawning period precisely, the sheer size of the drainage and the number of spawning streams, and because the cost of flying more than one survey for chum salmon could not be justified (Bucher 1981, Middleton 1983). After the 1980 season, it was concluded that future chum salmon surveys, would be conducted only in the Togiak District, that Nushagak system chum salmon would be "noted" during chinook salmon surveys and that the general strength of the chum salmon run would be assessed from these figures.

   Escapement estimates in the Nushagak District have averaged 268,000 since 1966, with a range of 80,000 in 1966 and 1975 to 969,000 in 1980; and 256,000 in the Togiak District, with a range of 85,000 in 1969 to 496,000 in 1977. Since escapement estimates are based on aerial survey methods, it is probable that these estimates are minimal but nevertheless reflective of the relative magnitude of escapement levels (ibid.).

   Table 47 presents the chum salmon run estimate for the Nushagak and Togiak districts, and table 37 in the Human Use section presents by district the areawide catch statistics.

D. Chinook Salmon

1. Distribution. Chinook salmon are found chiefly in the Togiak, Nushagak, Alagnak (Branch), and Naknek river systems (ADF&G 1977b). The main Nushagak and Mulchatna rivers comprise a significant portion of the total chinook salmon spawning ground habitat within the Nushagak District (Bucher 1983). In addition, the Klutispaw and King Salmon rivers are important chinook tributaries to the Nushagak River proper, and the Stuyahok, Koktuli, and Chilikadrotna systems are important chinook tributaries to the Mulchatna River (Bucher pers. comm.).

2. Abundance. Chinook salmon are the fourth most abundant salmon species in Bristol Bay. The primary chinook salmon-producing rivers in Bristol Bay are those draining into the Nushagak and Togiak districts, where most of the Bristol Bay production occurs. Other than minimal aerial survey coverage of the

Table 47. Nushagak and Togiak Districts of Bristol Bay Management Area Chum Salmon Run Estimates, 1966-1982 (in Thousands of Fish)

	Nushagak			Togiak		
Year	Catch	Escapement[a,b]	District Total Run	Catch	Escapement[a,c]	District Total Run
1966	129.3	80.0*&	209.3	95.4	---	---
1967	388.3	200.0&	538.3	63.3	179.0	242.3
1968	178.8	100.0§&	278.8	108.0	348.0	456.0
1969	214.2	130.0	344.2	66.4	85.0	151.4
1970	435.0	273.0≠	708.0	100.7	241.0	341.7
1971	360.0	226.0≠	586.0	123.8	229.0	352.8
1972	310.1	195.0≠	505.1	178.9	170.0	348.9
1973	336.3	200.0§	536.3	195.4	163.0	358.4
1974	157.9	100.0§	257.9	80.7	161.0	241.7
1975	152.9	80.0#	232.9	87.1	114.0	201.1
1976	801.1	500.0#	1,301.1	153.6	392.0	545.6
1977	899.7	609.0#	1,508.7	270.6	496.0	766.6
1978	651.7	293.0#	944.7	275.0	396.0	671.0
1979	440.3	166.0$	606.3	219.9	293.0	512.9
1980	681.9	969.0$	1,650.9	299.7	415.0	714.7
1981	772.9[d]	117.0$	949.9	236.4[d]	331.0	567.4
1982	456.4[d]	256.0	712.4	159.1[d]	86.0	245.1

Source: ADF&G 1982c.

a Escapement estimates are based on data collected on comprehensive aerial surveys of spawning grounds; these estimates supercede previously reported escapements and are rounded to the nearest thousand fish.

b Comprehensive aerial coverage was begun in 1977; escapements are derived from the following:

- * 1966 - tower enumeration data from Nushagak River; and estimates of total escapement accounted for by tower enumeration;
- & 1967 - tower enumeration data, and proportion of escapement-to-catch in 1966 and 1968;
- § 1968 & 1973-74 - tower enumeration and aerial survey data;
- ≠ 1970-72 - average catch/escapement ratio for 1968-69 and 1973-81;
- \# 1975-78 - aerial survey data; and
- $ 1979-81 - adjusted sonar estimate from Portage Creek site.

c Comprehensive aerial survey coverage was begun in 1967.

d Preliminary.

Alagnak (Branch) and Naknek rivers, the majority of escapement studies have centered in the Nushagak and Togiak districts, where an extensive aerial survey data base has been developed. Aerial survey assessment of chinook salmon spawning populations began in the Nushagak area in 1966 and in the Togiak area in 1967. Presently, the aerial survey project forms the basis for escapement estimates in both districts. The Togiak District escapements represent data for some 12 streams throughout the district, with the Togiak and Kulukak rivers being the major producers. The Nushagak surveys involve 21 streams, and six of these are the key index streams, or major producers (Middleton 1983).

During the five-year period from 1978 through 1982, the chinook salmon runs have all been above average for the Nushagak District, averaging 280,000 fish, compared to the 16 year (1966-1982) average of 169,000 fish. The two years from 1981 through 1982 have been especially strong, averaging 346,000 chinook salmon. Recent years have also been above average for the Togiak District, with a peak year run of 97,000 in 1978. The Togiak chinook salmon run has averaged 41,000 since 1967. Overall, chinook salmon production in Bristol Bay has definitely been up over the past few years. The outlook for the next several years is promising because of the very good escapements in recent years and a reduction in the high seas foreign fisheries interception of Western Alaska chinook salmon (ibid.). Table 48 presents Nushagak and Togiak run-strength estimates for chinook salmon, and table 39 in the Human Use section gives by district commercial catch figures for all districts.

E. Coho Salmon

1. Distribution. Coho salmon are found throughout the Bristol Bay Management Area; however, as is the case with chinook and chum salmon, the majority of the harvest occurs in the Nushagak and Togiak districts.

2. Abundance. Middleton (1983) summarizes what is known of the coho salmon in the Bristol Bay Management Area as follows: "Coho salmon is a rather notorious species for unpredictable production. Their life history of extended juvenile stream life (in Bristol Bay mainly two or more years) makes them particularly susceptible to environmental mortalities during the freshwater phase of their existence. Their production pattern in Bristol Bay tends to be somewhat erratic, but there are other factors that have contributed to this pattern other than basic production. Generally speaking, coho salmon have not been of great interest to processors until recently. Relatively low numbers and their lateness in the season have detracted from the larger canneries operating for coho salmon once the sockeye salmon season is over. Fishing effort also tends to drop off significantly after July. Recent higher interest in the frozen fish market and the advent of more freezer-processor vessels in Bristol Bay has stimulated more interest in coho salmon."

Table 48. Nushagak and Togiak Districts of Bristol Bay Management Area Chinook Salmon Run Estimates, 1966 to 1982 (in Thousands of Fish)

	Nushagak District			Togiak District		
Year	Catch	Escapement[a,b]	District Total Run	Catch	Escapement[a,c]	District Total Run
1966	58.2	40.0[b1]	98.2	10.0	---	---
1967	96.2	65.0[b2]	161.2	13.4	10.0	23.4
1968	78.2	70.0	148.2	13.5	16.0	29.5
1969	80.8	35.0	115.8	20.2	8.0	28.2
1970	87.5	50.0	137.5	28.7	15.0	43.7
1971	82.8	---[d]	---	27.0	20.0	47.0
1972	46.0	25.0	71.0	20.0	14.0	34.0
1973	30.5	35.0	65.5	10.9	11.0	21.9
1974	32.1	70.0	102.1	10.8	15.0	25.8
1975	21.5	70.0	91.5	7.2	11.0	18.2
1976	60.7	100.0	160.7	29.7	14.0	43.7
1977	85.1	65.0	150.1	35.2	20.0	55.2
1978	118.5	130.0	248.5	57.0	40.0	97.0
1979	157.3	95.0	252.3	30.0	20.0	50.0
1980	65.0	141.0	206.0	12.5	12.0	24.5
1981	194.9[e]	150.0	344.9	24.3[e]	27.0	51.3
1982	200.1[e]	147.0	347.1	40.0[e]	17.0	57.0

Source: ADF&G 1982c.

a Escapement estimates are based on data collected on comprehensive aerial surveys of the spawning grounds; these escapement estimates supercede previously reported escapements and are rounded to the nearest thousand fish.

b Comprehensive aerial coverage was begun in 1968; escapements prior to 1968 were derived from the following:

b1 Tower enumeration data from Nushagak River and estimate of total escapement accounted for by tower enumeration;

b2 Tower enumeration data, minimal aerial survey coverage, and general run-strength indicators (commercial and subsistence catches).

c Comprehensive aerial survey coverage was begun in 1967.

d Escapement estimate precluded by adverse weather; however, information indicates a "light escapement" compared to previous years.

e Preliminary.

Very little escapement data are available for the Nushagak and Togiak districts, where 87% of the Bristol Bay coho salmon catch has been produced since 1966. Because of the relatively low interest in this species until quite recently, no special effort has been directed toward developing escapement assessment techniques.

The Nushagak River sonar enumeration program, started in 1979, shows considerable promise for assessing coho salmon escapements. In 1980, 102,000 coho salmon were counted into the Nushagak River through 6 August; this was the first escapement estimate ever made for coho salmon into the Nushagak River. The actual 1980 escapement into the Nushagak River was significantly higher than the 102,000 fish recorded since the sonar project was terminated 10 days before the coho salmon commercial fishery peaked. The project objective was to count pink salmon, and the coho salmon counting capability was not fully realized until after the fact. Coho salmon were not enumerated in 1981, because of inadequate funding; but in 1982 the sonar coho salmon escapement estimate was 227,000 fish. Future plans entail expanding the project duration for complete assessment of the coho salmon escapement.

Togiak District coho salmon escapement studies were started in 1980 using aerial survey techniques, and this first-year effort indicated an escapement of 50,000 to 80,000 coho salmon to the Togiak River, its tributaries, and to the Kulukak River system. Aerial surveys were continued in 1981 and 1982, with 41,000 and 54,000 coho salmon enumerated, respectively, by this method. These coho salmon escapements derived from aerial surveys are considered minimal total estimates.

Table 38 in the Human Use section presents coho salmon catch data for the Bristol Bay Management Area.

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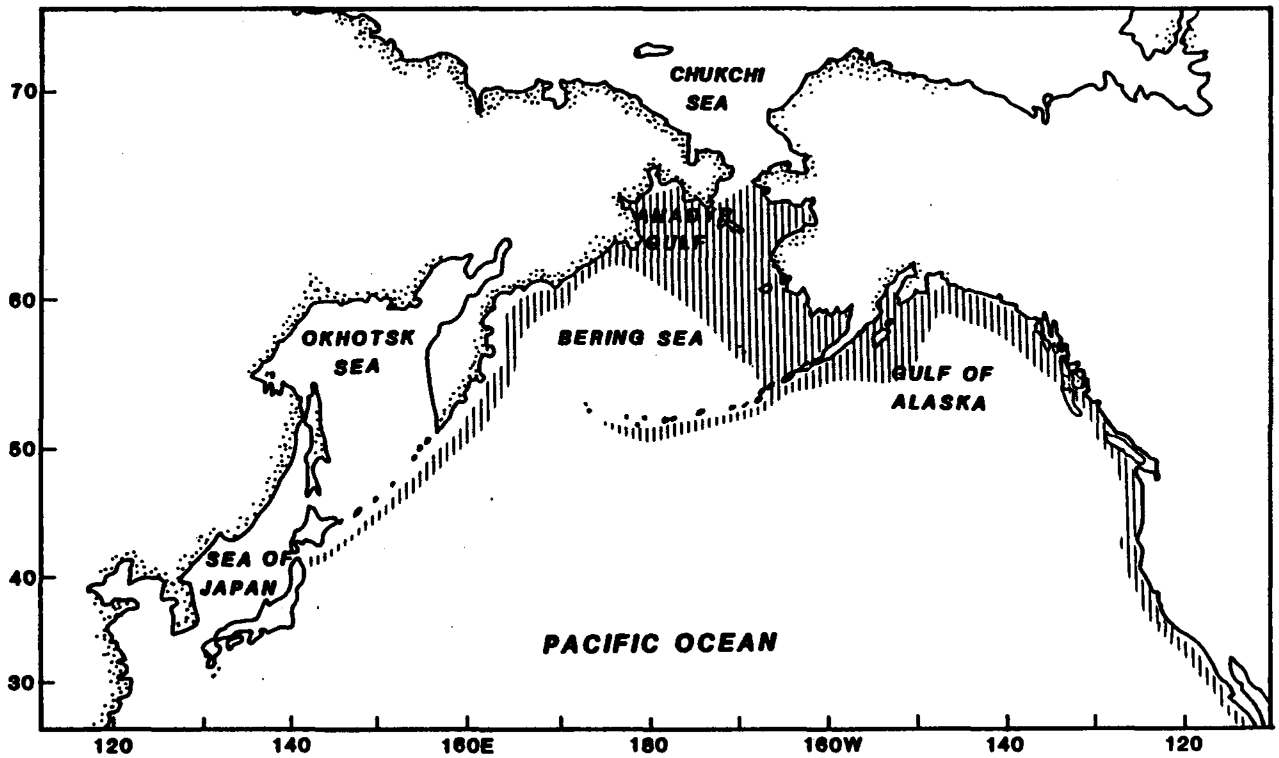
Marine Fish and Shellfish

Pacific Halibut Life History



Map 28. Range of Pacific halibut (IPHC 1978, Best 1981, Bell and St. Pierre 1970)

I. NAME
   A. Common Name: Pacific halibut
   B. Scientific Name: <u>Hippoglossus stenolepis</u>

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
      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).

III. PHYSICAL HABITAT REQUIREMENTS

Halibut are concentrated in areas with bottom water temperatures ranging from 3 to 8°C (IPHC 1978). The bathymetric range for halibut is between 55 and 1,100 m (Rogers et al. 1980).

IV. NUTRITIONAL REQUIREMENTS

A. Preferred Foods

Adult halibut are omnivorous, eating anything available. Halibut less than 10 cm feed primarily on small crustaceans (Smith et al. 1978). Larger halibut feed on shrimps, crabs, and fish, especially sand lances (*Ammodytes hexapterus*) (ibid.). In the Gulf of Alaska, halibut feed on Tanner crab (*Chionoecetes* spp.) and king crab (*Paralithodes* spp.) (Gray 1964).

Small halibut (30 cm or less) in the southeastern Bering Sea feed primarily on crustaceans (Novikov 1964), but larger (30 to 60 cm) halibut consume fish and crustaceans. Fish consumed include flatfishes, smelt, capelin (*Mallotus villosus*), pollock (*Theragra chalcogramma*), and sand lances. Halibut over 60 cm feed mainly on fishes, especially the yellowfin sole (*Limanda aspera*) (Novikov 1964).

B. Feeding Locations

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 limited when halibut are abundant (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 Gulf of Alaska include troughs on the east side of Kodiak and the Chirikof Island area.

In the Bering Sea, halibut apparently spawn between Unimak and the Pribilof Islands (Best 1981). Spawning must also take place at other locations along the continental edge west of the Pribilof Islands, as well as along the Aleutian Islands (ibid.).

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 years at a length of 122 cm. Males in the Bering Sea averaged 7.5 years and 72 cm (ibid.).

D. Fecundity

The number of eggs produced per female is related to size. A 23 kg female produces about 500,000 eggs, but a 113 kg female may produce 4 million eggs (IPHC 1978).

E. Frequency of Breeding

The long immaturity of female halibut (approximately 12 years) 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 caught in trawl surveys after the spawning period and mistaken for nonspawning adults.

F. Incubation period

Eggs hatch after about 15 days (Webber and Alton 1976); 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 that 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. Timing of Movements and Use of Areas

Eggs, larvae, and postlarvae are free-floating at depths down to 686 m and in the Gulf of Alaska are transported great distances by westward ocean currents (Gusey 1978). The free-floating stage lasts about six months (Webber and Alton 1976). Larvae in later developmental stages tend to rise in the water column and are moved by prevailing winds to the shallow (about 12 m) sections of the shelf (Gusey 1978). Halibut move from deep (up to 1097 m) water along the edge of the continental shelf to shallower (27 to 274 m) banks and coastal waters during the summer (IPHC 1978). These movements and coastwide migrations, which may encompass hundreds of miles, have been documented by extensive IPHC tagging studies. Though winter information is limited, it appears that migration is not as extensive in the winter as in the summer and that the distance and direction of movements may differ between the seasons (ibid.). 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 they are any threat to free-swimming halibut (ibid.).

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
- Increase in sedimentation
- Alteration of preferred substrate
- Reduction in food supply
- Human harvest
- Seismic shock waves

VIII. LEGAL STATUS

The IPHC manages the Pacific halibut fishery. The commission monitors catch and effort, restricts gear and the size of fish landed, and defines fishing areas. Commission rules are enforced by the National Marine Fisheries Service (NMFS) and the State of Alaska.

IX. LIMITATIONS OF INFORMATION

Little information is available on western Bering Sea stocks (Best 1981). Best (1981) also suggested that more information is needed concerning juvenile halibut movements and the similarities and differences between Bering Sea and Gulf of Alaska stocks.

X. DISTRIBUTION

In Alaskan waters, the largest concentrations of Pacific 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). In the eastern Bering Sea, halibut are distributed as far north as Norton Sound, St. Lawrence Island, and the Gulf of Anadyr, and occur from shallow waters to depths of 700 m (Webber and Alton 1976). In winter, the main body of the population in the eastern Bering Sea resides along the outer shelf from Unimak Island to west of the Pribilof Islands. In summer, they move to shallower (50 to 150 m) waters of the inner shelf (ibid.).

Spawning occurs along the continental shelf at depths from 228 to 456 m (Bell 1981). In the western Gulf of Alaska, halibut spawn in Chiniak Trough and Kiliuda Trough on the east side of Kodiak, south of the Trinity Islands, west of Chirikof Island, and east of the Shumagin Islands (St. Pierre, in press). In the Bering Sea, spawning takes place between Unimak Island and the Pribilof Islands, and north of Amchitka Island (ibid.).

XI. ABUNDANCE

Currently, the largest concentrations of Pacific halibut are in the Gulf of Alaska, with a smaller population in the Bering Sea (Best 1981).

Annual surplus production is defined as the catch that can be taken in a given year without changing biomass (IPHC 1982). The estimated surplus for halibut in the North Pacific in 1982 was 64 million pounds. Of this, however, 28 million pounds was expected to be lost to incidental catch, and 9 million pounds was set aside to help increase the stocks, leaving 27 million pounds available to the commercial catch. The 1982 recommended catch limit for the Gulf of Alaska (IPHC area 3) was 17 million pounds and for the Bering Sea (IPHC area 4) 1 million pounds (IPHC 1982).

IPHC juvenile surveys have suggested that the abundance of young halibut is increasing. These are predominantly two-to-five-year-olds that will contribute to the fishery in the late 1980's (ibid.). Rebuilding of halibut stocks will be slow, however, and will be strongly influenced by the success of efforts to reduce the incidental catch of halibut in other fisheries (ibid.).

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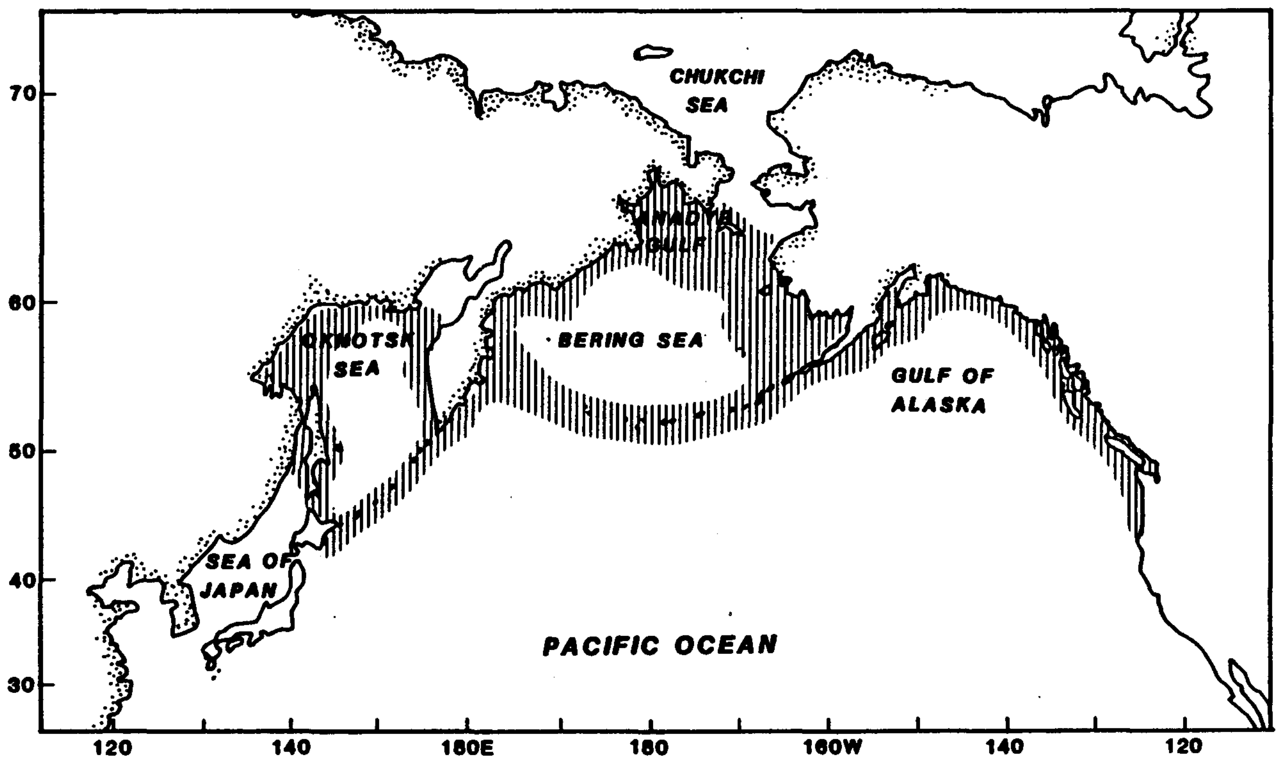
Pacific Cod Life History



Map 29. 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
      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 1973-76 found the highest cod catch per unit effort (CPUE) in the Kodiak and Sanak regions (Ronholt et al. 1977). In

the Bering Sea, the most productive fishing areas for cod are in the outer shelf, northwest of Unimak Island (Jewett 1977, Low 1974).

III. PHYSICAL HABITAT REQUIREMENTS

Pacific cod are mostly benthic and are found at depths ranging from 15 to 550 m (Moiseev 1953). Their depth distribution varies with the location of the stock (i.e., Asian or Canadian waters) and with the time of year. 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 to 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 in temperatures below optimum more rapidly than in temperatures above optimum. Yamamoto and Nishioka (1952) found that optimal larval survival was at 7 to 8°C. 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 to 3 ppm and salinities from at least 12.71 to 23 ^{o}/00 (Alderdice and Forrester 1971).

IV. NUTRITIONAL REQUIREMENTS

A. Preferred Foods

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 (Bakkala 1981). Young cod feed on copepods and similar organisms (Morrow 1980).

B. Feeding Locations

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 migration 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 (Moiseev 1953). Location of spawning is probably more closely correlated to water temperature than to depth (see 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). Peak spawning in Asian water takes place between February and April (Moiseev 1953). In the southern Asian range, spawning occurs between December and February (ibid.).

C. Breeding 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). Female cod at 50% maturity are age three (55 cm) (Forrester 1969). In the west Kamchatka area, cod first reach maturity at age five (55 cm) (ibid.).

E. Fecundity

Fecundity increases with the size of the fish. A 55 cm female off British Columbia will produce about 860,000 eggs, whereas one 80 cm female will produce about 3,350,000 eggs (Thomson 1962, Forrester 1969).

Thompson (1962) found that the length-fecundity relationship for cod in Asian waters (Sakhalin and West Kanchatka) was the same as that for cod in British Columbia waters.

F. Frequency of Breeding

Cod breed annually.

G. Incubation Period

Pacific cod eggs are demersal (they 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 and 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), in Cook Inlet (5.3 to 9.0 mm) in May and July, 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 ASSOCAITED WITH LIFE FUNCTIONS

A. Timing of Movements and Use of Areas

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 (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, resulting 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-soluable substances
- Increase in suspended organic or mineral material
- Increase in sedimentation
- Reduction in food supply
- Human harvest
- Seismic shock waves

VIII. LEGAL STATUS

Management of Pacific cod stocks is by the North Pacific Fishery Management Council (NPFMC) through their groundfish management plans.

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 have been available (Bakkala 1981). Such information is essential for management of the resource.

X. DISTRIBUTION

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 to 1976 found the highest cod catch per unit effort (CPUE) in the Kodiak and Sanak regions (Ronholt et al. 1977). In the Bering Sea, the most productive fishing areas for cod are in the outer shelf area northwest of Unimak Island (Jewett 1977, Low 1974).

Pacific cod are mostly benthic and are found at depths ranging from 15 to 550 m (Moissev 1953, Salveson and Dunn 1976). Their depth distribution varies with the location of the stock and the time of year. Cod generally move into deep water in late winter (January to April) and back to shallow water in the spring, after spawning (Salveson and Dunn 1976). In the Bering Sea, migrations that extend to the inner shelf apparently involve substantial numbers of cod only in relatively warm years (ibid.).

XI. ABUNDANCE

Maximum sustainable yield (MSY) for Pacific cod in the Gulf of Alaska is estimated to be 88,000 to 177,000 metric tons (NPFMC 1983a). In the Bering Sea/Aleutians region, it is estimated to be 55,000 metric tons (NPFMC 1983b). Pacific cod, however, is a relatively short-lived and fast-growing species. Thus, only a few year-classes contribute to the population, and large fluctuations in population size occur, depending upon whether strong or weak year classes are present (Natural Resources Consultants 1981). Because of this, MSY estimates, which are based on long-term population stability, do not have much meaning when applied to cod.

Cod stocks off Alaska declined in the mid 1970's but have recently increased in abundance (ibid.). The increase is due to the presence of relatively strong 1977 and 1978 year classes (Bakkala 1981, Natural Resources Consultants 1981). Optimum yield for the the Gulf of Alaska has been set at 60,000 metric tons, with 16,560 metric tons coming from the western region and 33,540 metric tons from the eastern region (NPFMC 1983a). Optimum yield for the Bering Sea and Aleutian area has been set at 120,000 metric tons (NPFMC 1983b). This is at the high end of MSY because of the recent population increase.

Current harvest levels of Pacific cod in the Gulf of Alaska and in the Bering Sea are below MSY. In the Bering Sea, cod are usually taken only as incidental catch in the pollock fishery, though boats will target on cod when concentrations are encountered (Bakkala 1981). Thus, cod stocks have apparently not been reduced by fishing pressure.

The cod population may decrease after 1982, following the decline of the strong 1977 and 1978 cohorts in the population (ibid.).

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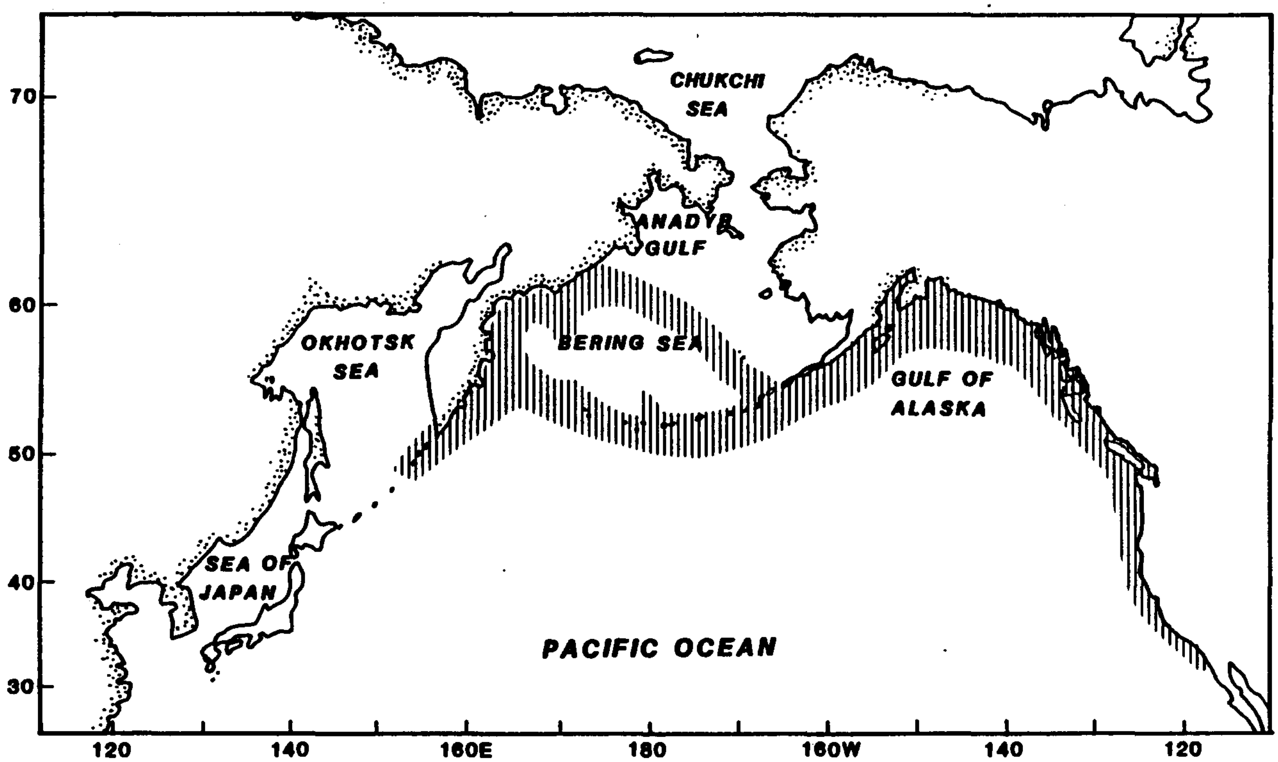
Pacific Ocean Perch Life History



Map 30. 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
   In April-October 1973-1976, the National Oceanic and Atmospheric Administration (NOAA) conducted 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 Pacific ocean perch are found in the Unimak, Shumagin, Kodiak, and Yakutat regions in spring and summer (Lyubimova 1965). Chikuni (1975) defined two stocks of Pacific ocean perch in the Bering Sea: the Aleutian stock, found on both sides of the Aleutian archipelago, and the eastern slope stock, found on the southeastern Bering Sea continental slope. The Aleutian stock is much larger than the eastern slope stock.

III. PHYSICAL HABITAT REQUIREMENTS

Water temperature is an important environmental factor, controlling migration patterns and distribution of Pacific ocean 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).

Reeves (1972) noted that Pacific ocean perch occur in large concentrations around submarine canyons.

Lyubimova (1965) related the vertical distribution of Pacific ocean 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.

Carlson and Haight (1976) reported that both juvenile and adult Pacific ocean perch 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 the availability of food and by hydrographic conditions than by substrate.

IV. NUTRITIONAL REQUIREMENTS

A. Preferred Foods

Skalkin (1964) found that immature perch fed mainly on copepods, but mature fish fed mainly on euphausiids. Chikuni (1975) noted that stocks in the Gulf of Alaska fed almost entirely on euphausids, whereas those in the Bering Sea consume fishes, euphausids, and other crustaceans.

B. Feeding Locations

Lyubimova (1964) found dense concentrations of feeding perch in the western Gulf of Alaska southeast of Kodiak Island, southwest of the Shumagin Islands, and south of Unimak Island. Schools of feeding perch are found mainly at depths of 150 to 200 m (Lyubimova 1963).

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 (e.g., 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. Breeding Habitat
High larval densities are 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 from October through February, and spawning (release of young) takes place from March through June (Chikuni 1975).

C. Reproductive Behavior
Mating has not been observed (Morin and Dunn 1976); Lisovenko (1964) suggested, however, that males may copulate several times with different females. Paraketsov (1963) stated that mating and fertilization take place simultaneously; Chikuni (1975), however, believed 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. 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.

F. Frequency of Breeding
Pacific ocean perch breed annually (Morin and Dunn 1976).

G. Incubation Period
Spawning (release of live young) takes place four to five months after copulation (Chikuni 1975).

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

A. Timing of Movements and Use of Areas
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 (up to 320 to 370 m or deeper) waters (Buck et al. 1975).

B. Migration Routes

Early researchers (Lyubimova 1963, Paraketsov 1963) described elaborate spawning and feeding migrations for Pacific ocean perch in the Gulf of Alaska and Bering Sea. This work, however, has been shown to be incorrect. Pacific ocean perch do not undertake any long migrations (Blackburn, pers. comm.).

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

Carlson and Haight (1976) noted strong fluctuations in year-class strength and that extreme success or failure of year classes is apparently characteristic of the species.

Lisovenko (1964) noted that female perch in the Gulf of Alaska cast their larvae in places where water currents are conducive of high productivity. Cooney et al. (1979) have speculated that weather and current conditions resulting in dispersal of plankton may have a negative effect on larval pollock survival. It seems possible that perch larvae are similarly affected.

Before heavy commercial exploitation began in the early 1960's, Pacific ocean perch were a dominant groundfish in the Gulf of Alaska. But perch stocks now have been severely reduced, and, possibly as a result of release from competition with perch, pollock have become much more abundant (NPFMC 1979).

Pollock and perch feed on largely the same organisms (Somerton 1978), and it is possible that competition with pollock will prevent perch stocks from recovering even if fishing pressure is relieved (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
- Introduction of water soluble substances
- Increase in suspended organic or mineral material
- Increase in sedimentation
- Alteration of preferred substrate
- Reduction of food supply
- Seismic shockwaves
- Human harvest

VIII. LEGAL STATUS

A management plan for groundfish within the 200-mi limit (including Pacific ocean perch) has been developed by the North Pacific Fishery Management Council. Harvest quotas are enforced by the National Marine Fisheries Service and the State of Alaska.

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).

X. DISTRIBUTION

Pacific ocean perch are generally found in outer shelf and upper continental slope zones (Ronholt et al. 1977). Commercial quantities usually occur between 100 and 500 m (Quast 1972). Reeves (1972) noted that ocean perch occur in large concentrations around submarine canyons. Larval Pacific ocean perch are planktonic, with their distribution largely controlled by ocean currents. In their first year, 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).

In the southwest Gulf of Alaska, feeding schools of ocean perch are found in the Unimak, Shumagin, and Kodiak regions in the spring and summer (Lyubimova). In the eastern Bering Sea, the largest concentrations of ocean perch are located in the vicinity of the Pribilof Islands and in the southeastern portion of the continental slope (Pautov 1972). Chikuni (1975) defined two main stocks in the Bering Sea: the Aleutian stock, found on both sides of the Aleutian archipelago, and the eastern slope stock, located along the southern half of the eastern Bering Sea slope. Of the two stocks, the Aleutian stock is as much as four times larger than the eastern slope stock (Chikuni 1975). In the Aleutian region, the largest concentration occurs on the north side of the chain between 175°w and 180°w (Low 1976).

XI. ABUNDANCE

Prior to 1960, Pacific ocean perch stocks in the Gulf of Alaska were unexploited and probably at the level of maximum abundance. Quast (1972) estimated the total catchable biomass for the area off western North America at that time to be about $1,750 \times 10^3$ tons (1.58×10^6 metric tons), a high fraction of which was in the Gulf of Alaska (OCS Socioeconomic Studies 1980).

Perch are slow-growing and do not become sexually mature until around age seven. Adult perch form dense schools that are easily accessible to trawls (Quast 1972). These factors, combined with periodic extreme variations in year-class strength, made perch stocks particularly vulnerable to unregulated fishing (OCS Socioeconomic Studies 1980).

Intensive foreign fishing for perch began in the 1960s, and harvests that exceeded the reproductive potential of the population continued for several years. Perch stocks in the central Gulf may now be no higher than 5% of their virgin abundance (Ito 1982). The maximum sustainable yield for the Gulf of Alaska is estimated to be 125,000 to 150,000 metric tons, but catches now are far below that level (NPFMC 1983a). Optimum yield for the central gulf is now set at 7,900 metric tons and for the western gulf at 2,700 metric tons (ibid.).

Maximum sustainable yield for the Bering Sea is estimated to be 32,000 metric tons and for the Aleutians 75,000 metric tons. Optimum yield is set well below those values, at 3,250 metric tons in the Bering Sea and 75,000 metric tons in the Aleutians (NPFMC 1983b).

Quast (1972) predicted that decades may be required for even a moderate recovery of Pacific ocean perch stocks. The potential for recovery is lessened by the concurrent increase in pollock stocks. Juvenile perch and pollock occupy approximately the same trophic position (NPFMC 1979); thus it is possible that competition with pollock will prevent perch stocks from recovering even if fishing pressure is released.

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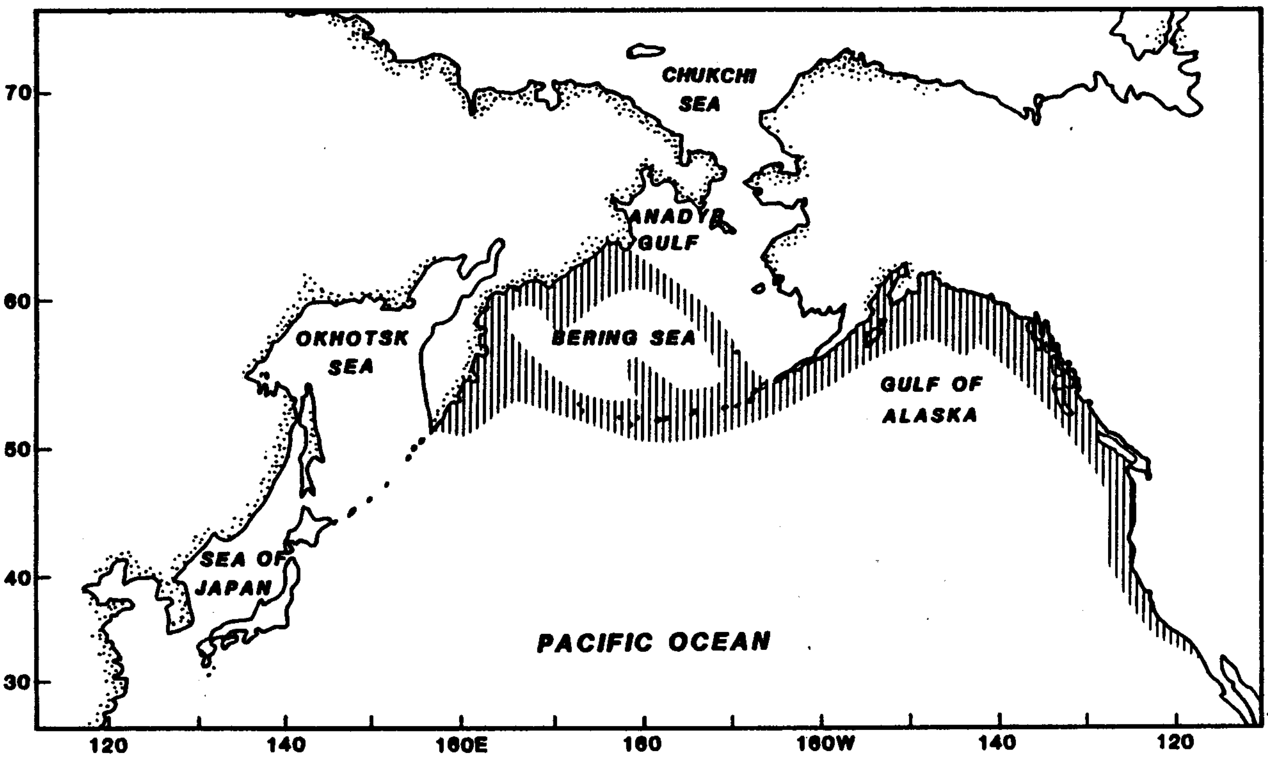
Sablefish Life History



Map 31. Range of sablefish (Low et al. 1976)

I. NAME
   A. Common Name: Sablefish, black cod
   B. Scientific Name: Anoplopoma fimbria (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
      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.

III. PHYSICAL HABITAT REQUIREMENTS

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, which are found in shallower (70 to 200 m) areas than adults, occupy a wider range of temperatures (Alton and Webber 1976).

IV. NUTRITIONAL REQUIREMENTS

A. Preferred Foods

Sablefish are opportunistic feeders, feeding on a wide variety of organisms. Their diet is dependant upon their life stage, geographic location, the season, and the 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 to 38 cm) off southern British Columbia gather in estuaries of rivers, where they feed on young salmon.

B. Feeding Locations

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. However, Sullivan and Smith (1982) 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 be attributable to an evolutionary adaptation to that feeding strategy. Weather patterns and ocean currents that cause a dispersal of planktonic organisms may have a negative effect on the feeding and growth of larval sablefish, as with larvae of other marine fishes (Cooney et al. 1979).

D. Feeding Behavior

Shubnikov (1963) noted an annual cycle in the feeding intensity of sablefish. 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 that seek out selected prey, then leave and allow 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 spawn in the southeastern portion of the 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

Shubinikov (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 breeding 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. 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).

F. Frequency of Breeding

Sablefish breed annually.

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 semi-pelagic. The move from a pelagic to a 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 (less than 45 mm) fish are found in shallow (70 to 200 m), more coastal waters (Kulikov 1965). As the fish get larger (45 to 50 cm) they migrate to deeper waters (Bracken 1982), with adults found in areas with depth greater than 150 m (Alton and Webber 1976).

Kulikov (1965) reported that sablefish follow a diurnal vertical migratory 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). 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, whereas small (less than 60 mm) fish tend to move westward (possibly drifting with prevailing ocean currents). He speculated that the change in direction 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, which carry them into areas where temperatures 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 soluable substances
- Increase in suspended organic or mineral material
- Reduction in food supply
- Human harvest
- Seismic shock waves

VIII. LEGAL STATUS

Sablefish within the 200-mi limit are managed by the North Pacific Fishery Management Council within their groundfish fishery management plan.

IX. LIMITATIONS OF INFORMATION

The extent and prevalence of migration of sablefish among management areas has very strong implications for management of this species. Studies of the direction and extent of movements should be continued, along with analysis of movements by sex (Bracken 1982).

X. DISTRIBUTION

Sablefish are found throughout the Gulf of Alaska, with a band of high abundance stretching from the Shumagin Islands southeastward to northern Queen Charlotte Sound (Low et al. 1976). Sablefish in the Bering Sea are found along the edge of the continental shelf but are not as abundant as they are in the Gulf of Alaska (ibid.).

Sablefish occupy a wide range of depths, with pelagic eggs and larvae in surface waters, juveniles (one to four years) in surface and inshore waters down to 150 m and adults from 150 m down to 1,200 m (ibid.). Density is generally low in the 100 to 200 m and 800 to 1,000 m depth zones.

Tagging studies indicate that many of the mature adult sablefish (greater than 60 cm) in the western Gulf of Alaska migrate eastward, toward the southeastern gulf. Bracken (1982) speculates that the southeastern gulf may be a major spawning area drawing sablefish from throughout the gulf.

XI. ABUNDANCE

Sablefish are widely distributed throughout the North Pacific but are most abundant in the Gulf of Alaska. The distribution of sablefish biomass is approximately 67% in the Gulf of Alaska, 13% in the Bering Sea, 13% in the Vancouver-California region, and 7% in the Aleutian region (west of 170°W) (Low et al. 1976).

In studies done in the Gulf of Alaska from 1979 to 1980, highest average density in the Chirikof (159°W to 154°W) and Kodiak (154°W to 147°W) areas was in the 200 to 400 m depth zones, in the 400 to 600 m depth zone in the Shumagin (170°W to 159°W) and eastern Aleutian (180°W to 170°W) areas, and in the 600 to 800 m depth zone of the western Aleutian area (West of 180°W) (Sasaki 1981).

Maximum sustainable yield (the largest catch that could be taken continuously from a stock, usually based on historic catch data) for sablefish in the Gulf of Alaska has been estimated to be 22,000 metric tons (NPFMC 1983a). Catches now, however, are held well below that value.

Catch per unit effort statistics (CPUE) indicate that sablefish abundance throughout the Gulf of Alaska and Bering Sea declined in the 1970's. The NPFMC has set optimum yield (that harvest level providing greatest overall benefit) for sablefish in the western gulf at 1,670 metric tons and in the central gulf at 3,060 metric tons (ibid.). This level is less than equilibrium yield (yield that would maintain stock at its current level over several years) and is thus intended to increase sablefish abundance in the gulf and, as the stocks are intermixed, also in the Bering Sea (ibid.).

Optimum yield for the Bering Sea for 1984 has been set at 3,500 metric tons and at 1,500 metric tons in the Aleutians. This level is equal to equilibrium yield, as it is hoped that rebuilding the Gulf of Alaska stocks will have a sufficient positive effect on Bering Sea stocks (NPFMC 1983b).

Research survey data indicate that stock abundance of sablefish in the 100 to 1,000 m depth zones increased by 150% in the eastern Aleutian region and by 22% in the Gulf of Alaska from 1979 to 1980. These increases were caused by the recruitment of juvenile sablefish with a mode of 50 cm fork length (Sasaki 1981). It is hoped that, as these juvenile fish grow and reach catchable size, the allowable catch can gradually be raised from the present level (ibid.).

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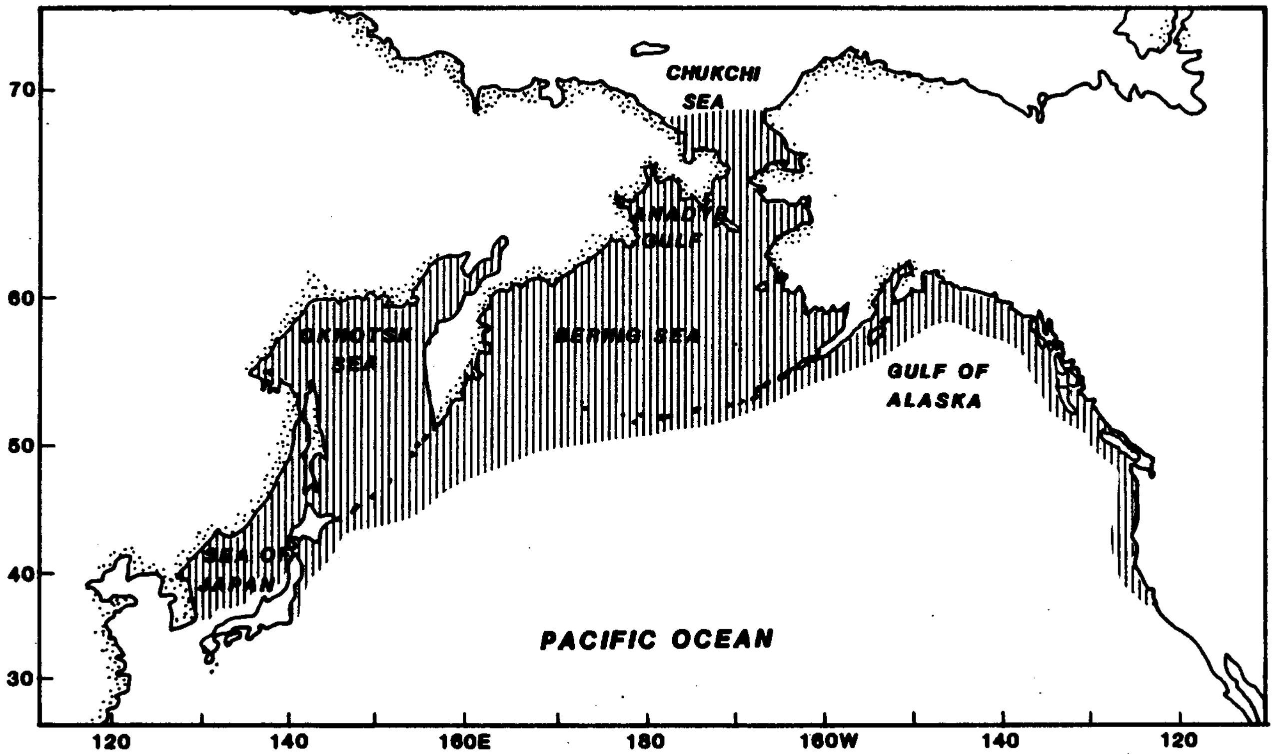
Walleye Pollock Life History



Map 32. 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
      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 NMFS survey of 1973-1976 (Ronholt et al. 1977).

III. PHYSICAL HABITAT REQUIREMENTS

Walleye pollock are found from the surface to below 366 m, although most catches are between 50 and 300 m (Rogers et al. 1980). Concentrations of adult walleye pollock in the Bering Sea are usually found in water temperatures between 2° and 4°C (Serobaba 1970). Spawning has been recorded in the Bering Sea at temperatures of 1 to 3°C (Serobaba 1968).

Temperature is, however, probably not an important habitat requirement. Pollock consistantly return to Shelikof Strait and spawn though the temperature varies from 3.5 to 6.5°C. (Blackburn, pers. comm.; NMFS 1983).

IV. NUTRITIONAL REQUIREMENTS

A. Preferred Foods

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).

In the Bering Sea juveniles (less than 35 cm) consume mainly copepods, euphausiids, and amphipods. Adults (more than 35 cm) consume mainly euphausiids, small pollock, and other fish (gadids, cottids, hexagrammids, and zoarchids) (Bailey and Dunn 1979).

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).

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 to 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). Spawning occurs at temperatures of 1 to 3°C in the Bering Sea (Serobaba 1968), and evidence indicates that some spawning may occur under the sea ice (Kanamaru et al. 1979).

There is also evidence of pollock spawning in oceanic areas, off the continental shelf. Oceanic spawning has been reported to occur in waters over 640 m south of Seward and in the Aleutian Basin (Blackburn, pers. comm.).

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 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 the potential reproduction of the population (Smith 1981, Chang 1974).

E. Fecundity

Estimates of individual female fecundity are difficult to achieve because ovaries of female pollock contain oocyte populations composed of two or three size classes. The percentage of each size class released during spawning is uncertain (Smith 1981, Foucher and Beamish 1977). Serobaba (1971) found fecundities of 37,000 to 312,000 eggs per female over fish lengths of 40 to 80 cm in the Bering Sea.

F. Frequency of Breeding

Pollock breed yearly.

G. Incubation Period

The 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 (Gorbunova 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.

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 (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 fall prey to several animals, including fur seals (Salveson and Alton 1976), seabirds (Hunt et al. 1981), and other fish. Cannibalism also is extremely important. Young pollock may constitute over 50% of the stomach contents of pollock over 50 cm in length (Takashashi 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

VIII. LEGAL STATUS

Pollock within the 200-mi limit are managed by the North Pacific Fishery Management Council within 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

There are large gaps in the available pollock life history information; however, more information is available 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 the movements of pollock stocks and the interchange among 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.).

X. DISTRIBUTION

Walleye pollock are found in the Gulf of Alaska and Bering Sea from surface waters to depths below 370 m, although most catches are between 50 and 300 m (Rogers et al. 1980). In the Gulf of Alaska, a trawl survey for pollock in 1972 found concentrations yielding 1,560 to 1,960 lb/hr at bottom depths of 60 to 130 fm off the southwestern coast of Kodiak (Alton and Nicholl 1973). Demersal trawl surveys in July and

August 1974 also revealed high pollock densities (3,138 to 5,170 lb/hr) at depths of 100 to 235 m in the area south of Unimak and Unalaska islands (NWFC 1974).

Walleye pollock spawning concentrations are found in southern Shelikof Strait in March and April (NMFS 1983; Blackburn, pers. comm.). A large concentration of pollock was also found in April 1983 by a fisherman between Kodiak and Middleton islands (Blackburn, pers. comm.).

Surveys from Unimak Pass to the east end of Kodiak Island along the shelf and associated gullies in 1983 failed to locate any spawning pollock schools of more than trace amounts (NPFMC 1983a).

After spawning, the pollock disperse all across the continental shelf.

In the Bering Sea, pollock over the continental shelf and slope 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.

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. Mathew Island. Summer concentrations are further north and more inshore in years when relatively warm water temperatures prevail than in years when the water temperature is relatively cold (Gusey 1979).

A 1978 trawl-handline survey conducted by the Japanese in the area of the Bering Sea beyond the continental shelf (waters deeper than 200 m) revealed that pollock were present in virtually all of the area surveyed, though rarely in commercial concentrations (NPFMC 1979). This population consists of fish significantly larger than those found in commercial pollock catches over the continental shelf and slope (ibid.).

XI. ABUNDANCE

A 1975 BLM/OCS survey found walleye pollock to be the most abundant groundfish species in the Bering Sea (Pereyra et al. 1976). Surveys conducted by the NMFS in 1973-1975 also found pollock to be the dominant groundfish species in the Gulf of Alaska, making up 45% of the total fish catch. This is in marked contrast to its abundance in 1961, when trawl survey data demonstrated that pollock contributed only 5% of the total fish catch in the Gulf of Alaska (Gusey 1978).

This increase in pollock abundance appears to be related to the concurrent population decline of other heavily exploited groundfish species, especially Pacific ocean perch (OCS Socioeconomic Studies Program 1980). Juvenile walleye pollock and Pacific ocean perch occupy approximately the same trophic position: pollock are apparently acting as a replacement species, filling in the position formerly occupied by Pacific ocean perch (ibid.).

Pollock are a strongly cannibalistic species; young pollock may constitute over 50% of the stomach contents of pollock over 50 cm in length.

The intensity of cannibalism tends to be greatest when the adult population is large. Thus, large adult pollock populations feed heavily on juvenile pollock, reducing the numbers of the younger age-classes. This pattern gives rise to periodic fluctuations in adult abundance, with peaks occurring at intervals of approximately 12 years (ibid.). Heavy commercial exploitation, however, tends to reduce these cycles. The fishery removes older age-groups, thus reducing cannibalism on juveniles. Increased recruitment and the eventual return of the adult biomass to preharvest levels results.

Catch data indicate that the exploitable biomass of pollock in the western and central Gulf of Alaska was higher in 1979-1981 than in 1976-1979. Maximum sustainable yield for the central Gulf of Alaska has been estimated to be 95,200 to 191,000 metric tons and for the western Gulf of Alaska 57,000 to 114,000 metric tons (NPFMC 1983b). This yield is estimated to be attainable with stocks at their present level of abundance. Optimum yield for the central gulf has been set at 183,000 metric tons (ibid.) and for the western gulf at 57,000 metric tons (the low end of MSY) (ibid.).

The large pollock stocks in the Gulf of Alaska in 1978-1980 have been attributed to the relatively large 1975 and 1976 year classes (NPFMC 1983a). Preliminary catch at age data for the 1982 fishery suggest that the 1977, 1978, and 1979 year classes are of average abundance, rather than weak, as first indicated by 1981 surveys (Stauffer 1983). Surveys conducted in 1982, however, also found few pollock smaller than 35 cm, suggesting that no strong year classes were recruiting to the 1983 spawning stock (NPFMC 1983a). This may indicate a decline in the stocks available to fishermen in 1984 (Alaska Fishermans Journal 1983).

In the Bering Sea, pollock catches peaked in 1972 (at 1.9 million metric tons) and have since declined because of fishery restrictions and declining stock abundance (NPFMC 1979). Stocks now appear to have stabliized, with catches around 1 million metric tons. Maximum sustainable yield for the Bering Sea is estimated at 1.1 to 1.6 million metric tons. Optimum yield is set at 1 million metric tons for the Bering Sea and at 100,000 metric tons for the Aleutian Islands area (NPFMC 1983c).

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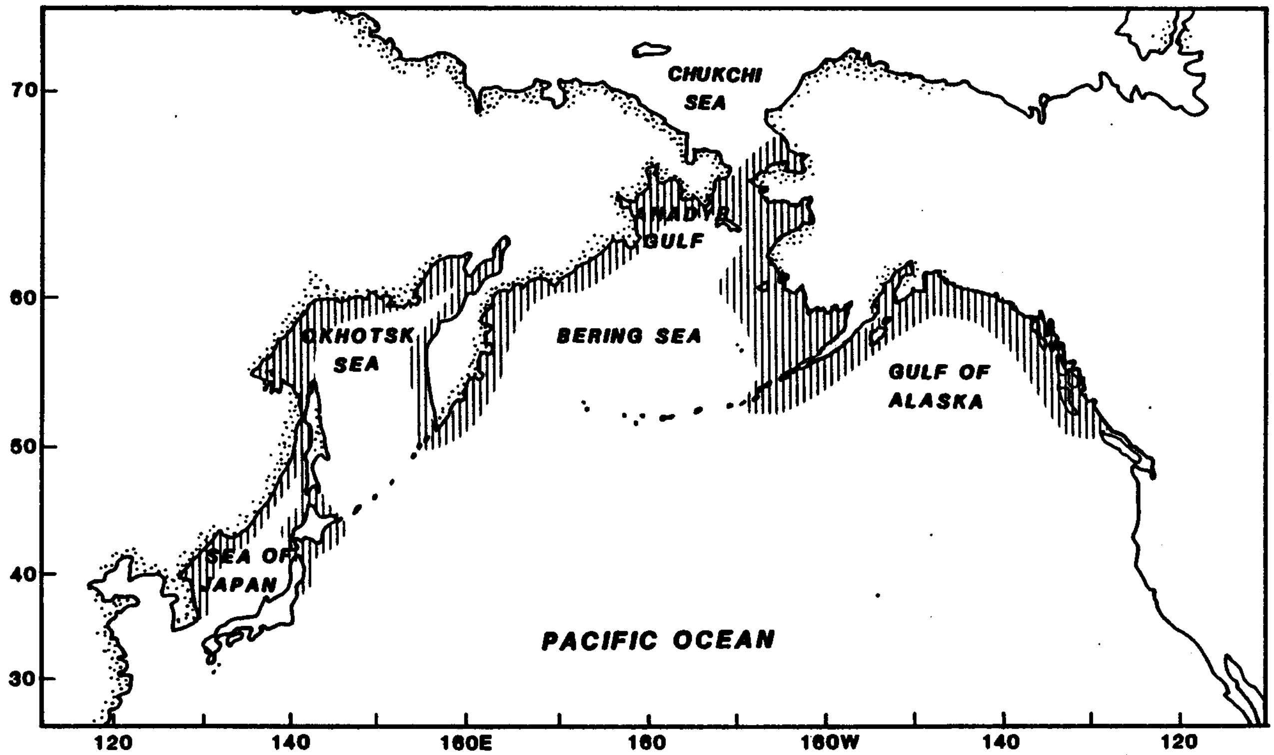
Yellowfin Sole Life History



Map 33. Range of yellowfin sole (Salverson and Alton 1976)

I. NAME
   A. Common Name: Yellowfin sole
   B. Scientific Name: Limanda aspera

II. RANGE
   A. Worldwide
      The yellowfin sole is found in continental shelf and slope waters of the North Pacific Ocean, the Bering Sea, and the Chukchi Sea. Its range along the Pacific coast of North America extends from Vancouver Island north to the Chuckchi Sea and along the Asian coast from the Gulf of Anadyr south to Hokkaido Island and along the Asian mainland to about 35° N off South Korea (Bakkala 1981).
   B. Regional
      Dense concentrations of yellowfin sole are found in the Bering Sea in the vicinity of Unimak Island and west of St. Paul Island.

Lesser winter concentrations have also been found in the area of St. George Island and in Bristol Bay (ibid).

III. PHYSICAL HABITAT REQUIREMENTS

Yellowfin sole are found at depths from 5 to 360 m, though in Gulf of Alaska, Cook Inlet, and British Columbia waters they are confined to shelf waters of generally 100 m or less (Salveson and Alton 1976.) Evidence suggests that water temperature and the extent of winter ice cover in the Bering Sea affect the rate of northern summer migrations and the summer distribution patterns of yellowfin sole (Bakkala 1981). Evidence indicates also that year-class strength of yellowfin sole in the Bering Sea is affected by variations in water temperature (ibid.). Strong year classes have been associated with years when June bottom water temperatures were relatively warm (2.0° to 4.5°C); weak year classes correspond to relatively cold June bottom temperatures (near 1.0°C) (ibid.).

Fadeev (1970) stated that yellowfin sole are found mainly in areas with sandy-muddy bottoms and predominately fine sediments. Yellowfin sole have also been found at times over sandy and silty-sand bottoms but never in large numbers on gravel or pure silt sediments (Fadeev 1970, Salveson and Alton 1976).

IV. NUTRITIONAL REQUIREMENTS

A. Preferred Foods

Skalkin (1963) found that the diet of yellowfin sole in the Bering Sea varied with both location and depth. The major food items in yellowfin sole stomachs from the southeastern Bering Sea included small amphipods, mysids and euphausiids, bivalve mollusks, and ascidians. Other frequently consumed prey were sea urchins, shrimp, and brittle stars. Yellowfin sole from the Kodiak area feed on fish and polychaetes in the spring and summer (Rogers et al. 1980). Fish consumed include smelt (Osmeridae), Pacific sand lance (*Ammodytes hexapterus*), and Pacific cod (*Gadus macrocephalus*). Rogers et al. noted that the yellowfin sole did not concentrate on any one food item but had a large variety of foods in their diet.

B. Feeding Locations

Yellowfin sole feed most intensively during the summer, when they are found in shallow (40 to 60 m) waters (Skalkin 1963, Smith et al. 1978). Sole are mainly benthic feeders; however, when benthic organisms are scarce, they are able to feed on organisms found off the bottom (Fadeev 1970).

C. Factors Limiting Availability of Food

Weather conditions and water current patterns that result in concentrations of plankton in rearing areas are probably important for the survival and growth of yellowfin sole larvae, as with other marine species (Cooney et al. 1979).

Fadeev (1965) noted the slow growth of yellowfin sole in the Bering Sea compared to Asian populations and suggested that growth in the Bering Sea is limited by food abundance.

D. Feeding Behavior

In the Bering Sea, yellowfin sole on the wintering grounds generally do not feed until late April, though cases of intense winter feeding have been reported (Fadeev 1970). Feeding intensity remains low as the fish migrate to shallow (less than 100 m) water in May (Skalkin 1963, Smith et al. 1978). In June and July, feeding is most intense, and another feeding peak occurs in September (Skalkin 1963). In fall, as the fish move back to the wintering grounds, feeding once again drops off (Smith et al. 1978).

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

In the Bering Sea, spawning is most intense south and southeast of Nunivak Island (Bakkala 1981). Spawning has also been observed between Nunivak and St. Lawrence islands (Kashkina 1965) and in Bristol Bay (Bakkala 1981, Fadeev 1965). Musienko (1970) reported that spawning in the Bering Sea occurs at depths up to 50 m in waters with a bottom salinity of 32.1 to 33.7 ^{0}/oo, a surface salinity of 30.1 to 33.1 ^{0}/oo, and temperatures of 4.41 to 11.4°C at bottom and 6.4 to 11.4°C at surface.

B. Reproductive Seasonality

In the Bering Sea, spawning begins in early July and probably ends in September (Musienko 1970). Kashkina (1965) suggested that spawning probably occurs later and is completed within a shorter time in the northern Bering Sea than in the south.

In the Kodiak Island nearshore zone, "ripe" yellowfin sole were found by Rogers et al. (1980) from May to August.

C. Reproductive Behavior

Soviet investigators have reported that yellowfin sole rise to the surface during spawning (Salveson and Alton 1976).

D. Age at Sexual Maturity

Females may begin to mature as early as age five (with a length of 19 cm), but most mature at age nine (length 30 to 32 cm) (Fadeev 1963, 1970). Males mature earlier than females. Some males may mature at age four (length 14 cm); most mature at age five (length 16 to 18 cm) (ibid.).

E. Fecundity

Fecundity is related to size, with a 32.1 to 34 cm female producing 1.5 million eggs and a 40.1 to 42 cm female producing 3.3 million eggs (Fadeev 1963).

F. Frequency of Breeding

Yellowfin sole breed annually.

G. Incubation Period

Yellowfin sole eggs are pelagic. Laboratory studies indicate that hatching occurs in about four days at 13°C (Pertseva - Ostroumova 1961). Yolk sacs are absorbed after three days (Bakkala 1981). Partially metamorphosed young have been found at lengths of 16.5 to 17.4 mm. Lengths greater than that are not found in the plankton, so it is assumed that after that size larvae have metamorphosed and begun a bottom existence (ibid.). These larvae are perhaps four to five months old (Morris 1981).

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

A. Timing of Movements and Use of Areas

Yellowfin sole in the eastern Bering Sea follow complex bathymetric and geographical movements (Salveson and Alton 1976). During the winter (September to March) adults (older than age seven) are concentrated in large schools on the outer shelf and upper slope at depths of 100 to 360 m, with highest trawl catches found at depths of 100 to 200 m (Salveson and Alton 1976, Bakkala 1981, Fadeev 1970). These fish are in two main concentrations: the largest north of Unimak Island, and another west of St. Paul Island (Bakkala 1981). In spring (May), these wintering groups move into shallower (100 m) water, generally to the northeast (Bakkala 1981, Salveson and Alton 1976). By summer, the Unimak wintering group is found in outer Bristol Bay between the 40 and 100 m depth contours (Bakkala 1981). The migration patterns of the St. Paul wintering group have not been as well defined, but fish found in the vicinity of Nunivak Island in the summer may be from this group (Bakkala 1981, Salveson and Alton 1976).

With the approach of winter, both groups move back into deep water, probably in response to the advance of pack ice that covers portions of the Bering Sea in winter (Bakkala et al. 1982). In warmer years, yellowfin sole may remain in shallow, central shelf waters throughout the winter (ibid.).

Young (less than eight years old) yellowfin sole are found year-round in Bristol Bay (Fadeev 1970).

Fadeev (1965) reported that in the winter yellowfin sole rise from the bottom at night. These movements are apparently not associated with food, as sole generally do not feed during the winter months. Fadeev (1965) also reported that these fish follow daily horizontal movements.

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

Yellowfin sole is heavily consumed by Pacific halibut (*Hippoglossus stenolepis*) (Novikov 1964). Novikov noted a close relationship between the distributions of halibut and of yellowfin sole in the summer and stated that the distribution of halibut in the Bering Sea in summer is determined largely by the movements of yellowfin sole (ibid.). Yellowfin sole may also fall prey to other fish and marine mammals such as beluga whales (*Delphinapterus leucas*) and fur seals (*Callorhinus ursinus*) (Salveson and Alton 1976).

B. Human-related

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

- ° Alteration of preferred water temperatures, pH, dissolved oxygen, and chemical composition
- ° Introduction of water-soluble substances

- Increase in suspended organic or mineral material
- Reduction in food supply
- Human harvest
- Seismic shock waves

VIII LEGAL STATUS

Yellowfin sole are managed by the North Pacific Fishery Management Council as part of their fishery management plan for groundfish (NPFMC 1979). They are also incidentally protected by the North Pacific Fishery Management Council's closures of trawl fisheries to protect halibut stocks (Salveson and Alton 1976).

IX. LIMITATIONS OF INFORMATION

Because yellowfin sole are not abundant in the Gulf of Alaska, little information can be found concerning this species in that area.

X. DISTRIBUTION

Dense concentrations of yellowfin sole are found in the Bering Sea in the vicinity of Unimak Island and west of St. Paul Island. Lesser winter concentrations have also been found in the area of St. George Island and in Bristol Bay (Bakkala 1981). In the Gulf of Alaska, yellowfin sole are generally a minor component of the flounder complex (ibid.).

Yellowfin sole in the eastern Bering Sea follow complex bathymetric and geographical movements (Salveson and Alton 1976). During the winter (September to March), adults (older than age seven) are concentrated in large schools on the outer shelf and upper slope between Unimak Island and the Pribilofs at depths of 100 to 360 m, with highest trawl catches occurring at depths of 100 to 200 m (Salveson and Alton 1976, Bakkala 1981, Fadeev 1970, Morris 1981). These fish are in two main concentrations: the largest north of Unimak Island and another west of St. Paul Island (Bakkala 1981). In spring (May), these wintering groups move into shallower water, generally to the northwest, where spawning takes place (Bakkala 1981, Salveson and Alton 1976, Morris 1981). By summer, the Unimak wintering group is found in outer Bristol Bay between the 40 and 100 m depth contours (Bakkala 1981). The migration patterns of the St. Paul wintering group have not been as well defined, but fish found in the vicinity of Nunivak Island in the summer may be from this group (Bakkala 1981, Salveson and Alton 1976). With the approach of winter, both groups move back into deep water, probably in response to the advance of pack ice that covers portions of the Bering Sea in winter (Bakkala et al. 1982). In warmer years, yellowfin sole may remain in shallow central-shelf water throughout the winter (ibid.).

Young yellowfin sole (less than 15 cm long) remain throughout the year in the inner-shelf region, including Bristol Bay. Large numbers of juvenile yellowfin sole (greater than 10 cm long) have been found during IPHC surveys along the southern shore of Bristol Bay and on the northern side of the Alaska Peninsula and Unimak Island (Morris 1981).

Evidence suggests that water temperature and the extent of winter ice cover in the Bering Sea affects the rate of northern summer migrations and the summer distribution patterns of yellowfin sole (Bakkala 1981). Fadeev (1970) stated that yellowfin sole are found mainly in areas with sandy-muddy bottoms and predominantly fine sediments. Yellowfin sole have also been found at times over sandy and silty-sand bottoms but never in large numbers on gravel or purely silt sediments (Fadeev 1970, Salveson and Alton 1976).

XI. ABUNDANCE

The virgin biomass of exploitable yellowfin sole (age six and older) in the eastern Bering Sea has been estimated to range from 1.3 to 2.0 million metric tons (Alverson et al. 1964, Wakabayashi 1975). Intensive foreign fishing began when the Soviets entered the fishery in 1958, and catches averaged about 400,000 metric tons/year from 1959 to 1962 (ADNR/USFWS 1983). By 1963, the exploitable population was reduced to approximately 40% of the maximum estimate of virgin biomass size (NPFMC 1983). The resource showed signs of recovery in the mid 1960's but declined again in 1970 (Bakkala 1981).

Since 1970, the yellowfin sole population has improved and has continued strong through 1981 (NPFMC 1983, INPFC 1982). The primary reason for this increase has been the recruitment of a series of strong year classes originating in 1966-1970 (Bakkala 1981, INPFC 1982). Current abundance is estimated to be 55 to 85% of the virgin biomass (NPFMC 1983).

Maximum sustainable yield for the Bering Sea and Aleutian Islands area is estimated as 169,000 to 260,000 metric tons. Optimum yield is set at 117,000 metric tons to maintain the stock at its current level.

Evidence indicates that variations in summer water temperatures in the Bering Sea may affect the year-class strength of yellowfin sole (Bakkala 1981). Year classes originating in the warmer years of 1966-1970 (water temperature 2.0 to 4.5 C) were relatively strong, whereas in the colder (near 1.0 C) years of 1971 and 1972, abundance of year classes was much lower (ibid.). On the basis of this relationship, it can be seen that water temperature, as well as fishing pressure, may have a controlling influence on the future strength of yellowfin sole stocks in the Bering Sea.

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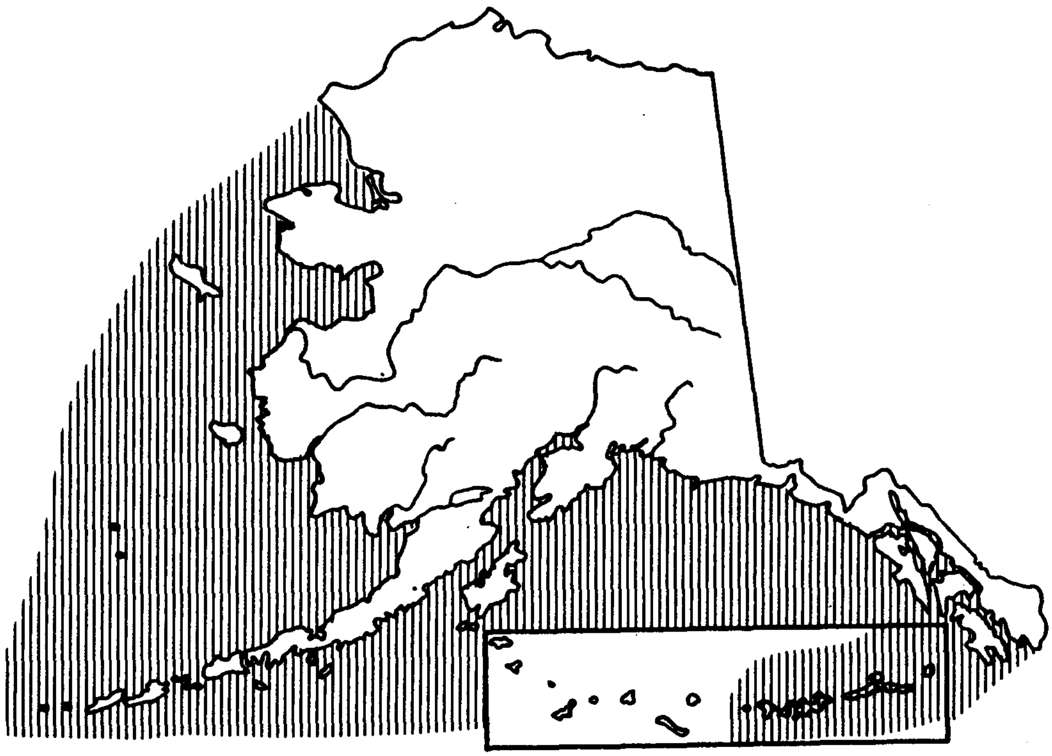
Pacific Herring Life History



Map 34. 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
      Major concentrations exist in Prince William Sound, Lower Cook Inlet, the Kodiak area, along the Alaska Pennisula and Aleutian Islands, and in Bristol Bay.

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

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.

X. DISTRIBUTION AND ABUNDANCE

Pacific herring occur throughout the Southwest Region. Herring schools move inshore to spawn during spring months, where they deposit and fertilize eggs in intertidal or subtidal areas along the Gulf of Alaska and Bering Sea coastline. They characteristically move offshore to feed after spawning, usually migrating to deeper waters during winter months. Correlation of offshore or overwintering concentrations of herring to their respective spawning populations has, in most cases, yet to be accomplished. Most existing information regarding Pacific herring has been collected for spawning populations because of the easier access to the fish during the spawning season and the emphasis of the directed fishery upon herring in spawning condition.

Currently, aerial surveys are the best technique for determining the abundance of herring populations in the Southwest Region. During the spawning season and concurrent sac roe fishery, biomass estimates are calculated from the size and frequency of herring schools recorded during aerial surveys. These biomass estimates are not absolute, as test fishing programs have shown that the density and apparent surface size of the school may be dependent upon the water depth in a particular area. Survey estimates are also affected by the presence of other pelagic fishes that may school in a similar configuration (i.e., capelin, smelt, and sand lance) and by the frequency of the surveys and the visibility variable (ADF&G 1982c).

The narratives that follow provide more detailed herring distribution and abundance information. They are organized by ADF&G commercial fisheries herring statistical areas, which are used to manage harvest. Within the Southwest Region, there are five such areas, which include Kodiak, Chignik, North Peninsula, South Peninsula-Aleutian Islands, and Bristol Bay. Boundary descriptions of the areas and a map may be found in the commercial harvest narrative in the Human Use portion of this publication. In addition, maps of the statistical areas are included in the Southwest Region Atlas.

A. Kodiak Statistical Area

1. Distribution. Herring in the Kodiak Statistical Area move inshore and spawn in at least 35 bays. Present distribution

may not be as widespread in the Kodiak area as in previous years when stocks were in greater abundance. Spawning concentrations in each of the bays appear to be independent of one another. Their relationship to overwintering populations, on which the food/bait fishery targets, has yet to be determined.

The appearance of spawning herring may not be consistent from year to year. In 1982, the largest concentrations of herring occurred in Malina Bay, Inner Alitak Bay, Upper Olga-Moser Bay, Ugak Bay, Women's Bay, and Inner Uganik Bay. Some winter concentrations have been defined through exploitation by the food/bait fishery and occur in Uyak, Terror, Viekoda, and Kupreanof straits and Alitak Bay (Malloy, pers. comm.).

2. Abundance. Herring move inshore to spawn in the Kodiak area from approximately mid April to late July. Spawning occurs earliest in the northern portion of the island, moving southerly as the season progresses. Spawning occurs in both intertidal and subtidal areas. The extent of subtidal spawning is unknown. Aquatic vegetation, such as rockweed (*Fucus* spp.) or eelgrass (*Zostera* spp.), is usually the preferred substrate for spawn deposition. Kodiak herring in spawning condition have been observed in temperatures from 36 to 37°F (ibid.). As with the run-timing of spawning populations into each bay, variations in the age composition of the return also occur. Overall, however, three, four, and five age classes comprise 90% of the harvest, which also indicates the age composition of the run (ibid.). Herring recruit into the Kodiak fishery at age three. Juvenile herring have been noted in Inner Alitak, Inner Sitkalidak, Ugak, Women's, Uganik, and Zacher bays. It is believed that rearing areas for a given population occur in the same bay in which that population has spawned (ibid.). As with most locations, the percentage of recruits increases through time during the spawning season.

Biomass estimates for the Kodiak area were first recorded in 1980. Estimates are presented for the entire statistical area rather than by bay, as collected. Biomass estimates for Kodiak have ranged from 6,339 short tons in 1981 to 7,593 short tons in 1982 (table 49). Overall, both biomass and recruitment of young herring into the fishery appear to be increasing, indicating a building trend in herring biomass for most of the Kodiak area (ibid.).

B. Chignik Statistical Area

1. Distribution. Herring spawn in small bays throughout the Chignik Statistical Area. The largest concentrations of herring occurs in Amber and Aniakchak bays (ADF&G 1982b). Warner, Kujulik, Outer Kuitka, Castle, Ivanof, Humpback, Hook, and Anchorage bays, Chignik Lagoon, and the Point Wrangell/Agripina area have also been locations in which

Table 49. Biomass Estimates of Pacific Herring by Statistical Area for the Southwest Region, 1978-82

	Kodiak		Chignik		North Peninsula		South Peninsula - Aleutian Islands				Bristol Bay	
							South Peninsula Portion		Eastern Aleutians Portion			
Year	Short Tons	Pounds	Short Tons	Pounds	Short Tons	Pounds	Short Tons	Pounds	Short Tons	Pounds	Metric Tons[a]	Pounds
1978	*		*		*		*		*		172,600	380,583,000
1979	*		*		*		*		*		216,800	478,044,000
1980	7,385	14,770,000	*		*		*		*		62,300	137,371,500
1981	6,339	12,678,000	4,116	8,232,000	*		*		*		143,900	317,299,500
1982	7,593	15,186,000	1,295	2,590,000	4,000	8,000,000	800	1,600,000	No data		88,800	195,804,000

Sources: Larry Malloy, pers. comm., for Kodiak, Chignik, South Peninsula; ADF&G 1982, for Bristol Bay.

* No estimate available.

a 1 metric ton = 1.102 short tons.

spawning concentrations of herring have occurred (ADF&G 1980, 1981b, 1982b).

2. Abundance. Known spawning activity in Chignik occurs from late April to mid June. Spawn is deposited in both subtidal and intertidal areas (Malloy, pers. comm.). The location of spawning activity varies from year to year (ADF&G 1980, 1981b, 1982b). The herring harvested have primarily been ages three through eight. Recruitment since the beginning of the commercial fishery activity in 1980 has been below average, resulting in what may appear to be a declining trend in resource abundance. Biomass estimates were first conducted in 1981. The largest areawide estimate of 4,116 short tons was recorded in 1981, declining to 1,295 short tons during the 1982 season (table 49), supporting the premise of population decline (Malloy, pers. comm.).

C. North Peninsula Statistical Area

1. Distribution. In 1976, numerous schools of herring were sighted during the spring months in the Port Moller-Herendeen Bay area. Though surveys of the area have been conducted in recent years, commercial quantities of herring had not been discovered since the 1976 sightings until 1982 (ADF&G 1982a). The possibility of the presence of overwintering concentrations has not been explored (Malloy, pers. comm.).

2. Abundance. Because of the recent development of the sac roe fishery, little information is available regarding spawning populations in the North Peninsula Statistical Area. Known spawning occurs from early May through mid June (ibid.). Age composition is similar to that of other Western Alaska stocks spawning in Bering Sea waters. Biomass estimates to date are an inadequate means of assessing herring abundance in this area. Recruitment has been relatively low since 1980 (ibid.).

D. South Peninsula-Aleutian Islands Statistical Area

1. South Peninsula portion of area:

   a. Distribution. As in other areas, the presence of herring is widespread in the South Peninsula during the spring months. Between 1980 and 1982, Stepovak, Balboa, Beaver, Coal, Pavlof, Canoe, Belkofski bays, and the Volcano Bay and Cold Bay sections have supported spawning populations of herring. During the 1982 season, however, Canoe Bay was the only area where roe herring were found in any significant concentrations (ADF&G 1982a).

   b. Abundance. Herring in spawning condition are found in the South Peninsula area from late April through late July. Spawning occurs subtidally and intertidally, primarily in areas where aquatic vegetation is present. In portions of the South Peninsula, the appearance of new recruits into the fishery is not gradual. A distinct break in time occurs between the presence of older herring and the appearance of younger recruit herring, which indicates the presence of two spawning stocks. Biomass estimates upon spawning stocks were first conducted in 1982 and were calculatied at 800 tons. During the winter fishery, fishermen encountered large quantities of herring in the Stepovak fishery (ADF&G 1981a). Though the 1982 commercial harvest of sac roe herring was less than the levels in 1980 and 1981, it appears that certain South Peninsula herring stocks are experiencing an increase in biomass levels (Malloy, pers. comm.)

2. Aleutian Islands portion of area. Knowledge of herring distribution and abundance in the Aleutian Islands is limited. Most of the data presented below pertain to the eastern end of the Aleutian Islands chain.

   a. Distribution. Spawning populations of herring have been noted in the vicinity of the eastern Aleutians, primarily in the area near Unalaska (ibid.). Main interest, however, is directed toward commercial quantities of herring in the postspawning and nonspawning condition that move into the eastern Aleutians area to feed during summer months. Known areas of concentration are the straits and passes of the Four Islands group and especially the area from Unalaska and Makushin bays to Chelan Bank.

   b. Abundance. Spawning populations of herring in the eastern Aleutians area are small. Spawning activity occurs from late April through mid July. Biomass and age composition data are not available. Interest, particularly during the 1981 and 1982 seasons, was directed toward herring in the nonspawning and, usually, feeding condition. These fish migrate into the area from mid July to late September. Abundance appears to decline by the end of September (ADF&G 1982a). In 1981, older fish were more abundant earlier in the season, and younger fish were more dominant in catches from mid August until mid September. In 1982, this separation by age was not so distinct. Herring appear to recruit into the fishery at age four. In 1982, for eastern Bering Sea spawners, the dominant age classes were five and eight-year-old fish. Length-at-age comparisons indicate that summer feeding stocks may belong to the larger Bering Sea race of herring, whose spawning range extends westward at least to Unalaska Island. Scale-pattern analysis has indicated that a large percentage of these fish are actually Bristol Bay spawning stocks feeding and eventually migrating to overwintering areas (Walker and Schnepf 1982, Rogers et al. 1983, ADF&G 1982c).

      Biomass estimates within the harvest area are not available. Recent development of the fishery and the influence of weather and adverse environmental conditions in the area have made trends in stock abundance difficult to assess at this time (Malloy, pers. comm.).

E. Bristol Bay Statistical Area

1. Distribution. Pacific herring move into Bristol Bay to spawn along the coastline in numerous rocky bays from the Nushagak Peninsula to Cape Newenham (Skrade, pers. comm.). Though herring spawn on both rocky headlands and bays, major bays where spawning has occurred are Kulukak, Metervik, Eagle, Nunavachak, Ungalithluk, and Togiak. Herring spawn has also been documented on Hagemeister and Summit islands and Asigyukpak Spit.

2. Abundance. Herring move into Bristol Bay from the Bering Sea when the spawning grounds become ice-free, usually beginning in late April and extending through mid May (Barton 1978). Spawning activity has been noted as late as July 4 (Skrade, pers. comm.). Spawning may last from a few days to several weeks. Generally, older herring are the first to spawn, followed by successively younger fish. Adhesive eggs are deposited on vegetation in intertidal and subtidal waters, predominantly on rockweed (*Fucus* spp.), eelgrass (*Zostera* spp.), and ribbon kelp (*Laminaria* spp.) (Barton 1979). The distribution and extent of subtidal spawning is unknown. Little is known about juvenile herring in the Bering Sea, though it is believed that they feed in coastal waters in the summer and move to deeper water in the winter. Herring begin to appear in the fishery at age three, though recruitment is most notable at age four. Age composition of the harvest has shown variation between years. In most years, however, age four, five, and six herring dominated the run (Fried et al. 1982a, 1982b, 1983a, 1983b).

During 1982, about 56% of the biomass was comprised of age five herring, with age four and age eight year classes accounting for the remainder (ADF&G 1982d). Abundance estimates for the Bristol Bay herring area are obtained by aerial surveys conducted during the sac roe fishery. Comparative estimates are available since 1978. Biomass estimates have fluctuated between years and ranged between 62,300 metric tons in 1980 to a peak of 216,800 metric tons during the 1979 season. About 88,000 metric tons were accounted for in 1982 (table 49) (ibid.).

Herring in the Bering Sea spawn in a number of locations along the Alaskan coast from the Chukchi Sea to the Aleutian Islands. The Togiak District of Bristol Bay supports the largest spawning population along the eastern Bering Sea coast (Barton and Steinhopff 1980). Growth studies indicate that herring spawning in areas north of Bristol Bay are consistently smaller than Bristol Bay spawners (Barton and Steinhopff 1980; Rowell 1980; McBride et al. 1981; Fried et al. 1982a, 1982b, 1983a, 1983b). The relationship of spawning stocks to one another, however, has yet to be defined. Currently, it appears that Bristol Bay herring spawn in the Togiak District, then migrate south along the Alaska Peninsula enroute to overwintering areas off the continental shelf northwest of the Pribilof Islands. Growth and age composition analyses indicate that the harvest of nonspawning herring in the Unalaska-eastern Aleutians area during August and September is largely comprised of herring from the Bristol Bay spawning population (Walker and Schnepf 1982, Rogers et al. 1983).

Bristol Bay supports one of three spawn-on-kelp fisheries in the state. The harvest occurs in the intertidal area and is primarily comprised of the brown algae rockweed (*Fucus* spp). Biomass or standing crop estimates have been performed during the 1977, 1978, and 1979 seasons. Findings by the University of Alaska indicate that two to three growing seasons may be required in areas not severely cleared for regrowth of the beds to harvestable levels (Stekoll 1983). The guideline harvest base for the spawn-on-kelp harvest is 350,000 lb. This level is equivalent to production from about 1,353 tons of herring (ADF&G 1984).

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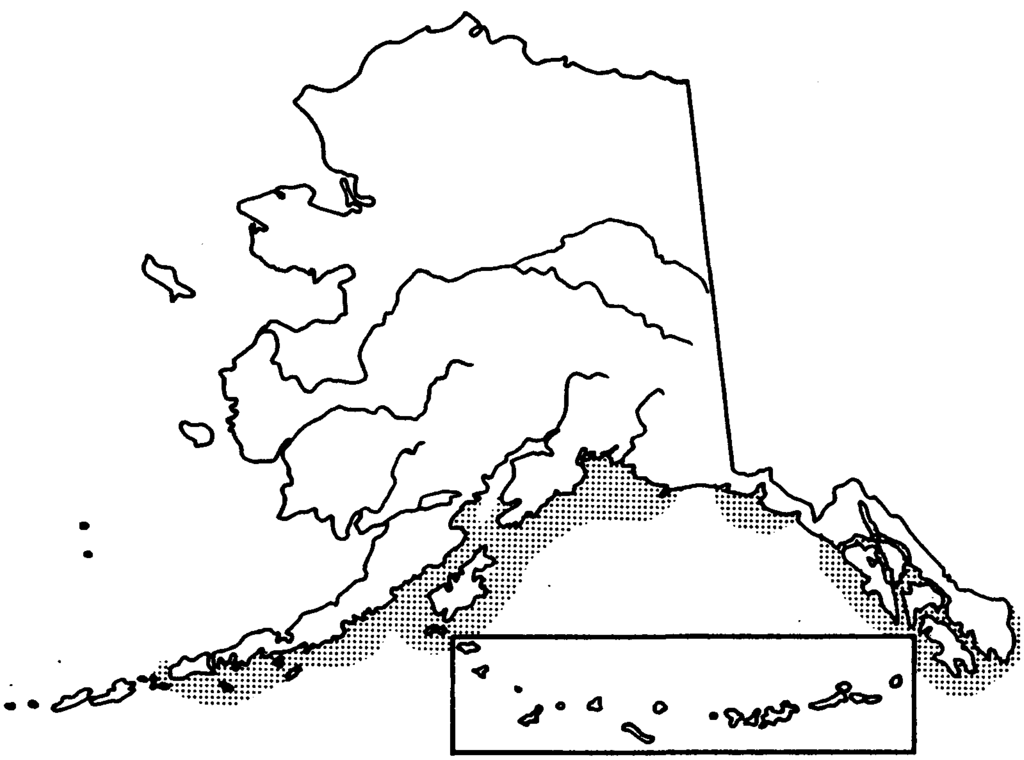
Dungeness Crab Life History



Map 35. 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

Concentrations occur in the Southeast Alaska, Prince William Sound, Lower Cook Inlet, Kodiak, and South Peninsula areas.

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).

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 crab (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 full-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)

VIII. LEGAL STATUS

The Dungeness crab is managed by the Alaska Department of Fish and Game.

IX. DISTRIBUTION AND ABUNDANCE

A. Summary

Dungeness crab distribution and abundance information for the Southwest Region is presented in the following narrative. A regional summary is provided in section A below. Sections B and C provide more detailed information and are organized by ADF&G, Commercial Fisheries Division, Dungeness crab districts. There are four such districts in the division's Statistical Area J (the Westward Registration Area), an area where marine waters are included within the Southwest Region. The districts include Kodiak, Aleutian, Alaska Peninsula, and North Peninsula. Since no Dungeness crabs are yet harvested in the North Peninsula District, no abundance data are available.

Distribution of the Dungeness crab is widespread, particularly in subtidal areas. Dungeness crabs inhabit bays, estuaries, and open ocean near the coast from the intertidal zone to depths of 300 ft.

Stock assessment or biomass estimates independent of the commercial harvest rates are not available. Harvest levels of Dungeness crab are related more to market conditions than to abundance and therefore may not be a good indicator of abundance. Dungeness crabs inhabit shallow water most of the year. Adult crabs migrate nearshore in the early spring and summer to reproduce (ADF&G 1978). Both sexes of Dungeness crab mature in about three years. Male Dungeness crabs with a CW greater than 140 mm are mature, whereas females reach maturity at 100 mm carapace width. Regionwide, recruitment of male crabs into the fishery is controlled by regulation. The size limit is 165 mm (6.5 inches).

B. Kodiak District

1. <u>Distribution</u>. The Dungeness crab inhabit all bottom areas shallower than 300 ft, with a distinct preference for sand or mixed substrate (ADF&G 1978). Exploratory drags by the NMFS have indicated a scattered distribution of this species in the western Gulf of Alaska. Best catches in the Kodiak area occurred during summer months. Greatest quantities of crab have been found during summer months between 1 and 20 m. During the remainder of the year, the largest catches taken have been between depths of 20 and 50 m (Nippes, pers. comm.).
2. <u>Abundance</u>. Assessment of Dungeness crab stocks is not conducted independently of the commercial fishery. Though the fishery is heavily dependent upon recruitment, no assessment of recruitment into the fishery is conducted, and therefore no realistic figures exist on harvestable stock size (ADF&G 1983). The timing of migration and reproduction and age at maturity are similar to the conditions stated in the introductory summary.

C. Alaska Peninsula and Aleutian Districts

1. Distribution. Small numbers of Dungeness crab occur in waters north and south of the Alaska Peninsula and Unalaska Island, generally in depths less than 350 ft (Hilsinger, pers. comm.). Trawl surveys by the NMFS have found concentrations of Dungeness crab in Beaver Bay and along the southern coast of Unimak Island (Nippes, pers. comm.). Within the area, Pavlof and Belkofski bays contain the biggest stocks (Hilsinger 1984). Shallow habitats suitable for Dungeness crab are minimal in the Aleutian area. Concentrations as currently indicated by commercial fishing activity occur in Makushin and Unalaska bays and in the Rootek Island area (ADF&G 1983).
2. Abundance. Stock assessment surveys are not conducted in the Alaska Peninsula-Aleutian Islands area. Reproductive timing, age at maturity, and migration patterns are believed similar to the conditions cited in the introductory summary.

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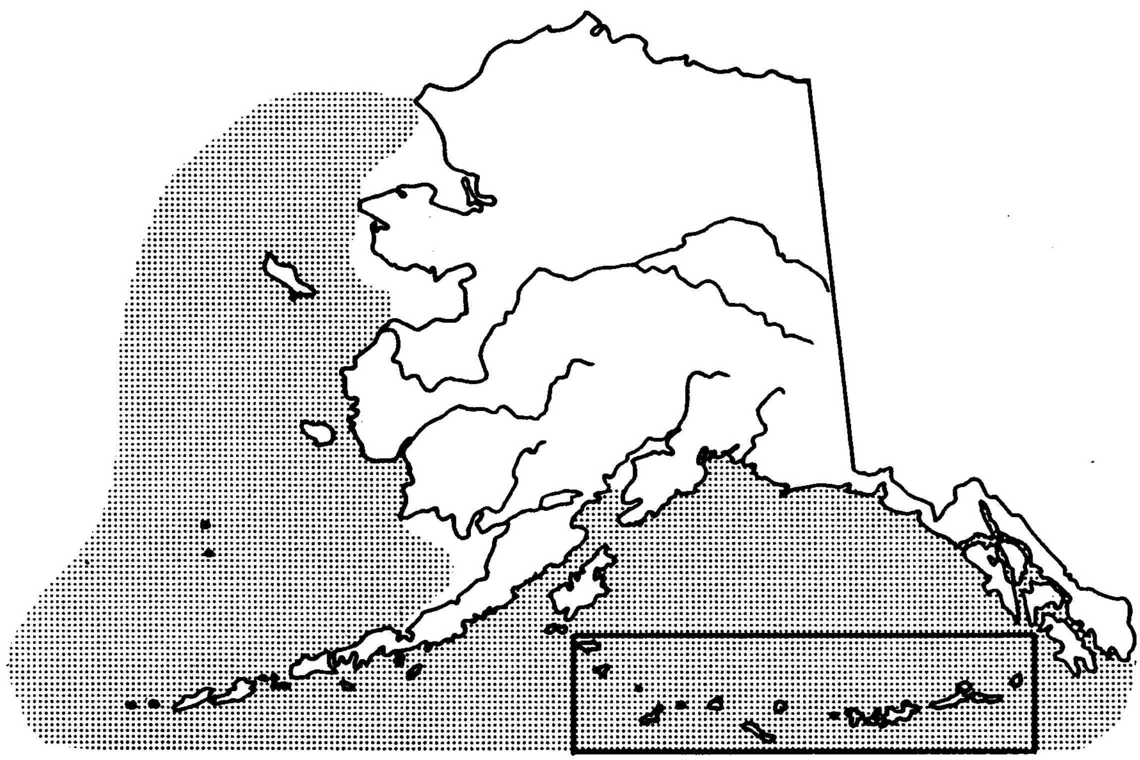
King Crab Life History



Map 36. 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. DISTRIBUTION

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 crab is found from the Sea of Japan northward into the Sea of Okhotsk and along the shores of the Kamchatka Peninsula. The northern limit on the Asian coast is Cape Olyutorsky. On the west coast of North America, distribution extends northward from Vancouver Island, British Columbia, to 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

Major concentrations of red king crab are located in lower Cook Inlet, Prince William Sound, 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, Bering Sea, Prince William Sound, and Southeast Alaska areas.

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 crab, 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 (Eldridge 1972). 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 (1965) 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 be 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 crab 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. 1982). 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 food supply and age of the individual female since males very rarely mate with females larger than themselves (Hilsinger 1983).

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 (Reynolds and Powell 1965).

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 migration 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 1965). 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 feeding migration offshore occurs in the fall (Marukawa 1933). 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 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)
   - Rhizocephalens: infects P. platypus, P. camtschatica, and L. aquispina

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)

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).

X. DISTRIBUTION AND ABUNDANCE

King crab distribution and abundance information for the Southwest Region is presented in the following narrative. A regional summary is provided in sections A and B. Sections C to H provide more detailed information and are organized by ADF&G, Division of Commercial Fisheries, king crab statistical areas. Within the Southwest Region are six such areas: Kodiak, Alaska Peninsula, Dutch Harbor, Adak, Bristol Bay, and the Pribilof District of the Bering Sea Area. The boundaries of these areas are described in the king crab commercial harvest narrative found in the Human Use portion of this publication. In addition, a map of these areas is included in the Atlas to the Southwest Region.

A. Distribution: Regional Summary

The red king crab (Paralithodes camtshatica) is found throughout the Southwest Region. Red king crabs occur at depths of 2,400 ft, although the commercial fishery is largely confined to depths of less than 600 ft (ADF&G 1978). The blue king crab (Paralithodes platypus) occurs in few discrete concentrations in the Bering Sea, along the Alaska Peninsula, and in the Kodiak area. The brown king crab (Lithodes aequispina) occupies areas throughout the Southwest Region where water depth exceeds 100-200 fathoms (NPFMC 1980; Otto, pers. comm.).

B. Abundance: Regional Summary

Red king crab populations in the Southwest Region are surveyed to obtain indices of population size and biological information that will allow the department to achieve its management goals and objectives. Determining population size and migrational patterns of king crab populations is necessary in order to designate the number of crab that may be commercially harvested and to determine in what areas the harvest may occur. Collecting biological data such as the age and condition of egg-bearing females is important to determining the reproductive potential of the population and the ideal or relative abundance of crabs that may be available to the fishery two to three years in advance.

Using pots in the Kodiak, Dutch Harbor, and Alaska Peninsula areas, the ADF&G conducts stock assessment surveys to obtain data on population size, age, migrational patterns, and the condition of egg-bearing females. Mark-recapture estimates are also used to determine population size. Estimates are dependent upon the number of tags recovered in the commercial fishery. The accuracy of these estimates is conditional upon natural tag loss and the cooperation of both fishermen and processors in retaining tags. It is possible that at low abundance levels current surveys are not sufficiently intensive to attain accurate population size information (Hilsinger 1983).

Knowing the age at which these populations reach maturity is also important in order to prevent the harvest of immature crabs and to establish a size or age at which crabs may be harvested, so that at least one season of reproductive capacity is assured prior to the crab's removal from the population. Aging crabs, however, is difficult. Gauging age by size is speculative because although molting results in an increased size within one season, crabs tend to skip the molt as they become older. If skip-molting is a function of age, older crabs may be the same size as younger crabs. Nevertheless, gauging age by size is the best method currently available. Therefore, age is estimated in terms of size, and crabs are designated as recruit or prerecruit in order to indicate the time required for the crabs to attain legal size for recruitment into the fishery and therefore to permit accurate selection of a certain age for harvest.

Red king crabs segregate by sex at maturity. Although the timing is different in each area, migration inshore to spawning areas occurs during spring months, with the return to deeper water occurring during summer months (Kessler, Powell, pers. comm.). Most life history and migration data collected to date concern the red king crab. Little is known about the development and migration of the blue and brown king crabs.

Because the fishing periods and annual surveys occur at other times than during the reproductive season, data regarding the early life history, mortality, and reproduction of the red king crab are minimal. Forecasts of harvest levels of king crabs can therefore be only speculative because it is not presently possible to age crabs accurately or to determine the causes of mortality.

Red king crab populations have declined throughout the Southwest Region. Although theories have been proposed that attribute the decrease in abundance to predation by groundfish or to mortality from warmer-than-average water temperatures or disease, insufficient data exist to permit a positive identification of the cause of the decrease in crab populations throughout the region at this time.

C. Kodiak Statistical Area

1. Distribution. The red king crab occurs throughout the entire Kodiak area to a depth of 1,200 ft. Crab distribution is not uniform throughout the area, as crabs congregate in schools. Distribution also differs between months because king crabs migrate for breeding purposes (ADF&G 1978).

   Limited numbers of brown king crabs are distributed throughout the deeper waters of Kodiak (ibid.). Blue king crabs regularly occur only in Olga Bay (Powell, pers. comm.).

   Spawning and rearing areas are extensive and continuous throughout Kodiak waters. Though inshore and nearshore areas are most critical for king crab spawning, offshore regions such as Portlock Bank, Marmot Flats, Alitak Flats, and the Albatross Banks are important. The shallow region surrounding Chirikof Island north to the Trinity Islands is significant for both the spawning and rearing of red king crabs (ADF&G 1978).

2. Abundance. Biological and population information in the Kodiak area is obtained for king crabs from annual pot surveys.

   Male red king crabs in the Gulf of Alaska mature sexually at five to seven years and at a carapace length smaller than 86 mm (Gray and Powell 1966). Females mature at about 100 mm. Carapace length is the measurement used in growth studies. The equation used to relate carapace length to the carapace width measurement (between the outside spines), which corresponds to the measurement used for legal size, is CW = 1.198L + 4.285 where 'L' = carapace length. The corresponding carapace widths (CW) at maturity for male and female king crabs are 107 mm (4.2 inches) and 124 mm (4.9 inches), respectively (Blau, pers. comm.). Legal size is 178 mm (6 inches) and 191 mm (7.5 inches) CW. Upon maturity, adult crabs segregate by sex. Female crabs begin moving toward the spawning grounds in November (Powell, pers. comm.). Young females and older males reach the spawning grounds first and begin breeding as early as mid March.

   Through tagging studies, distinct stocks have been delineated in the Kodiak area. Mixing between stocks is minimal, and segregation of populations is usually due to geographical factors (Powell, pers. comm.). Major producing stocks occur in the Northeast, Southeast, and Southwest districts (ADF&G 1983c). Since 1960, the Southeast District has produced the greatest percentage of the harvest. During the 1981-1982 season, production in the Southeast and Northeast Districts increased, whereas the contribution to the harvest of all other stocks decreased. Though the total catch for the Kodiak District increased during the 1981-1982 season, population surveys showed a decrease in the number of crabs per pot, dropping from 27.7 crabs per pot in 1981 to 4.2 crabs per pot in 1982. In addition, the number of prerecruit crabs (sublegal size crabs that will obtain legal size after one molt) diminished from 10.3 crabs per pot in 1979 to 4.2 crabs per pot in 1982. Numbers of recruit crabs dropped from 6.0 crabs per pot in 1981 to 0.8 crabs per pot in 1982. Estimates of recruitment to the legal-size male red king crab population dropped from 53.8 million pounds in 1979 to 12.0 million pounds in 1982 (table 50). The reduced clutch size of females and the increased ratio of female to male crabs in the fishery also supported evidence for a definite decline in population size (ADF&G 1983).

Table 50. Abundance Estimate in Millions of Pounds of Legal Male Red King Crabs in the Kodiak Area, 1974-82

Year	Millions of Pounds
1974	37.8
1975	26.0
1976	17.7
1977	13.6
1978	23.5
1979	53.8
1980	39.1
1981	26.0
1982	12.0

Source: NPFMC 1980: 1974-80. ADF&G 1981, 1982: 1981-82.

D. Alaska Peninsula Statistical Area

1. Distribution. The red king crab is widely distributed south of the Alaska Peninsula. Major producing areas are Davidson Bank, Pavlof Bay, Stepovak Bay, Unga Strait, Volcano Bay, the Ikutan-Morzhovai area, Chignik Area, and Sanak Island (ADF&G 1983).

   Distribution of the blue king crab south of the Alaska Peninsula is typically in bays, freouently in association with glaciers (Otto 1981).

2. Abundance. Biological and abundance information for king crabs in the South Peninsula area is obtained from pot surveys and commercial catch sampling. As in other areas, king crabs move inshore during spring months to spawn. Reproductive timing and age at maturity are similar to those of Kodiak king crabs (Hilsinger, pers. comm.).

   Total abundance of prerecruit and recruit king crabs peaked in 1980, with an estimated population size of 2.3 million crabs. Prerecruit abundance began a declining trend in 1978, and the abundance of male crabs has decreased since 1981 (table 51).

   The explanations for the trend toward decreasing abundance are uncertain. To date, the decrease has been attributed to a combination of increased fishing effort and a population fluctuation caused by environmental conditions (Hilsinger 1983).

Table 51. Annual Abundance Estimate in Thousands of Crabs of Legal Sized Male Red King Crabs from the Alaska Peninsula Area, 1976-82

Year	Population Estimate
1976	275.0
1977	680.0
1978	1,363.0
1979	2,045.0
1980	2,272.0
1981	1,360.0
1982	475.0

Source: Hilsinger, pers. comm.

E. Dutch Harbor Statistical Area

1. Distribution. The red king crab has primarily been caught in bays and flats throughout the Dutch Harbor area that are 100 fathoms or less in depth (ADF&G 1983). The brown king crab inhabits deeper waters of large passes where strong tidal currents occur (ibid.).

2. Abundance. Population estimates are not available for the red king crab in the Dutch Harbor area. Performance in the commercial fishery shows a sharp decline in harvest during the 1981-1982 season. Catch per pot and number of prerecruit crabs caught in the commercial fishery have decreased steadily each year since the 1979-1980 season. This information and the large percentage of barren females present on the grounds indicate that the Dutch Harbor king crab stocks are at historically depressed levels (Griffin 1983).

   No stock assessment surveys have been performed for the brown king crab. The nature of the more challenging habitat may require development of new stock-assessment techniques. Harvest by the commercial fleet, however, indicates that brown king crabs in the area are fairly abundant. Because increased harvest rates may be the result of fishermen gaining efficiency at exploiting a new resource, any reliance upon catch data to determine stock conditions at this time may be premature (ADF&G 1983).

F. Adak Statistical Area

Stock assessment surveys have not been conducted in the Adak area since 1977. As with other Southwest Regional fisheries, the Adak fishing area is extensive. King crabs are exploited throughout the area, making implementation of index and tagging programs difficult. The Adak king crab stocks decreased precipitously during the mid 1970's. Catch levels have since increased slightly as a result of increased effort in the fishery and the exploitation of king crab populations previously not fished. Overall, Adak red king crab stocks, though depressed, appear to be in relatively stable condition (ADF&G 1983, Griffin 1983).

Distribution, abundance, and composition of brown king crab populations in the Adak area is virtually unknown. Most of the harvest is currently taken from the North America and Petrel Bank districts. However, harvestable populations may yet be discovered in other districts and areas further west (ADF&G 1983).

G. Bering Sea and Bristol Bay Statistical Areas

In 1980, the Southeastern District of the Bering Sea Statistical Area became the Bristol Bay Statistical Area. Because the majority of the distribution and abundance information for king crab in the southeast Bering Sea relates to both of the statistical areas, the two areas will be combined for discussion in this section.

1. Distribution. The red king crab occurs north of the Alaska Peninsula and throughout the eastern Bering Sea, primarily in an area extending up to 100 mi offshore between Unimak Pass and

Port Heiden (ADF&G 1978). Distribution of the red king crab is primarily associated with the continental land mass (Otto 1981). The blue king crab is primarily found surrounding the Pribilof Islands (ADF&G 1978). Distribution of the blue king crab in the Bering Sea tends to be associated with offshore areas near islands. The brown king crab is found in the eastern Bering Sea along the continental shelf break in deeper waters. Trawl surveys have not encountered this species in waters shallower than 128 m (Otto 1981).

The annual behavior of sexually mature red king crabs is dominated by two migrations: a molting and mating/spawning migration has been documented in the Bering Sea in the spring and a feeding migration in the summer and fall months (Marukawa 1933). Known spawning areas in the Bering Sea are near Amak Island, Black Hills, and Port Moller. Distribution of the red king crab is widespread, and it is possible that suitable spawning habitat is available in other areas of the eastern Bering Sea (Stahl, pers. comm.). The timing of the spring migration has yet to be confirmed. It is believed that migration to spawning areas occurs in late winter and that mating takes place from February through June (Kessler, pers. comm.). After the spawning season, crabs return to deeper water to feed (Bartlett 1976).

2. Abundance. Because most biological and population information available has been collected for the red king crab, this discussion emphasizes the red king crab, with limited blue king crab information included as available (tables 52 and 53).

Male red king crabs in the Bering Sea recruit into the fishery at about 135 mm (5.3 inches) in CW. Prerecruit crabs (crabs that will be available to the fishery the following year) range from 120 to 134 mm CW.

Population estimates have been obtained for the red king crab from trawl surveys in the Bering Sea since 1969. The population of legal-size crabs reached a low in 1970 and increased through 1978, when the total population of male prerecruit and legal king crabs reached 77.5 million (Otto 1981). The combined abundance of recruit and prerecruit crabs declined steadily since reaching a total of 13.2 million crabs in 1982 (Otto et al. 1982). The abundance of prerecruit crabs declined each year since 1978, stabilizing from 1981 through 1982 (ibid.).

Surveys of blue king crabs in the Pribilof area since 1974 indicate that the abundance of male legal-size blue king crabs peaked in 1975 at 12.7 million crabs. Legal-size crab abundance levels remained stable from 1978 to 1981 and declined about 50% in 1982 (ibid.).

The abundance of brown king crabs in the Bering Sea is unknown. Research by the NMFS and catch sampling by the ADF&G are being directed toward the species (Griffin 1983). Interest is

Table 52. Annual Abundance Estimate in Millions of Crabs for Red King Crabs Larger than 120 mm CW for the Pribilof and Bristol Bay Districts, 1972-82

Year	Population Estimate
1972	10.1
1973	25.0
1974	40.9
1975	39.6
1976	63.4
1977	72.9
1978	47.5
1979	71.3
1980	51.4
1981	20.2
1982	13.2

Source: Otto et al. 1982.

Table 53. Annual Abundance Estimate for Legal Male Blue King Crabs in Millions of Crabs in the Pribilof District of the Bering Sea, 1974-82

Year	Population Estimate
1974	3.5
1975	12.7
1976	5.0
1977	10.5
1978	7.6
1979	5.9
1980	5.2
1981	5.0
1982	2.5

Source: Otto et al. 1982

expected to shift to the brown king crab with the decline in red king crab populations.

Distribution and areas of concentration for both red and blue king crabs have appeared to change with decreasing population size (Otto et al. 1982). The cause of the decline of king crab populations in these areas, as in other Southwest areas, is not understood.

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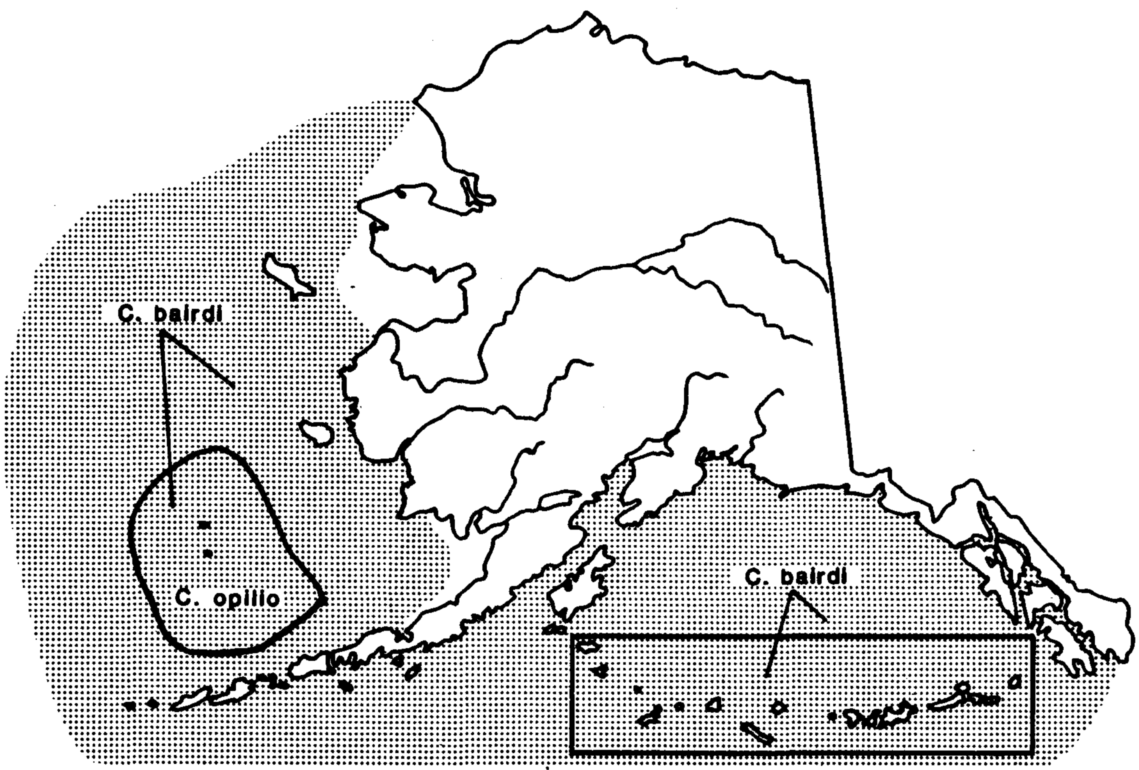
Tanner Crab Life History



Map 37. Range of Tanner crab (ADF&G 1978; Kessler, pers. comm.; Otto, pers. comm)

I. NAME
   A. Common Names: Tanner crab, snow crab, queen crab, spider crab
   B. Scientific Names: Chionoecetes bairdi, C. opilio, C. angulatus, C. tanneri

II. EXTENT TO WHICH SPECIES REPRESENTS GROUP

Chionoecetes bairdi and Chionoecetes opilio are the only species commercially harvested in the North Pacific (NPFMC 1981). A hybrid of C. bairdi and C. opilio occurs in the eastern Bering Sea. C. tanneri and C. angulatus, 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. Regionwide

Concentrations of *C. bairdi* occur in Prince William Sound, lower Cook Inlet, Kodiak Island, Bristol Bay, and the South Peninsula/Aleutian Islands. *C. opilio* occurs in the eastern Bering Sea, with greatest concentrations north of 58° north latitude.

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* reach 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 1982).

C. Substrate

Preferred substrate of *C. bairdi* has been described as green and black mud, fine gray and black sand, and shell (Garth 1958). Post-larval 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

1. Larvae feed in the water column.
2. 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.). 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 crab 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 juvenile 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 1.5×10^{10} crab are eaten annually by the Kodiak cod population of 6.9×10^{7} fish (Jewett 1982). Tanner crabs have comprised a large percentage of diets for four species of sculpins (cottidae). In the Gulf of Alaska and Kodiak Island area, yellow Irish lords (Hemilepidotus jordani) and the great sculpin (Myoxocephalus polyacanthocephalus) preyed significantly upon Tanner crabs. The great sculpin seems to prefer mature female crabs (Hilsinger 1984). 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 1984).

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)

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.

XI. DISTRIBUTION AND ABUNDANCE

Tanner crab distribution and abundance information for the Southwest Region is presented in the following narrative. A regional summary is provided in section A below. Sections B to G summarize the region's fisheries by ADF&G, Commercial Fisheries Division, Tanner crab districts. There are six districts for Tanner crab management in Statistical Area J (the Westward Registration Area). They include the Kodiak, Chignik, South Peninsula, Eastern Aleutians, Bering Sea, and Western Aleutians districts. Boundaries of these areas are described in the Dungeness crab Human Use portion of this publication. In addition, a map of the areas is included in the Southwest Region Atlas.

A. Regional Summary

The Tanner crab occurs throughout the Southwest Region. C. bairdi is distributed throughout the Southwest Region and is the principal commercial species in the Bering Sea and Gulf of Alaska. C. opilio is the smaller of the two species, occurring only in the Bering Sea from the littoral zone to depths of 155 m. Greatest concentrations of C. opilio are north of latitude 58°N (ADF&G 1978).

Males appear to migrate to relatively stationary schools of females during the reproductive period. Segregation of schools by sex in some areas does not occur. Timing of the reproductive cycle differs by geographical area, usually beginning in January and extended into early June.

Biological data and information regarding the condition of the population is obtained from population surveys, the fishery's performance, and samplings of the commercial catch. Tanner crab populations in the Southwest Region are surveyed 1) to define and monitor the distribution and relative abundance of Tanner crabs with respect to size and sex, 2) to study other aspects of Tanner crab biology that could affect management strategy, and 3) to study the reproductive biology of the Tanner crab. The ADF&G conducts population surveys using either pots or trawls in the Kodiak, Chignik, and South Peninsula areas. Bering Sea stock assessment is performed with trawls by the NMFS. Population estimates may be derived from trawl surveys, whereas pot surveys provide only an annual comparative index of the number per pot of prerecruit crabs (crabs that will be available to the fishery in subsequent years) and recruit crabs (crabs that have reached fishable size and will enter the fishery that year). Information regarding the crab's life history is obtained during the commercial fishery and during annual stock assessment surveys. Determining the size and migrational patterns of Tanner crab populations is necessary in order to determine the percentage of the population that may be removed for commercial harvest and to decide in what areas the commercial harvest may occur.

Currently, the age-class structure of a population is based on carapace width and is defined in terms of the number of years required for the crab to reach maturity and legal, or fishable, size. A reliable technique for aging crabs has yet to be developed. Size-at-age figures therefore are speculative. Determining how many years it would take a size class to recruit into the fishery and therefore forecasting population levels is further complicated by the tendency of Tanner crabs to skip molt, which would result in no exhibition of growth for a given year. Molt-skipping thus causes difficulty in determining at what age crabs have recruited into the fishery. Common to Tanner crab stocks for all districts is the paucity of information regarding early life history, migrational patterns, aging, reproductive behavior, and causes of mortality (Colgate, pers. comm.).

Considerations in using pots as a sampling tool for the Tanner crab are that 1) success in catching crabs is variable and dependent on the crab's size, the degree of attraction to the bait, and their ability to escape from a pot they have entered; 2) determination of the fishing power of the pot(s) or the fraction of the population captured per unit of time and area has produced variable results; and 3) Tanner crabs one or more years from entering the fishery do not appear to be captured by successive surveys in a manner reflecting their subsequent predicted abundance as recruits.

Trawl surveys using the area-swept technique are made at preselected stations. The intensity of sampling is determined by the amount of data required, the size of the area to be surveyed, and the time available to complete surveys in a given area. Estimated stock size is obtained by comparing the stratified number of crabs per unit area and multiplying by the area of crab habitat within the survey area (Colgate and Hicks 1983, Otto 1981). The effectiveness of trawl surveys is determined by the degree to which the habitat is trawlable and the crabs catchable. The population estimates are reported as numbers of crabs for the area (Colgate and Hicks 1983).

B. Kodiak District

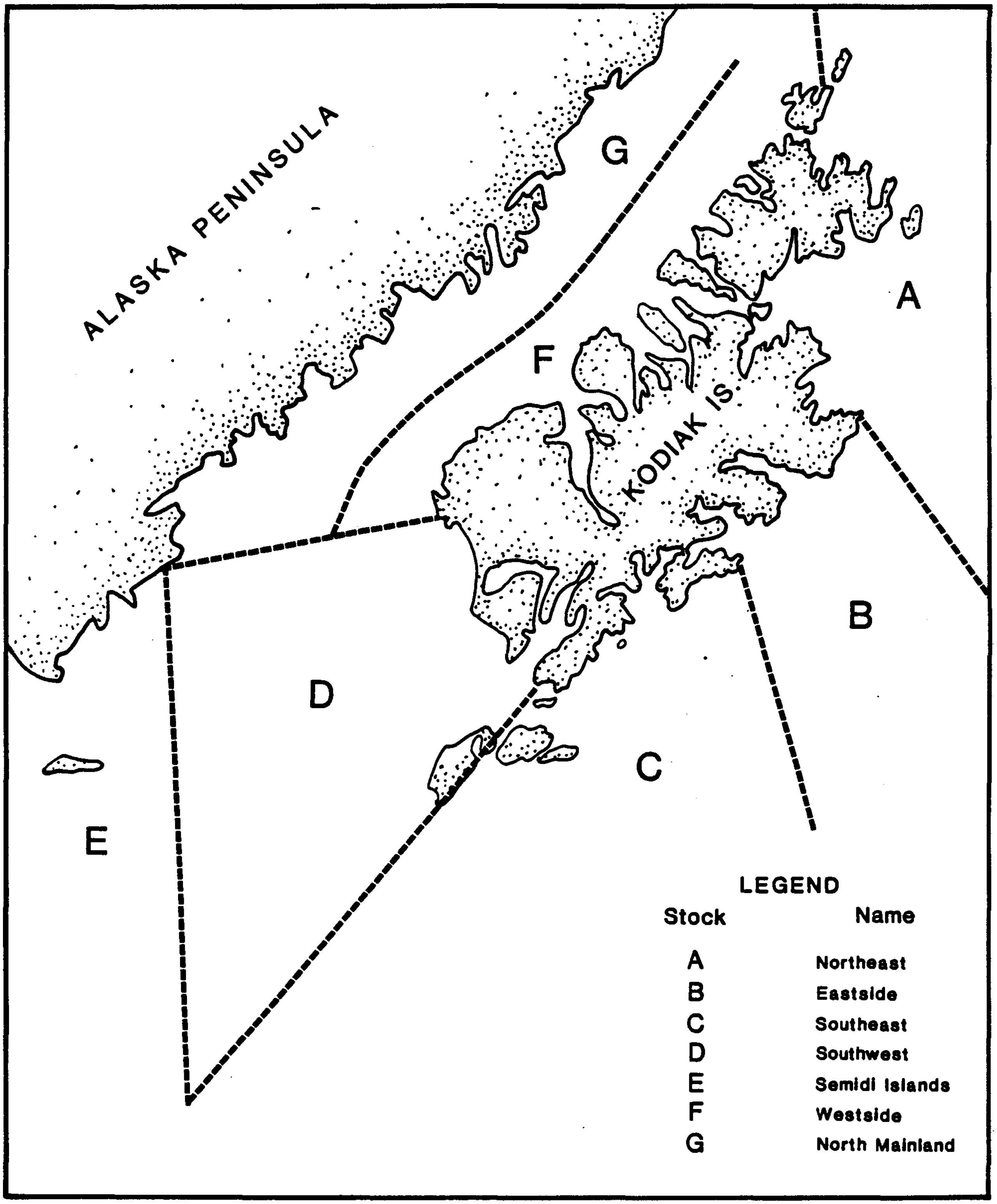
1. Distribution. Tanner crabs in the Kodiak area are known to inhabit the entire Kodiak shelf to a depth of over 1,200 ft. Largest concentrations have been found deeper than 450 ft. Tanner crabs appear to prefer areas of gullies with mud bottoms (ADF&G 1978; Colgate, pers. comm.).

   Any directional movement associated with Tanner crab populations in the Kodiak area appears to be movement from inshore areas to offshore as crabs increase in age. Migration is common to the mating practices of *Chionoecetes*, males migrating toward females during the breeding period. In some areas, however, such as Shelikof Straits, segregation between sexes during the nonbreeding period has yet to be proven (Colgate, pers. comm.). Portions of some populations do move into shallower waters from January through March for mating (ibid.).

   The yearly reproductive cycle begins in January and extends into June. Molt to maturity and mating of primiparous (first time) females may occur from January to early June. Hatching from eggs fertilized the previous season occurs in April and May, and deposition of new egg clutches by multiparous (one plus matings) occurs in April and May (ADF&G 1978).

   Female Tanner crabs mature sexually upon reaching an average carapace width of 83 mm and males when they reach an average carapace width of 90 mm (Donaldson et al. 1981).

2. Abundance. Tanner crabs in the Kodiak District have been delineated into stocks that correspond to major fishing sections (map 38). Major producing schools within these stocks are the North Mainland (from stock G), Chiniak Gulley (from stock A), Twoheaded Island (from stock C), and Alitak Bay (from stock D). In 7 of 10 fishing seasons between 1974 and 1983, stock D has been the leading producer of Tanner crabs (Colgate, pers. comm.). These stocks have historically been assessed by means of joint king/Tanner crab pot surveys. Indices are reported as legal male crabs per pot. In an attempt to learn



Map 38. Tanner crab, Chionoecetes bairdi, stocks in the Kodiak Management District (Colgate 1983).

about sublegal or prerecruit crabs, trawl surveys and resultant population estimates have also been attempted for stock G in the North Mainland fishing section (ADF&G 1983).

Districtwide, the Tanner crab resource has fluctuated throughout the history of the fishery but had shown a steady decline of legal crabs from 1973 until the 1981 season. The mean catch per pot from surveys dropped from 10.0 crabs for all schools in 1973 to a low of 2.9 crabs in 1980. Indices increased to 4.2 and 9.7 crabs per pot in 1981 and 1982, respectively (table 54). Trawl surveys performed in 1981 and 1982 for stock G have indicated a slight increase in population from 1.23 million legal crab in 1981 to 1.86 legal male crabs available to the fishery in 1982 (table 55).

During the 1982 season, the percentage increase for all stocks and the increase in number of prerecruit crabs in 1981 and 1982 surveys indicate possible recovery in the crab population. The low percentage of barren females observed from 1979 through 1982 indicates that the reproductive potential of female Tanner crabs during this period has appeared healthy (Colgate, pers. comm.).

C. Chignik District

1. Distribution. Major producing areas for the Tanner crab in the Chignik District are Ivanof Bay, Mitrofania Island, Chignik Bay, and Kujulik Bay (Colgate and Hicks 1983). The timing of reproduction and the movement of Tanner crabs in the Chignik area appears to be similar to that of Kodiak stocks (ADF&G 1978).

2. Abundance. Population estimates from trawl surveys for the Chignik area are available for two years (table 55). The method and constraints placed on these estimates is outlined in the Regional Summary (section A). The estimate of legal male crabs for 1981 was 1.91 million crabs, increasing to 3.23 million crabs in 1982 (Colgate, pers. comm.). Though a slight increase in population size has been apparent, the absence of prerecruit crabs in the surveys possibly indicates poor recruitment into the fishery and a subsequent decrease in population size through 1986 (ADF&G 1983). Overall population has been in decline since 1978 (Hilsinger 1983).

   Harvest levels during the 1981-1982 fishery increased 36% above the previous year's catch because of increased effort. Catch per effort, however, dropped to 28 crabs per pot, the second lowest figure in nine years (ADF&G 1983). Overall, population levels are low. The decrease in population decline is believed to be a result of poor survival during the early life stages (Hilsinger 1983).

D. South Peninsula District

1. Distribution. Tanner crabs occur throughout the South Peninsula area. Schools are located in the Ikutan/Morzhovoi area, Deer Island, Pavlof Bay, Beaver Bay, Balboa Bay, and Mountain Point. Tanner crab concentrations are also found in the Belkofski-Cold Bay area, Stepovak Bay, and Nagai Straits (Colgate and Hicks 1983).

Table 54. Mean Catch/Pot of Legal Male Tanner Crabs, Chionoecetes bairdi, by School and Stock by Year Obtained by Annual Surveys for the Kodiak District[ac]

Stock/School	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
Stock A										
Portlock	0.0	0.2	9.9	2.9	2.2	b	1.4	0.5	0.1	0.1
Marmot Bay	8.0	10.4	11.6	10.9	6.9	b	2.9	4.4	3.6	9.8
Marmot Gully	4.6	5.4	b	6.4	9.2	b	10.3	3.1	1.0	4.8
Outer Marmot Gully	8.7	18.9	7.7	0.9	1.1	b	3.0	0.5	0.2	0.8
Chiniak Bay	16.7	8.1	11.9	8.2	1.8	b	6.4	2.0	1.6	7.8
Chiniak Gully	30.9	19.0	5.0	11.3	7.0	b	4.1	2.9	0.9	2.0
Average catch/pot Stock A	11.5	10.3	9.2	6.8	4.7	b	4.7	2.2	1.2	4.2
Stock B										
Ugak/Barnabus	13.1	24.8	10.0	4.4	6.3	b	6.7	2.8	3.8	15.3
Eastside other	8.4	b	b	b	b	b	b	b	b	b
Average catch/pot Stock B	10.8	24.8	10.0	4.4	6.3	b	6.7	2.8	3.8	15.3
Stock C										
Twoheaded Island	26.1	15.7	25.2	14.5	28.6	b	0.7	2.1	0.8	15.1
Horses Head	4.3	10.4	15.2	6.1	13.7	2.8	4.6	1.1	0.7	1.9
South Trinity Island	2.6	7.6	8.0	15.1	4.9	7.5	0.8	2.9	0.6	1.8
Average catch/pot Stock C	11.0	11.2	16.1	11.9	15.7	5.2	2.0	2.0	0.7	6.3
Stock D										
Alitak Bay	8.7	34.1	2.7	31.1	18.2	b	2.9	8.1	13.3	14.1
Ikolik/Alitak	9.2	6.8	5.1	5.1	6.2	3.8	0.5	1.3	2.8	3.7
Compass Rose	8.4	15.6	10.6	7.7	12.8	5.3	3.5	2.9	3.7	8.2
Average catch/pot Stock D	8.8	18.9	6.1	14.6	12.4	4.6	2.3	4.1	6.6	8.7

(continued)

Table 54 (continued).

Stock/School	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
Stock F										
Kupreanof/Uganik	1.0	3.3	14.1	12.7	7.1	b	3.1	3.2	8.7	14.1
West Afognak	b	b	b	33.4	b	b	8.9	-	-	-
Average catch/pot Stock F	1.0	3.3	14.1	23.1	7.1	-	6.0	3.2	8.7	14.1
Average catch/pot All schools combined	8.6	13.7	11.1	12.1	9.2	4.9	4.3	2.9	4.2	9.7

Sources: Colgate 1983; Colgate, pers. comm.

a Indices do not necessarily reflect catch for the same station within each school in subsequent years.

b No survey performed.

c Indices are not adjusted for differences in stock abundance.

Table 55. Tanner Crab Population Estimate in Millions of Crabs from Trawl Surveys for Kodiak Stock G and the Entire Chignik District, 1980-82

Area	1980	Year 1981	1982
Kodiak stock G	1.23	1.42	1.86
Chignik District	a	1,910.0	3,230.0

Source: Colgate, pers. comm.

a No survey.

2. Abundance. Little is known about the mating and migrational patterns of Tanner crabs in the South Peninsula area (Colgate, pers. comm.). Major Tanner crab production areas are Pavlof Bay, Deer Island, and Sanak Island.

   Stock assessment of Tanner crabs in the South Peninsula area is performed through pot surveys, as described in the Regional Summary (section A). Tanner crab populations in the South Peninsula area have been declining since 1978. Evidence of decreasing abundance has also been apparent in catch per effort from pot surveys, where the catch per pot decreased from 24.5 crabs during the 1974 survey to 2.2 crabs in the 1982 survey. The incidence of barren females was the lowest observed in three years (ibid.). The decrease in population size has been attributed to poor recruitment and the unlimited increase of fishing effort, which coincided with natural fluctuations (Hilsinger 1983).

E. Eastern Aleutians District

1. Distribution. *C. bairdi* inhabits the areas south of the Alaska Peninsula and throughout the Aleutian Islands from the littoral zone to a depth of 1,600 ft (ADF&G 1978). The Aleutians, however, appear to offer marginal habitat for *C. bairdi*, as commercial quantities are found only in a few bays and inlets (ADF&G 1983). *C. opilio* is found in Akutan Bay, Unalaska Bay, and Beaver Inlet (ibid.).

2. Abundance. Stock assessment surveys have not been performed in the Eastern Aleutian area since 1978. Although the 1982 harvest of C. bairdi was slightly greater than the previous year's catch, the average number of crabs per pot in the commercial fishery was the lowest in nine years (Colgate and Hicks 1983). The percentage of recruits and the average weight of crabs in the commercial fishery indicate no dramatic change in the population (Griffin 1983).

   Introduction of C. opilio into the eastern Aleutians area has resulted from disposal of male crabs, which were either discarded as dead or were otherwise unacceptable to processing plants (ADF&G 1983). The C. bairdi population might be affected by introduction of C. opilio in local areas. The direct competition for food and the hybridization of the two species are matters of concern. Hybridization could reduce the size of the crabs, decrease the number of crabs available, produce a less commercially desirable population, and possibly reduce the reproductive capacity of this resource (ADF&G 1983).

F. Bering Sea District

1. Distribution. Both C. bairdi and C. opilio are found in commercial quantities in the Bering Sea. The distribution of each species may shift slightly each year in relation to both water temperature and population size. The general distribution of C. bairdi is along the Alaska Peninsula coast, in continental slope areas, and among the Pribilof Islands (Otto 1981). Concentrations occur along the continental shelf edge west and northwest of the Pribilofs, in the Pribilof Island area, and north of the Alaska Peninsula from Unimak Pass to Port Moller. C. opilio is widely distributed in the Bering Sea. The range of C. opilio extends from the Alaska Peninsula north to the Chukchi Sea, west to the United States-USSR convention line, and east to the Canadian Arctic. Concentrations in recent surveys have been located 100 to 720 nautical miles southwest of Nunivak Island and also in the area between St. Matthews and the Pribilof Islands (Otto et al. 1982). The distribution of the hybrid (C. opilio and C. bairdi) Tanner crab corresponds to the zone of overlap of the parent species (ibid.).

   Specific mating areas for Tanner crab in the Bering Sea are unknown. Females remain relatively stationary throughout the year. It is believed that male crabs begin to migrate in late winter to areas where females are concentrated (Kessler, pers. comm.) and that mating occurs from February to early June (NPFMC 1981). Egg-bearing females have been caught throughout the outer continental shelf (Kessler, pers. comm.). The peak hatching period for eggs fertizlized the previous year appears to occur in mid May (Drury 1980).

   Environmental factors such as ocean currents and water temperatures determine the depth and location at which juvenile Tanner crabs settle (Adams 1979). Juvenile and adult crabs of the species C. bairdi are found in the same areas throughout their Bering Sea range. Concentrations of C. opilio, however, are usually dominated by either juvenile or adult crabs (Somerton 1981). Most juvenile crabs of the species C. opilio have been found north of 58° north latitude (Kessler, pers. comm.).

Size at maturity differs by species and by sex. For C. bairdi, females reach maturity at 89 mm (3.6 inches) CW and males at 110 mm (4.4 inches). Female and male C. opilio mature at 50 mm (2.0 inches) and 85 mm (3.4 inches) CW, respectively (Otto, pers. comm.).

2. Abundance. In addition to harvest and size data collected during the commercial fishery, biological data and population estimates for Tanner crab in the Bering Sea are obtained from trawl surveys performed by the NMFS. Surveys occur annually during June, July, and August. Therefore, information regarding crab populations the remainder of the year and during the reproductive period is scarce.

Catch rates from the Japanese fishery are the earliest historical indicator of abundance. Since king crabs were abundant during the late 1950's and early 1960's, it is probable that Tanner crabs (C. bairdi) were in high abundance during the early 1960's (Otto 1981). Trawl surveys since 1970 have provided the only indicators of the abundance of Tanner crab.

Population estimates are derived for each species of Tanner crab in the Bering Sea. Surveys are performed south of 58° north latitude. In past years, two centers of abundance have been evident for C. bairdi. These have been located in the Pribilof Islands and north of the Alaska Peninsula.

In recent years, C. bairdi has become relatively scarce in areas east of 165° west longitude and more abundant in areas along the continental shelf edge. Scattered small populations of large males and females (greater than 110 mm and 85 mm) still occur near the Pribilofs and north of the Alaska Peninsula from Unimak Pass to Port Moller, particularly northwest of the Pribilof Islands. A good concentration of small males has also been established along the continental shelf edge west and northwest of the Pribilofs. Size frequency distributions differ between the crabs from the two areas. Though biological differences are apparent between concentrations, C. bairdi in the eastern Bering Sea is managed and surveyed as a single stock (ibid.).

Surveys depict a relative index of prerecruit and recruit C. bairdi crabs. Prerecruit crabs before 1976 were 3.3 inches (83 mm) to 5.0 inches (127 mm) in size. Between 1976 and 1982, prerecruit crabs have been 4.3 inches (109 mm) to 5.5 inches (140 mm). In parallel, recruit crabs prior to 1976 were greater than 5.0 inches (127 mm) and since 1976 have been greater than 5.5 inches (140 mm) (Otto et al. 1982).

The population of legal male C. bairdi greater than 129 mm in size increased through 1975 to 209.6 million (table 56). The population size continued to decrease to a low of 17.4 million recruit crabs in 1982 (ibid.). The number of prerecruit males and females has also declined steadily.

The population size of male C. opilio greater than 109 mm in size followed the same trend as the C. bairdi population, increasing from 84.7 million crabs in 1973 to a high of 274.8 million crabs in 1975, then declining gradually to 10.8 million crabs in 1982 (table 56).

Hybrid Tanner crabs (C. opilio and C. bairdi) comprise less than 1% of the Bering Sea Tanner crab resource. Population estimates have also been derived for hybrid Tanner crabs in the Pribilof and Bristol Bay areas. The decline in abundance for the hybrid crab has also followed that of C. bairdi and C. opilio. Population estimates of large hybrid male crabs greater than 110 mm show a decline in abundance from 33.8 million crabs in 1975 to about 0.5 million crabs in 1982 (table 56) (ibid.).

Though theories have been proposed that attempt to account for the decline in terms of disease or predation by groundfish, the reason for the decline in Tanner crab populations at this time has not been determined (Kessler, pers. comm.).

G. Western Aleutians District

1. Distribution. Tanner crabs occur along the continental shelf (ADF&G 1978). Major producing areas are Nazan Bay, Korovin Bay, and the waters around Adak Island (ADF&G 1983).
2. Abundance. Tanner crab stocks in the Western Aleutian area are not surveyed for population or biological information. Based on the commercial harvest, stocks appear to be in healthy condition (Griffin 1983). The largest recorded harvest of 838,697 lb was taken in 1982. Catch per pot in the commercial fishery averaged 17 crabs per pot (ADF&G 1983). Based on commercial fishing statistics, the Western Aleutians crab stocks appear to be stable (Griffin 1983).

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Table 56. Population Estimates in Numbers of Crabs of Legal Size Male Tanner Crabs (Genus *Chionoecetes*) by Species for the Pribilof and Bristol Bay Districts of the Bering Sea Management Area from 1973 Through 1982

		Survey Year									
Species	Size	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
C. bairdi	Greater than 129 mm [a]	66.9	130.5	209.6	157.8	111.1	57.9	38.2	40.7	22.7	17.4
C. opilio	Greater than 129 mm [a]	84.7	246.7	274.8	181.6	137.3	78.4	105.9	53.6	15.7	10.8
Hybrid *C. opilio* X *C. bairdi*	Greater than 129 mm [a]	0	0	33.8	16.5	15.4	5.6	4.9	1.7	0.8	0.5

Source: Otto et al. 1982.

a Carapace width in mm corresponds to size at recruitment to the fishery.

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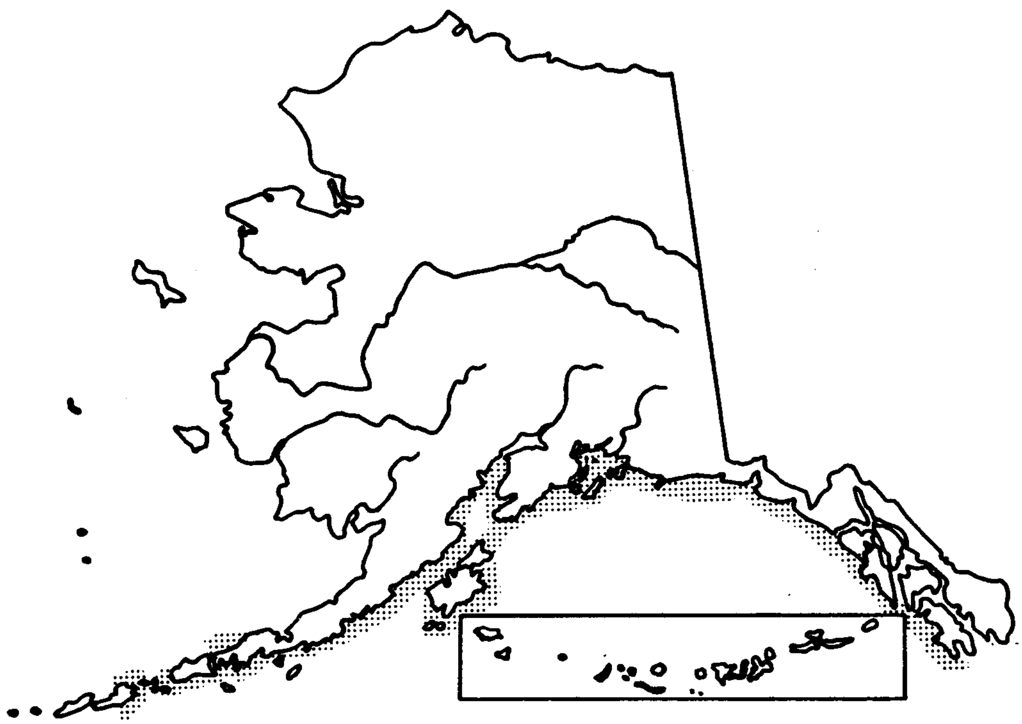
Razor Clam Life History



Map 39. 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
      Commercial quantities of razor clams in Southwest Alaska occur on beaches in the Swikshak area of the Alaska Peninsula (Paul and Feder 1976). Nickerson (1975) lists known razor clam beaches in Alaska.

III. PHYSICAL HABITAT REQUIREMENTS

Razor clams are found intertidally to a depth of several meters (Keen 1963) on exposed beaches of the open coast (Nosho 1972). Productive beaches include those that consist of fine sand with some glacial silt (Karls Bar at Orcas Inlet near Cordova), fine sand, volcanic ash, and some glacial mud (Swikshak Beach 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, Nickerson et al. 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.

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 Cook Inlet (Nickerson 1975: calculated from values arrived at in his Cordova study).

Nickerson (1975) 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 of Cook Inlet.

IV. NUTRITIONAL REQUIREMENTS

A. Preferred Foods

Razor clams are filter feeders, consuming detritus and drifting plankton (ADF&G 1978).

B. Feeding Locations

Razor clams feed within the intertidal zone.

C. Factors Limiting Availability of Food

Nickerson (1975) noted that large clams are found at low tide levels, and he speculated that their apparently faster growth may be due to longer exposure to nutrient-rich sea water. Razor clam growth accelerates in the 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. Nelson (1982) speculated that these observations may also apply to razor clams.

D. Feeding Behavior

Adult razor clams lie buried in the sand, with their siphons protruding above the surface. Food particles are brought in along with water through the incurrent tube, are then filtered out of the water by the gills, and passed to the mouth for ingestion (ADF&G 1978).

VI. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Razor clams breed within the intertidal zone.

B. Reproductive Seasonality

Nosho (1972) states that razor clam spawning occurs when temperatures reach 13°C, which usually occurs during 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 observed from January 1 to the time of spawning). He found that spawning ocurred when 1,350 or more temperature units had accumulated, usually between late May and mid July in the Cordova area (ibid.)

C. Reproductive Behavior

Spawning occurs over a period of several weeks (Nosho 1972). Eggs and sperm are released through the excurrent siphon, and fertilization takes place in the open water (ibid.).

D. Age At Sexual Maturity

Attainment of sexual maturity is more closely related to size than to age (Nickerson 1975), with 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. 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.

F. Frequency of Breeding

Razor clams breed annually.

G. Incubation Period

Eggs hatch into free-swimming, ciliated larvae (veligers) within a few hours to a few days of incubation, 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.

VII. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

Clam veligers are dependent upon water currents to carry them to desirable habitat (ADF&G 1978).

Young razor clams up to 10 mm (valve length) are capable of voluntary lateral movement along the beach surface to about 60 cm (Nickerson 1975). Large razor clams are believed to be incapable of voluntary lateral movement, though relocations may occur as a consequence of rapidly shifting substrate, or washout (ibid.). Razor clams are, however, capable of very rapid vertical movements (several feet per minute).

VIII. 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.

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 yearclass of razor clams at Clam Gulch to unseasonably cold weather that delayed spawning that year. The young clams were probably not ready to settle until fall, when low tides and cold weather exposed and froze them.

Influxes of fresh water, caused by high-flowing streams or heavy rain, also result in increased mortality of adult and young razor clams (Nelson 1982).

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, 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

IX. LEGAL STATUS

Sport and commercial harvests of razor clams are regulated by the Alaska Department of Fish and Game.

X. DISTRIBUTION

In the Southwest Region, razor clams are found on surf-swept sandy beaches of Kodiak Island, the south side of the Alaska Peninsula, and Unimak and Unalaska islands. The clams inhabit open beaches consisting of fine or coarse sand with some glacial silt and/or gravel (Amos 1966).

XI. ABUNDANCE

Little quantitative information is available concerning razor clam populations in the Southwest Region. Two beaches on the Alaska Peninsula, however, have been quantitatively surveyed. Swikshak Beach, 18 mi southwest of Cape Douglas, which has been approved for commercial harvest of razor clams, was found to have a mean average density of .38 clams larger than 115 mm per sq yd (Kaiser and Konigsberg 1975 [unpubl.]; cited in Kaiser and Konigsberg 1976). The substrate of Swikshak beach, however, has changed dramatically in recent years, and it no longer supports a substantial population of razor clams (Nippes, pers. comm.).

Big River Beach, which is 4 mi west of Swikshak, has an area of 850,000 sq yd inhabited by clams readily available to commercial diggers. The average density of clams larger than 115 mm on Big River Beach is 1.59 clams per sq yd, or a total of 1.3 million clams larger than 115 mm (Kaiser and Konigsberg 1976). However, the substrate of Swikshak beach has changed dramatically in recent years, and it no longer supports a substantial population of razor clams (Nippes, pers. comm.).

Qualitative abundance estimates of clam populations on other Southwest Alaska beaches are given by Nickerson (1975). Nickerson lists nine beaches in this region having excellent abundance levels: Cape Douglas, Swikshak, Big River, Village Beach, Kukak Bay, Kashvik Bay, Imwya Bay, Yantarni Bay, and Aniakchak Bay.

Razor clams suffer high mortality in the larval and juvenile stages due to adverse weather conditions, unfavorable currents that carry them away from suitable beaches, predation, and possibly competition with larger adults. Because of this, it appears that environmental factors, rather than the size of the parent spawning population, determine the size of each year class (Nelson 1982). Studies from the Cook Inlet beaches indicate that the success of year classes varies greatly and that occurrence of dominant year classes is irregular and infrequent (ibid.)

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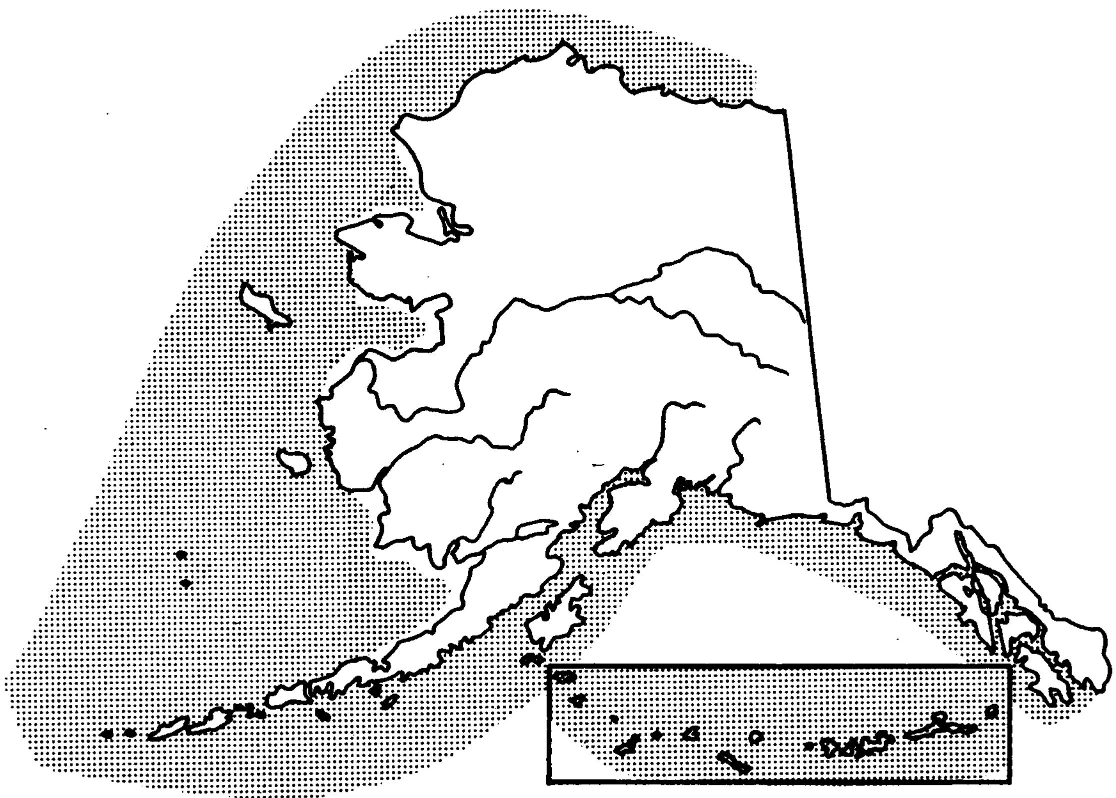
Shrimp Life History



Map 40. 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. DISTRIBUTION

A. North America

1. The range of the northern pink shrimp extends from the Bering Sea southward to the Columbia River mouth in Washington (Rathjen and Yesaki 1966).
2. Humpy shrimp have been found from the Arctic coast of Alaska southward to Puget Sound.
3. Coonstripe shrimp have been reported from the Bering Sea to the Strait of Juan de Fuca.
4. The range of the spot shrimp extends from Unalaska Island, Alaska, southward to San Diego, California.
5. Sidestripe shrimp are distributed from the Bering Sea, west of the Pribilof Islands, southward to Manhattan Beach, Oregon (ADF&G 1978).

B. Statewide

1. 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 (ibid., McCrary 1984).
2. Greatest concentrations of humpy shrimp are found off southeastern Kodiak Island and the Shumagin Islands.
3. Coonstripe shrimp are primarily found in lower Cook Inlet, off Kodiak Island, and among the Shumagin Islands.
4. Spot shrimp have been reported in lower Cook Inlet, off Kodiak Island, and along the Alaska Peninsula.
5. Sidestripe shrimp concentrations have been located off Kodiak Island and among the Shumagin Islands (ADF&G 1978).

C. Regionwide

See Statewide.

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 is apparently selective to colder water temperatures. 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

1. Larvae feed in the water column.
2. 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.).

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).

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

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.

X. DISTRIBUTION AND ABUNDANCE

Shrimp distribution and abundance information for the Southwest Region is presented in the following narrative. A regional summary is provided in sections A and B below. Sections C to G provide more detailed information and are organized by ADF&G Commercial Fisheries Division shrimp districts. There are five such districts in the division's Statistical Area J (the Westward Registration Area), an area whose marine waters are within the Southwest Region. The districts include Kodiak, Chignik, South Peninsula, North Peninsula, and Aleutian. Where appropriate, the district narratives are subdivided into the fishing sections found within the district. Boundaries of the shrimp districts are described in the shrimp Human Use portion of this publication. In addition, a 1:1,000,000-scale map of the districts is included in the Atlas that accompanies this text.

A. Distribution Summary

Shrimp, primarily pink shrimp, are distributed throughout the Kodiak, South Peninsula, and eastern Aleutians areas in bays and offshore banks (ADF&G 1978). The optimum depth of the best commercial catches differs by area but is generally between 180 and 600 ft (30 and 100 fathoms) (ibid.).

B. Abundance Summary

The stock condition, or abundance, of shrimp in the Southwest Region is determined by three methods: 1) comparison of annual catch-per-effort figures as provided by the commercial fleet in a voluntary logbook program, 2) stock assessment surveys using trawls, and 3) analysis of size-composition data outlined in both the commercial catch and the research surveys.

Information presented in the narratives that follow will be from the stock assessment trawl surveys, which provide continuing indices of abundance that can be compared among seasons and areas. The survey approach is based on the premise that shrimp concentrations found in major grounds are genetically discrete. These independent stocks remain intact between seasons and do not migrate between grounds.

Trawl sampling consists of a series of straight-line, 1-mi tows in each fishing section. Station selection for surveys from 1972 to 1977 was on a simple random basis. From 1977 on, each area to be surveyed has been systematically divided into blocks of four stations. Within each block, a station is chosen at random, thereby allowing for random selection of stations while ensuring a uniform distribution of tows throughout the survey area. The result is a lower sampling variance than was obtained with simple random sampling (ADF&G 1982).

The trawl results are to be recognized as abundance indices only and not as total biomass estimates. This is the case because smaller shrimp may escape through the net and because at times some shrimp may be further from the sea bottom than the trawl. In addition, surveys can cover only those seabottoms that are trawlable, and catch rates are not expanded to include those areas not trawlable (Jackson et al. 1983). Differences between indices of fall and spring surveys are attributed to the seasonal movement of shrimp, growth, recruitment, natural mortality, fishery removal in some cases, and differences in the amount of area surveyed (McCrary 1984).

Regionwide, shrimp stocks, with few exceptions, have declined. The progressive decline seen in all size cohorts suggests that juvenile mortality and overexploitation are not the only contributors to the decrease in abundance. These two causes would not be expected to affect all size groups simultaneously. The population decline appears to be the result of a mortality factor that is not size-selective. There are three potential causes of mortality that may not be size-selective. The first could be an environmental change that affects survival or the food supply. A decrease in food supply could result in either high mortality in all segments of each stock or a progressive migration of the population to more favorable grounds. The second could be the occurrence of disease, which could cause progressive mortality in all portions of each stock simultaneously. The third could be immigration of a predator affecting all stocks simultaneously (Jackson et al. 1983).

Currently, two factors tend to support the hypothesis that predation has contributed significantly to the decline in shrimp abundance. These factors are 1) the simultaneous decline of all shrimp size groups (indicating no selection by size) and 2) the fact that the decline of shrimp abundance has been concurrent with the increased incidence of cod and pollock in shrimp survey catches (ibid.). More information, however, must be obtained before this theory as to the cause of the decrease in shrimp abundance can be confirmed.

C. Kodiak District

1. Distribution. During years of high population levels, shrimp have inhabited the entire Kodiak continental shelf to a depth of over 600 ft. Major concentrations have been found in Kodiak's east-side bays and nearshore areas. Less abundant stocks are found in all west-side bays, offshore areas, and along the Alaska Peninsula. Bay areas and offshore gullies, particularly those east of Kiliuda Bay and Twoheaded Island, are believed to be critical spawning and rearing habitat. The Kodiak area shrimp catches include all the major pandalid species, though pink shrimp (*Pandalus borealis*) comprise greater than 65% of all trawl-caught shrimp (ADF&G 1978).

2. Abundance. Within the Kodiak District several fishing sections have historically provided the bulk of the shrimp harvest. They are discussed in sections a to e below.

   a. Ugak Bay Section. Ugak Bay historically has been a major shrimp-producing area in the Kodiak District. Apparent low abundance and low harvest during the 1973-1974 season, however, resulted in Ugak Bay being closed to fishing until the 1979-1980 season. The fishery opened again for the 1980-1981 season and again was closed for the 1981-1982 season.

The Ugak stock, after the closure of the fishery in 1973, showed some upward trend from 1974 through 1976 with abundance indices stabilizing between 4 and 5 million pounds of shrimp (table 57). A decision was made in 1979 to allow a small fishery if the abundance index was at least 4.0 million pounds. From the fall of 1981 to the fall of 1982 the abundance index declined from 3.6 to .06 million pounds. No commercial fishery was allowed during this period but large concentrations of Pacific cod were observed in ADF&G surveys that had never previously been encountered. Predation by Pacific cod is believed to have contributed to the unexplained shrimp decline between 1981 and 1982 (McCrary 1984).

b. Twoheaded Island and Kiliuda Bay sections. The small harvest of shrimp in Twoheaded and Kiliuda bays has been attributed to heavy commercial fishing pressure coupled with recruitment of weak year classes reflecting poor larval conditions. Strong recruitment by 1978 and 1980 year classes, however, has helped stabilize stock levels. Abundance nevertheless remains low. Fall abundance indices in Kiliuda Bay have ranged from 21.30 million pounds in 1976 to 0.953 million pounds in 1981. Twoheaded Island fall indices dropped from a high of 27.80 million pounds in 1972 to 3.04 million pounds in 1981 (table 57) (ibid.).

c. Alitak Bay Section. Alitak Bay stocks have remained at harvestable levels, although a declining trend has been evident in both abundance indices and harvest levels in recent years. The apparent reasons for the stability of Alitak Bay shrimp stocks are 1) the consistently broad age structure supporting the fishery, 2) the restriction of harvest levels prior to the occurrence of heavy fishing exploitation, and 3) the historically low abundance of predacious fish compared to most other major shrimp population areas (ADF&G 1982, McCrary 1984).

Alitak Bay, unlike other Southwest areas, supports a significant population of humpy shrimp (*P. goniurus*). Where abundance indices for pink shrimp have remained relatively stable at 2.5 million pounds to 5.3 million pounds, indices for humpy shrimp have varied from 1.1 million pounds to 14.6 million pounds (ibid.). The greater variations in abundance for humpy shrimp have been attributed to the wider depth distribution of this species and its tendency to migrate. Although the exact reason for this migratory behavior is unknown, it is probably in response to changes in the availability of food and is

Table 57. Shrimp Abundance Indices in Millions of Pounds by Year and Fishing Section in the Southwest Region, 1971-81[a]

District	Section	Month	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Kodiak	Ugak Bay	Jan.										j	
		Feb.						3.51					
		Mar.		0.00								2.25	
		Apr.	1.25	0.32			1.88						
		May										1.86	3.12
		June							1.41				
		Aug.				2.28	0.84	1.95	4.21			4.98	
		Sept.						4.20		3.18			3.59
		Oct.					3.21				4.15		
		Dec.	2.35				2.60	2.35		4.30			
	Kiliuda Bay	Jan.										1.62	
		Feb.						1.16					
		Mar.		7.69									
		Apr.	9.70	8.74			9.70						
		May				15.3		4.44				1.62	2.54
		June			17.10								
		July						3.67			0.45		
		Aug.				14.3	7.65	17.40	6.98	2.88[c]	0.96	2.15	
		Sept.		1.61	5.52	14.3		21.30		1.12			.953
		Oct.					10.40						
		Nov.					12.30						
		Dec.	16.90	9.81			10.20	7.20	8.54	0.97			
	Twoheaded Is.	Jan.										2.8[j]	
		Mar.	15.50	21.60									
		Apr.		13.30			11.20						
		May				26.30						8.7	14.14
		June			38.10[d]								
		July						22.50			7.50		
		Aug.					28.10		8.86			14.7	
		Sept.		27.80	10.60	17.10				4.36	6.27		3.04
		Oct.							3.33				
		Nov.					20.20						
		Dec.	25.80					12.10	7.28	0.99			

(continued)

Table 57 (continued).

District	Section	Month	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
			Year										
Kodiak	Alitak Strata 2 (Alitak Bay)	Jan.										4.5	
		Apr.					2.99						
		May				8.24					8.6	4.4	8.69
		July						10.20					
		Aug.					15.90		8.65	10.80	7.3	19.46[m]	
		Sept.											5.44
		Dec.							8.13	5.89			
	Strata 3 (Alitak Flats)	May										13.8[l]	1.64
		Sept.										6.63	5.75
	Marmot Is.	May					66.36						2.06[i]
		June						16.19					
		Sept.								3.70	3.45[i]	1.8[i]	6.64
		Oct.						61.40	13.80				
	Inner Marmot Bay	May					7.09						7.18
		June						2.04					
		Sept.								6.50	4.4	2.29	2.78
		Oct.						13.00	7.14				
	Chiniak Bay (Kalsin Bay portion)	Jan.									1.8		2.31
		May									2.7	1.62	
		June							1.2				
		Aug.								4.3			
		Sept.										1.3	3.90[l]
		Oct.									2.58		
		Nov.							2.5				
	Uganik Bay	Apr.											
		May					2.26[k]	3.16[f]			2.2	1.64	1.8[n]
		June							5.18[k]				
		July									2.32		
		Sept.										2.48[n]	1.81

(continued)

Table 57 (continued).

District	Section	Month	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
			Year										
Kodiak	Uyak Bay	Apr.					2.98[l]						
		May						1.78[f]			1.13	2.28	.42
		June							1.4				
		July									1.50		
		Sept.										1.44	.51
	Mainland (Wide Bay portion)	May								9.27[l]	2.52[k]	2.53	1.95
		Aug.									4.2		
		Sept.										2.03	1.4
	Mainland (Puale Bay portion)	May								7.2[l]	1.08		2.76
		June										1.47	
		Aug.									3.7		j
		Sept.										.76	
	Mainland (Kukak Bay portion)	May											.78
		Sept.											.29
Chignik	Chignik Bay	May					7.32[e]		5.38		10.22	10.47	2.4
		June				8.05		5.04					
		July					10.20						
		Aug.								7.19[f]	13.90		
		Sept.				16.32[f]	10.70[f]	10.61[f]	8.76[f]	12.23[f]		14.67	.960
	Kujulik Bay	May					4.60[e]		4.07		11.75	3.1	.47
		June				4.66		3.31				3.5	
		July					11.40			6.63			.783
		Aug.									21.26[m]		
		Sept.				7.70[e]	6.30[e]	8.90[e]	17.60[e]	7.60[e]		2.39	.77
	Mitrofania Is.	May							9.40		11.75	2.06	.02
		June				16.14		12.56					
		July					13.13			6.40			
		Aug.									2.72	9.7	
		Sept.				8.59[e]	5.88[e]	8.28[e]	7.77[e]	4.05[e]			0.17

(continued)

Table 57 (continued).

District	Section	Month	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
			Year										
Chignik	Kuiukta Bay	May						1.78[f]					
		June						1.76	3.27				1.16
		July					3.57						.036
		Aug.									1.3		
		Sept.				5.2[f]	3.89[f]	5.2[f]	2.4[f]	3.12[f]		.965	.036
	Ivanof[h] Bay	May							14.00		4.66		0
		June				11.60		15.00				.85	
		July					15.43						
		Aug.									12.18[g]	.35	.065
	Aniakchak Bay	May											
		June										0	
		Aug.									3.57		0
		Sept.										j	j
	Nakolilok	June										.73	.73
		Aug.									.5	.35	.07
		Sept											
	Chiginagak	May											1.05
South Peninsula	Stepovak Bay	May											3.0
		June										2.95[j]	
		Aug.									9.37	5.16	
		Sept.		133.4[f]	136.1[f]	112.1[f]	29.9[f]	31.9[f]	11.3[f]	2.40[f]			.59
	Balboa/Unga	May											0
		June									11.8	.96	
		Aug.									6.94	3.46	
		Sept.		19.6[f]	16.7[f]	30.3[f]	9.3[f]	4.6[f]	1.6[f]	1.9[f]			.32
	West Nagai	Sept.		28.4[f]	22.4[f]	23.4[f]	9.6[f]	10.2[f]	0.1[f]	0.4[f]			0
	Beaver Bay	May											0
		June									0	.41	
		Aug.									.48	.05	
		Sept.		25.2[f]	12.9[f]	14.1[f]	4.6[f]	11.7[f]	3.8[f]	5.4[f]			.176

(continued)

Table 57 (continued).

			Year										
District	Section	Month	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
South Peninsula	Pavlof Bay	Feb									17.3		
		May											5.24
		June									10.1	.52	
		Aug									2.79[f]	2.3	
		Sept.		48.4[f]	22.1[f]	50.2[f]	45.5[f]	52.6[f]	53.1[f]	11.9[f]	2.03[f]		1.50[f]
	Morzhovoi Bay	Feb.									.9		
		May											5.54
		Aug.									.15	1.21	
		Sept.				29.6[f]	20.60[f]	33.00[f]	38.70[f]	4.32[f]			1.47[f]
	Belkofski Bay	Aug.									.42		

Source: ADF&G 1982.

a Surveys conducted by ADF&G unless otherwise noted.

b Repeat survey conducted with index of 4.02.

c Repeat survey conducted with index of 2.67.

d Repeat survey conducted with index of 32.10.

e Survey conducted by NMFS.

f Survey conducted by NMFS but weighted by ADF&G strata.

g 9.25 of the 12.8 index was in the Jacob Island area (Strata 2).

h Abundance indices shown are based on Strata 2 and 3 only as these were the only ones consistently surveyed and therefore directly comparable. Sizable shrimp populations in offshore strata, 1974 and earlier.

i Izhut Bay only.

j Incomplete.

k Area considered in estimate expanded over original survey area.

l Regression method.

m High abundance of P. goniurus (humpy shrimp).

n Error in calculation of previous published estimate.

therefore unpredictable. The Alitak fishery is managed for pink shrimp, which attained high indices of 4.8 million pounds in 1976 and 2.6 million pounds in 1979. Fall abundance in 1981 was 3.1 million pounds (ADF&G 1982).

d. Mainland Section (Wide and Puale bays). Wide and Puale bays are situated on the mainland side of Shelikof Strait, west of Kodiak Island. Significant effort in this area first occurred during the 1978-1979 season. These fisheries are supported by resident stocks, and recent recruitment to the fishery has been minimal. Catches and abundance indices since the 1978-1979 seasons have declined steadily. Indices from May of 1978 in Wide Bay were 9.27 million pounds and dropped to 1.95 million pounds in 1981. Spring indices for Puale Bay dropped from 7.2 million pounds during 1978 to 2.8 million pounds in 1981. These declines have been attributed to fishing (table 57) (ibid.).

e. Chiniak Bay Section (Kalsin Bay). Kalsin Bay, an arm of Chiniak Bay, has been exploited for shrimp since the early days of the fishery. Both catch and population size have increased, probably in response to favorable environmental conditions and the resulting good recruitment and carry-over of previous years' age classes. Fall indices increased from 1.3 million pounds in 1980 to 3.9 million pounds in 1981 (table 57). A declining trend in abundance, however, has been evident in subsequent years (Jackson, pers. comm.).

D. Chignik District

1. Distribution. Historically shrimp have been distributed throughout the Chignik area and concentrated along the continental shelf. Shrimp are not distributed uniformly, however, as concentrations occur in specific areas and bays. Areas of major shrimp concentrations have been Chignik Bay, Kujulik Bay, Mitrofania Island, Kuilita Bay, Ivanof Bay, Aniakchak Bay, and Nakalilok Bay (ADF&G 1978).
The largest commercial harvest areas for shrimp in the Chignik District have been Kujulik, Chignik, and Ivanof bays and Mitrofania Island.

2. Abundance. As with other Southwest shrimp districts, Chignik District's shrimp stocks have shown a substantial decrease in abundance. In addition to the possibility of predation by ground fish species, the decline in Chignik Bay and Kujulik Bay shrimp stocks is probably due to heavy fishing pressure. The unexpected decline in the Kujulik Bay area occurred the year following a peak harvest. Kujulik Bay fall indices peaked at 17.60 million pounds in 1977 and decreased to .77 million pounds in 1981 (table 57). The decline in Chignik Bay was not apparent until the spring of 1981. Chignik Bay's fall survey

indices dropped from a peak of 16.32 million pounds in 1975 to .96 million pounds in 1981 (ADF&G 1982).

As with other areas within the Chignik District, both the Mitrofania Island area and Ivanof Bay have been classified as severely depressed. A significant decline in abundance was noted in the Mitrofania Island area during the 1979-1980 season. Fall abundance indices dropped from 8.59 million pounds in 1974 to a low of 0.017 million pounds in 1981 (table 57). The species' decline has also been evident in the less important areas of Kiutka, Aniakchak, Nakolilak, and Chiginagak and Kuiukta bays in the Chignik area for which indices have been computed.

E. South Peninsula District

1. Distribution. Shrimp in past years have had a wide but uneven distribution throughout the Alaska Peninsula area. Concentrations have been located in Stepovak Bay, Unga Strait, Balboa Bay, Beaver Bay, Pavlof Bay, Volcano Bay, Sanak Island, and Morzhovoi Bay (ADF&G 1978).

2. Abundance. In the South Peninsula District, abundance indices are obtained for Stepovak Bay, the Balboa/Unga area, West Nagai, Beaver Bay, Pavlof Bay, and the Morzhovoi and Belkofski areas. With the exception of Belkofski, data have been available since 1972.

   All areas have experienced a significant decline in shrimp abundance, particularly within the past five years. The areas where the greatest shrimp concentrations have occurred are Stepovak and Pavlof bays. In Stepovak Bay, abundance indices ranged from 136.1 million pounds in 1973 to 0.59 million pounds in 1981. Abundance in Pavlof Bay peaked in 1977 at 53.1 million pounds (table 57). No positive explanation exists at present for the decline observed in Stepovak and Pavlof bays other than the high fishing effort expended shortly before the decline in abundance and subsequent fishery closure. In Pavlof Bay, age composition studies suggest the fishery was recently supported by a strong year class and was not followed by another of similar strength. Stepovak Bay age-composition data are not available. Stock assessment of Pavlof Bay indicates the presence of a small but relatively stable brood stock, which is nonexistent for Stepovak Bay, suggesting this stock may have been harvested below the point from which it is able to recover (ADF&G 1982).

F. North Peninsula District

1. Distribution. Surveys performed by the NMFS have shown pink shrimp (*P. borealis*) to occur northwest of the Pribilof Islands and in Bristol Bay. This species appears to require relatively warmer temperatures than other species. It occurrs near the continental shelf edge, where there are intrusions of warmer water. The humpy shrimp (*P. goniurus*) also occurs in the Bering Sea. Humpy shrimp comprised the major share of the catch from the gulf of Anadyr and along the Koryan Coast of the

Bering Sea. Humpy shrimp seem to tolerate sustained low temperatures and are therefore found in shallower shelf waters, where residual water covering depresses water temperatures (Morris 1981, Balsiger 1979).

2. Abundance. Currently, shrimp stocks in the Bering Sea are very depressed, even though directed commercial exploitation of shrimp in the Bering Sea has not occurred since the mid 1960's (Morris 1981, Balsiger 1979).

G. Aleutian District

1. Distribution. Historically, shrimp have been distributed throughout the South Peninsula and Aleutians along the continental shelf to a depth of over 1,200 ft (ADF&G 1978). Major concentrations in the Aleutian District occur in Usof, Makushin, Unalaska, and Beaver bays (ADF&G 1982).

2. Abundance. Knowledge of shrimp stock abundance is restricted to the eastern Aleutians area. In 1981, Unalaska Bay was judged to be in a distressed condition, with Makushin Bay supporting a fishable stock of shrimp. Beaver Inlet was classified as depressed and capable of supporting only a small effort. The stock condition of shrimp has since declined, and the bays are instead full of large numbers of juvenile fish, presumably pollock and cod (ADF&G 1983).

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