Alaska Habitat Management Guide

Arctic Region Volume I:

Life Histories and Habitat Requirements of Fish and Wildlife

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



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

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

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* LH=life history and habitat requirements; DA=distribution and abundance; HU-C=human use-commercial fishing; HU-T=human use-trapping; HU-H=human use-hunting; HU-P=human use-subsistence fishing; HU-S=human use-sportfishing; RO=regional overview (summary of DA and HU-C). Katherine A. Rowell, Fisheries Biologist: Pacific herring LH, HU-C; king crab LH, HU-C; Tanner crab LH, RO; chinook, coho, sockeye, chum, and pink salmon HU-C and P.

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The process of developing the initial plan and procedures for this project involved a number of individuals who are not otherwise listed as authors and contributors. These include many staff within the Division of Habitat, as well as planners and research and management coordinators of other divisions. This group also includes all project team members and all ADF&G regional supervisors. Special mention should be made of the support from Alvin Ott and Lance Trasky, Regional Supervisors of the Division of Habitat for the Arctic and Southwest regions (Regions III and IV, respectively), and of the contributions of Rai Behnert, who was the original coordinator of this project. We would also like to acknowledge the many contributions of John A. Clark, who was Director of the Division of Habitat until his untimely death in 1985.

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Overview of Habitat Management Guides Project

Background

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

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

Purpose

This project presents the best available information on selected fish and wildlife species: mapping and discussing their geographical distribution; assessing their relative abundance; describing their life functions and habitat requirements; identifying the human uses made of them, including harvest patterns of rural communities; and describing their role in the state's economy. This last kind of information, because of the variety of values humans place upon fish and wildlife, is not easily derived. There are, however, several methods to estimate some of the economic values associated with these resources, and such estimates have become particularly important in land use planning because many potentially conflicting uses must be evaluated in economic terms.

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

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

Applications

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

The guides have been designed to provide users with interrelated subject areas that can be applied to specific questions regarding habitat management. Each type of data will be presented in a separate volume, as indicated in figure 1. Material from the project's database can be used,



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



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

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

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

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

Statewide Guides Volumes

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

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

- ° 0il and gas development
- Harbors and shoreline structures
- ° Water development

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

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

A separate statewide volume describing the life history and habitat requirements of selected fish and wildlife species is being prepared region by region; therefore the information in the Arctic guide addresses the species requirements in the Arctic, Southwest, and Southcentral regions, and also in the Western and Interior regions for belukha and bowhead whales, Pacific walrus, polar bear, and caribou. Other information will be added as reports are prepared for the remaining regions.

Arctic Region

Organization and Use of the Guide

<u>Narratives</u>. The two narrative volumes of the guide to the Arctic Region are closely related and interdependent. The first highlights important aspects of selected species life histories, emphasizing the interrelationships of the species with their habitats. The life histories include information for the Arctic, Southwest, and Southcentral regions, and, in some cases, the Western Region, as mentioned in the preceding overview section. The second, or distribution and human use volume, provides the most current estimates of species' distribution and relative abundance and delineates the regional and subregional patterns, locations, and types of human uses of fish and wildlife resources. This portion of the guide provides an understanding of the importance of fish and wildlife to the people within and outside the Arctic Region.

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

For the fourth category of human use information, the Arctic Region has been divided into three subregions (map 2) to portray patterns of subsistence use of local fish and wildlife resources. These subregions are 1) Bering Strait/Norton Sound. 2) Kotzebue Sound, and 3) North Slope. The patterns of use described in these narratives are based primarily upon community studies coordinated by the Division of Subsistence, with additional source materials from other anthropological studies on the history and patterns of activity in the subregions.

<u>Maps</u>. A major portion of the guides project in the Arctic Region was committed to the production of updated fish and wildlife maps at two scales of resolution. Species distributions and human use were mapped at a reference scale of 1:250,000 and then were mapped at the index scale of 1:1,000,000 for most subjects. Some reference maps for marine species were actually prepared at the 1:1,000,000-scale because that is the most appropriate scale to portray the level of detail of data on those species distributions. Reference maps are being reproduced as blue-line copies compiled in catalogues that are available at ADF&G offices of the region. Additional copies will be available for other users, at cost of reproduction, from our contract vendor. These maps can guite easily be



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Map 2. The Arctic Region and its three subregions: 1 - Bering Strait/Norton Sound; 2 - Kotzebue Sound; and 3 - North Slope.

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updated. The index maps are being printed in color and will be included in atlases.

For the Arctic Region, there are approximately 675 reference maps that depict fish and shellfish species distribution, wildlife species distribution, subsistence, commercial, recreational, and general use of fish and wildlife.

Species Selection Criteria

Each species covered in the guides was selected because it met the following criteria: 1) its habitat is representative of some portion of the spectrum of the Arctic Region's habitats (this criterion ensures that regional habitats are well represented); 2) it constitutes an important resource to human users in the region; 3) the species or its habitat is liable to be adversely affected by present or proposed land or water uses; and 4) adequate information on its life history, abundance, and distribution was available.

Based on the above criteria and the prioritized requests of each division, the species list for the Arctic Region was developed to include 27 individual species, plus species groups, dabbling and diving ducks (10), and geese (4). The individual species are as follows:

Belukha whale Bowhead whale Ringed seal Pacific walrus Polar bear Brown bear Caribou Dall sheep Moose

- Arctic char/Dolly Varden Arctic grayling Broad whitefish Lake trout Least cisco Sheefish Chinook salmon Chum salmon Coho salmon Pink salmon Sockeye salmon
- Arctic cod Capelin King crab Pacific herring Saffron cod Starry flounder Tanner crab

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

Muskox Wolverine Beaver Land otter Mink Wolf Lynx Marten Spruce grouse Peregrine falcon Loons Tundra swan Snowy owl Gyr falcon Rough-legged hawk Golden eagle Ribbon seal Bearded seal Spotted seal Gray whale Seabirds Shorebirds Grebes

Northern pike Smelt Lingcod Hardshell clam Starry flounder Sand lance Sculpin

Overview of the Arctic Region

The Arctic Region (map 2) includes the Davidson, Philip Smith, Endicott, DeLong, Baird, and Bendeleben mountains. A few of the larger river basins in the region include the drainages of the Canning Savavanirktok, Colville, Ikpikpuk, Kuk, Utukok, Noatak, and Kobuk rivers. Marine waters associated with the region are comprised of the Norton and Kotzebue sounds and the Bering, Chukchi, and Beaufort seas.

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

Biophysical Features

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

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

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

Biota

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

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

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

Human Activities in the Region

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

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

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



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

- I. NAME
 - A. Common Names: Beluga, belukha
 - B. Scientific Name: Delphinapterus leucas (Pallas 1776)
- II. RANGE
 - A. Worldwide

Belukhas occur off North America, Europe, and Asia in seasonally ice-covered waters of the Arctic Ocean and subarctic seas (Kleinenberg et al. 1964). They have been sighted as far south as Tacoma, Washington (Scheffer and Slipp 1948), the New Jersey coast (Anthony 1928), the Loire River, France, (Fraser 1974), and the Sea of Japan (Gurevich 1980, Seaman and Burns 1981). The several somewhat discrete stocks of this monotypic species are separated on the basis of adult size, concentration areas, seasonal movement patterns, and physical and geographical barriers; the number of stocks is still being debated (Sergeant and Brodie 1969, Gurevich 1980).

B. Statewide

1.

Belukhas in Alaska are considered to comprise two stocks.

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

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

C. Regional Distribution Maps

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

D. Regional Distribution Summary

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

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

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

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

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

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

Alaska Habitat Management Guide for the Southwest Region.)

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

Belukhas gradually move offshore in late summer/autumn and probably winter in the pack ice in the Bering Sea and southern Chukchi seas (Klinkhart 1966, Harrison and Hall 1978, Lowry 1984).

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

3. <u>Western</u>. Prior to the 1950's there were several concentration areas along the Yukon-Kuskokwim coast that were used from spring through autumn. Sightings in recent years, however, have been irregular and consist of small numbers of animals (Frost et al. 1982). One areas in the Western Region where moderately large groups of belukhas still occur is the delta of the Yukon River. These groups appear in May or June and remain through September and October (ibid.).

(For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Western and Interior regions.)

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

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

1. <u>Water quality</u>. Belukhas have been recorded in fresh waters of larger rivers (Kleinenberg et al. 1964), brackish estuarine areas (Fraker et al. 1978) and marine areas (Seaman and Frost 1983, Lowry 1984). Fraker et al. (1979) found that in areas where belukhas concentrated in the MacKenzie River estuary, salinities ranged from less than 1 ppt to 12 ppt saline and turbidities ranged from less than 6 to over 150 ppm sediment. He concluded that they appeared neither to avoid nor select areas because of salinity or turbidity. Belukhas leave the MacKenzie River estuary before the salinity, turbidity, and temperature ranges change from summer conditions (ibid.).

2. <u>Water depths</u>. Belukhas have been observed in water depths ranging from shallow coastal waters to deep marine pelagic areas (Fay 1978). During the summer, belukhas frequent the shallow coastal and shelf waters to take advantage of the seasonal food supplies and warm water (Murray 1979, Consiglieri and Braham 1982, Lowry 1984). Fraker et al. (1979) reported belukhas in the MacKenzie River estuary in water depths of less than 2 m. The western arctic stock overwinters over the continental shelf in the southern Chukchi Sea, and the southern and contral Boring. Soa, fooding on species found at depths from

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

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

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

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

- 4. <u>Acoustic properties</u>. Belukhas possess the finest resolution biosonar described to date for cetaceans (Leatherwood et al. 1982). Commercial whalers called the belukha the "sea canary," because of its range of vocalizations (ibid.). Belukha sounds are varied and complex and are probably used mainly for communication and food location in turbid waters of estuaries and rivers (Fay 1978). Although no unequivocal evidence was found on acoustical habitat requirements, many observations of bowhead reactions to various types of noise have been reported; the significance of the observed behavior changes in unclear (see the references in the Impacts of Land and Water Use volume).
- B. Ice
 - 1. Effects on movement and distribution. In general, belukhas spend considerable time in ice-covered offshore waters. They are unable to make and maintain breathing holes in ice more than 8 cm thick (Kleinenberg et al. 1964) and so are found in areas where geographic, oceanographic, or meteorologic factors cause ice motion and the formation of open water (Burns et al. 1981).

Fraker et al. (1979) reported that belukhas can travel up to 3 mi under the ice without surfacing; however, according to Kleinenberg et al. (1964), 2-3 km is the maximum reported submerged swimming distance.

Rapid ice formation in bays or polynyas can block escape routes, trapping belukhas in the ice, where they die if breathing holes are frozen over (Porsild 1918, Kleinenberg et al. 1964, Leatherwood and Reeves 1982).

Murray (1979) reported that few belukhas were observed in Cook Inlet in years of extensive ice conditions.

- 2. <u>Protection from natural elements</u>. Burns et al. (1981) point out that turbulence caused by winter storms in the Bering Sea is depressed by sea ice. The calmer water inside the ice fringe may allow easier feeding in the productive waters of the continental shelf under the ice pack (ibid.).
- 3. <u>Protection from predators or other disturbances</u>. Although killer whales (<u>Orcinus orca</u>) occur along the southern fringe of the pack ice, the ice offers more protection from killer whales than the open sea (Burns et al. 1981). Polar bears (<u>Ursus maritimus</u>) occasionally kill belukhas; however, they do not range into the unstable ice zone in the Bering Sea where the majority of belukhas winter (ibid.).
- IV. NUTRITIONAL REQUIREMENTS Studies of food habits of belukha whales throughout their range have identified more than 100 different species in the diet (Kleinenberg et al. 1964). In coastal waters of Alaska, belukhas feed on a series of

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

- A. Food Species Used
 - 1. Spring and summer foods:
 - a. Arctic Region:

1)

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

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

2) Point Hope. The stomachs of 35 belukhas taken by subsistence hunters at Point Hope in May 1977 and 15 taken in April 1978 were examined by Seaman et al. (1982). In 1977, 30 stomachs were empty, and in 1978 six stomachs were empty.

Stomach contents examined in May 1977 contained almost exclusively octopus beaks, with 625 occurring in one stomach. Contents examined in April 1978 contained mostly crangonid shrimp. (See table 2.)

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

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

Source: Seaman et al. 1982.

--- means no data were available.

Prey Item	22-27 May 1977, n=5			25-26 April 1978, n=9			
	Percent Volume	Percent Number	Percent Frequency	Percent Volume	Percent Number	Percent Frequency	
Shrimp	< 1		20	99		67	
Squid	0		0	< 1		11	
Octopus Other in-	75		100	< 1		78	
vertebrate Total	< 1		60	< 1		11	
invertebrat	e 75		100	100		100	
Rocks an d pebbles	25		40	1		22	
Total			_				
fishes	0	~ - ~	0	< 1		11	
Arctic cod		0	0	+	100	11	
Mean volume of contents (ml)	53.3			48.4			
Total numbe identified fishes	r 0			43			

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

Source: Seaman et al. 1982.

--- means no data were available.

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

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

- B. Types of Feeding Areas Used
 - 1. <u>Spring/summer</u>. In spring and early summer, belukhas move inshore and frequent shallow bays and the mouths of large rivers (Cook Inlet, Bristol Bay, the Yukon-Kuskokwim delta, Norton Sound) to feed on seasonally abundant migrating fishes (Brooks 1955, Klinkhart 1966, Seaman et al. 1982).
 - 2. <u>Summer/fall</u>. Belukhas in Bristol Bay remain and feed in estuarine areas and the mouths and main stems of major rivers, especially of the Kvichak and Nushagak rivers (Lowry et al. 1982); other portions of the western arctic stock summer and feed in the nearshore areas of the northern Bering, Chukchi, and Beaufort seas (Norton Sound, especially in Golovin and Norton Bays; the passes and waters adjacent to Kasegaluk Lagoon; and the MacKenzie River estuary) (ibid.).
 - 3. <u>Winter</u>. Winter distribution is determined by the abundance and distribution of potential food species and sea ice (Seaman and Burns 1981, Seaman et al. 1982). Most feed offshore, near the pack ice edge, or in polynyas in water to 50 fathoms in depth (Braham et al. 1982).
- С. Factors Limiting Availability of Food The prey consumed by belukha whales are also major foods of other species of cetaceans and pinnipeds in the Bering and Chukchi seas (Johnson et al. 1966, Frost and Lowry 1981, Lowry and Frost 1981). Arctic and saffron cods, pollock, herring, capelin, and smelt are of particular importance in the diet of at least six species of pinnipeds and four other species of cetaceans (ibid.). Competition for food may be particularly great between belukhas and spotted seals (<u>Phoca largha</u>) because their distributions and food habits overlap broadly throughout much of the year (Lowry and Frost 1981). Saffron cod and sculpins eaten by belukhas are generally larger than those eaten by seals whereas arctic cod, capelin, smelt, and herring consumed by belukhas and seals are probably of similar size classes (Frost and Lowry 1981). The number of fish-eating pinnipeds in the Bering and Chukchi seas is difficult to estimate but certainly exceeds 2 million (ibid.). Given the broad dietary overlap with pinnipeds and the relatively much smaller population of belukha whales, limitation of the belukha population through competition for food is a possibility If so, the carrying capacity of the Bering-Chukchi (ibid.). system for belukha whales, as expressed by population size and productivity, may be influenced by the foraging activities and population sizes of other species of marine mammals. In addition, commercial fisheries, particularly for herring and salmon in coastal areas of the Bering and Chukchi seas and for groundfish in the southeastern Bering Sea, remove great quantities of marine mammal forage fishes (Pruter 1976; Lowry et al. 1979, 1982). The combined effects of predation and fishing on fish stocks and the possible resultant effects on marine mammal populations remain unclear (Lowry et al. 1982, Seaman et al. 1982).
D. Feeding Behavior

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

- V. REPRODUCTIVE CHARACTERISTICS
 - A. Reproductive Habitat

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

B. Reproductive Seasonality

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

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

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

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

Sergeant (1973) computed a production rate of 11-14% for belukhas in Hudson Bay, Canada. Lowry (1984) estimated the gross annual production of belukha calves in Alaska to be 9%, a low rate, compared to marine mammals with annual breeding periods (ibid.).

- G. Gestation Period Gestation requires 14 to 14.5 months (Brodie 1971, Seaman and Burns 1981).
- H. Lactation Period Females nurse young for 18 months to two years (ibid.).

VI. FACTORS INFLUENCING POPULATIONS

- A. Natural
 - 1. <u>Mortality</u>. Although no mortality rates for Alaskan belukhas were located, known causes of mortality (other than hunting by humans) are predation by polar bears (Freeman 1973) and killer whales (Sergeant and Brodie 1969) and entrapment in sea ice (Porsild 1918). Lowry et al. (1982) state that "the relatively low rate of production and large proportion of older animals in harvests suggest that natural mortality rates are low."
 - 2. <u>Competition</u>. Interspecific competition for food could affect belukha distribution and/or abundance.

Although belukhas prey on the same fish species as a number of other marine mammals and birds, their feeding habits are most similar to those of spotted seals and harbor porpoises (<u>Phocoena phocoena</u>) (Lowry 1984). By exploiting pack ice habitat, belukhas avoid direct competition with harbor porpoises during winter (Burns et al. 1981; Frost and Lowry, pers. comm.). Both their seasonal range and food habits, however, extensively overlap those of the spotted seal (Lowry 1984).

B. Human-related

Possible impacts of human-related activities include the following:

- [°] Barriers to movement, physical and behavioral
- ° Chronic debilitation due to ingestion or contact with petroleum or petroleum products
- Entanglement in fishing nets or marine debris
- Prey base, alteration of
- ° Harassment, passive
- Harvest, change in level
- [°] Interference with intraspecies communication
- Interference with reproductive behavior
- [°] Interruption of ongoing behavior: alarm, flight

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

VII. LEGAL STATUS

A. Federal

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

B. State

1.

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

- C. Population Management History
 - Data are presented for the entire state rather than by GMU.
 - Summary of harvest. A few belukhas from the Cook Inlet stock are harvested by humans (Lowry 1984). In the 1930's, about 100 whales were netted and processed for meat and oil before the attempted commercial venture was abandoned (ibid.). A few Cook Inlet whales were taken by recreational hunters in the 1960's.

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

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

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

2. <u>Period of state authority</u>. Belukhas were managed by the state of Alaska from statehood in 1959 until passage of the MMPA in 1972. Harvest levels were low and reduced from

previous years, so no limit was imposed on the take, although harvests were monitored.

- 3. <u>Period of federal authority</u>. Passage of the MMPA had little effect on the overall harvest of belukhas because although only Alaskan Natives could harvest belukhas after the MMPA and sale of belukha products to non-Natives was prohibited, most of the take and use had always been by Eskimos (Lowry 1984). No federal program was instituted to gather harvest or biological data; state biologists, however, again monitored harvests from 1977 through 1979 and from 1981 to the present (ibid.).
- 4. <u>International agreements</u>. The United States has entered into no international agreements concerning belukhas.
- D. Current Population Management

The National Marine Fisheries Service (NMFS) of the Department of Commerce has the responsibility for management of belukhas for the federal government.

- 1. <u>Management objectives</u>. NMFS has no published plan for management of belukha whales (Zimmerman, pers. comm.).
- 2. <u>Management considerations</u>. Conflicts with fisheries, especially the Bristol Bay salmon fishery, the unknown effects of development on belukhas, the lack of a federal management plan, and data gaps in the basic biological information for the stock are problems in the management of belukhas in Alaska.

VIII. LIMITATIONS OF INFORMATION

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

REFERENCES

- ADNR/USFWS. 1983. Bristol Bay Cooperative Management Plan. Anchorage. 495 pp.
- Anthony, H.E. 1928. Field book of North American mammals. New York, London: G.P. Putnam's Sons. 571 pp.
- Bakkala, R., K. King, and W. Hirschberger. 1981. Commercial use and management of demersal fish. Pages 1,015–1,036 <u>in</u> D.W. Hood and J.A. Calder, eds. The eastern Bering Sea shelf: oceanography and resources. Vol. 2. USDC: OMPA, NOAA.
- Blackburn, J.E., K. Anderson, C.I. Hamilton, and S.J. Starr. 1983. Pelagic and demersal fish assessment in the lower Cook Inlet estuary system.

Pages 107-383 in Environmental assessment of the Alaskan continental shelf. Final report of principal investigators. Vol. 17. USDC: NOAA.

- Braham, H.W., and B.D. Krogman. 1977. Population biology of the bowhead (<u>Balaena mysticetus</u>) and beluga (<u>Delphinapterus leucas</u>) whale in the Bering, Chukchi, and Beaufort seas. Processed rept. USDC: NOAA, NMFS. Natl. Mar. Mamm. Lab., Seattle, WA. 29 pp.
- Braham, H.W., B.D. Krogman, and G.M. Carroll. 1982. Bowhead whale (<u>Balaena</u><u>mysticetus</u>) migration, distribution, and abundance in the Bering, Chukchi, and Beaufort seas, 1975–1978, with notes on the distribution and life history of white whales (<u>Delphinapterus</u> <u>leucas</u>). NOAA tech. memo. NMFS SSRF-100.
- Brodie, P.F. 1971. A reconsideration of aspects of growth, reproduction, and behavior of the white whale (<u>Delphinapterus leucas</u>) with reference to the Cumberland Sound, Baffin Island, population. J. Fish. Res. Bd. Can. 28:1,309-1,318.
- Brooks, J.W. 1954. Beluga. Annual rept. for 1954. Alaska Department of Fisheries, Juneau.
- _____. 1955. Beluga investigation. Annual rept. for 1955. Alaska Department of Fisheries, Juneau.
- Burns, J.J., L.H. Shapiro, and F.H. Fay. 1981. Relationship of marine mammal distribution, densities, and activities to sea ice conditions. Pages 489-670 <u>in</u> Environmental assessment of the Alaskan continental shelf. Final report of principal investigators. Vol. 11. ERL, Boulder, CO.
- Burns, J.J., K.J. Frost, G.A. Seaman, and L.F. Lowry. 1985. Biological investigations of belukha whales in waters of western and northern Alaska. Final rept., RU 612. Outer Continental Shelf Environmental Assessment Program. USDC: NOAA. Reporting period 1 January 1980-31 December 1982.
- Calkins, D.G., and K.W. Pitcher. 1977. Unusual sightings of marine mammals in the Gulf of Alaska. Abstract. Proceedings of the second conference on the biology of marine mammals. San Diego, CA.
- Consiglieri, L., and H. Braham. 1982. Seasonal distribution and relative abundance of marine mammals in the Gulf of Alaska. Draft final rept. OCSEAP. 204 pp.
- Fay, F.H. 1971. Belukha, arctic white whales. Pages 23-27 in A. Seed, ed. Toothed whales in the eastern North Pacfic and arctic waters. Seattle, WA.: Pacific Search Press.

_____. 1978. Belukha whale. Pages 132-137 <u>in</u> D. Haley, ed. Marine mammals of the eastern North Pacific and arctic waters. Seattle, WA.: Pacific Search Press.

- Fish, J.F., and J.S. Vania. 1971. Killer whale, <u>Orcinus orca</u>, sounds repel white whales, <u>Delphinapterus leucas</u>. Fish. Bull. 69:531-535.
- Fraker, M.A. 1977. The 1977 whale monitoring program, MacKenzie estuary, N.W.T. IOL: F.F. Slaney and Co. Ltd., Vancouver, B.C., Can.
- Fraker, M.A., D.E. Sergeant, and W. Hoek. 1978. Bowhead and white whales in the southern Beaufort Sea. Beaufort Sea Proj. Tech. Rept. No. 4. 114 pp.
- Fraker, M.A., C. Gordon, J. McDonald, J. Ford, and G. Chambers. 1979. White whale (<u>Delphinapterus</u> <u>leucas</u>) distribution and abundance and the relationship to physical and chemical characteristics of the Mackenzie estuary. Can. Fish. Marine Serv. Tech. Rept. No. 863. Dept. Fish and Environ., Winnipeg, Manitoba. 56 pp.
- Fraser, F.C. 1974. Report on Cetacea stranded on the British coasts from 1948 to 1966. British Museum (Natural History), London.
- Freeman, M.M.R. 1973. Polar bear predation on beluga in the Canadian arctic. Arctic 26:163-164.
- Frost, K.J. 1984. Personal communication. Marine Mammal Biologist, ADF&G, Div. Game, Fairbanks.
- Frost, K.J., and L.F. Lowry. 1981. Foods and trophic relationships of cetaceans in the Bering Sea. Pages 825-836 in D.W. Hood and J.A. Calder, eds. The eastern Bering Sea shelf: oceanography and resources. Vol. 2. Seattle, WA.: Univ. Washington Press.
- Frost, K.J., L.F. Lowry, and J.J. Burns. 1982. Distribution of marine mammals in the coastal zone of the Bering Sea during summer and autumn. Final rept., NOAA, OCSEAP Contract No. NA-81-RAC-00050. 166 pp.
- Gurevich, V.S. 1980. Worldwide distribution and migration patterns of the white whale (beluga), <u>Delphinapterus leucas</u>. Rept. Int. Whal. Comm. 30:465-480, SC/31/SM 14.
- Harrison, C.S., and J.D. Hall. 1978. Alaskan distribution of the beluga whale (Delphinapterus leucas). Can. Field-Nat. 92:235-241.
- Johnson, M.L., C.H. Fiscus, B.T. Ostenson, and M.L. Barbour. 1966. Marine mammals. Pages 897-924 in N.J. Wilimovsky and J.N. Wolfe, eds. Environment of the Cape Thompson region, Alaska. Oak Ridge, Tennessee: U.S. Atomic Energy Commission.

- Kleinenberg, S.E., A.V. Yablokov, B.M. Belkovich, and M.N. Tarasevich. 1964. Beluga (<u>Delphinapterus leucas</u>). Investigation of the species. 376 pp. (Transl. from Russian by Israel Prog. Sci. Transl., Jerusalem, 1969.)
- Klinkhart, E.G. 1966. The beluga whale in Alaska. ADF&G, Juneau. 11 pp.
- Leatherwood, S., and R.R. Reeves. 1982. Bottlenose dolphin and other toothed cetaceans. Pages 369-414 <u>in</u> J.A. Chapman and G.A. Feldhammer, eds. Wild mammals of North America. Baltimore: Johns Hopkins University Press.
- Leatherwood, S., R.R. Reeves, W.F. Perrin, and W.E. Evans. 1982. Whales, dolphins, and porpoises of the eastern North Pacific and adjacent arctic waters: a guide to their identification. NOAA Tech. Rept. NMFS Circular 444.
- Lensink, C.J. 1961. Status report: beluga studies. File rept. ADF&G, Juneau.
- Lono, O., and P. Oynes. 1961. White whale fishery at Spitsbergen. Norsk Hvalfangst-Tidende 7:267-287.
- Lowry, L.F. 1984. Personal communication. Marine Mammal Biologist, ADF&G, Div. Game, Fairbanks.
 - _____. 1984. Belukha whale. In J.J. Burns, ed. Marine mammal species accounts. Wildl. Tech. Bull. No. 7. ADF&G, Juneau.
- Lowry, L.F., and K.J. Frost. 1981. Feeding and trophic relationships of phocid seals and walruses in the eastern Bering Sea. Pages 813-824 in D.W. Hood and J.A. Calder, eds. The eastern Bering Sea shelf: oceanography and resources. Vol. 2. USDC: OMPA,NOAA.
- Lowry, L.F., K.J. Frost, and J.J. Burns. 1979. Potential resource competition in the southeastern Bering Sea: Fisheries and phocid seals. Pages 287-296 in B.R. Melteff, ed. Proceedings of the 29th Alaska science conference, Fairbanks, Alaska, 15-17 August 1978. Univ. Alaska Sea Grant Rept. No. 70-6.
- Lowry, L.F., K.J. Frost, and J.J. Burns. 1980. Variability in the diet of ringed seals, <u>Phoca</u> <u>hispida</u>, in Alaska. Can. J. Fish. Aquat. Sci. 37:2,254-2,261.
- Lowry, L.F., K.J. Frost, and R.R. Nelson. 1982. Investigations of belukha whales in coastal waters of western and northern Alaska: marking and tracking of whales in Bristol Bay. Annual rept. Contract No. NA-81-RAC-00049, OCSEAP, Juneau, AK. 43 pp.

- Murray, N. 1979. Belukha whales in lower Cook Inlet. Pages 192-208 in Environmental assessment of the Alaskan continental shelf. Annual report of principal investigators for the year ending March 1979. NOAA.
- Nelson, E.W. 1887. Report upon natural history collections made in Alaska between the years 1881 and 1887. Arctic Ser. Publ. No. 3, Signal Service, U.S. Army, Washington, DC.
- Nelson, R.R. 1985. Personal communication. Game Biologist, ADF&G, Div. Game, Nome.
- Ognetev, G.N. 1981. Studies on the ecology and the taxonomy of the white whale (<u>Delphinapterus leucas</u> Pallas 1776) inhabiting the Soviet arctic. Rept. Int. Whal. Comm. 31:515-520, SC/32/SM1.
- Pereyra, W.T., J.E. Reeves, and R.G. Bakkala. 1976. Demersal fish and shellfish resources of the eastern Bering Sea in the baseline year 1975. Processed rept. NMFS, NOAA, NWAFC. Seattle, WA.
- Porsild, M.E. 1918. On "savssats": a crowding of arctic animals at holes in the sea ice. Geogr. Rev. 6:215-228.
- Pruter, A.T. 1976. Soviet fisheries for bottomfish and herring off the Pacific and Bering Sea coasts of the United States. Mar. Fish. Rev. 38:1-14.
- Scheffer, V.B., and J.W. Slipp. 1948. The whales and dolphins of Washington State with a key to the cetaceans of the west coast of North America. Am. Midl. Nat. 39:257-337.
- Seaman, G.A., and J.J. Burns. 1981. Preliminary results of recent studies of belukhas in Alaskan waters. Rept. Int. Whal. Comm. 31:567-574, SC/32/SM 13.
- Seaman, G.A., and K.J. Frost. 1983. Distribution, abundance, and movements of belukha whales in western and northern Alaska. Pages 1-65 in J.J. Burns, K.J. Frost, G.A. Seaman, and L.F. Lowry, Biological investigations of belukha whales in waters of western and northern Alaska. Final rept. RU-612. Reporting period 1 January 1980-31 December 1982.
- Seaman, G.A., L.F. Lowry, and K.J. Frost. 1982. Foods of belukha whales (Delphinapterus leucas) in western Alaska. Cetology 44:1-19.
- Sergeant, D.E., and P.F. Brodie. 1969. Body size in white whales (Delphinapteras leucas). J. Fish. Res. Bd. Can. 26:2,561-2,580.

- Tarasevich, M.M. 1974. Characteristics of white whale migration toward the coast. Translation by National Technical Information Service, USDC, Springfield, VA. Rept. No. NOOT-1. 11 pp.
- Zimmerman, S. 1985. Personal communication. Marine Mammal Biologist, NMFS, Juneau, AK.

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Bowhead Whale Life History and Habitat Requirements Arctic and Western Regions

Map 1. Range of bowhead whale (Braham 1983)

- I. NAME
 - A. Common Names: Bowhead whale, Greenland whale, Greenland right whale, arctic right whale, great polar whale
 - B. Scientific Name: <u>Balaena mysticetus</u> (Linnaeus 1758)

II. RANGE

A. Worldwide

Prior to the commercial whaling period (1842-1914), bowhead whales were nearly circumpolar in distribution in arctic and subarctic waters (map 1). Four separate stocks of bowheads occurred in 1) the Sea of Okhotsk; 2) the Bering, Chukchi, and Beaufort seas (western arctic stock); 3) Hudson Bay, Baffin Bay, Davis Strait, and adjacent waters; and 4) the Greenland and Barents seas (Spitsbergen stock) (Tomilin 1957, Marquette 1977). Commercial whaling severely depleted all of these stocks (Marquette 1977). B. Statewide

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

C. Regional Distribution Maps To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for each

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

- D. Regional Distribution Summary
 - Arctic. The summer range for most of this stock is in Amundsen Gulf and the Canadian Beaufort Sea east and north of Herschel Island (Fraker and Bockstoce 1980). Some bowheads may not migrate into Canadian waters and may spend the summer in the northern Chukchi Sea and/or western Beaufort Sea (Braham et al. 1980b, Bogoslovskaya et al. 1982). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Arctic Region.)
 - 2. <u>Western</u>. Old whaling records show that bowheads historically overwintered in the pack ice between St. Lawrence and St. Matthew islands in the Bering Sea, but the specifics of wintering areas are poorly known (Brueggeman 1982). During years of extensive pack ice formation, bowheads may winter as far south as the Pribilof Islands (Braham et al. 1980a). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Western and Interior regions.)
- III. PHYSICAL HABITAT REQUIREMENTS
 - A. Aquatic
 - 1. <u>Water quality</u>. No specific information was found; however, bowheads occur in areas of both clear and turbid water. Oil in the water may foul baleen plates and reduce filtering efficiency (Braithwaite 1980a, b, 1983).
 - 2. Water depth. Bowheads migrate over fairly deep water, but in summer the "20-25 fathom whaling ground" (40-50 m water depth) was considered the most productive (Bodfish 1936). Although whales frequent both deeper and shallower water, many are found in water about 50 m deep off the Tuktoyaktuk Peninsula (N.W.T., Canada) in August and September (Fraker and Bockstoce 1980). Hazard and Cubbage (1982), however, suggest that "the greater proportion of whales seen in shallow water is an artifact of more observation time devoted to shallow water."

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

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

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

- A. Food Species Used
 - 1. <u>Spring</u>. Lowry and Frost (1984) found that most prey species in whale stomachs (53/56) were invertebrates, and most of those were primarily benthic organisms (35/53). Benthic organisms made up a small proportion of the overall stomach contents, however, with the exception of five small whales taken in spring in the Bering and Chukchi seas. Lowry and Frost (1984) believe "the incidence of feeding during the northward migration appears to be less in the Chukchi Sea than in the Bering. Feeding whales may be predominantly juveniles, and their prey are mostly benthic invertebrates."
 - Summer. Many bowheads summer in the eastern Beaufort Sea, where they presumably feed extensively (Wursig et al. 1981); no direct information on summer food items is available. Whales probably feed on locally abundant food items, especially pelagic crustaceans, during this period.
 - 3. <u>Autumn</u>. The caloric value of copepods collected in September was 1.5 times that of the same species collected in late July and early August. Therefore, although the autumn feeding time is short, it may be of relatively great importance (Lowry and Frost 1984).
 - Barter Island. Samples collected from five whales а. harvested near Barter Island between 20 September and 11 October 1979 indicate that in this area bowhead whales were feeding primarily on pelagic copepods, euphausiids, and mysids (Lowry and Burns 1980). Table 1 lists the major food items identified from bowhead stomach 2 presents samples. and table the quantitative composition of those samples.
 - b. <u>Barrow</u>. Stomach samples taken from two bowhead whales harvested near Point Barrow in September 1976 were almost entirely (90% of the volume) euphausiids, with some gammarid and hyperiid amphipods (Lowry et al. 1978). The principal euphausiid species, (<u>Thysanoessa</u> <u>raschii</u>) was the same found in whales taken at Kaktovik (Lowry and Burns 1980) and is widely distributed in arctic waters, primarily in the nearshore neritic zone (Nemoto 1966).
 - 4. Winter. No data on winter foods are available.
- B. Types of Feeding Areas Used
 - 1. <u>Summer</u>. The eastern Beaufort Sea and Amundsen Gulf may be important feeding areas for bowhead whales during early summer (Fraker 1979). Later, from mid July to mid September, they move to the MacKenzie River delta region, usually staying in water 50 m or shallower (Fraker and Bockstoce 1980). Although no stomach samples are available from bowheads in summer, presumed feeding behavior has been observed in these areas (Wursig et al. 1981, Wursig 1985).
 - 2. <u>Autumn</u>. Bowheads feed regularly in at least two main areas in the Alaskan Beaufort Sea in September and October: 1) east of Barter Island to at least the United States-Canada

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

(continued)

	Whale Specimen Number					
Food Item	7 9- KK-1	79-KK-2	79-KK-3	79-KK-4	79-KK-5	
Gammarid amphipods: <u>Monoculoides</u> c.f. M. <u>schneideri</u> <u>Munnopsis</u> c.f. M. <u>typica</u> <u>Onisimus</u> glacialis <u>Onisimus</u> litoralis <u>Rozinante</u> fragilis ^a <u>Weyprechtia</u> <u>heulgini</u> Family Lysianassidae	0 0 X X 0 0 0 X	0 0 0 0 0 0 0 0	X X O O O O O O	X O O X X X O	0 0 0 0 0 *	
Shrimps: <u>Eualus gaimardii</u> <u>Sabinea septemcarinata</u> Family Crangonidae Unidentified	0 0 X 0	0 0 0 X	0 0 0 0	X X O O	0 0 0 0	
Isopods: <u>Saduria</u> <u>entomon</u>	0	0	0	0	x	
Diastylis sp.	0	0	0	X	0	
Fishes: <u>Boreogadus saida</u> <u>Myoxocephalus quadricornis</u> <u>Pungitius pungitius</u> Unidentified	0 0 0 0	X O O O	0 X 0 0	0 0 0 X	* * 0	
Pebbles	X	0	0	0	X	

Table 1 (continued).

Source: Lowry and Burns 1980.

* = present in qualitative sample
only.

X = 1-10 individuals in sample.

XX = more than 10 individuals in sample.

only.

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

XXX = dominant item in sample.

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

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

Source: Lowry and Burns 1980.

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

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

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

C. Factors Limiting Availability of Food Sea ice limits the availability of food to bowhead whales by blocking light, thus limiting productivity, and by limiting the areas to which the whales have access (Ljungblad et al. 1985). Ringed seals (<u>Phoca hispida</u>) and arctic cod (<u>Boreogadus saida</u>) are the bowhead's most significant trophic competitors in the Beaufort Sea (Lowry and Burns 1980). Broad dietary overlap is probably less important to the euryphagus ringed seal, which eats many species of fishes and crustaceans, than to the relatively stenophagus bowhead, which depends more on "swarms of small to medium sized zooplankton" (Lowry et al. 1982).

D. Feeding Behavior

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

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

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

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

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

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

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

- V. REPRODUCTIVE CHARACTERISTICS
 - A. Reproductive Habitat
 - Mating probably takes place during spring migration (Braham and Krogman 1977, Everitt and Krogman 1979). Imm (1980) believes that mating is the principal bowhead activity prior to ice breakup in the Bering Strait. Apparent reproductive activity was observed in an open-water lead in the pack ice about 32 km east of Point Barrow (Everitt and Krogman 1979). Pack ice appeared to be solid east of the immediate area, suggesting that migration was delayed.
 - B. Reproductive Seasonality

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

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

- С. Reproductive activity has been observed only rarely in bowhead whales because of the difficulty in observing these animals in their natural environment. Everitt and Krogman (1979) observed a pod of six bowheads in a lead in the pack ice east of Point Barrow engaged in what they thought to be reproductive activity: aggregation of several whales, flipper-touching or twisting, one whale clasping another with its flippers, and attempted copula-Spring ice conditions (i.e., denser pack ice with few tion. open-water leads) may cause the population to be more aggregated than at other times of year, increasing the number of social interactions that eventually lead to mating (Braham and Krogman 1977, Everitt and Krogman 1979, Imm 1980). The rate of social encounters decreases steadily from spring to autumn (Wursig 1985). D. Age at Sexual Maturity
 - Most bowhead whales harvested in recent years are immature, making it difficult to obtain data about reproduction and sexual maturity. All data on sexual maturity are given as a function of body length, but there is no adequate method of aging bowheads or of correlating body length and age (Nerini et al. 1982).
 - 1. <u>Females</u>. Nerini et al. (1982) found that all sexually mature females examined were 13-14 m in length. Davis et al. (1983) found that 91% of all females observed to be accompanied by a calf were longer than 13.5 m.
 - 2. <u>Males</u>. Tomilin (1957) stated that bowheads are sexually mature at 14-18 m.
- E. Frequency of Breeding
 - Durham (1972) concluded from indirect evidence that bowheads calve every second year or less often. Marquette (1978) stated that the

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

F. Fecundity

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

G. Gestation Period

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

- H. Lactation Period The length of the lactation period is not known; however, lactating female bowheads have not been taken in the autumn harvest, indicating that weaning may occur at five to six months of age (ibid.).
- VI. FACTORS INFLUENCING POPULATIONS
 - A. Natural

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

B. Human-related

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

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

VII. LEGAL STATUS

A. Federal

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

B. State

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

- C. Population Management History
 - 1. Summary of harvest. During the commercial whaling period (1848-1914), over 18,000 bowheads were killed, and at least 16,000 were taken by Yankee whalers (Bockstoce and Botkin 1980). The western arctic stock was depleted quickly; two-thirds of the total Yankee harvest was taken within the first two decades of whaling (ibid.). By 1914, commercial take of bowheads ended because of the decline of the bowhead population and the collapse of the whalebone and whale-oil Between 1910 and 1969, the annual catch markets (ibid.). dropped sharply; records indicate that 704 bowheads were taken, for an average take of 11.7 whales per year (Marquette and Bockstoce 1980). The harvest then jumped: from 1970 through 1977, a total of 259 whales were landed, with an average of 32.4 per year (ibid.). Beginning in 1978, the annual harvest quota has been set by the International Whaling Commission (IWC) and has ranged from 14 to 18 whales landed (ibid.).
 - 2. <u>Period of state authority</u>. The State of Alaska has never had managerial authority or responsibility for bowhead whales.
 - 3. Period of federal authority and international agreements. Bowhead whales have been completely protected from commercial whaling since 1946 by the International Convention for the Regulation of Whaling, the same act that set up the IWC. In 1969, the Endangered Species Conservation Act (ESA, PL 91-135) placed the bowhead under further protection and ended all nonsubsistence whaling by the United States. The MMPA placed restrictions on the importation of marine mammal products and allowed only Alaskan Natives to take bowhead whales for subsistence and for creating handicraft items and clothing for personal use and sale. The MMPA and ESA allow for regulation of subsistence take if the stock is declared depleted. Rather than go through the lengthy hearing process to set up regulations under those laws, the United States proposed to the IWC a yearly quota system of whales struck The first quotas took effect in 1978; and whales landed. enforcement was through the Whaling Convention Act. At the same time (1978), the Alaska Eskimo Whaling Commission (AEWC) was organized.

D. Current Population Management

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

- 1. <u>Management objectives</u>. The AEWC Management Plan provides for the following:
 - * Enforcement powers held by the AEWC
 - [°] Definitions of permissible whaling equipment and methods
 - Registration of each Eskimo whaling captain in Alaska
 - Requirement of reporting all whaling occurences, strikes, landings, or accidents
 - Establishing the level of harvest in conjunction with NMFS and setting the level of fines for infractions
 Supporting bowhead and weapons personal (AEWC 1085)
 - Supporting bowhead and weapons research (AEWC 1985)
- 2. <u>Management considerations</u>. Research is continuing on more efficient and humane methods of whale harvest and reducing the number of whales struck and lost.
- VIII. LIMITATIONS OF INFORMATION

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

REFERENCES

- AEWC. 1985. The bowhead whale, <u>Balaena mysticetus</u>, management plan of the Alaska Eskimo Whaling Commission. Abstract of the third conference on the biology of the bowhead whale, 21-23 January 1985, Anchorage, AK.
- Bockstoce, J.R., and D.B. Botkin. 1980. The historical status and reduction of the western arctic bowhead whale (<u>Balaena mysticetus</u>) population by the pelagic whaling industry, 1848-1914. Final rept. to NMFS, Contract No. 03-78-M02-0212.
- Bodfish, H.H. 1936. Chasing the bowhead. Cambridge, MA: Harvard Univ. Press. 281 pp.
- Bogoslovskaya, L.S., L.M. Votrogov, and I.I. Krupnik. 1982. The bowhead whale off Chukotka: migrations and aboriginal whaling. Rept. Int. Whal. Comm. 32:391-399, SC/33/PS16.

- Braham, H.W. 1983. Summary of interorganization bowhead research planning and coordination, 1982-1983. Abstract of the second conference on the biology of the bowhead whale, March 7-9, 1983, Anchorage, AK.
- Braham, H.W., and B.D. Krogman. 1977. Population biology of the bowhead (<u>Balaena mysticetus</u>) and beluga (<u>Delphinapterus leucas</u>) whales in the Bering, Chukchi, and Beaufort seas. Processed rept. NWAFC, NMFS, NOAA. Seattle, WA. 29 pp.
- Braham, H.W., M.A. Fraker, and B.D. Krogman. 1980a. Spring migration of the western arctic population of bowhead whales. Mar. Fish. Rev. 42:(9-10)36-46.
- Braham, H.W., B. Krogman, J. Johnson, W. Marquette, D. Rugh., M. Nerini, R. Sonntag, T. Bray, J. Bruggeman, M. Dahlheim, S. Savage, and C. Goebel. 1980b. Population studies of the bowhead whale (<u>Balaena</u> <u>mysticetus</u>): results of the 1979 spring research season. Rept. Int. Whal. Comm. 30:391-404.
- Braithwaite, L. 1980a. Baleen plate fouling. Pages 471-492 in J. Kelley and G. Laursen, eds. Investigation of the occurence and behavior patterns of whales in the vicinity of the Beaufort lease area. Final rept. to BLM from NARL.
- . 1980b. The effect of oil on the feeding mechanism of the bowhead whale. In T. Sullivan, ed. Draft proceedings of the interagency meeting to review, coordinate, and plan bowhead whale research, other cetacean research and related research bearing upon the conservation and protection of endangered marine species in Alaska and elsewhere. 171 pp.

. 1983. The effects of oil on the feeding mechanism of the bowhead whale. Final rept. to USDI from Brigham Young Univ., Provo, UT. 45 pp.

- Brodie, P.F. 1980. A preliminary investigation of the energetics of the bowhead whale (Balaena mysticetus L.). Rept. IWC 31. SC/32/SP18.
- Brueggeman, J.J. 1982. Early spring distribution of bowhead whales in the Bering Sea. J. Wildl. Manage. 46:1,036-1,044.
- Burns, J.J., L.H. Shapiro, and F.H. Fay. 1981. Relationship of marine mammal distribution, densities, and activities to sea ice conditions. Pages 489-670 in Environmental assessment of the Alaskan continental shelf. Final reports of principal investigators. Vol. 11. OCS Environmental Assessment Program, Boulder, CO.
- Carroll, G.M., and J.R. Smithhisler. 1980. Observations of bowhead whales during spring migration. Mar. Fish. Rev. 42:80-85.

- Davis, R.A., W.R. Koski, and G.W. Miller. 1983. Preliminary assessment of the length-frequency distribution and gross annual reproductive rate of the western arctic bowhead whale as determined with low-level aerial photography, with comments on life history. Unpubl. rept. from LGL for National Marine Mammal Laboratory, NMFS, Seattle, WA. 91 pp.
- Davis, R., and W.J. Richardson. 1985. Observations on the variable distribution of bowhead whales, <u>Balaena</u> <u>mysticetus</u>, in the vicinity of the "industrialized area" of the Canadian Beaufort Sea, 1976-1984. Abstract of the third conference on the biology of the bowhead whale, 21-23 January 1985, Anchorage.
- Durham, F.E. 1972. Greenland or bowhead whale. <u>In</u> Baleen whales in eastern North Pacific and arctic waters. Seattle: Pacific Search Press.
- Eschricht, D., and J. Reinhardt. 1866. On the Greenland right whale (<u>Balaena mysicetus</u>). Pages 1-50 in W.H. Flower, ed. Recent memoirs on the cetacea. London: Ray Society (Orig. publ. in Danish, 1861).
- Everitt, R., and B. Krogman. 1979. Sexual behavior of bowhead whales observed off the north coast of Alaska. Arctic 32:277-280.
- Foote, D.C. 1964. Observations of the bowhead whale off Point Hope, Alaska. M.S. on file, NMML, NMFS, NOAA, Seattle, WA. 73 pp.
- Fraker, M.A. 1979. Testimony on Beaufort Sea whales. LGL Ltd., Vancouver, B.C. 9 pp.
- Fraker, M.A., and J.R. Bockstoce. 1980. Summer distribution of bowhead whales in the eastern Beaufort Sea. Mar. Fish. Rev. 42:57-64.
- Frost, K.J., and L.F. Lowry. 1981. Feeding and trophic relationships of bowhead whales and other vertebrate consumers in the Beaufort Sea. Final rept. Contract No. 80-ABC-00160, submitted to NMML, NMFS, NOAA. 142 pp.
- Gusey, W.F. 1983. Bowhead: <u>Balaena</u> <u>mysticetus</u>. Environmental Affairs, Shell Oil Co. Houston, TX. 154 pp.
- Hazard, K.W., and J.C. Cubbage. 1982. Bowhead whale distribution in the southeastern Beaufort Sea and Amundsen Gulf, summer 1979. Arctic: 35:519-523.
- Hazard, K.W., and L.F. Lowry. 1984. Benthic prey in a bowhead whale from the northern Bering Sea. Arctic 37:166-168.
- Imm, J.L. 1980. BLM-Alaska OCS office endangered whale research program. Presented Aug. 26, 1980, to environmental impact studies program review of COPRDM.

- Krogman, B.D. 1980. Sampling strategy for enumerating the western arctic population of the bowhead whale. Mar. Fish. Rev. 42:30-36.
- Ljungblad, D.K. 1981. Aerial surveys of endangered whales in the Beaufort Sea, Chukchi Sea, and Northern Bering Sea. Naval Ocean Systems Center. Tech. Doc. 449. San Diego, CA.
- Ljungblad, D.K., S. Moore, and D.R. Van Schoik. 1985. Observed densities of bowhead whales, <u>Balaena mysticetus</u>, in the Beaufort, Chukchi and Bering seas from 1979 through 1983 as noted by aerial survey. Abstract of the third conference on the biology of the bowhead whale, 21-23 January 1985, Anchorage, AK.
- Lowry, L.F., K.J. Frost, and J.J. Burns. 1978. Food of ringed seals and bowhead whales near Point Barrow, Alaska. Can. Field Nat. 92:67-70.
- _____. 1980. Foods utilized by bowhead whales near Barter Island, Alaska, autumn 1979. Mar. Fish. Rev. 42:88-91.
- Lowry, L.F., and K.J. Frost. 1984. Foods and feeding of bowhead whales in western and northern Alaska. Sci. Rept. Whal. Res. Inst. 35:1-16.
- Lowry, L.F., K.J. Frost, D.G. Calkins, G.L. Swartzman, and S. Hills. 1982. Feeding habits, food requirements, and status of Bering Sea marine mammals. Council Doc. No. 19. NPFMC, Anchorage, AK. 292 pp.
- Marquette, W.M. 1977. The 1976 catch of bowhead whales (<u>Balaena</u> <u>mysticetus</u>) by Alaskan Eskimos, with a review of the fishery, 1973-1976, and a biological summary of the species. Proc. rept. Natl. Mar. Mammal Lab., NOAA. Seattle, WA. 80 pp.

_____. 1978. Bowhead whale. Pages 71-81 <u>in</u> D. Haley, ed. Marine mammals of eastern North Pacific and arctic waters. Seattle: Pacific Search Press.

- Marquette, W.M., and J.R. Bockstoce. 1980. Historical shore-based catch of bowhead whales in the Bering, Chukchi, and Beaufort seas. Mar. Fish. Rev. 42:5-19.
- Nemoto, T. 1966. <u>Thysanoessa</u> euphausiids, comparative morphology, allomorphosis, and ecology. Sci. Rept. Whales Res. Inst. 20:109-155.
- Nerini, M.K., H.W. Braham, W.M. Marquette, and D.J. Rugh. 1982. some aspects of reproduction in the bowhead whale (<u>Balaena mysticetus</u>). Rept. Int. Whal. Comm. Doc. SC/34/PS 9.
- Reeves, R.R., D.K. Ljungblad, and J.T. Clarke. 1984. Bowhead whales and acoustic seismic surveys in the Beaufort Sea. Polar Record 22:271-280.

Scoresby, W., Jr. 1820. An account of north arctic regions, with a history

and description of the northern whale fishery. Edinburgh: Archibald Constable and Co. 2 Vols. 551 pp.

- Tomilin, A.G. 1957. Animals of the USSR and adjacent countries. Vol. 9: Cetaceans. Moscow: Acad. Sci. USSR. 756 pp.
- Wursig, B. 1985. The behavior of undisturbed bowhead whales, <u>Balaena</u> <u>mysticetus</u> – a review of present knowledge. Abstract of the third conference on the biology of the bowhead whale, 21–13 January 1985, Anchorage, AK.
- Wursig, B, C.W. Clark, E.M. Dorsey, M.A. Fraker, and R.S. Payne. 1981. Normal behavior of bowheads. Pages 21-90 in W.J. Richardson, ed. Behavior, disturbance responses, and feeding of bowhead whales in the Beaufort Sea, 1980. LGL. Vancouver B.C.



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

Map 1. Range of Pacific walrus (Fay 1982)

- I. NAME
 - A. Common Name: Pacific walrus
 - B. Scientific Name: Odobenus rosmarus divergens (Illiger 1811)

II. RANGE

A. Worldwide

The single species of living walrus, <u>Odobenus</u> rosmarus, is holarctic in distribution and comprises six geographically isolated and morphologically different subpopulations centered in 1) the Hudson Bay-Davis Strait region, 2) eastern Greenland, 3) Svalbard and Franz Josef Land, 4) Kara Sea-Novaya Zemlya, 5) Laptev Sea, and 6) Bering and Chukchi seas (Fay 1982). Walruses from the first four areas are considered to be "Atlantic walrus" (<u>O. r. rosmarus</u>); those from the Bering and Chukchi seas are "Pacific walrus" (<u>0</u>. <u>r</u>. <u>divergens</u>); those from the Laptev Sea have been included in both subspecies by different authors and were put in their own subspecies, <u>0</u>. <u>r</u>. <u>laptevi</u>, by Chapskii (1940).

B. Statewide

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

C. Regional Distribution Maps

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

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



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

Nunivak Island to Kuskokwim and Bristol bays, depending on the extent of the ice (map 2) (Fay et al. 1984).

(For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Western and Interior regions.)

III. PHYSICAL HABITAT REQUIREMENTS

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

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

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

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

Floes of sufficient area and thickness (10 to over 100 m in diameter) are needed to accommodate hauled out groups, which may number hundreds of animals; these are usually thick, pressure-ridged floes. Open water or ice less than 20 cm thick between thicker floes is required to allow walruses to surface for air and to gain access to the water for feeding; no more than 80% of the water surface should be covered by thick ice (ibid.).

- 2. <u>Seasonal use</u>. Winter ice habitat is heavy ice located north of the ice front and in a loose pack; densely consolidated ice farther north is a barrier to winter walrus distribution (Burns et al. 1977). Summer ice habitat is near the southern edge of the pack ice, generally in the northern Chukchi Sea, and is characterized by multi-year floes and considerable open water (ibid.).
- 3. Functions of ice haulouts:
 - a. Escape from predators. The shifting nature of ice, as well as its location remote from most human activity, provides better refuge from human disturbance than terrestrial haulout areas (Fay 1982). Polar bears are the most numerous nonhuman predators of walruses in pack ice (ibid.).
 - b. <u>Protection from the elements</u>. Ice ridges provide shelter from wind, and ice cover moderates the severity of ocean waves in the immediate area (Burns 1981).
 - c. <u>Use as a resting platform</u>. Grooming, resting, basking, parturition, nursing, and molting take place on the ice.

The pack ice serves as the arena in which courtship display and breeding activities take place; and moving ice may serve as continuous transport to new feeding grounds (Fay 1982).

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

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

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

B. Types of Feeding Areas Used

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

C. Factors Limiting the Availability of Food During the southward fall migration, ice usually is too thin to be used for support; animals generally swim ahead of the ice, thus decreasing the amount of time they can feed (ibid.). Sessile bivalve mollusks are susceptible to excessive sedimentation and to pollution (Stoker 1981); activities that cause pollution or that alter sedimentation patterns will adversely affect the biomass of the food supply.

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

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

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

D. Feeding Behavior

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

Recent data from the central Bering Sea confirm that walruses can feed at greater depths, to at least 113 m (Fay, pers. comm.). Walruses are highly specialized for feeding on benthic bivalve mollusks (Fay 1982). They generally move snout-first along the bottom, dragging their tusks, and may search for visually conspicuous prey by sight as well as by "rooting" with snout and vibrissae for less obvious prey, not by digging with their tusks (Fay 1982). Instead, walruses may use a pulsing stream of water to excavate prey (Oliver et al. 1983). Hydraulic jetting, rooting, and consumption of prey during feeding bouts appear to leave a distinct record of furrows, pits, and discarded bivalve shells on the sea floor (ibid.). Continuous pit-furrow systems indicate the prey consumed in one dive; in one system, 34 clams had been consumed along more than 60 m of bottom. Dive times for that water depth averaged about five minutes (Fay 1982). suggesting that one walrus ate more than six clams per minute (Oliver et al. 1983). Prey are excavated before consumption; then soft parts of clams are sucked from between the two shells (Oliver et al. 1983, Vibe 1950).

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

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

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

- B. Reproductive Seasonality
 - Breeding takes place from December to March. Adult males are fertile from December to March; nonpregnant females are in estrus mainly from January to early March; a postpartum estrus takes place in June to August (Fay 1982). Males that are sexually potent but not yet physically mature reach their peak of testicular development about two months after fully adult males (ibid.). Implantation is delayed three to four months following mating. Calving takes place from mid April to mid June on stable ice in the central Bering and southern Chukchi seas (map 3) (Fay 1982, Fay et al. 1984).
- C. Reproductive Behavior

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

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

- D. Age at Sexual Maturity
 - Fay (1982) found that although some male walruses 1. Males. attain sexual potency as early as their seventh winter or spring, most become sexally mature in their eighth or ninth winter. In their eighth to tenth year, growth of secondary sexual characteristics begins (increased size of body, tusks, baculum, and thickening of the skin on neck and shoulders) and is completed by about age 15. They are probably then sufficiently large and powerful to compete successfully with other adult males for mates (ibid.). Captive walruses, which have no competitors, have sired their first calves in their tenth year, but wild walruses, which have many competitors, probably do not compete successfully for mates until they attain physical maturity (ibid.).
 - 2. <u>Females</u>. A few female walruses become pregnant for the first time at age 4; about two-thirds have ovulated at least once



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

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by age 6; and virtually all are fertile by age 10 (Fay 1982). Most "attain the peak of their reproductive performance" in their ninth or tenth year (Fay 1982).

E. Frequency of Breeding

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

F. Fecundity

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

G. Gestation Period

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

- H. Lactation Period
 - Fay (1982) reports:

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

VI. FACTORS INFLUENCING POPULATIONS

- A. Natural
 - 1. <u>Mortality</u>. Morbidity and mortality data through 1979 have been reviewed by Fay (1982), who remarked that "the walrus has the lowest known reproductive rate for a pinniped, is slow to mature, and has a long life-span. For those reasons, its rate of natural mortality probably is very low . . . the killing of walruses by man is a form of predation, and it appears to have been the most important single cause of death over the past 120 years or so." Other known predators of

walruses include polar bears, which reportedly take mainly calves, and killer whales, which take animals of all ages. Although many diseases and 16 species of parasites of walruses have been reported, they do not seem to be an important cause of death or illness (Fay 1982). Some walruses, especially calves, may be crushed or trampled when herds stampede off haulouts on ice or land in response to disturbance caused by humans or polar bears (ibid.). Fay and Kelly (1980) documented mass natural mortality on the Punuk Islands in the autumn of 1978; carcasses examined appeared to have been rolled and trampled.

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

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

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

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

VII. LEGAL STATUS

A. Federal

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

B. State

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

C. Population Management History

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

1. <u>Summary of harvest</u>. Pacific walruses are harvested by both the United States and the USSR. Coastal residents take about two-thirds of the Soviet harvest; about one third is taken by

a commercial high-seas fishery from large multipurpose vessels. The total Soviet harvest averaged about 5,000 animals per year in the 1940's and 1950's, decreased to about 900 per year from 1965-1971, increased again to 1,200-1,500 annually in the 1970's, and was approximately 4,000 animals in 1982 (Lowry 1984).

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

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

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

hunting by state regulation, the state returned responsibility for walruses to the federal government in August 1979.

- 3. Period of federal authority. After extreme exploitation of walruses by Yankee whalers in the mid-to-late 1800's and further depletion by "arctic traders" around the turn of the century, the United States government prohibited commercial taking of walruses in Alaskan territorial waters in 1909 (Madsen and Douglas 1957) and the taking of walruses for ivory alone in 1915 (Chandler 1943). The United States walrus harvest was further curtailed by the Walrus Act of 1941 (Fay 1982). In response to a second major population decline brought about by the increased Soviet harvest, the USSR enacted a decree for "security of the animals of the arctic" in 1956 and phased out the government-operated walrus hunting vessels by 1962 (ibid.). The USFWS now administers walruses for the federal government. (See section D. Current Population Management for more details.)
- 4. <u>International agreements</u>. Although Pacific walruses occur in both United States and Soviet waters, the two countries have no cooperative agreement for their management (Fay 1982). Research information is exchanged under the Marine Mammal Project (V.6) of the United States-USSR Environmental Protection Agreement of 1972, but walruses are still managed unilaterally (ibid.).
- D. Current Population Management
 - Under the MMPA of 1972 and amendments enacted in 1981, the USFWS is responsible for administering Pacific walruses, but it cannot manage by regulation or protection unless it can demonstrate that the population is depleted. Their overall goal for the walrus is "to conserve the Pacific walrus and its habitat while providing for beneficent human use" (USFWS 1982).
 - 1. <u>Management objectives</u>. The goals of the USFWS with regard to walruses are as follows (ibid.):
 - Maintain the Pacific walrus population within a range of 140,000 to 300,000 animals
 - ^o Monitor the harvest
 - ^o Determine effects of human activities, other than hunting, on walrus populations
 - [°] Minimize illegal take, trade, and use of walrus
 - Identify and protect essential walrus habitat to maintain populations within Optimum Sustainable Populations (OSP)
 - Maintain sufficient natural food supply to maintain OSP
 - ^o Minimize adverse impacts on the walrus population as a result of natural resource development activities
 - Provide for subsistence use as the primary consumptive use of the resource
 - Provide for regulated sport hunting use after subsistence needs are met

- Provide for other uses
- Develop effective communications between management agencies and both urban and rural inhabitants to improve mutual understanding of management objectives and regulations
- Promote public involvement and education in programs to conserve the walrus
- Promote a formal agreement between the United States and the USSR to conserve and manage the walrus and other pinnipeds of the Bering and Chukchi seas
- 2. <u>Management considerations</u>. Potential management problems identified by the USFWS (1982) include the following: The walrus population may have exceeded the carrying capacity of the habitat and probably will decline, perhaps rapidly. Increased human disturbance and harassment may disrupt reproductive behavior. Public concern over illegal take, trade, and use is intense

(harvest of walruses for ivory only, e.g., and the high percentage of walruses shot but not retrieved).

VIII. LIMITATIONS OF INFORMATION

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

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

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

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

REFERENCES

Burns, J.J. 1965. The walrus in Alaska, its ecology and management. ADF&G, Juneau. 48 pp.

. 1981. Ice as marine mammal habitat in the Bering Sea. Pages 781-798 in D.W. Hood and J.A. Calder, eds. The eastern Bering Sea shelf: oceanography and resources. Vol. 2. USDC: OMPA, NOAA. 1,339 pp.

Burns, J.J., L. Shapiro, and F. Fay. 1977. The relationships of marine mammal distributions, densities and activities to sea ice conditions. Annual report of the principal investigators for the year ending March 1977. RU-248. Pages 503-554 in Environmental assessment of the Alaska continental shelf. Vol. 1. USDC: NOAA, ERL; USDI: BLM.

- Chandler, E.W. 1943. The walrus gets a rest. Alaska Sportsman 9(2):14-15, 18. Cited in Fay 1984.
- Chapskii, K.K. 1940. Distribution of the walrus in the Laptev and East Siberian seas. Problemy Severa (Leningrad) 6:80-94.
- Fay, F.H. 1981. Walruses: <u>Odobenus rosmarus</u> (Linnaeus, 1758). Pages 1-23 in S. Ridgway and R. Harrison, eds. Handbook of marine mammals. Vol. 2. New York: Academic Press.
- _____. 1982. Ecology and biology of the Pacific walruses (Odobenus rosmarus divergens Illiger). N. Am. Fauna 74. USFWS. 279 pp.

_____. 1985. Personal communication. Professor, Univ. Alaska, Fairbanks.

- Fay, F.H., and B.P. Kelly. 1980. Mass natural mortality of walruses (<u>Odobenus rosmarus</u>) at St. Lawrence Island, Bering Sea, autumn 1978. Arctic 33:226-245.
- Fay, F.H., and L.F. Lowry. 1981. Seasonal use and feeding habits of walruses in the proposed Bristol Bay clam fishery area. Council Doc. 18, NPFMC, Anchorage. 60 pp.
- Fay, F.H., and S. Stoker. 1982. Reproductive success and feeding habits of walruses taken in the 1982 spring harvest, with comparisons from previous years. Final rept. to Eskimo Walrus Commission. 91 pp.
- Fay, F.H., B.P. Kelly, P.H. Gehnrich, J.L. Sease, and A.A. Hoover. 1984. Modern populations, migrations, demography, trophics and historical status of the Pacific walruses. Unpubl. final rept. RU-611. Environmental assessment of the Alaska continental shelf.
- Frost, K.J., L.F. Lowry, and J.J. Burns. 1982. Distribution of marine mammals in the coastal zone of the Bering Sea during summer and autumn. Unpubl. final rept. RU-613. Environmental assessment of the Alaska continental shelf. 166 pp.
- Gehnrich, P.H. 1984. Nutritional and behavioral aspects of reproduction in walruses. Unpubl. M.S. Thesis, Univ. Alaska, Fairbanks. 147 pp.
- Gol'tsev, V.N. 1975. Reproduction of the Pacific walrus. Pages 113-115 in Tezisy Doklad. Svesoiuz. Sovesch. Biol. Resur. Dal'n. Vost. Morei. TINRO, Vladivostok.
- Lowry, L.F. 1984. Personal communication. Marine Mammal Biologist, ADF&G, Fairbanks.

______. 1984. The Pacific walrus (<u>Odobenus rosmarus divergens</u>). In J.J. Burns, ed. Marine mammal species accounts. Wildl. Tech. Bull. No. 7. ADF&G, Juneau.

- Lowry, L.F., and F.H. Fay. 1984. Seal eating by walruses in the Bering and Chukchi Seas. Polar Biol. 3:11-18.
- Lowry, L.F., K.J. Frost, and J.J. Burns. 1980. Feeding of bearded seals in the Bering and Chukchi seas and trophic interactions with Pacific walruses. Arctic 33:330-342.
- Lowry, L.F., and K.J. Frost. 1981. Feeding and trophic relationships of phocid seals and walruses in the eastern Bering Sea. Pages 813-824 in D.W. Hood and J.A. Calder, eds. The eastern Bering Sea shelf: oceanography and resources. Vol. 2. USDC: OMPA, NOAA. 1,339 pp.
- Lowry, L.F., K.J. Frost, D. Calkins, G. Swartzman, and S. Hills. 1982. Feeding habits, food requirements, and status of Bering Sea marine mammals. Council Doc. 19. NPFMC, Anchorage. 291 pp.
- Madsen, C., and J.S. Douglas. 1957. Arctic trader. New York: Dodd, Mead. 273 pp. Cited in Fay et al. 1984.
- McDonald, J., H. Feder, and M. Hoberg. 1981. Bivalve mollusks of the south eastern Bering Sea. Pages 1155–1204 in D.W. Hood and J.A. Calder, eds. The eastern Bering Sea shelf: oceanography and resources. Vol. 2. USDC: OMPA, NOAA. 1,339 pp.
- Oliver, J.S., P.N. Slattery, E.F. O'Connor, and L.F. Lowry. 1983. Walruses, <u>Odobenus rosmarus</u>, feeding in the Bering Sea: a benthic perspective. Fish. Bull. 81:501-512.
- Ronald, K., J. Shelley, and P. Healy. 1982. Seals (Phocidae, Otariidae, and Odobenidae). Pages 769-827 in J. Chapman and G. Feldhamer, eds. Wild mammals of North America. Baltimore: Johns Hopkins Univ. Press.
- Stoker, S. 1981. Benthic invertebrate macrofauna of the eastern Bering/Chukchi continental shelf. Pages 1,069-1,090 in D.W. Hood and J.A. Calder, eds. The eastern Bering Sea shelf: oceanography and resources. Vol. 2. USDC: OMPA, NOAA.
- Taggart, J., and C. Zabel. 1982. Six summers on Round Island. Alaska Fish Tales/Game Trails 14:35-37.
- USFWS. 1982. Management plan for the conservation of the Pacific walrus. Unpubl. draft, Anchorage. 19 pp.
- Vibe, C. 1950. The marine mammals and the marine fauna in the Thule District (Northwest Greenland) with observations on ice conditions in 1939-41. Medd. om Grønl. 150(6):1-115.



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

- I. NAME
 - A. Common Name: Polar bear
 - B. Scientific Name: Ursus maritimus Phipps

II. RANGE

A. Worldwide

Polar bears are found only in the northern hemisphere and are distributed throughout the north polar basin, particularly in association with shorefast and drifting pack ice (Lentfer 1982). Although most abundant around the perimeter of the polar basin, generally within 200 to 300 km of land, polar bears have been found as far north as 88° north latitude and south to St. Matthew, Nunivak, and the Pribilof islands in the Bering Sea, James Bay and Newfoundland in Canada, southern Greenland, Iceland, and the Barents and Kara seas (ibid.). Polar bear densities are not uniform but are divided into six somewhat discrete groups centered at 1) Wrangel Island - western Alaska; 2) Cape Bathurst - northern Alaska; 3) northern Canadian archipelago; 4) Greenland; 5) Spitsbergen-Franz Joseph Land; and 6) central Siberia (ibid.). Statewide

Β.

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

C. Regional Distribution Maps

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

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

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

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

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

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

B. Terrestrial

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

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

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

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

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

C. Ice

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

IV. NUTRITIONAL REQUIREMENTS

- A. Food Species Used
 - Polar bears in Alaska feed primarily on ringed seals (Phoca hispida) and, to a lesser extent, on bearded seals (Erignathus (Elev barbatus) 1978, Amstrup 1984). Belukha whales (Delphinapterus leucas) and walruses (Odobenus rosmarus) are occasionally taken (Freeman 1973, Eley 1978, Killian and Stirling 1978), and carrion, including whale, seal, and walrus carcasses, scavenged frequently, especially along the coasts of is St. Lawrence Island and the northern Bering Sea (Eley 1978). In other areas, polar bears are known to occasionally eat small mammals, birds, eqgs, and vegetation when on land, especially in postdenning and summer periods (Russell 1975, Hansson and Thomassen 1983); however, the small amount of time that Alaskan polar bears spend on land makes these sources of food relatively unimportant (Lentfer, pers. comm.).
 - B. Types of Feeding Areas Used Polar bears feed primarily in the flaw zone but also hunt and/or scavenge on the shorefast ice, on land, on the drifting pack ice, and, occasionally, in open water (Stirling et al. 1975, Stirling and Archibald 1977, Stirling et al. 1981). Stirling (1980) noted that

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

Stirling et al. (1981) analyzed 627 sightings of polar bears or their tracks in the spring (March-May) of 1970-1979 in the western Canadian Arctic; 82% of all sightings were from floe edges and areas with 88% (7 oktas) or greater coverage of moving ice. Their analyses showed that adult males preferred moving ice; subadult males' preference was less pronounced but still significant; slightly more sightings occurred at floe edges. Adult females with cubs of the year preferred fast ice, as did subadult females, but to a slightly lesser extent. Observations of lone adult females and females with older cubs showed no significant difference in choice of ice habitat, but females with yearlings were found more often in areas with 88% (7 oktas) or greater coverage of moving ice, and females with two-year-olds were found more often at floe edges (ibid.).

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

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

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

C. Factors Limiting Availability of Food

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

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

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

D. Feeding Behavior

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

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

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

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

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

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

A. Reproductive Habitat

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

B. Reproductive Seasonality Male Alaskan polar bears show evidence of spermatogenesis from February through April (Lentfer and Miller 1969); pairs of an adult male and a female in estrous have been seen in Alaska through May (Lentfer et al. 1980) and, in Spitsbergen, Lønø (1970) observed mating or attempted mating through late June.

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

Mating in Alaskan polar bears therefore occurs mostly in March, April, and May. Ovulation is probably induced (Amstrup, pers. comm.) and implantation is delayed until about September (Lønø 1970). In late October or November, pregnant females seek out denning areas on land or on drifting sea ice, depending on ice movements and the speed of the freeze-up (Lentfer and Hensel 1980). Cubs are born in December or January, and the female and cubs break out of the dens in late March or early April (ibid.) Hansson and Thomassen (1983) studied bear families in Svalbard in the immediate postdenning period and found that the average time spent in the maternity den area after initial breakout was 14 days (range, 5-28 days). The females ate little, the cubs nursed, acclimated to outside temperatures, played, and developed their motor skills before moving out of the den area and onto sea ice (ibid.).

C. Reproductive Behavior

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

1

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

E. Frequency of Breeding

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

F. Fecundity

In the Alaskan Beaufort Sea, female polar bears usually give birth to two cubs, less often one, and rarely three (Lentfer et al. 1980). Mean litter sizes of cubs (observed sometime after leaving the den), yearlings, and two-year-olds were 1.58, 1.65, and 1.47, respectively (ibid.). DeMaster and Stirling (1983) feel that the average number of cubs born per litter is underestimated by these and other figures and developed a model to derive litter size at birth from the observed number of yearlings and two-year-olds per litter and the calculated survival rate of yearlings. When the model was applied to published North American population data, the estimated average number of cubs born per litter was between 1.70 and 1.98.

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

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

- VI. FACTORS INFLUENCING POPULATIONS
 - A. Natural

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

Changes in the abundance of seals may affect the distribution of polar bears as well as their reproductive and cub survival rates (Stirling et al. 1975, 1976, 1977; Lentfer 1983). In the Canadian Beaufort Sea during the winters of 1973-1974 and 1974-1975, numbers of ringed and bearded seals dropped by about 50% and their productivity by 90%. Numbers of adult polar bears declined markedly in the area, and the large reduction of yearlings observed in 1974 and 1975 indicated a high level of cub mortality prior to one year of age (ibid.). Both adult males and adult females have been observed eating cubs, but this is not common and is unlikely to be a major source of mortality (Uspenski and Kistchinski 1972, Belikov and Kuprijanov 1977, Lentfer 1982, Hansson and Thomassen 1983).

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

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

B. Human-related

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

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

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

VIII. LEGAL STATUS

A. Federal

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

B. State

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

- C. Population Management History
 - Summary of harvest. Within the Arctic and Western regions, the harvest of polar bears has ranged from 29 bears reported taken in 1979 to 405 bears reported taken in 1966 (Amstrup et al. in prep.). These figures are minimum estimates of harvest, especially after 1973, when implementation of the MMPA made reporting harvest voluntary (ibid.). Prior to the late 1940's, most polar bear hunting in Alaska was by Eskimos for food and hides for sale (Lentfer 1982). Based on fur export records for 1925-1953, estimated annual harvest averaged 117 bears (Lentfer 1982). Trophy hunting with the aid of aircraft began in the late 1940's, and the

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

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

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

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

 Ω

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

USFWS policies with respect to polar bears are as follows:

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

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

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

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

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

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

VIII. LIMITATIONS OF INFORMATION

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

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

REFERENCES

Amstrup, S.C. 1984. Project review. Alaskan polar bear research. Unpubl. rept. Denver Wildl. Res. Center, USFWS, Anchorage. 70 pp.

______. 1985. Personal communication. Polar Bear Biologist, Denver Wildl. Res. Center, USFWS, Anchorage.

- Amstrup, S.C., I. Stirling, and J.W. Lentfer. In press. Size and trend of Alaska polar bear populations. Wildlife Society bulletin.
- Belikov, S.E., and A.G. Kuprijanov. 1977. Behaviour of the polar bear in the Wrangel Island. Pages 40-54 in The polar bear and its conservation in the Soviet Arctic. Cent. Lab. Nat. Conserv., Moscow, USSR.
- Best, R.C. 1977. Ecological aspects of polar bear nutrition. Pages 203-211 in R.L. Phillips and C. Jonkel, eds. Proceedings of the 1975 predator symposium, Univ. Montana, Missoula, MT.
- DeMaster, D.P., and I. Stirling. 1983. The estimation of survival and litter size of polar bear cubs. Int. Conf. Bear Res. and Manage. 5:260-263.
- Eley, T.J. 1978. An analysis of polar bear predation on Alaskan iceinhabiting pinniped populations. Unpubl., ADF&G, Fairbanks. 11 pp.
- Fay, F.H. 1974. The role of ice in the ecology of marine mammals of the Bering Sea. Pages 383-399 in D.W. Hood and E.J. Kelly, eds. Oceanography of the Bering Sea with emphasis on renewable resources. Occas. Publ. No. 2, Inst. Mar. Sci., Univ. Alaska, Fairbanks.

_____. 1982. Ecology and biology of the Pacific walrus. N. Am. Fauna No. 74. USFWS, Washington, DC.

- Freeman, M.M.R. 1973. Polar bear predation of beluga in the Canadian arctic. Arctic 26:163-164.
- Furnell, D.J., and D. Oolooyuk. 1980. Polar bear predation on ringed seals in ice-free water. Can. Field-Nat. 94:88-89.
- Hansson, R., and J. Thomassen. 1983. Behavior of polar bears with cubs in the denning area. Int. Conf. Bear Res. and Manage. 5:246-254.
- Harington, C.R. 1968. Denning habits of the polar bear (<u>Ursus maritimus</u> Phipps). Can. Wildl. Serv. Rept. Ser. 5. 30 pp.
- Jonkel, C.J., G.B. Kolenosky, R.J. Robertson, and R.H. Russell. 1972. Further notes on polar bear denning habits. Pages 142–185 <u>in</u> S. Herrero, ed. Bears: their biology and management. IUCN Publ. New Ser. 23.
- Killian, H.P.L., and I. Stirling. 1978. Observations on overwintering walruses in the eastern Canadian high arctic. J. Mammal. 59:197-200.
- Kolenosky, G.B., and J.P. Prevett. 1983. Productivity and maternity denning of polar bears in Ontario. Int. Conf. Bear Res. and Manage. 5:238-245.
- Lentfer, J.W. 1972. Polar bear sea ice relationships. Pages 165-171 in S. Herrero, ed. Bears: their biology and management. IUCN Publ. New Series 23.

_____. 1974. Discreteness of Alaskan polar bear populations. Proc. Int. Congr. Game Bio. 11:323-329.

_____. 1975. Polar bear denning on drifting sea ice. J. Mammal. 56:716-718.

. 1976. Environmental contaminants and parasites in polar bears. Fed. Aid in Fish and Wildl. Rest., final rept. Proj. 5.5R. ADF&G, Juneau. 22 pp.

. 1982. Polar bear. Pages 557-566 <u>in</u> J. Chapman and G. Feldhamer, eds. Wild mammals of North America. Baltimore: The Johns Hopkins Univ. Press. 1,147 pp.

_____. 1983. Polar bear movements from mark and recovery. Arctic 36:282-288.

_____. 1985. Personal communication. Polar Bear Biologist (retired USFWS), Juneau, AK.

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- Lentfer, J.W., and R.J. Hensel. 1980. Alaskan polar bear denning. Pages 101-108 in C.J. Martinka and K.L. McArthur, eds. Bears: their biology and management. Government Printing Office, Washington, DC.
- Lentfer, J.W., R.J. Hensel, J.R. Gilbert, and F.E. Sorensen. 1980. Population characteristics of Alaskan polar bears. Pages 109-115 in C.J. Martinka and K.L. McArthur, eds. Bears: their biology and management. Government Printing Office, Washington, DC.
- Lentfer, J.W., and L.H. Miller. 1969. Report on 1968 polar bear studies. Fed. Aid in Wildl. Rest. Seg. rept. Projs. W-15-R-3 and W-17-1. ADF&G, Juneau. 29 pp.
- Lønø, O. 1970. The polar bear (<u>Ursus maritimus</u> Phipps) in the Svalbard area. Norsk Polarinst. Skrifter 149. 103 pp.
- Lowry, L.F., K.J. Frost, D.G. Calkins, G.L. Swartzman, and S. Hills. 1982. Feeding habits, food requirements, and status of Bering Sea marine mammals. NPFMC 19, Anchorage, AK.
- Martin, S.K., and C.J. Jonkel. 1983. Use of sea ice by polar bears. Int. Conf. Bear Res. and Manage. 5:255-259.
- Patten, S. 1985. Personal communication. Area Mgt. Biologist, ADF&G, Div. Game, Bethel.
- Russel, R.H. 1975. The food habits of polar bears of James Bay and southwest Hudson Bay in summer and autumn. Arctic 28:117-129.
- Stirling, I. 1974a. Polar bear research in the Beaufort Sea. Pages 721-733 in J.C. Reed and J.E. Slater, eds. The coast and shelf of the Beaufort Sea. Arct. Inst. North Am., Arlington, VA. 750 pp.
- _____. 1974b. Midsummer observations on the behavior of wild polar bears. Can. J. Zool. 52:1,191-1,198.
- _____. 1980. The biological importance of polynyas in the Canadian Arctic. Arctic 33:303-315.
- Stirling, I., D. Andriashek, P. Latour, and W. Calvert. 1975. The distribution and abundance of polar bear cubs in the eastern Beaufort Sea. A final report to the Beaufort Sea Project. Fisheries and Marine Service, Department of the Environment, Victoria, B.C. 59 pp.
- Stirling, I., and W.R. Archibald. 1977. Aspects of predation of seals by polar bears. J. Fish. Res. Bd. Can. 34:1,126-1,129.
- Stirling, I., R. Archibald, and D. DeMaster. 1977. Distribution and abundance of seals in the eastern Beaufort Sea. J. Fish. Res. Bd. Can. 34:976-988.

- Stirling, I., and P.B. Latour. 1978. Comparative hunting abilities of polar bear cubs of different ages. Can. J. Zool. 56:1,768-1,772.
- Stirling, I., A.M. Pearson, and F.L. Bunnell. 1976. Population ecology studies of polar and grizzly bears in northern Canada. Trans. N. Am. Wildl. Conf. 41:421-430.
- Stirling, I., D. Andriashek, and W. Calvert. 1981. Habitat preferences and distribution of polar bears in the western Canadian arctic. Rept. to Dome Petroleum Ltd., Esso Resources Ltd. and Can. Wildl. Serv. 49 pp.
- USFWS. 1982. Management plan for the conservation of the Alaskan polar bear. Anchorage, AK. 19 pp.
- Uspenski, S.M. 1977. The polar bear. Nauka, Moscow. 107 pp. (English transl. by Can. Wildl. Serv.)
- Uspenski, S.M., and A.A. Kistchinski. 1972. New data on the winter ecology of the polar bear (<u>Ursus maritimus</u> Phipps) on Wrangel Island. Pages 181-197 in S. Herrero, ed. Bears: their biology and management. IUCN Publ. New Ser. 23.



Ringed Seal Life History and Habitat Requirements Arctic Alaska

Map 1. Range of ringed seal (Frost 1984)

- I. NAME
 - A. Common Name: Ringed seal
 - B. Scientific Name: Phoca hispida hispida (King 1964)

II. RANGE

A. Worldwide

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

B. Statewide Seasonally, ringed seals range as far south as Nunivak Island and Bristol Bay and are abundant in the northern Bering Sea, Norton and Kotzebue sounds, and throughout the Chukchi and Beaufort seas (Frost 1984).

C. Regional Distribution Maps

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

D. Regional Distribution Summary

The ringed seal is a species primarily associated with ice. Although they can and do occur in all types of sea ice, the seasonal cycle of sea ice has a great effect on their distribution and regional abundance (Burns 1970, Frost 1984). During the summer, ringed seals range freely, most spending the summer season in the pack ice of the northern Chukchi and Beaufort seas, as well as in nearshore ice remnants in the Beaufort Sea. With the onset of freeze-up, their movements become increasingly winter Many seals that have summered in the Beaufort Sea restricted. move west and south with the advancing ice pack and disperse throughout the Bering and Chukchi seas. Some seals remain in the Beaufort, probably concentrating in areas of abundant prey (Lowry et al. 1980).

The distribution of ringed seals during the open water period is poorly understood because they spend virtually all of their time in the water feeding (Frost and Lowry 1984).

(For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Western and Interior regions.)

III. PHYSICAL HABITAT REQUIREMENTS

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

A. Aquatic

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

Water temperature does not appear to affect distribution, other than as it relates to ice formation.

B. Terrestrial Cover Requirements

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

C. Ice

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

 Winter and spring (November-June). During winter and spring, the highest densities of breeding adult seals occur on stable land-fast ice. During spring, subadults may be excluded from fast ice where adults, which may be territorial, are numerous during the pupping and breeding season. Subadults are the most numerous age group in the adjacent flaw zone (McLaren 1958, Burns 1970, Smith 1973). Throughout the pack ice, seals of all ages are found at low densities (Frost 1984).
 a. Lairs. Ringed seals use open leads and cracks in the

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

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

Smith and Stirling (1975) found two distinct types of lairs in the Admudsen Gulf and Prince Albert Sound areas. The most common type in both offshore and inshore areas were what they referred to as "haulout lairs," which are used for resting and consist of a single round or oval chamber. The second distinct type was termed the "birth lair," where pups are born and weaned, and consists of a network of tunnels made by the pup. Two major lair types were found in the Chukchi and Beaufort seas of Alaska (Frost, pers. comm.). These were single-chambered haulout lairs and multichambered "complex" lairs. Some complex lairs consisted of only two chambers and contained no evidence of a pup. Others consisted of 2 to as many as 10 chambers, with many small pup tunnels and pup chambers as well as other evidence of pups, such as claw marks, white pup hair, birth blood, or placenta.

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

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

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

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

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

C. Feeding Behavior

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

The ringed seal is probably not a deep diver; a depth of 600 ft is probably the limit for this species. In very deep water, seals feed on organisms in the upper part of the water column (Burns 1978). Fedoseev (1965) suggests that the cusps of the postcanine teeth are functional in filtering small organisms such as euphausiids from bites of water.

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

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

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

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

- D. Age at Sexual Maturity Sexual maturity occurs at about the same age in both males and females, between four and seven years of age. Female ringed seals may ovulate for the first time at three years of age, but successful pregnancy does not occur until the fourth to seventh year of life (ibid.).
- E. Frequency of Breeding Most ringed seals breed annually. For various reasons, such as intrauterine mortality, some females do not produce a pup each year (Frost 1984).
- F. Fecundity

A single pup is by far the most common, although twinning has been reported (Frost and Lowry 1981). The average for adult female ringed seals is one pup/1.2-1.4 years (Lowry et al. 1982). The observed pregnancy rates for seals in Alaska from 1975 through 1977 was 72% for females 7 years or older and 84% for those 10 years or older. The minimum estimated gross productivity is 16 to 18% (Frost 1984). G. Gestation Period

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

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

VI. FACTORS INFLUENCING POPULATIONS

A. Natural

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

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

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

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

B. Human-related

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

- Chronic debilitation due to ingestion or contact with petroleum or petroleum products
- * Mortality due to ingestion of petroleum products
- ° Displacement from preferred habitats due to disturbance
- Entanglement in fishing nets or marine debris
- ° Human harvest
- [°] Interference with intraspecific communication

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

- VII. LEGAL STATUS
 - A. Federal

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

B. State

The State of Alaska currently has no responsibility for ringed seals but may request return of management of 10 species of marine mammals, including ringed seals.

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

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

VIII. SPECIAL CONSIDERATIONS

- Molting occurs from late March until July, with the peak in June. Α. During this period, seals haul out on the fast ice as well as on relatively large flat floes in the pack, and feeding intensity is greatly reduced (Frost and Lowry 1981). Reproductively immature animals molt earlier than do breeding adults. Vibe (1950) found that older animals began to haul out about 10 days later than did young animals. He also found that early in the molt the maximum number of seals hauled out on ice occurred between 10:00 A.M. and The amount of time spent on the ice increases as the 3:00 P.M. molt season progresses because daylight and temperatures increase, and basking in the sun raises skin temperature for faster hair growth. Animals lose weight and may be physiologically stressed during the molt and therefore more susceptible to additional exogenous stress (Frost, pers. comm.).
- B. Vocalization

Four types of vocalization made by ringed seals were classified by Stirling (1973). Frost and Lowry (1981) suggested that because all four types were heard at all times of the year, it appears unlikely that any have a specific relationship to reproductive behavior. Stirling (1983), however, suggests that vocalizing probably serves an important role in the reproductive behavior of this species and that calls may be used for social organization and determining access to breathing holes.

IX. LIMITATIONS OF INFORMATION Mortality rates are difficult to estimate, although most causes of mortality are known (Frost 1984). It is unknown whether ringed seals use the same wintering and summering areas every year. Because of this gap in knowledge, the identity and degree of interchange between populations is unknown (Frost and Lowry 1981). It is not known whether or not ringed seals are food-limited (Lowry et al. 1980). The effects of human activity on ringed seals and their food species are inadequately known (Frost 1984). It has yet to be investigated how ringed seals locate food in the total darkness of the arctic winter (Frost and Lowry 1981).

REFERENCES

- ADF&G. 1977. A fish and wildlife resource inventory of southeastern Alaska. Vol. 1: Wildlife. Juneau. 239 pp.
- Andriyshev, A.P. 1954. Keys to the fauna of the USSR. Fishes of the northern seas of the USSR. No. 53. (Transl. from Russian by Israel Prog. Sci. Transl., Jerusalem, 1964.)
- Burns, J.J. 1970. Remarks on the distribution and natural history of pagophilic pinnipeds in the Bering and Chukchi seas. J. Mammal. 51:445-454.
- ______. 1978. Ice seals. Pages 192-205 <u>in</u> D. Haley, ed. Marine mammals of eastern North Pacific and arctic waters. Seattle: Pacific Search Press.
- Fedoseev, G.A. 1965. Food of the ringed seal (<u>Pusa hispida</u> Schr.). Izv. TINRO 59:216-223.
- Frost, K.J. 1985. Personal communication. Marine Mammal Biologist, ADF&G, Div. Game, Fairbanks.
- . 1984. The ringed seal (<u>Phoca hispida</u>). In J.J. Burns ed., Marine mammal species accounts. Wildl. Tech. Bull. No. 7. ADF&G, Juneau.
- Frost, K.J., and L.F. Lowry. 1981. Ringed, Baikal and Caspian seals: <u>Phoca hispida Schreber</u>, 1775; <u>Phoca sibirica Gmelin</u>, 1799; and <u>Phoca</u> <u>caspica Gmelin</u>, 1788. Pages 29-54 in S.H. Ridgeway and R.J. Harrison, eds. Handbook of marine mammals. Vol. 2: Seals. London: Academic Press.
- . 1984. Trophic relationships of vertebrate consumers in the Alaskan Beaufort Sea. Pages 381–401 in P.W. Barnes, D.M. Schell, and E. Reimnitz, eds. The Alaskan Beaufort Sea: ecosystems and environments. Orlando, Fl: Academic Press.
- King, J. 1964. Seals of the world. British Museum (Natural History), London. 154 pp.
Lowry, L.F., K.J. Frost, and J.J. Burns. 1979. Trophic relationships among ice-inhabiting phocid seals. Pages 573- 630 in Environmental assessment of the Alaskan continental shelf. Final reports of principal investigators. Vol. 6: Biological studies. ERL, Boulder.

_____. 1980. Variability in the diet of ringed seals, <u>Phoca hispida</u>, in Alaska. Can. J. Fish. Aquat. Sci. 37:2,254-2,261.

- Lowry, L.F., K.J. Frost, D.G. Calkins, G.L. Swartzman, and S. Hills. 1982. Feeding habits, food requirements, and status of Bering Sea marine mammals. Council Doc. No. 19. NPFMC, Anchorage. 292 pp.
- Lowry, L.F., and F.H. Fay. 1984. Seal eating by walruses in the Bering and Chukchi seas. Polar Biol. 3:11-18.
- Mansfield, A.W. 1967. Seals of arctic and eastern Canada. Fish. Res. Bd. Can. Bull. 137.
- McLaren, I.A. 1958. The biology of the ringed seal, <u>Phoca hispida</u>, in the eastern Canadian arctic. Fish. Res. Bd. Can. Bull. 118. 97 pp.
- Pastukhov, V.B. 1969. Onset of sexual maturity of the female ringed seal. Fish. Mar. Serv. Transl. Ser. No. 1474.
- Smith, T.G. 1973. Population dynamics of the ringed seal in the Canadian eastern arctic. Fish Res. Bd. Can. Bull. 181. 55 pp.
- _____. 1976. Predation of ringed seal pups (<u>Phoca hispida</u>) by the arctic fox (<u>Alopex lagopus</u>). Can. J. Zool. 54:1,610-1,616.
- Smith, T.G., and I. Stirling. 1975. The breeding habitat of the ringed seal (<u>Phoca hispida</u>) the birth lair and associated structures. Can. J. Zool. 53:1,297-1,305.
- Smith, T.G., and M.O. Hammill. 1981. Ecology of the ringed seal, <u>Phoca</u> <u>hispida</u>, in its fast ice breeding habitat. Can. J. Zool. 59:966-981.
- Stirling, I. 1983. Vocalizations in the ringed seal (<u>Phoca hispida</u>). J. Fish. Res. Bd. Can. 30:1,592-1,594.
- Vibe, C. 1950. The marine mammals and the marine fauna in the Thule district (Northwest Greenland) with observations on ice conditions in 1939-41. Medd. om. Gron. 150:1-115.



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

- I. NAME
 - A. Common Names: Brown bear, Kodiak bear, grizzly bear
 - B. Scientific Name: Ursus arctos
 - 1. Ursus a. horribilis and U. a. middendorffi are subspecies of Ursus arctos; the latter subspecies occurs only on the Alaska islands of Kodiak, Afognak, and Shuyak (Rausch 1963). All other brown/grizzly bears in North America belong to the first subspecies. In this report, all bears of the species Ursus arctos will be referred to as brown bears.
- II. RANGE
 - A. Statewide
 - Brown bears are distributed throughout Alaska, except on the islands south of Frederick Sound in Southeast Alaska, the islands

west of Unimak along the Aleutian chain, the islands of the Bering Sea, and several island groups south of the Alaska Peninsula and the Yukon-Kuskokwim delta (Eide 1978).

- B. Regional Distribution Maps
 - To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for each region. Most of the maps in this series are at 1:250,000 scale, but some are at 1:1,000,000 scale. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of selected fish and wildlife species has been prepared and may be found in the Atlas that accompanies each regional guide.
- D. Regional Distribution Summary
 - 1. Southwest. Brown bears are distributed throughout the Southwest Region, except on the islands west of Unimak along the Aleutian chain, the islands of the Bering Sea, and several island groups south of the Alaska Peninsula (such as the Semidis, Shumagins, Senaks, and the Yukon-Kuskokwim delta)(ADF&G 1976a). (For more detailed narrative information, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)
 - 2. Southcentral. Brown bears are distributed throughout the Southcentral Region, including Montague, Hitchinbrook, and Hawkins islands in Prince William Sound (ADF&G 1976b). Major ice fields, such as occur on the south side of the Kenai Peninsula and the Wrangell Mountains, are not considered brown bear habitat. (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)
 - 3. Arctic. Brown bears are found throughout the Arctic Region, with the exception of St. Lawrence Island and Diomede Island (ADF&G 1976c, 1976d). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Arctic Region.)
- III. PHYSICAL HABITAT REQUIREMENTS
 - A. Aquatic
 - Water is believed to be a necessary factor in brown bear habitat (USDA Forest Service 1975), but in Alaska water is not considered a limiting factor.
 - B. Terrestrial Cover Requirements
 - 1. Denning requirements. Most dens are excavated, although natural cavities are used to some extent when available (Reynolds et al. 1976, Craighead and Mitchell 1982). Den entrances are bare or may be enclosed by brush. Tunnels and chambers are commonly dug under the root systems of trees or shrubs or located beneath boulders or rock strata that provide roof support. Although den re-use may occasionally occur, most bears construct new dens each fall because most

excavated dens collapse after the spring thaw (Reynolds 1980, Craighead and Mitchell 1982).

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

а.

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

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

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

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

- b. <u>Southcentral</u>. Reported den locations of radio-collared bears in studies conducted along the Susitna River ranged in elevation from 635 m to 1,570 m and averaged 1,255 m. Typically, dens were dug in gravelly soil on moderately sloping (average 32°) southerly exposures. None of the radio-collared bears in these studies re-used the same den; however, many of these bears tended to den in the same general area in successive years (Miller and McAllister 1982, Miller 1983).
- c. Arctic. Studies conducted along the North Slope of the Brooks Range (Reynolds 1980) found radio-collared bears denning in a variety of terrain, ranging from creek banks at low (270 m) elevations to mountain slopes near the crest of the Brooks Range (1,280 m). Of 45 newly excavated dens located, most were found within the individual bear's home range; however, in 1978 four radio-collared bears denned from 16.1 km to 43.8 km from their spring, summer, and fall ranges. Additionally, three bears were not located and had presumably moved from their previously identified home ranges.

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

Den sites were located on all exposures. There were differences between 1977, when 72% of the dens (13 of 18) had a generally southern exposure, and 1978, when only 38% faced generally south. Wind direction and snow deposition were probably important factors in den site selection. All of the observed den sites were located in areas of snowdrift deposition. The depth of permafrost, which influenced the exposures selected by bears in the eastern Brooks Range (Reynolds et al. 1976), was not important in the North Slope study area, possibly because of the difference in soil types. Another factor that may be responsible for north- or south-facing den exposures is that the topographic character of the foothill area is dominated by a series of east-westrunning ridges that have northern and southern exposures, making the occurrence of these exposures highest (Reynolds 1980). There does not appear to be a pattern of selection of similar types of terrain, exposure, or elevation by individuals from year to year (ibid.).

IV. NUTRITIONAL REQUIREMENTS

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

A. Food Species Used

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

- Spring (mid April to early July). On Kodiak Island, the ADF&G (1976e) reported that brown bears "feed primarily on newly emerged plant species such as cow parsnip and red poque, sedges, horsetails, lupine, false hellebore, and grasses; they will also scavenge carion from winter kills of elk, deer and marine mammals . . . " Moose and/or caribou calves may be important food species for some bears on the Alaska Peninsula (Glenn 1975), in the Nelchina Basin (Spraker et al. 1981), and on the North Slope (Reynolds 1980). On the North Slope, Hechtel (1979) found viscid oxytroperoots (Oxytropis borealis), American hedysarum (Hedysarum alpinum), and the overwintered berries of alpine bearberry
- (Arctostaphylos rubra) to be the most important foods used. Summer (early July to mid August). On Kodiak Island, Atwell 2. 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 (Salix spp.). Alaska long-awned sedge was used predominantly. Red elderberry (Sambucus racemosa) and salmonberry (Rubus spectabilis) are heavily used on Kodiak. Bears feed heavily on red elderberries well before they On Afognak Island, bears feed upon huckleberry ripen. (Vaccinium ovalifolium) (Smith, pers. comm.). Sellers (pers.

comm.) indicated that <u>Carex lyngbyaei</u> is an important food source in estuarine areas on the Alaska Peninsula and that bears use the berries of devil's club (<u>Oplopanax horridum</u>) and seeds of cow parsnip. On the North Slope, Hechtel (1979) found that during the growing season brown bears seemed to concentrate on grasses and sedges, the leaves, stems, and flowers of boykinia (<u>Boykinia richardsonii</u>), and the fruiting and vegetative stems of common horsetails. Salmon (Oncorhynchus spp.) are used extensively when and

where they are available (Glenn 1975, Berns et al. 1980).

- 3. Fall (mid August to mid December). Crowberries (Empetrum nigrum), blueberries (Vaccinium uliginosum), soapberries (Shepherdia canadensis), and lowbush cranberries (Vaccinium vitis-idaea) are readily eaten when available (Murie 1944, Erickson 1965, Somerville 1965, Crook 1971, Pearson 1975, Reynolds 1976). Bears will shift back to hedysarum roots if berries are not abundant (Murie 1944, Dean 1957, Crook 1971, Valkenburg 1976, Reynolds 1976). Lupine roots and broomrape (Boschniakia rossica) roots are also preferred as foods by Kodiak bears. Also, deer (<u>Odocoileus hemionus sitkensis</u>) and elk (Cervus elaphus roosevelti) gut piles are becoming increasingly important fall foods on both Kodiak and Afognak islands as harvest of these animals increases (Smith, pers. comm.). Salmon remain important along coastal areas (Somerville 1965, Erickson 1965, Berns and Hensel 1972). Bears have been observed salmon fishing during December on the Alaska Peninsula (Glenn 1975). Hechtel (1979) found that hedysarum roots, alpine bearberry, and ground squirrels (Spermophilus parryii) were important foods for bears in the North Slope.
- B. Types of Feeding Areas Used
 - Spring. On the Alaska Peninsula, there was high use of the 1. coastal plain along the beaches, where bears searched for Grassland areas, especially grass dead marine mammals. flats, sedge meadows, and saltwater wetlands are also used extensively by foraging bears (Glenn and Miller 1980). In the Nelchina basin, Miller and McAllister (1982) found that spruce and shrubland vegetation types were used most during the spring. On the North Slope, bears were observed foraging along river courses and snow-free ridges and mountain slopes during early spring. During late spring, bears foraged along small creeks and moist drainages. In addition, during the breeding season (late May through mid July), bears were observed in all types of terrain, from tussock tundra to talus slopes (Reynolds 1980, Hechtel 1979).
 - 2. <u>Summer</u>. Anadromous fish streams along coastal areas (Somerville 1965, Erickson 1965, Berns and Hensel 1972, Glenn 1975, Glenn and Miller 1980, Smith and Van Daele 1982) and lowland areas (Berns et al. 1980) are frequently used by

bears. Atwell et al. (1980) reported that bears in the Kodiak NWR made extensive use of alpine habitat during summer. Sedge-forb meadows are used extensively on the Kodiak NWR (Atwell et al. 1980). In the Nelchina basin, brown bears tended to move to shrublands at higher elevations (Miller and McAllister 1982). On the North Slope, Hechtel found wet sedge meadows, late snowbank communities, and tussock tundra used most frequently.

- On the Alaska Peninsula and Kodiak Island, salmon 3. Fall. feeding areas continued 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, Glenn and Miller In the Nelchina basin, Miller and McAllister (1982) 1980). found that brown bears move to shrublands at higher elevations in late summer and early fall. On the North Slope, bears tended to use the floodplains of large creeks and rivers as well as dry ridge areas or mountain slopes with ground squirrel populations (Reynolds 1980, Hechtel 1979).
- C. Factors Limiting Availability of Food During spring, snow cover and depth can limit food availability. The size of the salmon escapement can be influenced by both natural factors and human management.

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

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

D. Activity Patterns

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

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

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

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

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

C. Reproductive Behavior

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

D. Age at Sexual Maturity

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

E. Fecundity

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

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

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

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

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

Source: Adapted from Modafferi 1984.

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

- b Mean litter size for 5.6-year-old litters.
- c Mean litter size for 3.5-year-old litters.
- d Aerial surveys along salmon streams.
- e Aerial surveys along salmon streams, excluding the Black Lake area.

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

F. Frequency of Breeding

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

- G. Gestation Period Including delayed implantation, gestation lasts about six months (Craighead et al. 1969).
- VI. FACTORS INFLUENCING POPULATIONS
 - A. Natural

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

B. Human-related

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

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

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

VII. LEGAL STATUS

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

VIII. LIMITATIONS OF INFORMATION

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

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

IX. SPECIAL CONSIDERATIONS

A. Homing

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

- B. Nuisance Bears Brown bears often become "nuisance" bears in the vicinity of villages, remote cabins/lodges, and work camps. These animals can cause extensive damage and may be dangerous to humans. Factors such as improper garbage disposal and poor siting of camps often intensify the problem, but proper procedures can often prevent the occurrence of the problem.
- C. Importance of Species Because the brown bears that occur in the Southwest Region are among the largest in the world they attract particular interest from hunters and viewers. The bears are considered a very important species economically to the guiding industry, air taxi services, and other related industries.

REFERENCES

ADF&G. 1976a. Alaska's wildlife management plans, Southwestern Alaska: a public proposal for the management of Alaska's wildlife. 238 pp.

_____. 1976b. Alaska's wildlife management plans, Southcentral Alaska: a public proposal for the management of Alaska's wildlife. 291 pp.

- _____. 1976c. Alaska's wildlife management plans, northwestern Alaska: a public proposal for management of Alaska's wildlife. 146 pp.
- _____. 1976d. Alaska's wildlife management plans, Arctic Alaska: a _____public proposal for management of Alaska's wildlife. 139 pp.

. 1976e. A fish and wildlife resource inventory of the Cook Inlet-Kodiak areas. Vol. 1: Wildlife [E.G. Klinkhart, comp.].

- Atwell, G.C., D.L. Boone, J. Gustafson, and V.D. Berns. 1980. Brown bear summer use of alpine habitat on the Kodiak National Wildlife Refuge. Pages 297-305 in Martinka and McArthur 1980.
- Aumiller, L. 1985. Personal communication. Game Technician, ADF&G, Div. Game, King Salmon.

- Ballard, W.B., S.D. Miller, and T.H. Spraker. 1982. Home range, daily movements, and reproductive biology of brown bear in Southcentral Alaska. Canadian Field-Naturalist 96(1):1-3.
- Berns, V.D., G.C. Atwell, and D.L. Boone. 1980. Brown bear movements and habitat use at Karluk Lake, Kodiak Islands. Pages 293-296 in Martinka and McArthur 1980.
- Berns, V.D., and R.J. Hensel. 1972. Radio-tracking brown bears on Kodiak Island. Pages 19-25 in Herrero 1972.
- Chapman, J., and G. Feldhamer, eds. 1982. Wild mammals of North America. Baltimore: Johns Hopkins Univ. Press.
- Cole, G.F. 1972. Preservation and management of grizzly bears in Yellowstone National Park. Pages 274-288 in Herrero 1972.
- Craighead, J.J., M.G. Hornocker, and F.C. Craighead, Jr. 1969. Reproductive biology of young female grizzly bears. J. Reprod. Fert., Suppl. 6:447-475.
- Craighead, F.C. 1976. Grizzly bear ranges and movement as determined by radio-tracking. Pages 97-109 in Pelton, Lentfer, and Folk 1976.
- Craighead, J.J., and F.C. Craighead. 1976. Grizzly bear-man relationships in Yellowstone National Park. Pages 304-332 in Herrero 1972.
- Craighead, J.J., and J.A. Mitchell. 1982. Grizzly bear (<u>Ursus arctos</u>). Pages 515-556 in Chapman and Feldhamer 1982.
- Crook, J.L. 1971. Determination of abundance and distribution of brown bear (<u>Ursus arctos</u>) north of the Brooks Range, Alaska. M.S. Thesis, Univ. Alaska, Fairbanks. 78 pp.
- Dean, F.C. 1957. Investigations of grizzly bears in interior and arctic Alaska. Rept. No. 1., work done in Mt. McKinley National Park, 1957. Rept. to Arctic Institute of North America. Unpubl. 40 pp.
- Egbert, A.L., and A.W. Stokes. 1976. The social behavior of brown bears on an Alaskan salmon stream. Pages 41-56 <u>in</u> Pelton, Lentfer, and Folk 1976.
- Eide, S.E. 1978. The brown bear in Alaska. ADF&G, Wildlife Notebook Series, Juneau. 2 pp.
- Erickson, A.W. 1965. The brown-grizzly bear in Alaska: its ecology and management. ADF&G, Juneau.

- Erickson, A.W., and D.B. Siniff. 1963. A statistical evaluation of factors influencing aerial survey results on brown bears. Trans. N. Am. Wildl. Conf. 28:391-407.
- Glenn, L.P. 1973. Report on 1972 brown bear studies. ADF&G, Fed. Aid in Wildl. Rest. prog. rept. Proj. W-17-4, Job 4.2. Juneau. 16 pp.

_____. 1975. Report on 1974 brown bear studies. ADF&G, Fed. Aid in Wildl. Rest. prog. rept. Proj. 4-17-6 & 7, Job 4.4. Juneau. 54 pp.

_____. 1984. Personal communication. Game Biologist, ADF&G, Div. Game, _____Anchorage.

- Glenn, L.P., J.W. Lentfer, J.B. Faro, and L.H. Miller. 1976. Reproductive biology of female brown bears, McNeil River, Alaska. Pages 381-390 in Pelton, Lentfer, and Folk 1976.
- Glenn, L.P., and L.H. Miller. 1980. Seasonal movements of an Alaska Peninsula brown bear population. Pages 307-312 in Martinka and McArthur 1980.
- Hensel, R.S., W.A. Troyer, and A.W. Erickson. 1969. Reproduction in the female brown bear. J. Wildl. Manage. 33:357-365.
- Hechtel, J. 1979. Behavioral ecology of a barren-ground grizzly bear female and her young in the National Petroleum Reserve, Alaska. Prelim. rept. Montana Coop. Wildl. Res. Unit. Univ. Montana, Missoula. 11 pp.
- Herrero, S., ed. 1972. Bears: their biology and management. IUCN New Ser. 23 (Morges).
- Lentfer, J.W., R.J. Hensel, L.H. Miller, L.P. Glenn, and V.D. Berns. 1972. Remarks on denning habits of Alaska brown bears. Pages 125-132 in S. Herrero 1972.
- Linderman, S. 1974. Ground tracking of arctic grizzly bears. Alaska Fed. Aid. in Wildl. Rest. rept. Proj. W-17-6, Job 4.12R. 17 pp.
- Martinka, C.J., and K.L. McArthur, eds. 1980. Bears: their biology and management. Bear Biol. Assoc. Conf. Ser. 3. 375 pp.
- Miller, S.D. 1984. Susitna Hydroelectric Project, 1983 annual report, big game studies. Vol 6: Black and brown bear. ADF&G, Anchorage. Unpubl. 174 pp.
- . 1983. Susitna Hydroelectric Project, Phase II, first annual report, big game studies. Vol. 6: Black and brown bear. ADF&G, Anchorage. Unpubl. 99 pp.

- Miller, S.D., and D.C. McAllister. 1982. Susitna Hydroelectric Project, Phase I, final report, big game stuides. Vol. 6: Black and brown bear. ADF&G, Anchorage. Unpubl. 233 pp.
- Miller, S.D., and W.D. Ballard. 1982. Homing of transplanted Alaskan brown bears. J. Wildl. Manage. 46(4):869-876.

Murie, A. 1944. The wolves of Mt. McKinley. NPS, Fauna No. 5. Wash., DC.

Pearson, A.M. 1975. The northern interior grizzly bear <u>Ursus</u> <u>arctos</u> L. Can. Wildl. Serv. Rept. Ser. 34. 84 pp.

_____. 1976. Population characteristics of the arctic mountain grizzly bear. Pages 247-260 in Pelton, Lentfer, and Folk 1976.

- Pelton, M.R., J.W. Lentfer, and G.E. Folk, eds. 1976. Bears: their biology and management. IUCN New Ser. 40 (Morges). 467 pp.
- Rausch, A.L. 1963. Geographic variation in size in North American brown bears, <u>Ursus arctos</u> L., as indicated by condylobasal length. Can. J. Zool. 41-33-45.
- Reynolds, H.V. 1976. North Slope grizzly bear studies. ADF&G, Fed. Aid Wildl. Rest. rept. Projs. W-17-6 and 7, Jobs. 4.8R-4.11R. Juneau. 20 pp.
- ______. 1980. North Slope grizzly bear studies. ADF&G, Fed. Aid Wildl. Rest. rept. Proj. W-17-11, Jobs 4.14R and 4.15R. Juneau. 65 pp.
- Reynolds, H.V., J.A. Curatolo, and R. Quimby. 1976. Denning ecology of grizzly bears in northeastern Alaska. Pages 403-409 <u>in</u> Pelton, Lentfer, and Folk 1976.
- Reynolds, H.V., and J.L. Hechtel. 1984. Structure, status, reproductive biology, movement, distribution, and habitat utilization of a grizzly bear population. ADF&G, Fed. Aid in Wildl. Rest. final rept. Projs. W-21-1 and 2, W-22-1 and 2, Job 4.14R. Juneau. 29 pp.
- Sellers, R.A. 1983. Personal communication. Area Mgt. Biologist, ADF&G, Div. Game, King Salmon.
- Smith, R.B. 1984. Personal communication. Area Mgt. Biologist, ADF&G, Div. Game, Kodiak.
- Smith, R.B., and L. VanDaele. 1982. Terror Lake Hydroelectric Project, report on brown bear studies. ADF&G, Anchorage. Unpubl. 110 pp.
- Somerville, R.J. 1965. An evaluation of the 1961-1963 Alaskan brown bear and grizzly bear management program. Thesis, Univ. Montana, Missoula. 117 pp.

- Spencer, D.L., and R.J. Hensel. 1980. An assessment of environmental effects of construction and operation of the proposed Terror Lake Hydroelectric Facility, Kodiak, Alaska. Brown bear studies and mountain goat studies. Arctic Environmental Information and Data Center, Univ. Alaska, Anchorage. 100 pp.
- Spraker, T.H., W.B. Ballard, and S.D. Miller. 1981. Game Management Unit 13 brown bear studies. ADF&G, Fed. Aid Wildl. Rest. rept. Projs. W-17-10, W-17-11, and W-21-1, Job 4.13R. Juneau, AK. 57 pp.
- Troyer, W.A., and R.J. Hensel. 1964. Structure and distribution of a Kodiak bear population. J. Wildl. Manage. 28(4):769-772.
- USDA Forest Service. 1975. Criteria for grizzly bear critical habitat identification: a state of the art compendium. USDA For. Ser., Reg. I, Missoula, MT. 18 pp.
- Valkenburg, P. 1976. A study of the brown bear (<u>Ursus arctos</u>) in the proposed northeastern addition to Denali National Park. M.S. Thesis, Univ. AK, College. 88 pp.

Caribou Life History and Habitat Requirements Southwest, Southcentral, and Arctic Alaska



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

- I. NAME
 - A. Common Names: Caribou
 - B. Scientific Name: Rangifer tarandus granti (Banfield 1961)
- II. RANGE
 - A. Statewide

Caribou are distributed throughout Alaska except in Southeast Alaska and along the Gulf of Alaska coast from Southeast Alaska to the Alaska Peninsula and most offshore islands (Hemming 1971).

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

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

although portions of the PH do remain in the state throughout the year, and it is not uncommon for much of the herd to winter in Alaska. The Teshekpuk Herd (TH) is a subpopulation that occupies the area surrounding Teshekpuk Lake year-round. (See figure 1 and volume 2 of the Alaska Habitat Management Guide for the Arctic Region for more specific distribution and abundance information.)

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

During summer, except for the arctic herds, which avoid marshy areas during mosquito season, caribou tend to concentrate their feeding activity in moist boggy areas where sedges (<u>Carex</u> spp.) predominate. Riparian areas are also important during the mid summer. During winter, aquatic vegetation, such as sedges and horsetails (<u>Equisetum</u> spp.), are heavily used along lake margins and streams. Muskrat pushups, which consist of a variety of aquatic vegetation, are frequented by wintering caribou (Skoog 1968), but the total food content is neglible (Valkenburg, pers. comm.). (See the caribou Distribution and Abundance narrative in volume 2 of the Alaska Habitat Management Guide for the Arctic Region for additional information on calving habitat, winter use habitat, and areas of insect relief.)

B. Terrestrial Cover Requirements

The use of ridge tops, frozen lakes and bogs, and other open areas for resting may be learned behavior related to predator avoidance that may have resulted from wolf-caribou interactions. The caribou's apparent reluctance to enter riparian willow (Salix spp.) stands and other heavy brush cover and its state of alertness when passing through such areas suggest that caribou associate such cover with attacks by wolves and bears (Miller 1982). On the arctic coastal plain, where riparian stands are sparse, caribou do not show any apparent avoidance behavior of heavy brush cover types (Cameron, pers. comm.).

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

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

- IV. NUTRITIONAL REQUIREMENTS
 - A. Food Species Used (from Skoog 1968, unless otherwise noted)
 - 1. Winter (mid October to mid April). Fruticose lichens (Cladonia spp. and Cetraria spp.), sedges, and grasses are heavily utilized. Willow (Pegau et al. 1973), horsetails, and dwarf shrubs (e.g., Vaccinium uliginosum) may be used to some extent. Though these plants may be used less by caribou during winter, they may be nutritionally significant.
 - 2. Spring (mid April to mid June). The catkins of willow (especially Salix alaxensis, S. planifolia ssp. pulchra, and S. glauca) are among the first of the new-growth vegetation to be eaten. Various grasses and sedges (notably Carex bigelowii, C. membranacea, C. podocarpa, and Eriophorum vaginatum) are also used extensively. Fruticose lichens continue to be eaten during spring if available and especially if the growing season is late. Resin birch (Betula glandulosa), and dwarf birch (B. nana), become the favored foods as the season progresses, as do horsetails, which are especially attractive. (See Kuropat 1984 for information on the early summer food habits of the WAH.)
 - 3. <u>Summer (mid June to mid August)</u>. 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 <u>Alopecurus</u>, <u>Arctagrostis</u>, <u>Dupontia</u>, <u>Festuca</u>, <u>Poa</u>, <u>Puccinellia</u>, <u>Calamagrostis</u>, and <u>Hierochloe</u>), forbs, and horstails 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 <u>Astragalus</u> <u>umbellatus</u>, <u>Lupinus</u> <u>arcticus</u>, <u>Hedysarum</u> <u>alpinum</u>, and <u>Oxytropis</u> <u>nigrescens</u>. The herbs <u>Gentiana</u> <u>glauca</u>, <u>Swertia</u> <u>perennis</u>, and <u>Sedum</u> <u>roseum</u> are highly palatable.

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

- 4. Fall (mid August to mid October). During the fall, the 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. <u>Carex aquatilis</u>, which lines the shores of lakes, ponds, and sloughs, appears to be an especially favored food item.
- B. Types of Feeding Areas Used
 - 1. <u>Winter</u>. Depending on the availability and location of habitat, spruce forests (primarily spruce/lichen associations), bogs, and lake shores are used extensively (ADF&G

1976). On the Alaska Peninsula's poorly drained coastal plains, areas where sedges are abundant are used (Hemming 1971). Ridge tops and high plateaus are also important.

- 2. <u>Spring</u>. Open terrain with gentle slopes and shallow U-shaped valleys are used (Bos 1974). Vegetation falls primarily into grass meadow (Hemming 1971), shrub birch, dwarf heath types, and sedge meadows (Skoog 1968).
- 3. <u>Summer</u>. Areas of use consist primarily of treeless uplands where heath tundra, alpine tundra, and sedge wetland associations dominate. In response to insect harassment, caribou frequently use wind-swept ridges and coastal areas (ibid.).
- 4. <u>Fall</u>. Caribou remain on or near summer ranges until the quantity and quality of forage significantly decreases and/or weather forces them to begin migration toward the wintering grounds (Hemming 1971). Because fall migration generally occurs during this period and feeding often occurs on the move, it is difficult to relate specific feeding locations to this period (Skoog 1968).
- C. Factors Limiting Availability of Food
 - 1. <u>Winter</u>. Snow depth of 50 mm (20 inches) is generally considered the upper limit for use of areas by caribou. Ice crust of 4 to 6.5 cm (1.5-2.5 inches) on top of the snow is considered the upper limit caribou can paw through to obtain food (Pruitt 1959, Skoog 1968, Pegau 1972, LaPerriere and Lent 1977).
 - 2. <u>Spring</u>. Calving-area selections by caribou have been, in part, attributed to early snowmelt and the consequent availability of new vegetation (Lent 1980). Should a late snowmelt or a late snowstorm occur, use of otherwise preferred early green-up vegetation may be restricted (Skoog 1968). Other factors that may influence utilization of an area for calving include drainage, proximity to insect relief habitat, and predator avoidance (Cameron, pers. comm.). (Also see Kuropat 1984 for information from the North Slope area.)
 - 3. <u>Summer</u>. Insect harassment can restrict caribou feeding by causing them to move about constantly or occupy areas such as snowdrifts, where food is unavailable (Skoog 1968, Miller 1982). In the arctic coastal beaches, river deltas and sand dunes are heavily used for relief from insect harassment.
 - 4. <u>Fall</u>. Increasing frost and/or snow in the high country decrease the quantity and quality of forage, in part triggering fall migration (Skoog 1968).
- D. Feeding Behavior
 - 1. <u>Winter and fall</u>. Winter and fall feeding generally occurs during the mid portions of the day and night. Caribou prefer the finer parts of plants, such as the upper portions of lichens, leaves and stem tips of sedges and grasses, and the

stem tips and buds of willows. Their cursory grazing habits help reduce the possibility of overgrazing the range (ibid.).

- 2. <u>Spring</u>. Spring feeding behavior is similar to that of winter, but with an increased use of leaves of willow and dwarf birch (ibid.).
- 3. <u>Summer</u>. Caribou select plant species according to the occurrence of greening leaf and flower buds (ibid.). Feeding occurs throughout the day, but because of insect harassment most feeding takes place during the cooler twilight hours (Miller 1982). (See Kuropat 1984 and White et al. 1975 for more detailed information on the North Slope.)
- V. REPRODUCTIVE CHARACTERISTICS
 - A. Reproductive Habitat
 - 1. <u>Breeding areas</u>. The rut usually takes place during fall migration and is sometimes accompanied by a pause or slowdown of movement. Breeding usually takes place in areas above timberline (Skoog 1968), although this has not been the case during most recent years for the Nelchina Herd (Pitcher 1984).
 - 2. <u>Parturition areas</u>. (See III.b., PHYSICAL HABITAT REQUIRE-MENTS, and IV.A.2., NUTRITIONAL REQUIREMENTS, Spring.)
 - B. Reproductive Seasonality
 - 1. <u>Breeding</u>. Breeding seasonality varies in different parts of the caribou range. In central and southern Alaska, caribou breeding occurs primarily during the first two weeks of October (ibid.).
 - 2. <u>Parturition</u>. In southwestern and southcentral Alaska, parturition generally occurs from early May through the first week of June, with a peak during the third or fourth week of May (ibid.).

For the arctic herds, calving begins in late May, peaks around the end of the first week of June, and is completed by mid June.

- C. Reproductive Behavior
 - 1. <u>Breeding</u>. Bulls do not gather harems but rather join existing bands of cows and young. One or more bulls tend to become dominant within the band, depending on the size of the group (ibid.). As the rut peaks, dominant bulls reduce their foraging markedly, concentrating instead on tending estrous females. Copulation is brief and generally occurs at dawn or dusk (Espmark 1964). By the end of the rut, adult bulls have depleted their fat reserves and enter winter in lean condition (Skoog 1968).
 - 2. <u>Parturition</u>. According to Lent (1966), Kelsall (1968), and Skoog (1968), cows do not actively seek isolation to give birth. Bergerud et al. (1984), however, indicated that caribou in Spatsizi Provincal Park, British Columbia, dispersed to high south slopes in mountains for calving as an antipredator tactic. The mother-young bond is initiated

within the first minutes of the calf's life and is necessary for the survival of offspring during the first six months of life (Miller 1982).

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

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

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).
- G. Lactation Period

Little is known about the actual weaning process (Miller 1982). Kelsall (1968) concluded that weaning must occur during July because biting insects would greatly disrupt nursing after July. Skoog (1968), however, suggested that weaning takes place between September and December and mostly occurs prior to November.

VI. FACTORS INFLUENCING POPULATIONS

A. Natural

Emigration, which may be density-related, can cause large fluctuations in herd sizes. Precipitation, cold, and wind were thought to be a deadly combination for newborn calves, resulting in hypothermia (Banfield 1954). At present, this supposition has been rejected, because there is little or no evidence to support it (Valkenburg, pers. comm.). Wolf and bear predation in some areas can be an important factor in population control (Skoog 1968, Bergerud 1978, Miller 1982, Gassaway et al. 1983). Fire has changed successional stages in large expanses of winter range but in fact may not have caused major fluctuations in population numbers. It is possible, however, that fire has caused shifts in habitat use by caribou herds (Skoog 1968).

B. Human-related

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

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

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

VII. SPECIAL CONSIDERATIONS

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

VIII. LEGAL STATUS

The Alaska Department of Fish and Game has regulatory authority over caribou. (See the Human Use section for a more detailed description of managerial considerations.)

IX. LIMITATION OF INFORMATION Because caribou are nomadic and therefore occupy various kinds of habitat at different times, it is difficult to accurately describe caribou habitat requirements. Causes of large population fluctuations in many instances are also still unclear. Finally, the effects of fire on caribou habitat and distribution are not clearly understood.

REFERENCES

- ADF&G. 1976. Alaska's wildlife management plans, Southcentral Alaska: a public proposal for the management of Alaska's wildlife. 291 pp.
- Banfield, A.W.F. 1954. Preliminary investigation of the barren-ground caribou. Can. Wildl. Serv. Wildl. Manage. Bull., Ser. 1, No. 10B. 112 pp.
 - _____. 1961. A review of the reindeer and caribou genus <u>Rangifer</u>. Nat. Mus. Can. Bull. 177, Bio. Ser. No. 66. 137 pp.
- Bergerud, A.T. 1978. Caribou. Pages 83-101 <u>in</u> J.L. Schmidt and D.L. Gilbert, eds. Big game of North America: ecology and management. Harrisburg, PA: Stackpole Books. 494 pp.
- Bergerud, A.T., H.E. Butler, and D.R. Miller. 1984. Antipredator tactics of calving caribou: dispersion in mountains. Can. J. Zoo. 62(8):1,566-1,575.
- Bos, G.N. 1974. Nelchina and Mentasta caribou reports. Vol. 2. Proj. prog. rept, Projs. W-17-5 and W-17-6, Job 3.1, and final rept., Proj. W-17-6, Job 3.2.
- Cameron, R.O. 1985. Personal communication. Game Biologist, ADF&G, Div. Game, Fairbanks.
- Dauphine, T.C., Jr. 1976. Biology of the Kaminuriak population of barren-ground caribou. Part 4: Growth, reproduction, and energy reserves. Can. Wildl. Serv., No. 38. 71 pp.

- Espmark, Y. 1964. Rutting behavior in reindeer (<u>Rangifer tarandus L</u>.). Anim. Behav. 12:420-426.
- Gasaway, W., R. Stephenson, and J. Davis. 1983. Wolf/prey relationships in Interior Alaska. ADF&G, Fairbanks. 15 pp.
- Hemming, J.E. 1971. The distribution and movement patterns of caribou in Alaska. ADF&G Tech. Bull. 1. Juneau. 60 pp.
- Kelsall, J.P. 1968. The migratory barren-ground caribou of Canada. Can. Wildl. Serv., Wildl. Manage. Bull. 3. 340 pp.
- Kuropat, P.J. 1984. Foraging behavior of caribou on a calving ground in northwestern Alaska. M.S. Thesis, Univ. Alaska, Fairbanks. 95 pp.
- LaPerriere, A.J., and P.C. Lent. 1977. Caribou feeding sites in relation to snow characteristics in northeastern Alaska. Arctic 30(2):101-108.
- Lent, P.C. 1966. Calving and related social behavior in the barren-ground caribou. Zeitschrift fur Tierpsychologie 23(6):701-756.
- . 1980. Synoptic snowmelt patterns in Arctic Alaska in relation to caribou habitat use. Pages 71-77 in E. Reimers, E. Gaare, and S. Skjenneberg, eds. Proceedings of the second international reindeer/caribou symposium, Roros, Norway. 799 pp.
- Miller, F.L. 1982. Caribou. Pages 923-959 in J.A. Chapman and G.A. Feldhamer, eds. Wild mammals of North America. Baltimore and London: The Johns Hopkins Univ. Press. 1,147 pp.
- Pegau, R.E. 1972. Caribou investigations analysis of range. ADF&G, Fed. Aid in Wildl. Rest., Proj. W-17-3. Juneau. 216 pp.
- Pegau, R.E., G.N. Bos, and B.A. Neiland. 1973. Caribou report. ADF&G, Fed. Aid in Wildl. Rest. proj. prog. rept. Proj. W-17-4, Jobs 3.3R, 3.5R, 3.8R (2nd half), and 3.9R; and Proj. W-17-5, Jobs 3.3R, 3.5R, 3.8R, and 3.9R.
- Pitcher, V.W. 1984. Caribou. ADF&G. Susitna Hydroelectric Project ann. rept. Vol. 4: Big game studies. 43 pp.
- Pruitt, W.O., Jr. 1959. Snow as a factor in the winter ecology of the barren ground caribou (Rangifer arcticus). Arctic 12 (3):159-179.
- Sellers, R.A. 1983. Personal communication. Area Mgt. Biologist, ADF&G, Div. Game, King Salmon.
- Skoog, R.O. 1968. Ecology of the caribou (<u>Rangifer tarandus granti</u>) in Alaska. Ph.D. Dissert., Univ. Cal., Berkeley. 699 pp.

- Taylor, K.P. 1984. Personal communication. Area Mgt. Biologist, ADF&G, Div. Game, Dillingham.
- Valkenburg, P. 1985. Personal communication. Game Biologist, ADF&G, Div. Game, Fairbanks.
- White, R.G., B.R. Thompson, T. Skoglund, S.J. Person, D.E. Russell, D.F. Holleman, and J.R. Luick. 1975. Ecology of caribou at Prudhoe Bay, Alaska. Pages 15-187 <u>in</u> Ecological investigations of the tundra biome in the Prudhoe Bay region, Alaska. Biol. Pap., Univ. Alaska. Special Rept. No. 2.



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

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

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

Dall sheep are distributed throughout suitable alpine habitat, generally above 2,500 ft, in major mountain ranges of Alaska, including the Brooks Range, the Alaska Range from the Canadian border to Lake Clark, the Wrangell Mountains, Chugach Mountains, Talkeetna Mountains, and portions of the Kenai Peninsula Mountains. Small discontinuous populations exist in the Tanana/Yukon uplands (Nichols 1978a, Heimer and Smith 1975).

- C. Regional Distribution Maps To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for each region. Most of the maps in this series are at 1:250,000 scale, but some are at 1:1,000,000 scale. These maps are available for reveiw in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of selected fish and wildlife species has been prepared and may be found in the Atlas that accompanies each regional guide.
- D. Regional Distribution Summary
 - 1. <u>Southcentral Region</u>. Dall sheep are found in the Kenai Peninsula, Chugach, Wrangell, and Talkeetna mountains. Population densities and compositions vary through the range. (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)
 - 2. Arctic Region. Dall sheep are distributed throughout the Brooks Range. In some areas, Brooks Range sheep are found at lower elevations than sheep found in other Alaskan mountain ranges. During aerial surveys in 1983, researchers observed sheep at elevations as low as 700 ft (Singer et al. 1983). Also, sheep have been observed at low elevations along the Noatak River (James, pers. comm.). Population densities and compositions vary by area; however, densities are generally higher in the eastern portion of the Brooks Range. (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Arctic Region.)

III. PHYSICAL HABITAT REQUIREMENTS

A. Terrestrial

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

1. <u>Winter</u>. In winter, sheep utilize southern exposures where available, which provide areas of shallow snow and maximum solar radiation for warmth (Murie 1944, Geist 1971). In some locations, however, sheep utilize other exposures where the wind exposes forage on ridges (Nichols, pers. comm.; Murie 1944). They will sometimes move from exposed slopes to protected cliff areas prior to storms (Heimer, pers. comm.) and occasionally gather together in cliff crevices or caves for warmth and to avoid strong winds (Geist 1971, Hoefs and Cowan 1979).

- 2. <u>Spring/lambing</u>. The spring range of Dall sheep is in general similar to their winter range, except that they move to lower elevations and more southerly exposures (Heimer, pers. comm.). Near Cooper Landing and at Indian, south of Anchorage, for example, sheep are known to use the low-elevation, south-facing slopes in the spring (Nichols, pers. comm.). South-facing cliffs and slopes are apparently very important in spring, affording maximum solar radiation for warmth and faster snowmelt (Geist 1971, Nichols 1978b). Preferred lambing areas are on the most precipitous, inaccessible cliffs available (Pitzman 1970, Hoefs and Cowan 1979).
- 3. <u>Summer</u>. Dall sheep habitat requirements during summer are essentially the same as at other periods, although they may tend to utilize shady areas and ridge tops more frequently to obtain relief from insect harassment (Murie 1944).
- **IV. NUTRITIONAL REQUIREMENTS**
 - A. Food Species Used

Heimer (1983), in his study of different quality sheep populations in the Alaska Range, determined that selection of forage species by sheep is seasonal and location-specific, indicating that caution should be used when extrapolating sheep food species from area to area. He concluded that sheep select different forage plants on different ranges, partly on the basis of their availability. Therefore, groups of plants, rather than individual plant species, offer a more tenable means of categorizing the forage used by sheep. Heimer (1983) classified these plant groups as follows: grass and sedge/leaves and stems; woody stems and associated green leaves; leaves of willow (Salix spp.) and mountain avens (<u>Dryas</u> spp.); forb basal parts (mainly <u>Oxytropis</u> spp. in the Alaska Range); and lichens and mosses.

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

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

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

- c. <u>Yukon Territory</u>. Hoefs and Cowan (1979) found that sage (<u>Artemisia</u> spp.) was an important winter food, along with grasses and sedges.
- 2. <u>Spring/lambing, preferred foods</u>. As mentioned, sheep generally move to lower elevations in early spring (April) to take advantage of vegetation exposed by the snowmelt. Overwintered snow-cured grasses and sedges and lignified cranberry stems and associated leaves and berries are important forage items at this time (Heimer 1983). As vegetation begins to grow again, grasses (Festuca spp.) and sedges are initially sought, and mountain-avens, willow, and Vaccinium spp. are utilized as soon as they leaf-out (Whitten 1975).
- 3. Summer, preferred foods:

Alaska Range. Whitten (1975) observed that sheep during a. summer feed primarily on the most palatable and nutritious plant parts, the leaves, buds, flowers, and herbaceous stems. Winters (1980) found that relatively few plant species formed the major portion of the summer diet. The most commonly used food species during summer in the Alaska Range included Dryas octopetala; several grasses, notably Festuca altaica and Hierochloe alpina; sedge microchaeta); willows (Salix (Carex polaris pseudopolaris and S. reticulata); and forbs (Epilobium latifolium, Oxyria digyna, and Geum rossii).

- b. <u>Kenai Mountains</u>. Nichols (1974) found on the Kenai Peninsula that sedges were occasionally more abundant and made up a larger portion of the summer diet than other commonly utilized grasses (<u>Hierochloe alpina</u> and Festuca spp.) and willows.
- B. Types of Feeding Areas Used

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

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

As winter progresses and snow becomes deeper and/or more crusted by the wind, sheep move to exposed wind-blown, snowfree ridges (Murie 1944, Geist 1971, Whitten 1975, Nichols 1978a).

Hoefs and Cowan (1979), observing Dall sheep in the Yukon Territory, found that 49% of all winter feeding occurred in areas of no snow, 21% in areas with snow less than 5 cm (1.9 inches), and 17% in areas with snow up to 10 cm (3.9 inches). About 9% of all feeding occurred in areas with

snow up to 15 cm (5.9 inches), 2.4% in snow depths up to 20 cm (7.9 inches), and less than 1% in areas where snow depths were between 20 and 30 cm (7.9 to 11.8 inches).

- Spring. Sheep move to lower-elevation, snow-free southern slopes, and even into shrub tundra areas at the base of mountains to utilize early plant growth (Whitten 1975, Murie 1944). The winter-cured vegetation may have nutritional values comparable to late-summer vegetation (Whitten 1975; Heimer, pers. comm.).
- 3. <u>Summer</u>. Virtually all sheep range is available at this time; however, a general trend is for the sheep to move gradually up-slope, following the new plant growth, which is highly nutritious, mainly using southern slopes but also other aspects. In late summer, feeding is extended to northern slopes, where green plant growth occurs later (Whitten 1975).
- C. Factors Limiting Availability of Food
 - <u>Winter</u>. Heimer (pers. comm.), during his observations of Dall sheep in the Alaska Range, found that snow over 18 inches deep forced sheep to forage on wind-swept higher ridges for less readily available, less nutritious food species.

Nichols (1974), in his study on the Kenai Peninsula, determined that snow hardness appeared to be more important than snow depth; however, both factors combine to limit digging activity by sheep. Most digging for forage occurred in areas where snow was less than 1 ft deep. Wind-blown snow develops a crust that is difficult for sheep to paw through (Geist and Petocz 1977, Nichols and Erickson 1969).

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

- 2. <u>Spring</u>. Whitten (1975) speculated that sheep utilize areas of early green-plant growth to maximize their nutrient uptake.
- D. Feeding Behavior

1.

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

1. Winter. Pawing or cratering in snow by sheep allows access to forage plants underneath. Sheep will feed in one crater, enlarge it, gaining access to all forage plants, then move to another site and create another crater (Geist 1971, Nichols and Heimer 1972). Smaller or less dominant animals are sometimes forced to move from feeding craters by older or larger sheep (Nichols and Heimer 1972). Feeding craters on the Kenai were dug in snow up to 10 inches deep (ibid.). Murie (1944) reported that sheep had pawed through snow up to 14 inches deep.

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

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

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

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

- 1. Interior: Alaska Range-Dry Creek. Seasonal use of this lick occurs from mid May through early July, with the peak of use varying but usually occurring from the first to the third week of June (ibid.). Ewe fidelity, or annual return to the lick, was 100%; ram fidelity was 80% (ibid.). Rams begin use in mid May-early June, followed by juveniles, and then ewes and lambs in late June-early July (ibid.). Rams and ewes without lambs spent an average of four days at the lick. Ewes with lambs spent an average of six and one-half to seven days (ibid.).
- 2. <u>Southcentral</u>: <u>Watana Hills-Jay Creek</u>. Seasonal use of this lick occurs as early as 11 May through at least 10 August, with peak use occurring from mid May through June (Tankersley 1984). At least 31% of the estimated area sheep population visited this lick (ibid.). Rams begin lick use in early May, followed by ewe/yearling groups in late May and ewes and lambs in mid June (ibid.).
- 3. <u>Arctic: Brooks Range-Hulahula River</u>. Seasonal lick use occurs from April through October and perhaps all year, with peak use occurring in June (Spindler 1983). Rams utilized
the lick primarily before 26 June, with ewes, lambs, and yearlings increasing after that (ibid.).

Spindler (ibid.) observed a major change in the lick use pattern during 1980. Prior to 26 June, rams composed a substantial portion of the total sheep observed at the lick; after that date rams were seen less frequently. Spindler thought that increased daily temperatures and insect activity caused rams and other sheep to use higher elevations (greater than 1,400 m), away from the lick.

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

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

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

- B. Breeding Seasonality The peak of breeding activity extends approximately from mid November through mid December (Nichols 1978b). The lambing period extends from late May through mid June (ibid.). The estimated peak date of lambing on the Kenai Peninsula was 24 May (ibid.).
- C. Breeding Behavior

Breeding is polygamous and is conducted mostly by dominant rams (Geist 1971, Nichols 1978b). Dominance among rams is determined in September and October by a complicated display ritual and occasional combat (Geist 1971). The physical effort expended by dominant rams during breeding depletes their energy reserves, leaving them in poor physical condition. A severe winter may result in the death of these individuals (ibid.).

- D. Age at Sexual Maturity Rams are sexually mature at 18 to 30 months; however, dominance order usually prevents breeding until rams are six to eight years old (Nichols 1978b). Ewes are sexually mature at 18 to 30 months (ibid.).
- E. Fecundity Single births are usual, although twinning has been reported rarely (ibid.). The gestation period is approximately 171 days (ibid.).
- F. Frequency of Breeding Ewes can produce one lamb a year (ibid.). Under some conditions, ewes produce only one lamb every other year (Heimer 1983).

VI. FACTORS INFLUENCING POPULATIONS

A. Natural

Deep snow and severe icing conditions appear to be major factors in limiting sheep populations in maritime areas (Nichols 1978a, Murie 1944).

Wolves may be a major predator in areas where the wolf population is high and/or escape terrain is limited (Murie 1944, Heimer and Stephenson 1982). Predation by bears, coyotes, lynx, and other predators occurs but appears to be minimal (ibid.). Golden eagles are thought to be serious predators of lambs during their first few weeks of life (Heimer, pers. comm.; Hoefs and Cowan 1979). Major diseases and parasites associated with Dall sheep in Alaska include contagious ecthyma, lungworm-pneumonia complex, mandibular osteomylitis (lumpy jaw), and several species of gastro-intestinal helminth worms (Neiland 1972).

B. Human-related

The most serious human-related threat to Dall sheep in Alaska comes in the form of introduced diseases from domestic sheep. Wild animal populations seldom have the defenses necessary to withstand introduced diseases. These introductions were responsible for most of the decimation of wild sheep populations in the western United States (Heimer 1983). Other human-related factors influencing sheep populations are the following:

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

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

VII. LEGAL STATUS

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

VIII. LIMITATIONS OF INFORMATION

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

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

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

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

- Bee, J.W., and E.R. Hall. 1956. Mammals of northern Alaska. Museum of Natural History, Univ. Kansas, Lawrence, Kansas. Misc. Publ. No. 8.
- Geist, V. 1971. Mountain sheep: a study in behavior and evolution. Chicago and London: Univ. Chicago Press. 371 pp.
- Geist, V., and R.G. Petocz. 1977. Bighorn sheep in winter: do rams maximize reproductive fitness by spatial and habitat segregation from ewes. Can. J. Zool. 55(1):1,802-1,810.
- Heimer, W.E. 1973. Dall sheep movements and mineral lick use. ADF&G, Fed. Aid in Wildl. Rest. final rept. Projs. W-17-2 through 5, Job 6.1R.
- ______. 1983. Interior sheep studies. Fed. Aid in Wildl. Rest. final rept. Projs. W-17-8, 9, 11, and W-21-1 and 2, Job 6.12R.

_____. 1984. Personal communication. Game Biologist, ADF&G, Div. Game, Fairbanks.

- Heimer, W.E., and A.C. Smith. 1975. Dall ram horn growth and population quality and their significance to Dall sheep management in Alaska. Tech. Bull. 4. 41 pp.
- Heimer, W.E., and R.O. Stephenson. 1982. Responses of Dall sheep populations to wolf control in interior Alaska. Pages 320-329 in J.A. Bailey, ed. Proceedings of the third biennial symposium on northern wild sheep and goat council, March 17-19, 1982, Ft. Collins, CO.
- Hoefs, M., and I.M. Cowan. 1979. Ecological investigation of population of Dall sheep. Synesis, vol. 23, supplement 1. 81 pp.
- James, D. 1985. Personal communication. Area Mgt. Biologist, ADF&G, Div. Game, Kotzebue.
- Murie, A. 1944. The wolves of Mt. McKinley. NPS Fauna Ser. No. 5. USDI. 238 pp.
- Neiland, K.A. 1972. Sheep disease studies. ADF&G, Fed. Aid. in Wildl. Rest. prog. rept. Vol. 1. Proj. W-17-3, Job 6.6.R.
- Nichols, L. 1974. Sheep report. ADF&G, Fed. Aid in Wildl. Rest. prog. rept. Vol 15. Proj. W-17-5, Jobs 6.3R, 6.6R, and 6.7R; and Proj. W-17-6, Jobs 6.3R, 6.4R, 6.5R, and 6.7R.

______. 1978a. Dall's sheep. Pages 173-189 in J.L. Schmidt and D.L. Gilbert, eds. Big game of North America. Harrisburg, PA: Stackpole Books.

_____. 1978b. Dall sheep reproduction. J. Wildl. Manage. 42(3):570-580.

- Nichol, L., and W. Heimer. 1972. Sheep report. ADF&G, Fed. Aid in Wildl. Rest. prog. rept. Vol. 13. Proj. W-17-3, Jobs 6.1R through 6.5R; and Proj. W-17-4, Jobs 6.1R through 6.5R and 6.7R.
- Pitzman, M.S. 1970. Birth behavior and lamb survival in mountain sheep in Alaska. M.S. Thesis, Univ. Alaska, Fairbanks. 116 pp.
- Singer, F.J., D. Johnson, and R. Quimby. 1983. Dall sheep numbers and distribution in the Noatak National Preserve, 1983. NPS, Alaska Region. Natural Resources Survey and Inventory Rept. AR-83. Anchorage, AK.
- Spindler, M.A. 1983. Dall sheep mineral lick use and age and sex composition in selected river drainages, Arctic National Wildlife Refuge, 1979-1982. ANWR final rept. FY83. USFWS, Fairbanks, AK. 52 pp.
- Tankersley, N.G. 1984. Susitna Hydroelectric Project final report: big game studies. Vol. 8: Dall sheep. ADF&G, Anchorage.
- Whitten, K.R. 1975. Habitat relationships and population dynamics of Dall sheep (<u>Ovis dalli dalli</u>) in Mt. McKinley National Park, Alaska. M.S. Thesis, Univ. Alaska, Fairbanks. 177 pp.
- Winters, J.F. 1980. Summer habitat and food utilization by Dall's sheep and their relations to body and horn size. M.S. Thesis, Univ. Alaska, Fairbanks. 129 pp.

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



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

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

The Alaskan moose (Alces a. gigas) is distributed throughout most of Alaska, western Yukon Territory, and northern British Columbia (Franzmann 1978).

B. Statewide Moose are distributed throughout Alaska except for portions of the southeastern Panhandle, the southwestern Alaska Peninsula, most offshore islands, and glaciated areas. In Southeast Alaska, moose are found on the Malaspina forelands, Yakutat forelands, the river valleys between Haines and the Canadian border, Berners Bay and Taku River, the Stikine River valley, and other drainages abutting Canadian herds (ADF&G 1976a,b,c). Moose are generally found at or below 4,000 ft elevations (Ballard and Taylor 1980, Ballard et al. 1984).

C. Regional Distribution Maps

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

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

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

4. Interior and Western. Moose are distributed throughout the Interior and Western regions, with the exception of the Yukon-Kuskokwim delta, where they are infrequently seen (LeResche et al. 1974, ADF&G 1976f). Moose were generally unknown to most early residents of the Kuskokwim River drainage and were rarely seen along the Middle Yukon until the early 1900's. During the 1920's and 1930's, the moose population gradually expanded throughout the upper Kuskokwim and middle Yukon (ADF&G 1976f). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Western and Interior regions.)

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

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

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

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

- 3. <u>Summer</u>. Generally, moose feed in open areas and use the bordering shrubs and forest for cover (LeResche 1966). Calves, however, tend to avoid exposed areas in which cows browse and graze (Stringham 1974). Moose only occasionally bed down in open wet meadows, preferring the drier ground among hummocks near the edges of willow, spruce, and mixed forest stands (LeResche 1966).
- 4. Generally, moose tend to occupy higher open areas Fall. during the rut. Ballard and Taylor (1980) found that moose occupied willow habitats more during September, October, and December than through the remainder of the year in the upper Susitna valley. Most moose collared during the winter along the lower Susitna River floodplain did not spend the rut period in or near their winter ranges. Most rutted to the west of the floodplain, with some individuals as far as 40 km away from the Susitna River (Modafferi 1984). Generally, rutting concentrations of moose occur at or above timberline, but they occur at lower elevations also. Early snows may force moose to move to wintering areas, and, conversely, warm weather may enable them to linger in summering areas.
- **IV. NUTRITIONAL REQUIREMENTS**
 - A. Food Species Used
 - 1. Winter. Deciduous shrubs and trees protruding through accumulated snow on the ground and within reach of moose are the primary food in winter. In some areas, however, moose crater in snow to obtain nonbrowse forage such as ferns (LeResche and Davis 1973, Modafferi 1984). Several willow species are preferred, but the order of preference varies from area to area (Scott et al. 1958, Peek 1974). On the Kenai Peninsula, littletree willow (S. arbusculoides) is most preferred, followed by scouler willow (S. Scouleriana) and bebb willow (S. bebbiana) (Machida 1979). Barclay willow was (S. barclayi) least preferred. In Interior Alaska, the order of preference is feltleaf willow (S. alaxensis), diamondleaf willow (S. planifolia ssp. pulchra), with scouler willow and halbred willow (S. hastata) preferred least (ibid.). After willow, the most preferred browse is paper birch (Betula papyrifera) (LeResche and Davis 1973).

Because of the quantity of forage it produces, quaking aspen (<u>Populus tremuloides</u>) is also considered important in certain areas (Aldous 1944).

Foliose lichens (<u>Peltigera</u> 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. <u>Spring</u>. Willows are the most important food in spring. Horsetails (<u>Equisetum</u> spp.), sedges (<u>Carex</u> spp.), and aquatic plants are also important (Rausch 1967). On the Kenai Peninsula in late April and during May, foliose lichens and fruticose lichens (<u>Cladonia</u> spp.) made up more than half the diet of tame moose, with lowbush cranberry making up the remainder of the diet (LeResche and Davis 1973).
- 3. <u>Summer</u>. Variety in the diet is greatest during summer. During this period, emergent vegetation and other herbaceous plants may be grazed, but leaves and succulent leaders on shrubs and trees are also used (Coady 1982). Newly emergent aquatic and marsh plants, including sedges, horsetails, and pondweed (<u>Potomogeton</u> spp.), which are found in wetlands, lakes, and ponds in water up to 8 ft deep, are consumed (LeResche and Davis 1973, LeResche 1966). During early growth stages, forbs such as fireweed (<u>Epilobium</u> spp.) and lupine (Lupinus spp.) are heavily used. <u>Mushrooms</u>

spp.) and lupine (<u>Lupinus</u> 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. <u>Fall</u>. During fall, the transition from summer forage to winter forage occurs. The use of browse increases as fall progresses because many herbaceous plants become unpalatable.
- B. Types of Feeding Areas
 - 1. Winter. Shrub communities, such as alpine and lowland willow stands, are the most important winter habitat for food (LeResche et al. 1974, Peek 1974). When snow depths are minimal, moose generally prefer more open shrub-dominated areas and sedge meadows (Coady 1982). As snow depths increase, moose shift to coniferous and deciduous forests with closed canopies, when available, where snow accumulation is less (Coady 1976, Gasaway 1977) and understory vegetation more available (LeResche and Davis 1973).

Mature, undisturbed plant communities, occurring both in upland areas near timberline and in lowland areas, are important late winter habitat, as are areas recovering from man-caused or natural disturbances. Moose may remain on their summer range if not forced out by deep snow (Ballard and Taylor 1980). During late winter, some moose may remain at higher elevations, where wind action or temperature inversions reduce snow depth. Moose may crater through snow up to 40 cm deep (Coady 1982, Modafferi 1984).

Generally, upland areas of winter habitat are dominated by willow or shrub birch (<u>Betula glandulosa</u>) and lowland areas by stands of spruce interspersed with deciduous tree stands and wetland areas (ibid.).

2. <u>Spring</u>. Expanses of wetlands interspersed with dense stands of trees and shrubs, which are typically used for calving, provide abundant early spring forage (ibid.). Moose use natural mineral licks in some areas of Interior Alaska mostly in spring and early summer to obtain sodium (Tankersley and Gasaway 1983). Mineral licks used by moose occur in some areas of Southcentral Alaska also; however, there are no detailed reports on these areas (Tankersley, pers. comm.). No licks are known in Southwest Alaska. Studies in Michigan and Canada indicate that aguatic

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

- 3. <u>Summer</u>. Timberline shrub thickets (LeResche et al. 1974) and lowland areas with ponds containing preferred aquatic species (LeResche 1966) comprise primary feeding locations during the summer. (See comment on salt licks under B. 2.) In mid-to-late summer, moose tend to move to upland areas away from bog areas with standing water and to use browse in drier areas (Bishop, pers. comm.; Didrickson and Taylor 1978; Ballard et al. 1984).
- 4. <u>Fall</u>. Both lowland and upland shrub communities may be heavily used during fall (Coady 1982). In Southcentral Alaska, moose typically use upland areas (Ballard and Taylor 1980, Didrickson and Cornelius 1977).
- С. Factors Limiting Availability of Food Coady (1974) considered snow depth the most important limiting factor for moose. Migration between summer and winter range and daily winter activity may be influenced by initiation of first snow, snow depth, day length, and persistence of snow. Snow depths greater than 40 to 70 cm are generally considered the upper limit for areas utilized by moose (Coady 1974). Snow depths of 90 to 100 cm are considered critically limiting (Nasimovitch 1955, Kelsall 1969, Telfer 1970, Kelsall and Prescott 1971), because at these depths movement is restricted and adequate food intake may be impossible. Deep snow may also cover low-growing browse species, reducing their availability and requiring moose to exert greater effort to feed (Coady 1974). In Southcentral Alaska, moose generally confine their winter movements to areas less than 3,600 ft in elevation (Ballard et al. 1984). The next most important property of snow is hardness, which determines the force necessary for moose to move through the snow and their ability to crater for food.

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

D. Feeding Behavior

Peak feeding activity occurs at dawn and dusk. During fall, more feeding activity occurs throughout the day. Fall feeding activity is usually influenced by the rut, reflecting greater social contact (Best et al. 1978). Schwartz et al. (1981) found that bull moose at the Kenai Moose Research Center quit eating entirely during the rut and that food intake decreased in females. Geist (1963) found that 79% of summer activity involved feeding. Cratering in snow to reach plants is common throughout Alaska during fall and winter (LeResche and Davis 1973).

- V. REPRODUCTIVE CHARACTERISTICS
 - A. Reproductive Habitat
 - Breeding areas. There are little descriptive data regarding moose rutting habitat. Use of habitat during the rut may be influenced by whether particular groups of moose are migratory or nonmigratory. Use of upland brush-willow habitat types reaches a peak during the breeding period, corresponding with elevational movements of moose (Didrickson and Cornelius 1977; Ballard and Taylor 1980; Ballard et al. 1982a, 1984).
 - <u>Parturition areas</u>. Most studies conducted in the Southcentral Region have found calving to be widely dispersed (Didrickson and Cornelius 1977, Ballard et al. 1982a, Modafferi 1982) (see III. B. 2.).
 - B. Reproductive Seasonality
 - 1. <u>Breeding</u>. Breeding occurs during fall, with the peak of rutting activity occurring between late September and early October (Lent 1974). The timing of the rut is remarkably synchronous among moose in different areas and years in North America (ibid.); this synchronism is reflected in the consistency in calving dates observed throughout the range of moose (Coady 1982).
 - 2. <u>Parturition</u>. Parturition generally occurs between late May and early June. As a consequence of conception during later estrus periods, some calving may occur later, which is disadvantageous to calves because their reduced size in fall may lessen their ability to survive the winter (ibid.).
 - C. Reproductive Behavior

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

- D. Age at Sexual Maturity Moose breed annually. Females may breed as yearlings (16 to 18 months) and are capable of reproducing annually until at least year 18 (Houston 1968). Bulls are also physically capable of breeding as yearlings (ibid.).
- E. Pregnancy Rate/Number of Young Born Natality rates for adult females range from 1.00 to 1.20. Eighty to 90% of adult females in most moose populations in North America become pregnant annually (Pimlott 1959, Schladweiler and Stevens 1973, Simkin 1974). The birth rate for two-year-old females in North America was found to be 0 to 0.47 (Pimlott 1959, Schladwiler and Stevens 1973, Blood 1974, Simkin 1974). In the development of

their moose population model, Ballard et al. (1984) used Blood's (1974) estimate of .29 calves/two-year-old female.

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

- F. Gestation Period The gestation period is approximately 240 to 246 days (Peterson 1955).
- G. Lactation Period Cows lactate until fall, then gradually wean their calves (Franzmann 1978).

VI. FACTORS INFLUENCING POPULATIONS

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

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

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

Prior to the mid 1970's, both brown and black bears were thought to be scavengers rather than predators of moose. Studies of neonatal moose mortality indicate that both bear can be successful ungulate predators species of (Franzmann et al. 1980, Ballard et al. 1981). Bear predation is the primary cause of mortality in some moose populations and, similarly to wolf predation, is an additive source of Experimental mortality. bear-reduction programs have demonstrated that calf moose survival can be improved by temporarily reducing bear numbers (Ballard et al. 1982b). Most moose populations produce adequate numbers of calves to enable population growth. When growth fails to occur, it usually is the result of high neonatal mortality. The relationship between habitat carrying capacity and ungulate

density is confounded by predation. Managers attempting to

provide sustained yields of moose for human use will find predator management a necessity in systems containing naturally regulated predator populations.

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

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

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

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

VII. LEGAL STATUS

The Alaska Department of Fish and Game manages moose. (See the Human Use section in volume 2 for a summary of moose management.)

VIII. SPECIAL CONSIDERATIONS

A. Habitat Protection and Management

To sustain a moose population, high-quality habitat is essential. Habitat protection and management may consist of the following (Franzmann 1978):

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

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

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

REFERENCES

- ADF&G. 1973. Alaska's wildlife and habitat. Vol. 1 [R.A. Hinman and R.E. LeResche, eds.]. ADF&G, Anchorage. 144 pp. + maps.
 - _____. 1976a. Alaska's wildlife management plans, Southwestern Alaska: a public proposal for the management of Alaska's wildlife. 238 pp.
 - _____. 1976b. Alaska's wildlife management plans, Southcentral Alaska: a public proposal for the management of Alaska's wildlife. 291 pp.
 - _____. 1976c. Alaska's wildlife management plans, Southeastern Alaska: a public proposal for management of Alaska's wildlife. 156 pp.
 - _____. 1976d. Alaska's wildlife management plans, northwestern Alaska: a public proposal for the management of Alaska's wildlife. 146 pp.
- _____. 1976e. Alaska's wildlife management plans, Arctic Alaska: a public proposal for the management of Alaska's wildlife. 139 pp.
- _____. 1976f. Alaska's wildlife management plans, Western Alaska: a public proposal for the management of Alaska's wildlife. 150 pp.
- Aldous, S.E. 1944. A deer browse survey method. J. Mammal. 25(2):130-136.
- Ballard, W.B., and K.P. Taylor. 1980. Upper Susitna valley moose population study. ADF&G. Final rept. P-R Projs. W-17-9, 10, and 11. 102 pp.

- Ballard, W.B., T.H. Spraker, and K.P. Taylor. 1981. Causes of neonatal moose calf mortality in Southcentral Alaska. J. Wildl. Manage. 45:335-342.
- Ballard, W.B., C.L. Gardner, J.H. Westlund, and J.R. Dow. 1982a. Mooseupstream. ADF&G, Susitna Hydroelectric Proj. Phase I. Final rept. Vol. 3: Big game studies. 119 pp.
- Ballard, W.B., C.L. Gardner, and S.D. Miller. 1982b. Nelchina yearling moose mortality study. ADF&G, Fed. Aid in Wildl. Rest. Prog. rept. Projs. W-21-1 and W-21-2. Juneau. 37 pp.
- Ballard, W.B., J.S. Whitman, N.G. Tankersley, L.D. Aumiller, and P. Hessing. 1984. Moose-upstream. ADF&G, Susitna Hydroelectric Proj. Ann. rept. Vol. 3: Big game studies. 147 pp.
- Ballard, W.B., S.D. Miller, K.B. Schneider, and R.O. Stephenson. In press. Ecology and relationships of wolves, brown bear, and moose in Southcentral Alaska. Wildl. Monog.
- Best, D.A., G.M. Lynch, and O.J. Rongstad. 1978. Seasonal activity patterns of moose in the Swan Hills, Alberta. Proc. N. Am. Moose Conf. Workshop 14:109-125.
- Bishop, R.H. 1984. Personal communications. Regional Supervisor, ADF&G, Div. Game, Fairbanks.
- Blood, D.A. 1974. Variation in reproduction and productivity of an enclosed herd of moose (<u>Alces alces</u>). Trans. Int. Congr. Game Biol. 11:59-66.
- Botkin, D.B., P.A. Jordan, A.S. Dominski, H.S. Lowendorf, and G.E. Hutchinson. 1973. Sodium dynamics in a northern ecosystem. Proc. Natl. Acad. Sci. USA. 70:2,745-2,748.
- Bishop, R.H., and R.A. Rausch. 1974. Moose population fluctuations in Alaska, 1950-1972. Nat. Can. 101:559-593.
- Burris, O.E., and D.E. McKnight. 1973. Game transplants in Alaska. Wildl. Tech. Bull. No. 4. ADF&G, Juneau. 57 pp.
- Chapman, J., and G. Feldhamer, eds. 1982. Wild mammals of North America. Baltimore: Johns Hopkins Univ. Press.
- Coady, J.W. 1974. Influence of snow behavior on moose. Nat. Can. 101:417-436.
- _____. 1976. Status of moose populations in Interior Alaska. Wildl. Informational Leaflet No. 2. ADF&G, Fairbanks. 4 pp.

.

_____. 1980. History of moose in northern Alaska and adjacent regions. Canad. Field Nat. 94(1):61-68.

- . 1982. Moose. Pages 902-922 in Chapman and Feldhamer 1982.
- Didrickson, J.C., and D. Cornelius. 1977. Lower Susitna valley moose population identity study. ADF&G, Fed. Aid in Wildl. Rest. Prog. rept. Proj. W-17-8, Job 1.16 R. 6 pp.
- Didrickson, J.C., and K.P. Taylor. 1978. Lower Susitna valley moose population identity study. ADF&G, Fed. Aid in Wildl. Rest. Final rept. Projs. W-17-8 and 9, Job 1.16 R. Final rept. 20 pp.
- Flook, D.R. 1959. Moose using water as refuge from flies. J. Mammal. 40(3):455.
- Franzmann, A.W. 1978. Moose. Pages 67-81 <u>in</u> J.L. Schmidt and D.L. Gilbert, eds. Big game of North America: ecology and management. Harrisburg, PA: Stackpole Books.
- _____. 1981. <u>Alces</u> <u>alces</u>. American Society of Mammalogists. Mammal. Spec. 154:1-7.
- Franzmann, A.W., and R.O. Peterson. 1978. Moose calf mortality assessment. Proc. N. Am. Moose Conf. Workshop 14:247-269.
- Franzmann, A.W., C.C. Schwartz, and R.O. Peterson. 1980. Moose calf mortality in summer on the Kenai Peninsula, Alaska. J. Wildl. Manage. 44(3):764-768.
- Franzmann, A.W., C.C. Schwartz, and D.C. Johnson. 1983. Kenai Peninsula moose calf mortality study. Fed. Aid in Wildl. Rest. Prog. rept. Projs. W-22-1 and W-22-1. ADF&G, Juneau. 69 pp.
- Fraser, D., B.K. Thompson, and D. Arthur. 1982. Aquatic feeding by moose: seasonal variation in relation to plant chemical composition and use of mineral licks. Can. J. Zool. 60:3,121-3,126.
- Gasaway, W.C. 1977. Moose survey procedures development. Fed. Aid in Wildl. Rest. Prog. rept. Proj. W-17-9. ADF&G, Juneau. 69 pp.
- Gasaway, W.C., R.O. Stephenson, J.L. Davis, P.K. Shepard, and O.E. Burris. 1983. Interrelationships of wolves, prey, and man in Interior Alaska. Wildl. Monogr. 84:1-50.
- Geist, V. 1963. On the behavior of North American moose (<u>Alces alces</u> <u>andersoni</u>) (Peterson 1950) in British Columbia. Behavior 20:377-416. Cited in Chapman and Feldhamer 1982.

- Grauvogel, C.A. 1984. Seward Peninsula moose population identity study. ADF&G, Fed. Aid in Wildl. Rest. Final rept. Proj. W-22-2, Job 1.29R. Juneau. 93 pp.
- Hall, E.S., Jr. 1973. Archaeological and recent evidence for expansion of moose range in northern Alaska. J. Mammal. 54(1):244-295.
- Houston, D.B. 1968. The Shiras moose in Jackson Hole, Wyoming. Grand Teton Nat. Hist. Assoc. Tech. Bull. 1. 110 pp.
- Kelsall, J.P. 1969. Structural adaptations of moose and deer for snow. J. Mammal. 50(2):302-310.
- Kelsall, J.P., and W. Prescott. 1971. Moose and deer behavior in Fundy National Park, New Brunswick. Can. Wildl. Serv. Rept. Ser. No. 15, Ottawa. 27 pp.
- Lent, P.C. 1974. A review of rutting behavior in moose. Nat. Can. 101:307-323.
- LeResche, R.E. 1966. Behavior and calf survival in the Alaskan moose. M.S. Thesis, Univ. Alaska, Fairbanks. 85 pp.
- LeResche, R.E., R. Bishop, and J.W. Coady. 1974. Distribution and habitats of moose in Alaska. Nat. Can. 101:143-178.
- LeResche, R.E., and J.L. Davis. 1973. Importance of nonbrowse foods to moose on the Kenai Peninsula, Alaska. J. Wildl. Manage. 37(3):279-287.
- Machida, S. 1979. Differential use of willow species by moose in Alaska. M.S. Thesis, Univ. Alaska, Fairbanks. 96 pp.
- Milke, G.C. 1969. Some moose-willow relationships in the interior of Alaska. M.S. Thesis, Univ. Alaska, Fairbanks. 79 pp.
- Modafferi, R.D. 1982. Moose-downstream. ADF&G. Susitna Hydroelectric Proj. Phase 1. Final rept. Vol. 2: Big game studies. 114 pp.
 - _____. 1983. Moose-downstream. ADF&G. Susitna Hydroelectric Proj. Phase 2. Ann. prog. rept. Vol. 2: Big game studies. 114 pp.
- _____. 1984. Moose-downstream. ADF&G. Susitna Hydrolelectric Proj. Phase 2. Ann. prog. rept. Vol. 2: Big game studies. 116 pp.
- Nasimovitch, A.A. 1955. The role of snow regime in the life of the ungulates in the USSR. Acad. Sci. Publ. House, Moscow (in Russian): 1-403.

- Oldemeyer, J.L., A.W. Franzmann, A.L. Brundage, P.D. Arneson, and A. Flynn. 1977. Browse quality of the Kenai moose population. J. Wildl. Manage. 41:533-542.
- Peek, J.M. 1974. A review of moose food habits studies in North America. Nat. Can. 101:195-215.
- Peterson, R.L. 1955. North American moose. Toronto: Univ. Toronto Press. 280 pp.

_____. 1977. Wolf ecology and prey relationships on Isle Royale. NPS, Sci. Monogr., Ser. No. 11. 210 pp.

- Peterson, R.O., and D.L. Allen. 1974. Snow conditions as a parameter in moose-wolf relationships. Nat. Can. 101:481-492.
- Pimlott, D.H. 1959. Reproduction and productivity of Newfoundland moose. J. Wildl. Manage. 23:381-401.
- Rausch, R.A. 1967. Report on 1965-66 moose studies. Vol. 7. Fed. Aid in Wildl. Rest. Ann. proj. segment rept. Proj. W-15-R-1, Work Plan K.
- Schladweiler, P., and D.R. Stevens. 1973. Reproduction of Shiras moose in Montana. J. Wildl. Manage. 37:535-544.
- Schwartz, S.D., A.W. Franzmann, and D.C. Johnson. 1981. Moose research center report. ADF&G, Fed. Aid in Wildl. Rest. Prog. rept. Proj. W-21-2. Juneau. 42 pp.
- Scott, R.F., D.R. Klein, S.T. Olson, R.A. Rausch, R.O. Skoog, P.E.K. Shephard, and D.L. Sloan. 1958. Moose management studies. Wildl. Investigations, Work Plan A. Job comp. rept., Proj. W-3-R-12.
- Sigman, M. 1977. The importance of the cow-calf bond to overwinter moose calf survival. M.S. Thesis, Univ. Alaska, Fairbanks. 185 pp.
- Simkin, D.W. 1974. Reproduction and productivity of moose. Nat. Can. 101:517-525.
- Stringham, S.F. 1974. Mother-infant relations in moose. Nat. Can. 101:325-369.
- Tankersley, N.G. 1984. Personal communication. Game Biologist, ADF&G, Div. Game, Anchorage.
- Tankersley, N.G., and W.C. Gasaway. 1983. Mineral lick use by moose in Alaska. Can. J. Zool. 61:2,242-2,249.
- Telfer, E.S. 1970. Winter habitat selection by moose and white-tailed deer. J. Wildl. Manage. 35(1):63-71.

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Wolfe, M.L. 1974. An overview of moose coactions with other animals. Nat. Can. 101:437-456.

Zarnke, R.L. 1984. Personal communication. Disease and Parasite Specialist, ADF&G, Div. Game, Fairbanks.



Map 1. Range of dabbling ducks (Bellrose 1976)

- I. NAME
 - A. Common Names: Dabbling ducks, puddle ducks, or surface-feeding ducks
 - B. Scientific Classification
 - 1. Family. Anatidae
 - 2. Subfamily. Anatinae
 - 3. Tribe. Anatini
 - C. Species Commonly Occurring in the Southwest Region In the Southwest Region, the dabbling duck population consists of northern pintail (<u>Anas acuta</u>), mallard (<u>A. platyrhynchos</u>), American wigeon (<u>A. americana</u>), green-winged teal (<u>A. crecca</u>), northern shoveler (<u>A. clypeata</u>), and gadwall (<u>A. strepera</u>) (Gabrielsen and Lincoln 1959). Lesser numbers of other dabbling duck species, such as European wigeon (<u>A. penelope</u>), use the area as well (ibid.).

- D. Species Commonly Occurring in the Southcentral Region In the Southcentral Region, the dabbling duck population consists primarily of American wigeon, mallard, northern pintail, and green-winged teal. Lesser numbers of northern shoveler, gadwall, and other dabbling duck species use the region as well (ibid.).
- E. Species Commonly Occurring in the Arctic Region In the Arctic Region, the dabbling duck population consists primarly of northern pintail and American widgeon. Lesser numbers of mallard, green-winged teal, and northern shoveler also occur (Rothe, pers. comm.).
- II. RANGE
 - A. Worldwide

Dabbling ducks are cosmopolitan in distribution, with variations in abundance related to seasonal changes in habitat conditions (Terres 1980).

- B. Statewide Dabbling ducks are abundant and widely distributed seasonally throughout the state wherever habitat conditions are favorable (Gabrielson and Lincoln 1959).
- C. Regional Distribution Maps

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

- D. Regional Distribution Summary
 - 1. Southwest. In general, dabbling ducks are found throughout the Southwest Region at elevations below 1,200 ft. Major concentrations, however, occur in estuaries, lagoons, river deltas, tidal flats, and lowland ponds. In the Bristol Bay area, the largest concentrations of dabblers occur during the spring and fall migrations, whereas Kodiak and the Aleutian Islands are important wintering areas (King and Lensink 1971). (For more detailed narrative information, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)
 - 2. <u>Southcentral</u>. Dabbling ducks are found in favorable habitat throughout the Southcentral Region. Because of the lateness of snowmelt and vegetation growth at higher elevations, the most favorable habitat is located below 1,000 ft elevations. In the Southcentral Region, major concentrations occur during the spring and fall migrations along the tidal marshes of Cook Inlet (fig. 1). During a 1962 spring survey, an estimated 100,000 birds were observed utilizing the Susitna Flats area (Sellers 1979). The many estuaries and tide flats of Prince William Sound (PWS) and the extensive tidelands of the Copper River Delta (CRD) are also important concentration

areas. Estuarine and tidal flat areas of PWS and the CRD are important wintering areas for some species (Timm 1977). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)

3. <u>Arctic</u>. In the Arctic Region, pintail breeding habitat is in marshy, low country where shallow freshwater lakes occur, especially those with dense vegetative growth near shore. It also occurs in brackish estuaries and along sluggish streams that have marshy borders (Johnsgard 1975). (For more detailed information, see volume 2 of the Alaska Habitat Management Guide for the Arctic Region.)

III. PHYSICAL HABITAT REQUIREMENTS

Dabbling ducks are very mobile and opportunistic, characteristics that allow them to take advantage of a wide variety of habitat types, depending upon need and availability (Bellrose 1976). Preferred habitat types are closely associated with water, ranging from fresh water to salt and/or brackish water (King and Lensnik 1971). Dabblers in particular are frequently found on shallow, small ponds or lakes bordered by shrubs, trees, or aquatic plants (Bellrose 1976). Coastal habitats are also frequently used by dabblers. A study of coastal habitats in Alaska (Arneson 1980) found that dabbling ducks are the most ubiquitous of waterfowl. In the coastal zone, they are found most abundantly on protected delta water, lagoon water, and salt marshes, but they are also found on eight other habitats. During the study, only subtle differences in habitat selection among species were evident. Pintails, for instance, frequent lagoon island sand much more than other dabblers; green-winged teal are often on exposed mudflats; and American wigeon are more abundant on protected delta water and mud. Quimby (1972) studied waterfowl use of different plant communities at Chickaloon Bay in upper Cook Inlet (map 2). Waterfowl use occurred in 8 of 10 types, with most use occurring in the marsh, floating marsh, and mudflat community types (ibid.). The marsh community contains permanent brackish ponds of various sizes and depths bordered by sedges (Carex spp.) and bulrushes (Scirpus spp.). The ponds contain food plants and are good feeding, nesting, and resting areas (ibid.). The floating marsh community is similar but has fewer, deeper open-water greater plant species diversity, and mats of floating areas, vegetation. This type provides large areas of suitable habitat, but less nesting occurs because there is less open water. The mudflat community was near the upper limit of the tide and was utilized mostly by fall-migrating ducks resting and feeding in that type (ibid.).

- A. Arctic Region
 - 1. <u>Pintail</u>. Pintails at Icy Cape were observed more frequently in shallow and deep <u>Arctophila</u> (Classes III and IV) wetlands in June and July; shallow <u>Carex</u> (Class II) wetlands were used frequently in August. At Storkersen Point, habitat use by pintails was not limited to any particular wetland type, although shallow <u>Arctophila</u> (Class III) and basin-complex (Class IV) wetlands were used significantly more (Bergman et al. 1977). <u>Arctophila</u> wetlands have been found to be preferred in some areas (Derksen et al. 1979).

- 2. <u>Green-winged teal</u>. At Icy Point, migrating birds that landed in the area were noted to feed along pond edges in the salt marsh (Lehnhausen and Quinlan 1981).
- 3. <u>Northern shoveler</u>. At Icy Cape, migrating birds were noted to land in the mainland marsh and feed in its brackish ponds; shovelers were also observed on the tundra on shallow and deep Arctophila ponds (Classes III and IV) (ibid.).
- 4. <u>American wigeon</u>. At Icy Cape, migrating birds were noted to feed and rest in the mainland salt marsh; two pairs were also observed in the tundra, feeding on shallow <u>Arctophila</u> ponds (Class III) (ibid.).
- IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

Dabbling ducks have a wide seasonal variety of food items. They are highly opportunistic and will concentrate on food items most readily available to them (Peret 1962, Timm 1975). The following food items are known to be utilized by dabbling ducks during portions of the year (Bellrose 1976, Bartonek 1972, Quimby 1972, Sugden 1973). This list is incomplete but indicates the wide diversity of food items eaten by ducks.

Animal species - larval and flying forms of invertebrates, including: Water fleas (Cladocera) Amphipods (Amphipoda) Mayflies (Ephemeroptera) Dragonflies (Odonata) Water striders (Hemiptera) Caddis flies (Trichoptera) Black flies (Diptera) Mosquitoes (Diptera) Snails (Gastropoda) Spiders (Arachnoidea) Salmon carcasses (Onchorhynchus spp.) Crustaceans (Crustacea) Mollusks (Mollusca) Earthworms (Oligochaeta) Stickleback (Gaserosteus aculeatus)

<u>Plant species</u> - vegetative parts and seeds of numerous plants, including: Pondweeds (<u>Potamogeton</u> spp.) Cattails (<u>Typha</u> spp.) Bulrush (<u>Scirpus</u> spp.) Sedges (<u>Carex</u> spp.) Horsetails (<u>Equisetum</u> spp.) Algae (Cladophoraceae) Grasses (Graminae) Mares-tail (<u>Hippuris</u> spp.) Cultivated grains (e.g., barley) Buttercup (Ranunculus spp.)

Dabbling ducks prefer an early season diet high in animal matter, changing to a diet high in plant matter as the season progresses (Bartonek 1972, Sugden 1973). This seasonal change is related to both the availability and the nutritional value of food items (Sugden 1973, Krapu 1974). The rapid early growth of juveniles and the nutritional requirements of prebreeding and breeding adults require food sources high in protein. Krapu (1974) observed that female pintails fed heavily on invertebrates before and during egg laying. Esophogeal contents before egg laying averaged 56 \pm 27.1% animal matter, and during egg laying 77.1 \pm

11.6%. Invertebrate consumption declined sharply after the laying period (ibid.).

Bartonek (1972) found that juvenile American wigeons (Class IIa) contained an average of $66 \pm 22\%$ animal matter in their esophagi, whereas older juveniles (Class IIIa and flying) had only $12 \pm 20\%$ animal matter in their diet. Adult American wigeons examined during the same study contained an average of $31 \pm 34\%$ animal matter (ibid.). This represents significantly more animal matter in the diet of the adult wigeon than had been previously recorded (Bellrose 1976, Johnsgard 1975). Sugden (1973) found similar results in the American wigeon, with animal food dominating the diet at first, being largely replaced by plant food after three weeks of age.

Mallards also have a high percentage of animal material in their early season diets (Bartonek 1972). A small sample of juvenile mallards (Class IIc) had 99% animal matter in their esophagi, whereas a flying juvenile had only 35% animal matter (ibid.).

Sugden (1973) found that juvenile northern pintails followed a similar pattern, with up to 98% of their early diet comprised of animal matter. The percentage of plant material in the diet increased as the ducks grew (ibid.). 1. Southcentral Region: Cook Inlet (from Timm and Sellers 1979).

Southcentral Region: Cook Inlet (from Timm and Sellers 1979). During the summer and fall of 1978, a food habits study of dabbling ducks (mallard and pintail) was conducted by the ADF&G on tidal marshes of Cook Inlet (Palmer Hay Flats, Susitna Flats, Goose Bay, Chickaloon flats, and Trading Bay). Four genera of plants (Carex, Scirpus, Potomogeton, and Hippuris) comprised between 82 and 96% of gullet contents. Seeds of these plants were dominant in both summer and fall, although tubers of Scirpus paludosus and Potamogeton were important in the fall on the Susitna Flats and Goose Bay. Seeds of Potamogeton and Hippuris were more abundant, and therefore more important, during summer than during fall. whereas the inverse was true for Carex seeds. Mallards relied more heavily on Carex and less heavily on Scirpus seeds than did pintails.

The Chickaloon flats and Trading Bay do not have extensive stands of bulrush (Scirpus validus), and consequently birds collected there were nearly devoid of bulrush seeds. Palmer Hay Flats contain more bulrush than any other marsh in Cook Inlet, and the ducks collected there fed more heavily on this food item than did birds elsewhere. Because of biases in procedures for collecting and processing samples, the importance of animal foods was undoubtedly underestimated. Although not reflected in this study, ducks spent more time on intertidal areas as the hunting season progressed. Because birds were relatively invulnerable while feeding on the tide flats, few were included in the sample. Small crustaceans, mollusks, and algae are probably the major foods consumed by ducks in the exposed tidal zone.

2. Southcentral Region: Copper River Delta. Dabbling ducks on the CRD apparently rely more on soft vegetation and less on seeds than do mallards and pintails in Cook Inlet coastal marshes (ibid.). Seeds are an important part of the fall duck diet in Alaska because their high carbohydrate content helps to provide the energy necessary for migration (Campbell and Timm 1983). The 1981 autumn diet of four species of dabbling ducks (pintail, mallard, green-winged teal, and wigeon) was

(pintail, mallard, green-winged teal, and wigeon) was comprised of 36% vegetation, 33% seeds, and 29% animal matter. Pintails consumed the greatest amount of seed, as well as of animal matter, followed by mallards and greenwinged teal. Wigeons consumed the least amount of seed and animal matter but the most vegetation (ibid.). (See table 1.)

B. Types of Feeding Areas Used

Dabbling ducks feed in the shallow waters of small lakes, ponds, and other bodies of water and at the tide line in Alaska coastal waters (Timm 1975).

- C. Factors Limiting Availability of Food Lingering snow and ice from a late spring prevent ducks from foraging in all areas, especially upland areas. Early cold weather and accompanying ice conditions eliminate food resources in most freshwater areas in the fall (Rothe, pers. comm.). Feeding activity under these conditions usually occurs at or along ice-free coastal areas.
- D. Feeding Behavior Dabbling ducks feed either at the surface, where they skim the water at the edges of the shores and banks, or by "tipping" tail up in shallow places, reaching down to obtain food items from the bottom (ibid.).
- V. REPRODUCTIVE CHARACTERISTICS
 - A. Reproductive Habitat

Dabbling ducks generally require lowland ponded areas for nesting; however, some have been found over 500 yd from water (Sowls 1955). In areas where choice nesting habitat is limited, nests may be located up to 5 mi from water (Duebbert 1969). Nesting pairs of dabblers (and other species) are known to claim and defend areas of territory adjacent to their nest site (Sowls

and defend areas of territory adjacent to their nest site (Sowis 1955). Defense of these areas by the territorial drake can be quite vigorous but usually lasts only until the last egg is laid and the female starts incubation (ibid.).

B. Reproductive Seasonality The span of nest initiation depends on local temperatures and water conditions and varies among species. The initial nesting period usually occurs from mid April to mid June (Sellers 1979). Ducks are persistent nesters and will attempt to nest again, sometimes several times, if their first attempt is destroyed (Sowls 1955). Initial destruction by fluctuating water levels, mammalian or avian predators, and man-caused disturbance can be

Item	Aggregate % Volume	% Occurrence
Vegetation Water buttercup (Ranunculus spp.)	13.6	16.9
Pondweed (Potamogeton spp.)	11.6	13.8
Unidentified grass CRD #3	5.1	10.8
Misc. foliage	5.6	
Seeds Sedge (<u>Carex</u> spp.)	12.4	38.5
Rushes (<u>Eleochris</u> spp. & <u>Scirpus</u> sp	p.) 8.1	16.9
Unidentified seed #7	7.1	16.9
Marestail (<u>Hippuris</u> spp.)	3.3	16.9
Pondweed (<u>Potamogeton</u> spp.)		
Animals Diptera larvae (<u>Chironomidae</u> , <u>Ceratopogonidae</u> , Tipulidae)	13.4	29.2
Unidentified invertebrate eggs	4.2	4.6
Trichoptera larvae (<u>Brachycent</u> Limnephilidae, Polycentropod	ridae, idae) 3.8	23.1
Pelecypods (Sphaeriidae)	3.1	9.2
Gastropods	2.5	15.4
Stickleback (<u>Gaserosteus</u> aculea	<u>tus</u>) 1.4	3.1
Miscellaneous (Hirudinids, Arac Odonatids)	hinids, 1.0	

Table 1. Diet Composition of 62 Dabbling Ducks on the West Copper River Delta, September through October 1981

Source: Campbell and Timm 1983.

--- means no data were available.

quite severe, and during some years renesting may account for the total production (ibid.).

- C. Reproductive Behavior Dabblers have new mates each season. Courtship takes place in late winter and during early spring. On arrival at their nesting grounds, the females immediately search for a suitable nesting site and then commence nest construction (Timm 1975). As mentioned, males defend both the females and the nesting territory (Sowls 1955). This defense lasts until the eggs are layed and the males retreat to molting areas.
- D. Age At Sexual Maturity
- All dabblers mature at one year of age (Timm 1975).
- E. Fecundity

The number of eggs per clutch varies among species but ranges between 1 and 18 eggs, the average being between 6 and 9 eggs (ibid.). (See table 2.)

- F. Incubation Period The incubation period varies by species but usually averages between 21 and 29 days (ibid.). Hatching generally coincides with the longest days of the year and the peak production of aquatic invertebrates in late June.
- G. Rearing of Young As soon as the females are well into incubation, the males withdraw into flocks by themselves and proceed to molt. They take no part in raising young (ibid.).
- VI. FACTORS INFLUENCING POPULATIONS
 - A. Natural

Species composition and numbers for the Alaska population of dabbling ducks can change dramatically. Production is influenced primarily by spring weather and flooding. Production is less in years with "late" springs than in years when snow and ice disappear early in the season. Flooding in river valleys or from storm tides on coastal wetlands can delay nesting or destroy nests and significantly reduce production. Flooding in river valleys, however, causes beneficial effects from nutrient exchanges, which fertilize ponds, increasing the food they produce for waterfowl (ADF&G 1980).

A phenomenon that has occurred at least twice during the last 25 years is the drought displacement of millions of waterfowl from the southern Canada and northern United States prairie pothole area to the arctic coastal plain (Hansen and McKnight 1964, Derksen and Eldridge 1980).

During the first drought period (1956-1960), several duck species were recorded in Alaska for the first time or at much greater abundance than formerly (Hansen and McKnight 1964). In some areas, waterfowl population indices were three times the average (ibid.).

Table 2.	Breeding	Biology	of	Dabbling	Ducks	
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Species	Nest Locations	Mating	Incubation	Clutch Size		
				Range	Average	Sexual Maturity
Northern pintail	Dry ground, usually away from water	Late winter; arrive mated	22-24 days	1-12	6	For all dabblers, one year
Mallard	Ground, edges of of ponds, much variation	Late winter; arrive on breeding grounds mated	23-29 days, usually 26	1-15	8	
American wigeon	Dry ground, away from water, usually brushy area	May-June	24-25 days	1-12	6	
American green-winged teal	Dry ground, tall grass, bordering marshes	Late winter	21-23 days	1-18	9	
Northern shoveler	Hollows, on ground	May-June, with two males occasionally	21-23 days	1-14	7	

Source: Timm 1975, Bellrose 1976.

During 1977, surveys indicated the highest duck population index ever recorded in Alaska, a 61% increase over 1976 and 46% above the 10-year average (King and Bartonek 1977). The greatest increase was recorded by northern pintails, which increased 123% over 1976 and 87% over the 10-year average (ibid.). The 1978 population index was lower but still 5% above the 10-year average (ibid.).

These drought-related duck population increases did not result in increased production in Alaska. Although limited evidence indicates that some displaced duck species will increase their nesting attempts, there appears to be no related increase in production (Hansen and McKnight 1964, Derksen and Eldridge 1980). Hansen and McKnight (1964) and Derksen and Eldridge (1980) both concluded that drought-displaced ducks arrive in northern areas with depleted energy reserves, resulting in minimal nesting success. Also, late arrivals would have to compete for nesting sites with already established pairs, adding to poor nesting success (Calverley and Boag 1977).

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

Pollution of water and/or food

- Reduction of food supply
- ° Alteration of freshwater habitat
- ° Dredging/filling/draining of wetlands
- ^o Disturbance of fall/spring staging areas
- ° Oiling of feathers
- In-flight hazards (e.g., transmission lines, towers)
- [°] Alteration of nesting habitat
- [°] Lead poisoning in heavily utilized hunting areas

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

VII. LEGAL STATUS

In Alaska, waterfowl are managed by the U.S. Fish and Wildlife Service and the Department of Fish and Game. Waterfowl are protected under international treaties with Canada (Great Britain) 1916, Mexico 1936, Japan 1972, and the Soviet Union 1976.

- VIII. SPECIAL CONSIDERATIONS
 - A. Molting

Male dabbling ducks begin flocking by mid June and are flightless by late June and early July. Flight feathers are generally regained by early August (Bellrose 1976). The wing molt of females is delayed to coincide with the development of the young.

- IX. LIMITATIONS OF INFORMATION
 - 1. <u>Southcentral Region</u>. Surveys of nesting habitat need to be repeated for the Cook Inlet area. Information on ecological requirements is needed, especially in Cook Inlet, Alaska Peninsula coastal lagoons, and the Copper River delta. The relationship between drought-displaced birds and total annual production is unknown and needs investigation.
 - 2. <u>Arctic Region</u>. Very few scientific studies have been done on dabbling ducks in the Arctic Region. Therefore, there is little specific life history information available.

REFERENCES

- ADF&G. 1980. Alaska wildlife management plans: species management policies. Fed. Aid. in Wildl. Res. Proj. W-20-2. 113 pp.
- Arneson, P. 1980. Identification, documentation, and delineation of coastal migratory bird habitat in Alaska. BLM/OCS contract No. 03-5-22-69. ADF&G. 350 pp.
- Bartonek, J.C. 1972. Summer foods of American wigeon, mallards and a green-winged teal near Great Slave Lake, N.W.T. Can. Field Nat. 86(4):373-376.

- Bellrose, F.C. 1976. Ducks, geese, and swans of North America. Harrisburg, PA: Stackpole Books. 540 pp.
- Bergman, R.D., R.L. Howard, K. F. Abraham, and M.W. Weller. 1977. Waterbirds and their wetland resources in relation to oil development at Storkersen Point Alaska. USFWS Resource Publ. 129. Washington, DC. 38 pp.
- Calverley, B.K., and D.A. Boag. 1977. Reproductive potential in parkland-and arctic-nesting populations of mallards and pintails (Anatidae). Can. J. Zool 55:1,242-1,251.
- Campbell, B.H., and D.E. Timm. 1983. Waterfowl. Pages 9-11 in ADF&G, Survey-inventory progress rept., 1981-1982. Vol. 13, Part 5. Fed. Aid in Wildl. Rest., Proj. W-22-1.
- Derksen, D.V., and W.D. Eldridge. 1980. Drought-displacement of pintails to the arctic coastal plain. J. Wildl. Manage. 44(1):224-229.
- Derksen, D.V., W.D. Eldridge, and T.C. Rothe. 1979. Waterbird and wetland habitat studies. In P.C. Lent, ed. Studies of selected wildlife and fish and their use of habitats on and adjacent to NPR-A 1977-1978. Field Study 3, Vol. 2, USDI, National Petroleum Reserve of Alaska, Anchorage. 423 pp.
- Duebbert, H.F. 1969. High nest density and hatching success of ducks on South Dakota CAP Land. Pages 218-229 in Transactions of the 34th North American wildlife and natural resources conference.
- Gabrielson, I.N., and F.C. Lincoln. 1959. The birds of Alaska. Harrisburg, PA: Stackpole Books.
- Hansen, H.A., and D.E. McKnight. 1964. Emigration of drought-displaced ducks to the Arctic. Trans. N. Am. Wildl. and Nat. Res. Conf. 29:119-129.
- Johnsgard, P.A. 1975. Waterfowl of North America. Indiana Univ. Press. 575 pp.
- King, J.G., and J.C. Bartonek. 1977. Alaska-Yukon waterfowl breeding pair survey. Pac. Flyway Waterfowl Rept. 78:39-54.
- King, J.G., and C.J. Lensink. 1971. An evaluation of Alaskan habitat for migratory birds. Unpubl. rept., USFWS, Anchorage, AK. 46 pp.
- Krapu, G.L. 1974. Feeding ecology of pintail hens during reproduction. Ark. 91 (2):278-290.

- Lehnhausen, W.A., and S.E. Quinlan. 1981. Bird migration and habitat use at Icy Cape, Alaska. Unpubl. rept. USFWS, Anchorage, AK. 298 pp.
- Peret, N.G. 1962. The spring and summer foods of the common mallard (Anas <u>p. platyrhynchos</u> L.) in southcentral Manitoba. Unpubl. M.S. Thesis, Univ. B.C., Vancouver.
- Quimby, R.L. 1972. Waterbird habitat and use of Chickaloon flats. M.S. Thesis, Univ. Alaska, Fairbanks. 86 pp.
- Rothe, T. 1985. Personal communication. Waterfowl Biologist, ADF&G, Div. Game, Anchorage.
- Sellers, R.A. 1979. Waterbird use and management considerations for Cook Inlet state game refuges. Unpubl. rept., ADF&G, Anchorage.
- Sowls, L.K. 1955. Prairie ducks: a study of their behavior, ecology and management. Harrisburg Pa: Stackpole Co. 193 pp.
- Sugden, L.G. 1973. Feeding ecology of pintail, gadwall, American widgeon and lesser scaups ducklings. Canadian Wildlife Service rept. Series No. 24. Ottawa.
- Terres, J.K. 1980. The Audubon Society encyclopedia of North American birds. New York: Alfred A. Knopf. 1,109 pp.
- Timm, D. 1975. Northeast Gulf Coast waterfowl. Pages 264-343 in ADF&G, comp. A fish and wildlife resource inventory of Prince William Sound. Vol. 1: Wildlife. 1978.

______. 1977. Waterfowl. Pages 212-265 <u>in</u> ADF&G, comp. A fish and wildlife resource inventory of the Cook Inlet-Kodiak areas. Vol. 1: Wildlife. 1976.

Tinm, D., and R.A. Sellers. 1979. Waterfowl. Page 19 in ADF&G, Survey-inventory progress rept., 1978-1979. Fed. Aid in Wildl. Rest. Vol. 10. Proj. W-17-11.



Map 1. Range of diving ducks (Bellrose 1976)

- I. NAME
 - A. Common Names: Diving ducks, bay ducks, sea ducks
 - B. Scientific Classification
 - 1. Family. Anatidae
 - 2. Subfamily. Anatinae
 - 3. Tribe:
 - a. Bay ducks or inland diving ducks. Aythyini.
 - b. Sea ducks. Mergini.
 - С. Species Commonly Occurring in the Southwest Region The Southwest Region diving duck population is comprised of the greater scaup (Aythya marila); harlequin duck (Histrionicus histrionicus); oldsquaw (Clangula hyemalis); surf scoter perspicillata); white-winged scoter (Melanitta (M. fusca and black scoter (M. nigra); Barrow's goldeneye deglandi), (Bucephala islandica) and common goldeneye (B. clangula);

bufflehead (<u>Bucephala albeola</u>); red-breasted merganser (<u>Mergus serrator</u>) and common merganser (<u>M. merganser</u>); and Steller's eider (<u>Polysticta stelleri</u>), Pacific common eider (<u>Somateria mollissima v-nigra</u>), and king eider (<u>S. spectabilis</u>) (Gabrielson and Lincoln 1959).

- D. Species Commonly Occurring in the Southcentral Region In the Southcentral Region, the diving duck population consists primarily of scaup, scoter, goldeneye, bufflehead, and oldsquaw. Lesser numbers of canvasbacks (<u>Aythya valisineria</u>), ring-necked duck (<u>Aytha collaris</u>), mergansers, and other diving duck species use the region as well (ibid.).
- E. Species Commonly Occurring in the Arctic Region In the Arctic Region, the diving duck population consists primarily of oldsquaw, Pacific common, king, and spectacled eiders (Somateria fischeri), and greater scaup (Aythya marila) (Rothe, pers. comm.). Lesser numbers of white-winged, surf (Melanitta perspicillate), and black scoters also occur.
- II. RANGE
 - A. Worldwide

Diving ducks occur in suitable habitats throughout the northern hemisphere.

- B. Statewide Diving ducks occur throughout the state, generally near the larger and deeper inland bodies of water and along the sea coast (Timm 1975).
- C. Regional Distribution Maps

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

- D. Regional Distribution Summary
 - 1. <u>Southwest</u>. In general, diving ducks are distributed throughout the Southwest Region at elevations below 1,200 ft. Major concentrations, however, are found in coastal and riverine habitats. In the Bristol Bay area, the largest concentrations of diving ducks occur during spring and fall migrations, whereas Kodiak and the Aleutian Islands have their highest concentration of birds during the winter (ADNR/USFWS 1983, Gabrielson and Lincoln 1959). (For more detailed narrative information, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)
 - 2. <u>Southcentral</u>. Diving ducks are found in favorable habitat throughout the Southcentral Region. In general, this habitat is located at elevations below 1,000 ft. Large concentrations of diving ducks overwinter in coastal areas of Southcentral, in Cook Inlet, especially Kachemak Bay, and in

birds were in pairs and males were displaying. No salt marsh use was observed in August or September (ibid.). Common eiders also used lagoon areas from early June to mid August (ibid.).

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

Diving ducks eat a wide variety of plant and animal species. Animal species, however, comprise most of their diet during most of the year (Bartonek and Hickey 1969, Johnsgard 1975, Dirschl 1969). This preference can be related to the habitats diving ducks occupy during most of the year: coastal marine areas, estuaries, and larger, deeper lakes (Johnsgard 1975).

Locally abundant plant foods are also used by diving ducks. Aquatic plants, including pondweed (<u>Potamogeton</u> spp.), muskgrass (<u>Chara spp.</u>), and bulrush (<u>Scirpus</u> spp.) are extensively used by some species (ibid.).

Table 1 presents food species known to be used by diving ducks. This list, although incomplete, indicates the wide diversity of food species eaten by diving ducks.

Bartonek and Hickey (1969), studying diving duck food habits in Canada, reported that juvenile and adult canvasbacks, redheads, and lesser scaup had a high proportion of animal food species in their spring and summer diet. Juvenile and adult female canvasbacks had 87% and 92% animal matter in their diets, respectively (ibid.). Conversely, adult male canvasbacks had 97% vegetative material in their summer diets (ibid.). Age and sex class differences are probably attributable to nutritional requirements. Fall-collected canvasbacks had only 22% animal matter in their diets (ibid.). Juvenile redheads have a varied summer diet, with only 43% animal matter observed in esophageal contents. Adult. redheads had a higher percentage of animal species in their summer diet, with 86% and 81%, respectively, for males and females (ibid.). Lesser scaup juveniles and adults had an average of 98 to 99% animal matter in their summer diet (ibid.). The diets of fall-collected lesser scaup remained high in animal matter (ibid.).

Diving duck species that are primarily associated with coastal habitats have a high percentage of animal foods in their diet also (Johnsgard 1975). This category includes eiders, scoters, and oldsquaws.

The common eider has a reported winter diet of mussels (70.3%), barnacles (40.5%), and other mollusks (24.3%) (Dementiev and Gladkov 1967). The summer diet of juveniles and females showed that amphipods, mollusks, periwinkles, and crowberries (<u>Empetrum</u> <u>nigrum</u>) were important food sources (ibid.). The diet of king eider appears to be similar to the common eider (Johnsgard 1975). Juvenile spectacled eiders had a high percentage of insects in their summer diet. Pondweeds and crowberries were important plant foods during this period (Cottam 1939).

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

Table 1. Plant and Animal Species Utilized by Diving Ducks

Source: Bartonek and Hickey 1969, Johnsgard 1975.

Adult and juvenile oldsquaws feed extensively on amphipod crustaceans, mollusks, insects, and fish (Johnsgard 1975). Insects, both larval and flying forms, are important food sources for juveniles during summer months (ibid.). Crabs, shrimp, and other crustaceans averaged almost 50% of the food consumed by adults (ibid.). In the Arctic Region, oldsquaws eat primarily mysids and

amphipods, and, to a lesser extent, bivalves (Gabrielson and Lincoln 1959).

B. Types of Feeding Areas Used Inland diving ducks rarely feed on land. They generally frequent the larger and deeper inland bodies of water and protected estuarine habitats (ibid.). Marine diving species frequent coastal habitats. Shallow coastal waters of bays, inlets, and
estuaries, with a variety of substrates, are favored feeding areas for these species (Johnsgard 1975, Gabrielson and Lincoln 1959).

Most diving duck species have somewhat unique water/substrate/food preferences (Rothe, pers. comm.). Buffleheads and mergansers are usually associated with river systems, especially during winter (ibid.). Eiders, scoters, oldsquaws, and scaups are associated with coastal marine areas in winter (ibid.), except where ice conditions prevent feeding in open water.

Oldsquaws typically utilize the nearshore marine waters for feeding (Johnson and Richardson 1980).

- C. Factors Limiting Availability of Food Lingering snow and ice from a late spring may prevent diving ducks from utilizing lowland ponded areas. Cold weather, with accompanying ice conditions in the fall, prevents divers from using freshwater areas. Feeding activity under these conditions usually occurs in coastal marine waters. The abundant bogs and muskeg wetlands common in the Southcentral Region are acidic and are therefore low in productivity. Nutrients and food species are more abundant in river systems, deltas, and coastal zones (Rothe, pers. comm.).
- D. Feeding Behavior

Diving ducks usually dive for their food and will feed submerged. The depths to which they dive are generally between 2 and 10 ft; however, some may feed at greater depths. Oldsquaws, for example, have been recorded at depths of over 200 ft (Timm 1975, Johnsgard 1975).

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Most diving ducks require lowland pond habitats for nesting. Nest locations vary according to species (see table 2). The majority of diving ducks build their nests over shallow water in emergent vegetation or along the shorelines. The common and Barrow's goldeneyes and the bufflehead, however, are habitually tree nesters (Timm 1975). Ponds with good escape cover and high aquatic invertebrate populations are preferred.

In the Arctic Region, diving duck breeding habitat includes grassy, coastal sedge, upland tundra, coastal deltas, and inland lakes.

Breeding habitat varies by species.

- 1. <u>Oldsquaw</u>. Oldsquaw breeding was observed at Icy Cape in a salt marsh pond (Lehnhausen and Quinlan 1981).
- 2. <u>Common eider</u>. At Icy Cape, common eiders were observed using salt marshes for breeding (ibid.). <u>Elymus</u> coastal sites with grass were found to be preferred by nesting eiders (Schamel 1974, Lehnhausen and Quinlan 1981). Other types of sites utilized for nesting included sticks and logs, no cover, beaches covered with <u>Honckenya</u> spp., and old gull nests. <u>Elymus</u> sites appear to provide a camouflage protection, whereas sticks and logs may provide mainly a wind-break

					Clut	ch Size	
Species	Region	Nest Location	Mating	Incubation	Range	Average	Sexual Maturity*
Greater scaup	SW, SC	Not far from water; concealed in tufts of grass, close to shore	May-June	25-28 days	5-22	7-10	Breed at two years of age
	A	of ponds 			7-22**	8*	
Lesser scaup	SW, SC	Ground, near marshy creeks, sloughs, ponds, concealed in	May-June	25-28 days	6-15	9-12	11
	Α	Close to water (within 39 ft)**		25 days**		9**	
Canvasback	SW, SC	Just clear of high water; in bulrushes and reeds of sloughs and swampy areas	May-June	24-28 days		7-9	n
Ringneck	SW, SC	Wet, boggy areas bordering marshes, ponds, sloughs; most barely above level of water	May-june	24-28 days		8-12	
Bufflehead	SW, SC	Tree nester; usually placed in deserted hole of woodpecker or flicker, may nest in banks	April-May	20-28 days	6-14	10-12	n
Harlequin	SW, SC	Ground or in holes in trees or cliffs	March-May	24-26 days	5-10	6-7	Do not breed until their second year
Oldsquaw	SW, SC	Ground: small hollows, sometimes in grass; might be near water or away from it		24-29 days*	5-17	5-7	Most do not breed until they are at least two years of age

Table 2. Reproductive Characteristics of Diving Ducks

(continued)

Table 2 (continued).

					Clut	ch Size	
Species		Nest Location	Mating	Incubation	Range	Average	Sexual Maturity*
01dsquaw*	A	Usually on islands, either offshore along the coasts or in tundra ponds and lakes. Nests are placed in natural depressions or former nest sites; mosses, sedges, grasses, dwarf willow and dwarf birch leaves		24-29 days	2-11	7	Two years of age
Pacific common eider*	A	Close to the sea, usually on small islands or islets, but sometimes located on tundra ponds distant from coast		21-28 days	1-14	4	
Surf scoter	SW, SC	Ground: carefully concealed, lined with a small amount of grass; will breed inland	Usually June		5-9	7	
White-winged scoter	SW, SC	Ground: in hollow lined with sticks, leaves, and rubbish, concealed under shrubs or bushes	Usually June	25-31 days*	9-14	12	Probably reach breeding age in second year of life
Black scoter	SW, SC	Cround: 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	sw, sc	Cavity of trees, dead stumps, preferably near water from ground to 50 ft	March-June	19-22 days	6-15	10	Most Barrow's breed at two years of age
Common goldeneye	SW, SC	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

(continued)

					Clutch Size		
Species		Nest Location	Mating	Incubation	Range	Average	Sexual Maturity*
Red breasted merganser*	SW, SC	Ground, close to water	April-May	.30 days	5-11	7-8	Not known to breed before their second year
Common merganser*	SW, SC	Cavities of trees, from ground to 50+ ft, usually close to water	April-May	30-35 days	6-17	9-12	

Source: Timm 1975.

--- means no data were available.

* Bellrose 1976.

** Johnsgard 1975.

protection. Island sites appear to be preferred to mainland sites (Lehnhausen and Quinlan 1981).

- 3. <u>King eider</u>. King eider breed on inland ponds (Johnsgard 1975).
- 4. <u>Spectacled eider</u>. Spectacled eider breed in the grassy tundra (ibid.).
- B. Reproductive Seasonality

Most diving ducks have arrived at their breeding range by mid-tolate May (ibid.) in Southwest and Southcentral Alaska and by late May to late June in the Arctic Region (Bellrose 1976). Nest initiation extends from early to late June, depending on the species and weather conditions, with scoters generally the last to nest (ibid.).

- <u>Oldsquaw</u>. Oldsquaw mating was observed on 17 June at Icy Cape (Lehnhausen and Quinlan 1981). Common eider pairs and displaying males were observed around mid June at Icy Cape (ibid.).
- 2. <u>Common eider</u>. Nesting dates appear to be at least partially the result of weather conditions. Lehnhausen and Quinlan (1981) estimated egg-laying dates on two islands off Icy Cape to be from 23 June to 12 July. Schamel (1977) observed similar nesting chronology on the Beaufort Sea coast. Divoky (1978) reported that eider egg laying at Icy Cape occurred between 18 and 27 June in 1976 about 10 days earlier. Lehnhausen and Quinlan (1981) suggest this difference from Divoky's observation was due to the cold and late spring that occurred in their study and in Schamel's (1977).
- C. Reproductive Behavior

Diving ducks have new mates each season. Birds that have mated before arrival begin nesting as soon as a suitable site has been selected. Birds that have not mated begin to pair off soon after arriving at their breeding grounds; they court and then begin nesting activities (ibid.). In mid June, oldsquaw males left females after the start of nesting (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.).

- <u>Common eider</u>. On the Beaufort Sea coast, Schamel (1977) found a mean clutch of 5.1 in 1976 at Icy Cape. Lehnhausen and Quinlan (1981) found a mean clutch size of 2.9 on Amaulik Island and 3.8 on Tern Island (both near Icy Cape), with an overall range of 1 to 11 eggs. Smaller clutch sizes are typical of birds that must renest (Schamel 1977). Lehnhausen and Quinlan (1981) suggest that
 - the smaller mean clutch size on Amaulik Island may be due to the number of renests resulting from predation during early

egg laying. On Tern Island, nest success (nests producing young) was 34%. Similar success was found by Schamel (1977) (34%, 1974) for Pacific (common) and king eider.

F. Incubation Period

The incubation period varies by species but usually averages from 19 to 28 days (Rothe, pers. comm.).

1. <u>Common eider</u>. Schamel (1977) found the incubation period for common eiders along the Beaufort Sea to be 26 days.

In the Arctic Region on June 28, Lehnhausen and Quinlan (1981) noted that male/female common eider pairs were breaking up and the males leaving.

G. Rearing of Young

As soon as the female is well into incubation, the males withdraw into flocks by themselves; they take no part in the rearing of young (ibid.). In the Southwest and Southcentral regions, brood rearing occurs throughout July and August. In the Arctic Region, oldsquaw brood rearing occurs from mid to late June (Bellrose 1976).

- VI. FACTORS INFLUENCING POPULATIONS
 - A. Natural

Species composition and numbers for the Alaska populations of diving ducks can change dramatically. Production is influenced primarily by spring weather, flooding, and predation. Production is less in years with "late" springs than in years when snow and ice disappear early in the season. Flooding in river valleys or from storm tides on coastal wetlands can delay nesting or destroy nests and significantly reduce production. Flooding in river valleys, however, causes beneficial effects from nutrient exchanges, which fertilize ponds, increasing the food they produce for waterfowl (ADF&G 1980).

- 1. <u>Common eider</u>. Predators may play an important role in influencing population size. Lehnhausen and Quinlan (1981), who found 479 nests on Amaulik Island, reported that no nests survived to hatching as a result of predation by an arctic fox, which apparently swam out from the mainland and destroyed the colony late in the season. Evidence of avian predation of eggs, apparently by parasitic jaegers and glaucous gulls, was also noted.
- B. Human-related

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

- Aquatic substrate alteration (e.g., from accelerated aufeis, mechanical removal)
- Chronic debilitation due to ingestion or contact with petroleum or petroleum products
- [°] Electrocution, contact with powerlines
- [°] Entanglement in fishing nets or marine debris
- [°] Harvest, change in level
- ° Interference with reproductive behavior

- [°] Interruption of ongoing behavior (alarm, flight)
- Water level or water quality fluctuations (including changes in drainage patterns, long-term increase or decrease in water levels)
- [°] Terrain alteration or destruction (e.g., shoreline habitat, estuarine, and lagoon)
- Vegetation composition change to less preferred or useable species

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

VII. LEGAL STATUS

In Alaska, waterfowl are managed by the U.S. Fish and Wildlife Service and the Alaska Department of Fish and Game. Waterfowl are protected under international treaties with Canada (Great Britain) 1916, Mexico 1936, Japan 1972, and the Soviet Union 1976.

- VIII. SPECIAL CONSIDERATIONS
 - A. Molting
 - The requirements of molting adults vary by species.
 - 1. <u>Scoters</u>. Scoters leave the nesting areas in mid July to molt at sea, often near estuaries.
 - 2. <u>Scaup and goldeneye</u>. The divers molt on large inland lakes that are perennial molting areas. The molt extends from mid July to the end of August (Bellrose 1976).
 - 3. <u>Steller's eiders</u>. Steller's eiders migrate to their wintering areas on Izembek and other Alaska Peninsula lagoons prior to their molt. The molt period is variable, ranging from August through November (Johnsgard 1975).
 - 4. <u>Oldsquaw</u>. Oldsquaws leave their nesting areas in mid July to molt at sea, often near estuaries (Bellrose 1976). Oldsquaws in the Simpson Lagoon area utilize the nearshore area for molting (Johnson and Richardson 1980, Martin and Moitoret 1981). At Icy Point, Lehnhausen and Quinlan (1981) noted an increase in lagoon use around the beginning of molt in mid July.

At Icy Cape, 10% of male birds were flightless on 16 July; about 50% were flightless on 12 August; and in late August many birds regained flight (Lehnhausen and Quinlan 1981). Derksen et al. (1979a) noted that molting begins around mid July.

- 2. <u>Common eider</u>. At Icy Cape, molting birds were noted from mid July to about mid August (ibid.).
- IX. LIMITATIONS OF INFORMATION

Few scientific studies have been conducted on diving ducks in Arctic Alaska, and there is a need for much more life history information on these species.

REFERENCES

- ADF&G. 1980. Alaska wildlife management plans: species management policies. Fed. Aid in Wildl. Res. Proj. W-20-2. 113 pp.
- ADNR/USFWS. 1983. Bristol Bay Cooperative Management Plan. Anchorage. 495 pp.
- Bartonek, J.C., and J.J. Hickey. 1969. Food habits of canvasbacks, redheads, and lesser scaup in Manitoba. Condor. (71)3:280-290.
- Bellrose, F.C. 1976. Ducks, geese, and swans of North America. Harrisburg, PA: Stackpole Books. 540 pp.
- Bergman, R.D., R.L. Howard, K.F. Abraham, and M.W. Weller. 1977. Waterbirds and their wetland resources in relation to oil development at Storkersen Point Alaska. USFWS Resource Publ. 129. Washington, DC. 38 pp.
- Cottam, C. 1939. Food habits of North American diving ducks. USDA Tech. Bull. 643. 139 pp.
- Dementiev, G.P., and N.A. Gladkov. 1967. Birds of the Soviet Union. Vol. 4. Translated from 1952 Russian edition, Israel Prog. Sci. Transl. USDI and National Science Foundation, WA.
- Derksen, D.V., W.D. Elridge, and T.C. Rothe. 1977. Waterbird populations and habitat analysis of selected sites in NPR-A. Xerox report in files of USFWS. Ecological Services, Anchorage, AK.
- Dirschl, H.J. 1969. Foods of lesser scaup and blue-winged teal in the Saskatchewan River delta. J. Wildl. Manage. 33(1):77-87.
- Divoky, G.J. 1978. Breeding bird use of barrier islands in the northern Chukchi and Beaufort seas. Pages 482-548 <u>in</u> Environmental assessment of the Alaskan continental shelf. Annual reports of the principal investigators. Vol. 1. NOAA, Boulder, CO.
- Gabrielson, I.N., and F.C. Lincoln. 1959. Birds of Alaska. Harrisburg, PA: The Stackpole Co. 922 pp.
- Johnsgard, P.A. 1975. Waterfowl of North America. Don Mills, Ont: Fitzhenry and Whiteside Limited. 575 pp.
- Johnson, S.R., and J.W. Richardson. 1980. Beaufort Sea Barrier Island Lagoon ecological process studies: final report, Simpson Lagoon. Part 3: Birds. Environmental assessment of the Alaskan continental shelf. Annual reports of the principal investigators. BLM, NOAA, OCSEAP, Boulder, CO.

- King, J. 1983. Personal communications. Waterfowl Biologist, USFWS (retired), Juneau, AK.
- King, J.G., and G.J. Lensink. 1971. An evaluation of Alaska habitat for migratory birds. Unpubl. rept. USDI, Bureau of Sport Fish and Wildlife. Washington, DC. 72 pp.
- Lehnhausen, W.A., and S.E. Quinlan. 1981. Bird migration and habitat use at Icy Cape, Alaska. Unpubl. rept, USFWS, Anchorage, AK. 298 pp.
- Martin, P.D., and C.S. Moitoret. 1981. Bird populations and habitat use, Canning River delta, Alaska. USFWS, unpubl. rept., Fairbanks, AK.
- Rothe, T. 1985. Personal communications. Game Biologist, ADF&G, Div. Game, Anchorage.
- Schamel, D.L. 1974. The breeding biology of the Pacific eider (Somateria mollissima J. - nigra Bonaparte) on a barrier island in the Beaufort Sea, Alaska. M.S. Thesis, Univ. Alaska, Fairbanks. 95 pp.

_____. 1977. Breeding of the common eider (<u>Somateria mollissima</u>) on the Beaufort Sea coast of Alaska. Condor 79:478-485.

Timm, D. 1975. Northeast Gulf Coast waterfowl. Pages 264-343 in ADF&G, comp. A fish and wildlife resource inventory of Prince William Sound. Vol. 1: Wildlife.

Geese Life History and Habitat Requirements Southwest, Southcentral, and Arctic Alaska

Map 1. Range of geese (Bellrose 1976)

- I. NAME
 - A. Common Name: Geese, brant
 - B. Scientific Classification:
 - 1. Family. Anatidae.
 - 2. Subfamily. Anserinae.
 - 3. Tribe. Anserini.
 - C. Species Commonly Occurring in the Southwest Region
 - In the Southwest Region, goose populations are comprised primarily of the Pacific flyway population of greater white-fronted goose (Anser albifrons frontalis); the emperor goose (Chen canagica); the Pacific black brant (Branta bernicla nigricans); and three races of Canada goose, the cackling Canada goose (Branta canadensis minima), Aleutian Canada goose (B. c. leucopareia), and Taverner's Canada goose (B. c. taverneri) (Gabrielson and Lincoln

1959). The lesser snow goose (\underline{C} . <u>caerulescens</u>) occurs during migration (ibid.).

- D. Species Commonly Occurring in the Southcentral Region Goose species that commonly occur in the Southcentral Region include the lesser Canada goose (<u>B. c. parvipes</u>), the dusky Canada goose (<u>B. c. occidentalis</u>), possibly the Vancouver Canada goose (<u>B. c. fulva</u>), the tule white-fronted goose (<u>A. a. gambeli</u>), and, during migration, the lesser snow goose, greater white-fronted goose, and cackling Canada goose (Gabrielson and Lincoln 1959; Rothe, pers. comm.).
- E. Species Commonly Occurring in the Arctic Region Goose species that commonly occur in the Arctic Region include the lesser Canada goose (Branta canadensis tavernieri and B. c. parviptes, collectively), the Pacific black brant, the white-fronted goose, and the snow goose (Rothe, pers. comm.).
- II. RANGE
 - A. Worldwide
 - Geese are found in nearly all northern temperate and arctic zones. B. Statewide
 - Geese are found throughout the state where suitable habitat is available.
 - C. Regional Distribution Maps

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

D. Regional Distribution Summary

In general, geese are distributed throughout the Southwest Region at elevations below 500 ft (Sellers, pers. comm.). In Southcentral Alaska, geese are found in suitable habitat at elevations up to 1,000 ft (Timm 1977). Estuaries, lagoons, river deltas, marshes, and tidelands, however, support the largest concentrations of geese. In the Arctic Region, geese are generally found on and along the coastal plain (Johnsgard 1975).

- 1. <u>Southwest</u>. The largest concentrations of geese occur in the Bristol Bay and Alaska Peninsula areas during spring and fall migrations; Kodiak and the Aleutian Islands remain important wintering areas for some species (Gabrielson and Lincoln 1959, ADNR/USFWS 1983).
- 2. <u>Southcentral</u>. The largest concentrations of geese in the Southcentral Region occur during spring and fall migrations. The tidal salt marshes and extensive mud flats of Cook Inlet, the numerous small mud flats of Prince William Sound (PWS), and the large alluvial floodplain and delta of the Copper

River all provide important spring and fall habitat for geese (Timm 1977).

Additionally, important world populations of the tule goose and the dusky Canada goose are found in Cook Inlet and the Copper River delta, respectively. The tule goose has been found nesting along the west side of Cook Inlet, which is the only known breeding area. This subspecies winters in northern California (Timm 1975).

The world population of the dusky Canada goose is known to breed only on the Copper River delta. The wintering area for this subspecies is in the Willamette Valley, Oregon, and southwest Washington (ibid.). Additionally, Canada geese breed in the small bays and islands of PWS. This population is generally believed to be a small population of the Vancouver Canada goose (B. c. fulva) (ibid.). (For detailed distribution and abundance information, see volumes 1 and 2 of the Alaska Habitat Management Guides for the Southwest and Southcentral regions, respectively.)

- 3. <u>Arctic</u>. Geese in the Arctic Region are concentrated along and on the coastal plain (Johnsgard 1975).
 - a) Canada goose. Because of the extraordinarily great subspecific diversity in breeding habitats and the collective enormous breeding range of these races, no concise summary of distribution and habitat is possible Canada Virtually all for the qoose. of the nonmountainous portions of the Arctic Region can be considered breeding range for the Canada goose (ibid.). The following is as specific information as possible for the two primary subspecies found in the Arctic Region:
 - <u>Cackling Canada goose</u>. The cackling Canada goose breeds along the coast of western Alaska from Nushagak Bay to the vicinity of Wainwright, where it probably intergrades with Taverneri (ibid.).
 - <u>Taverner's Canada goose</u>. The Taverner's Canada goose is distributed along the coastline from the Seward Peninsula to Point Lay, where it probably intergrades with minima (ibid.).
 - b) <u>Black brant</u>. Black brant breeds abundantly from the Kuskokwim delta and Nelson Island northward along the coastline and east to the Yukon-Alaska border (Johnsgard 1975, Gabrielson and Lincoln 1959).
 - c) <u>Snow goose</u>. The snow goose historically breeds in the vicinity of Barrow and recently on Howe Island near Prudhoe Bay (Johnsgard 1975; Rothe, pers. comm.).
 - d) <u>White-fronted goose</u>. The white-fronted goose breeds primarily along the arctic coastal plain and nests mainly near the coast. At Barrow and to the east, it is a common coastal breeder, extending in marshy areas from 1 to 20 mi inland, with apparent centers of abundance at Smith Bay and the Colville delta. In the Kotzebue Sound

region along the Noatak and Kobuk rivers, white-fronts are also common nesters (Johnsgard 1975).

III. PHYSICAL HABITAT REQUIREMENTS

A. Southwest

Geese in the Southwest Region are usually found where lagoon water and embayment habitat are plentiful, particularly on the north side of the Alaska Peninsula. Brant are primarily restricted to lagoon water where eelgrass is found. Canada and snow geese use uplands, lagoons, and alluvial floodplains, whereas emperors use lagoon island sand and protected delta mud (Arneson 1980).

B. Southcentral

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

C. Arctic 1. G

<u>Geese</u>. In spring, during the molt, white-fronted geese in the Teshepuk area use flooded tundra and shallow <u>Carex</u> areas (Derksen et al. 1979). Brant commonly feed in salt marshes and lagoons (Lehnhausen and Quinlan 1981, Kiera 1979, and Seaman et al. 1981) and have been observed on barrier island beaches (Bailey 1948).

Molting geese in the National Petroleum Reserve-Alaska (NPR-A) showed a definite preference for deep, open lakes as opposed to those with emergent vegetation. Derksen et al. (1979) found 96% of the observed brant, 85% of the Canada geese, and 57% of the white-fronted geese to be associated with deep, open lakes. White-fronted geese clearly preferred smaller waterbodies than the other species, which preferred flooded tundra and braided streams. At Storkersen Point, however, white-fronted geese used deep, open lakes almost exclusively, with minimal use of shallow Arctophila and basin complexes (Bergman et al. 1977). Escape cover may be an important factor in selection of deep open lakes, because of the security provided from terrestrial predators such as arctic fox (Derksen et al. 1979). Low-relief shorelines that support grasses and sedges are used more frequently by molting geese than precipitous shorelines with adjacent uplands, apparently because of greater food availability in the former. Following molt, Canada geese and brant utilized coastal areas, whereas white-fronted geese did not (ibid.). Lehnhausen and Quinlan (1981) found brant at Icy Cape using deep Arctophila lakes primarily and shallow Arctophila ponds occasionally during the molt.

- IV. NUTRITIONAL REQUIREMENTS
 - A. Food Species Used

Geese are predominantly vegetarians and consume the leaves, roots, and seeds of a wide variety of plants. Cultivated grains comprise a large percentage of their diet in wintering areas of the continental United States (Bellrose 1976). Along coastal areas, geese are known to feed on mollusks, crustaceans, and other animal materials (table 1) (Terres 1980). Black brant feed almost exclusively on eelgrass (Bellrose 1976). During fall migration on the Alaska Peninsula, Canada geese feed extensively on crowberries (<u>Empetrum nigrum</u>) (Rothe, pers. comm.). (See tables 1, 2, and 3 for further information on food.)

- 1. Arctic:
 - a. <u>Geese</u>. Derksen et al. (1979) noted that geese utilize grasses and sedges.
 - b. <u>Čanada geese</u>. Derksen et al. (1979) observed occasional feeding on emergent <u>Arctophila fulva</u>. <u>Deschampsia</u> spp. and <u>Carex</u> spp. were the most important grass and sedge, respectively, for molting Canada geese at Teshepuk Lake; mosses were also evident in droppings (Derksen et al. 1982).
 - Black brant. Derksen et al. (1979) observed that brant с. in the NPR-A feed mainly on Dupontia fischeri. Derksen et al. (1982) found that, for molting birds around Teshepuk Lake, Deschampsia spp. and Carex spp. were the most important grass or sedge, respectively, based on analysis of brant droppings. Mosses were also eaten. In a salt marsh near Prudhoe Bay, Kiera (1979) found brants to feed predominantly on Carex subspathacea. Also, Kiera (1979) observed brant, prior to nesting, on mosses, freshwater algae, feeding Equisetum variegatum, and old seed heads of Carex aquatilis. however, they fed During nesting, primarily on C. aquatilis and Dupontia fischeri. Chironomids were taken on days of peak emergence.

Kiera (1979) determined that brant consumed an average of 1,207 kilo calories/goose/day.

B. Types of Feeding Areas Used Geese are opportunistic and forage in areas providing plentiful food supplies. Coastal salt marshes and adjacent shallow water

areas, cultivated fields, freshwater marshes, and a variety of other habitats all provide feeding areas for geese (Johnsgard 1975).

In the Arctic Region, salt marshes and lagoon areas appear to be commonly used feeding areas (Seaman et al. 1981, Kiera 1979, Lehnhausen and Quinlan 1981, Derksen et al. 1982). Kiera (1979) observed black brant feeding in salt marshes in the Prudhoe Bay area in mid August.

Table 1. Preferred Foods and Breeding Habitat of Geese in the Southcentral Region

Species	Preferred Food	Breeding Habitat	
Lesser snow goose	In marine areas: salt marsh vegetation; in upland areas: berries and grasses (Beilrose 1976)	Seasonal migrants in SC Region; none known to breed there (Timm, pers. comm.)	
Tule goose	On west side of Cook Inlet: sedges (<u>Carex</u> <u>Lyngbyaei</u> and <u>C. Ramenskii</u>), arrow grass (<u>Triglochin palustris and T. maritimum</u>), and alkali grass (<u>Puccinellia nutkaenis</u> & <u>P. phryganodes</u> (Timm 1982)	Apparently limited to saline sedge-grass habitat of western Cook Inlet; additional breeding areas possibly occur farther inland, in <u>Carex</u> & <u>Equisetum</u> riparian meadows and outwash plains (Timm 1982)	
Lesser Canada goose	Wide variety of foods eaten, including cattails (Typhaceae), grasses, algae, waste grains, bulrushes, (<u>Scirpus</u> sp.), and clover; marine invertebrates utilized in coastal areas (Terres 1980); also sedges (<u>Carex</u> sp.), alkali grass (<u>Puccinellia</u> sp.), seeds of mare's tail (<u>Hippuris</u> sp.), goose foot (<u>Atriplex</u> sp.), tubers of arrow grass (<u>Triglochin</u> <u>palustris</u>) and crowberries (<u>Empetrum</u> sp) (Sellers, pers. comm.)	Have greater diversity of nest sites than all other species of waterfowl; nest in dense marshes, on islands, cliffs, elevated platforms in trees, in muskeg, and on tundra	
Dusky Canada goose	Similar to above	World's population nests on CRD; vegetative and other changes since 1964 earthquake have apparently influenced nesting habitat: shrub habitat type and sedge habitat type are utilized as nesting habitat	
Vancouver Canada goose	Plant material comprises bulk of summer food, with skunk cabbage (<u>Lysicheton</u> <u>americanum</u>) heavily utilized; also sea lettuce (<u>Ulva</u> sp.), blueberry (<u>Vaccinium</u> sp.), horsetail (<u>Equisetum</u> sp.), and grasses and sedges; winter foods probably include more animal matter (Lebeda 1980)	Majority of nests in dense confier forest, at base of large trees; one nest reported in tree top, and and nearby trees used for perching (Lebeda 1980)	

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

Species	Preferred Food	Breeding Habitat	
Pacific white-fronted geese	Plants used include vegetative parts of various native grasses and sedges (Johnsgard 1975)	Nests on both coastal and upland areas, typically in tall grass bordering tidal sloughs or in sedge marshes and less often in grass-covered pingos or margins of tundra hummocks; infrequently, nests on heath tundra, sometimes as far as 50 to 100 yd from water (Bellrose 1976); most snows occurring in SW & SC nest on Wrangell Island in USSR	
Lesser snow goose	Snow goose diet is primarily salt marsh vegeta- tion; berries and grasses often important diet in upland areas (Bellrose 1976)	Usually locate nesting colonies on low grassy tundra plains with few miles of sea, along broad shallow rivers near coast, and on islands in shallow lakes 10-80 mi inland (Bellrose 1976); most snows occurring in the SW and SC regions nest on Wrangell Island in USSR	
Emperor goose	Major food sources: algae, eelgrass, pond- weeds, grasses, sedges, and other plant fibers; mollusks, crustaceans, and other animal materials make up smaller portions of diet (Johnsgard 1975); young birds feed on aquatic insects and marsh grass and later may consume berries	Tend to nest on coastal fringe slightly inland from black brant; almost all nest within several hundred yd of tide waters that may extend up to 30 or 40 mi inland along tidal grass lands, low pingo tundra, and sedge marshes (Bellrose 1976); most nesting occurs on the Y-K delta	
Pacific black brant	Eelgrass most important food in western Alaska when scarce or unavailable, brant use rockgrass and sea lettuce (Bellrose 1976); saltmarsh grasses (<u>Puccinellia</u> sp) are preferred in other areas	Nesting on Yukon Delta confined either to extreme coastal rim or to areas along major estuaries flanked by tidal meadows; nests on delta most frequently established on small islets or on shores of tidal ponds but sometimes as far as 30 yd from nearest water; nests placed in either short sedge or, rarely, in clumps of wild rye (Barry 1966)	
Canada goose	Cackling geese feed predominately on sedges and creeping alkali grass (<u>Puccinellia phryganodes</u>); also seeds of <u>Hippuris</u> and <u>Atriplex</u> and tuber of <u>Triglochin palustris</u> (Sellers, pers. comm.)	Cackling geese use pond-studded tundra of coastal Yukon Delta, select islets for 81% of nest sites, islets average 5-11 ft in size and 8 inches in height; 16% nested on small peninsulas extending	

(continued)

Table 2 (continued).

Species	Preferred Food	Breeding Habitat	
Canada goose(continued)	Major foods of Taverner's Canada goose: berries (especially crowberries) and other upland vege- tation and eelgrass in marine system	into tundra ponds, but only 3% placed nests on mainland shore (Mickelson 1973)	

Table 3. Preferred Foods and Breeding Habitat of Geese in the Arctic Region

Species	Preferred Food	Breeding Habitat			
Black brant	Mostly plant materials: eelgrass (<u>Zostera</u> <u>marina</u>), sea lettuce (<u>Ulva</u> spp., especially <u>U. lactuca</u>)	High arctic coastal sedge tundra; lowland coastal tundra, usually just above high tide line, nesting grounds highly susceptible to flooding by storm tides; low islands of tundra lakes and dry inland slopes well covered with vegetation			
Canada goose	Mostly plant materials, particularly root stocks of many marsh plants	High arctic grassy tundra; virtually all nonmoun- tainous portions of the arctic region			
Snow goose	Mostly plant materials: salt marsh rootstocks	High arctic coastal deltas; low grassy tundra associated with islands in braided deltas, usually near salt water; ponds or lakes			
White-fronted goose	Mostly plant materials: vegetative parts of native grasses, some horsetail (<u>Equisetum</u> spp.) and cotton grass (<u>Eriphorum</u> spp.) and sedges	High arctic upland tundras; coastal tundra with little surface relief; gently rolling upland tundra 50-700 ft above sea level, with lakes and ponds in the depressions; also willow and shrub-fringed streams and ponds			

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Source: Johnsgard 1975.

C. Feeding Behavior

Geese are essentially grazers and crop vegetation with their bills. During spring, they often dig up tubers and rhizomes, and in fall they often select berries. When eating submerged vegetation, they reach below the surface with their head and neck, tail tipped up, similarly to dabbling ducks. Geese feed primarily in the early morning and late afternoon (table 1) (Timm 1975). Except during nesting, geese feed socially in flocks that move and react to disturbance as a unit (Johnsgard 1975).

- Black brant. Kiera (1979) reports that brant begin arriving 1. in salt marshes near Prudhoe Bay in mid August just after salt marsh vegetation reaches peak production. He found no relationship between food preferences and the nutritional characteristics of the graminoid vegetation they ate. He observed brant to spent 77% of the daylight hours feeding and noted distinct daily patterns of feeding at different times of the summer. During nesting, he found brant exhibited a bimodal pattern in early evening. By late summer, when geese were migrating, he noted that they fed most heavily in the morning, feeding gradually tapering off through the day. Kiera (1979) also found that females during nesting fed significantly faster than males and that during migration juveniles picked at a significantly higher rate than adults.
- V. REPRODUCTIVE CHARACTERISTICS
 - A. Reproductive Habitat
 - Nesting sites vary by species, but there are three standard prerequisites for all geese: 1) proximity to water, 2) cover for the nest itself, and 3) an exposed view of the surrounding area for the incubating bird (Bellrose 1976, Johnsgard 1975). (See tables 3, 4, and 5.)
 - B. Reproductive Seasonality

С.

The span of nest initiation, which begins in early May, varies among species and is dependent on weather conditions. In years when snow cover and cold conditions persist later into the season, nesting efforts may be delayed for several weeks (Johnsgard 1975).

- <u>Arctic</u>. On the NPR-A and adjacent habitats, Derksen et al. (1979) observed nesting brant and white-fronted geese arriving in late May and early June, with the peak hatch occurring in early July. At Storkersen Point, estimated egg-laying dates for brant ranged from 5 to 18 June (Bergman et al. 1977). Mating was observed between brants at Icy Cape on 9 June (Laphaceneer and Quinter 1981)
 - (Lehnhausen and Quinlan 1981).

Reproductive Behavior Geese appear to form pair bonds that remain steadfast throughout life, but when separated by death, the survivor seeks a new mate. Most species of geese return to the same breeding grounds or nesting colonies each year, where they establish a territory prior to nesting. The size of the territory varies by species and

Table 4. Nesting, Rearing, and Molting Biology of Geese - Southwest Region

				Clutch	Size			Moltin	9
Species	Nest Location	Mating	Incubation	 Range	Average	Sexual Maturity	Fledging Period	Initiation	Flightless Period
Pacific white- fronted goose	Female selects shallow depression, building nest from nearby plant material as eggs are laid (Barry 1966)	Probably Feb. and Mar. (Dau, pers. comm.)	23-25 days (Bellrose 1976)	2-10 (Bellros	4.75 e 1976)	First breed at 3 yr; favorable nest conditions may induce some 2-yr- olds to breed	55-65 days	Adult molt begins when goslings about 3 weeks old (Bellrose 1976)	4 weeks (Mickelson 1973)
Lesser snow goose	No nesting occurs in SW Alaska	Mating apparently occurs during north- ward migration, part- icularly at rest stops immediately preceding their last passage to nesting grounds (Bellrose 1976)	23 days (Cooch 1958)	2-10 (Bellrose	3.9 1976)	Reach sexual maturity at 2 yr; majority do not breed until 3rd year and in some seasons not until 4th yr (Bellrose 1976)	45 days (Cooch 1958)	Adults molt about 2.5 weeks after young hatched (Barry 1966)	About 24 days (Cooch 1958)
Emperor goose	Prefer to nest on an elevated site near tidal pond; nest a scape lined with grass, sedges, or other adjacent vegetation, and small amount of down (Bellrose 1976)	Arrive on nesting grounds on Yukon Delta in May, mated and ready to begin nesting (Headley 1967); mating occurs probably Feb./Mar. (Dau, pers.	23-27 days (Eisenhauer	1-12 & Frazer	4.83 1972)	The age at breed- ing unknown, but most probably do not nest until 3rd yr (Bellrose 1976)	50-60 days (Mickelson 1973)	Adults molt when young are 20-25 days old (Headley 1967)	Third week of July to 3rd week of Aug. (Mickelson 1973)

(continued)

Table 4 (continued).

				Clutch Size				Molting		
Species	Nest Location	Nating	Incubation	Range Average		Sexual Maturity	Fledging Period	Initiation	Flightless Period	
Pacific black brant	Nests placed in depres- sions 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	3.52 1966)	Most breed at 3 yr, but good seasons encourage perhaps 10% of 2-yr birds to nest (Barry 1966)	40-45 days (barry 1966)	Adults molt 2 weeks after eggs hatched (Barry 1966)	3 weeks, controlled by day length (Barry 1966)	
Canada geese	If females do not use old scrapes, new ones are wallowed out in earth; usually female reaches out from saucer- shaped depressions to gather vegetation for bases and rims (Bellrose 1976)	Probably Feb./Mar. (Dau, pers. comm.)	24-30 days (Mickelson 1973)	1-12 (Bellros	4.27 .e 1976)	A few yearling geese have at- tempted to nest, but none have hatched a clutch successfully; some 2-yr and probably all 3-yr-olds nest (Hall and McGilvrey Mickelson 1973)	40-46 days (Mickelson 1973)	Adults molt when goslings are 1 to 2 weeks of age (Mickelson 1973)	3-4 weeks (Mickelson 1973)	

						Mot	lting
Species	Nest Location	Incubation	Clutch Size	Sexual Maturity	Fledging Period	Initiation	Flightless Period
Lesser snow goose	Seasonal migrants to SC Region;	none known to breed	in region				
Tule goose	Favored nest sites slightly elevated in saline sedge- grass flat habitat (Timm 1982)	App. 26 days (Timm 1982)	4-7 eggs; avg. 5.6 (Timm 1982)	Usually 3 yr, sometimes 2 (Bellrose 1976)	App. 55-65 days (Bellrose 1976)	Late June (Bellrose 1976)	App. 35 days (Bellrose 1976)
Dusky Canada goose	Nest locations vary; most preferred cover type is grass-form; increase in nest- ing use of sedge cover type observed since 1964 earthquake (Bromley 1976)	25-31 days (Bromley 1976)	1-8 eggs; avg. 5.2 (Bromley 1976)	Usually 3 yr; some 2-yr-olds breed (Bromley 1976)	App. 48 days (Bromley 1976)	App. 2nd week July (Bromley 1976)	App. 4 weeks; birds gather in large flightless flocks (Timm 1975)
Vancouver Canada goose	At base of trees; nest is a scrape depression, with vegetative material around rim (Lebeda 1980)	App. 25-31 days (Lebeda 1980)	2-6 eggs; avg. 4.4 (Lebeda 1980)	No specific info., 3 yr common for other Canada goose subspecies	Late Aug. (Lebeda 1980)	Late June- early July (Lebeda 1980)	4-6 weeks (Lebeda 1980)
Lesser Canada goose	Pairs are territorial and will defend nest sites; most nests are a depression on ground, with vegetation around rim (Bellrose 1976, Timm 1980)	24-30 days (Terres 1980)	1-12 eggs; avg. 4.3 (Terres 1980)	Some mature at 2 yrs but most at 3 (Terres 1980)	40-46 days (Terres 1980)	Adults begin molt when young are 1-2 weeks old (Terres 1980)	3–4 weeks (Bellrose 1976)

Table 5. Nesting, Rearing, and Molting Biology of Geese in the Southcentral Region

within the species, according to the demands made upon the available space (ibid.). Brant and snow geese are colonial nesters, and their nests may cover large areas. Some Canada goose subspecies and emperors may nest in loose aggregations, whereas white-fronted geese are solitary nesters (Rothe, pers. comm.). (See table 2.)

- D. Age at Sexual Maturity On the average, geese reach sexual maturity at two years of age, although the majority do not breed until their third year (Terres 1980, Bellrose 1976).
- E. Fecundity The number of eggs per clutch varies among species but ranges between 1 and 12 eggs, the average size being 4 eggs (Johnsgard 1975).
- F. Incubation Period The incubation is conducted solely by the female, with the male on guard nearby (Terres 1980). The incubation period varies by species but usually averages between 25 and 30 days (ibid.).
- G. Rearing of Young Both parents are attendant to their young, the male principally assuming the role of guarding them from predators (Bellrose 1976).

VI. FACTORS INFLUENCING POPULATIONS

A. Natural

Species composition and numbers of geese in areas of Alaska can change dramatically. Production is influenced primarily by spring weather and flooding. Production is less in years with "late" springs than in years when snow and ice disappear early in the season. Flooding in river valleys or from storm tides on coastal wetlands can delay nesting or destroy nests and significantly reduce production. Flooding in river valleys, however, causes beneficial effects from nutrient exchanges, which fertilize ponds and thus increase the food they produce for waterfowl (ADF&G 1980).

The 1964 earthquake uplifted parts of the Copper River delta by as much as 1.89 m. This has apparently resulted in drier, less saline soils, with subsequent changes in vegetation communities on the delta, including those utilized for nesting by dusky Canada geese. An increase in the use of sedge as a nesting cover type during the mid 1970's was due to 1) an increase in the suitability of that cover type (less flooding) and 2) high population levels and increased nesting density, which may have caused nesting to occur in less favorable habitat (Bromley 1976). In addition, increased nest predation, particularly by mammalian predators, appears to be a factor in the reduced nesting success of dusky Canada geese (Campbell and Timm 1983).

B. Human-related

The dusky Canada goose population, which winters almost exclusively in the Willamette Valley, Oregon, is probably the most heavily harvested Canada goose population in North America (Timm 1975). The intermixing of wintering populations of the more numerous lesser Canada geese (B. C. parvipes and B. C. taverni) with the less abundant dusky Canada goose complicates censusing and harvest management. Although duskys are diluted among more numerous subspecies, their high vulnerability to hunting causes a disproportionately high harvest of this subspecies compared to others (Simpson and Jarvis 1979).

Other human-related factors influencing goose populations include the following:

- Aquatic substrate alteration (e.g., from accelerated aufeis, mechanical removal)
- ^o Chronic debilitation due to ingestion or contact with petroleum or petroleum products
- ^o Collision with vehicles (including automobiles, boats, aircraft) or structures
- [°] Electrocution, contact with powerlines
- [°] Entanglement in fishing nets or marine debris
- Harassment, passive (e.g., construction noise, vehicle noise, human scent)
- ° Interference with reproductive behavior
- [°] Interruption of ongoing behavior: alarm, flight
- [°] Terrain alteration or destruction (e.g., raptor cliffs)
- Vegetation composition change to less preferred or useable species
- Water level or water quality fluctuations (including changes in drainage patterns, long-term increase or decrease in water levels)

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

VII. LEGAL STATUS

In Alaska, waterfowl are managed by the U.S. Fish and Wildlife Service and the Alaska Department of Fish and Game. They are protected under international treaties with Canada (Great Britain) 1916, Mexico 1936, Japan 1972, and the Soviet Union 1976.

VIII. SPECIAL CONSIDERATIONS

Molting

The first geese to molt are usually the subadults, followed by mature breeders that failed to nest successfully, and then by successful breeders. For breeding birds, the molt is initiated when the goslings are between one and three weeks old, varying by species. Geese are flightless for approximately three to four weeks (Bellrose 1976). During this period, geese are vulnerable to predation and are very sensitive to disturbance. Molting flocks are often found on large lakes and protected coastal waters away from nesting areas (Johnsgard 1975, Bellrose 1976).

In the Arctic Region, nonbreeding brants are in full molt in the first week of July; some individuals regain flight by the last week in July,

indicating the molt lasts 3 to $3\frac{1}{2}$ weeks. Canada geese molt slightly earlier, with some birds flying by 18–16 July (Derksen et al. 1979).

IX. LIMITATIONS OF INFORMATION The breeding grounds of the tule goose have only recently been partially delineated, and additional data on nesting areas and habitat requirements are needed. Studies to determine mammalian depredation of dusky Canada geese nests are ongoing and will continue. Additional studies to determine utilization of new nesting habitat created by the 1964 earthquake are being conducted by the ADF&G and the USFWS. The importance of Cook Inlet and Alaska Peninsula staging habitats needs to be further described. Banding studies and research on nesting areas needs to be increased substantially to determine movements and mortality sources.

REFERENCES

- ADF&G. 1980. Alaska wildlife management plans: species management policies. Fed. Aid in Wildl. Research, Proj. W-20-2. 113 pp.
- ADNR/USFWS. 1983. Bristol Bay Cooperative Management Plan. Anchorage. 495 pp.
- Arneson, P. 1980. Identification, documentation, and delineation of coastal migratory bird habitat in Alaska. BLM/OCS contract No. 03-5-022-69. ADF&G. 350 pp.
- Bailey, A.M. 1948. Birds of Arctic Alaska. Colo. Mus. Nat. Hist. Popular Series No. 88.
- Barry, T.W. 1966. The geese of the Anderson River delta, Northwest Territories. Cited in Bellrose 1976.
- Bellrose, F.C. 1976. Ducks, geese, and swans of North America. Harrisburg, PA: Stackpole Books. 540 pp.
- Bergman, R.D., R.L. Howard, K.F. Abraham, and M.W. Weller. 1977. Waterbirds and their wetland resources in relation to oil development at Storkersen Point, Alaska. USFWS Resource Publ. 129. Washington, DC. 38 pp.
- Bromley, R.G.H. 1976. Nesting and habitat studies of the dusky Canada goose (<u>Branta canadensis occidentalis</u>) on the Copper River delta, Alaska. M.S. Thesis, Univ. Alaska, Fairbanks. 81 pp.
- Campbell, B.H., and D.E. Timm. 1983. Waterfowl. Pages 9-11 in Surveyinventory progress report, 1981-1982. Vol. 13, Part 5. Fed. Aid in Wildl. Rest. Proj. W-22-1.

- Cooch, F.G. 1958. The breeding biology and management of the blue goose (Chen caerulescens). Cited in Bellrose 1976.
- Dau, C. 1983. Personal communication. Wildlife Biologist, USFWS, Cold Bay, AK.
- Derksen, D.V., W.D. Eldridge, and T.C. Rothe. 1979. Waterbird and wetland habitat studies. In P.C. Lent, ed. Studies of selected wildlife and fish and their use of habitats on and adjacent to NPR-A 1977-1978. Field Study 3, Vol. 2, USDI National Petroleum Reserve. Anchorage, AK. 423 pp.
- Derksen, D.V., W.D. Eldridge, and M.W. Weller. 1982. Habitat ecology of Pacific black brant and other geese molting near Teshepuk Lake, Alaska. Wildlfowl 33:39-57.
- Einarsen, A.S. 1965. Black brant: sea goose of the Pacific coast. Cited in Bellrose 1976.
- Eisenhauer, D.I., and D.A. Frazer. 1972. Nesting ecology of the emperor goose (<u>Philacte canagica</u> Sewastianov) in the Kokechik Bay region, Alaska. Dept. For. Conserv., Purdue Univ., West Lafayette, Ind. 82 pp.
- Gabrielson, I.N., and F.C. Lincoln. 1959. Birds of Alaska. Harrisburg, PA: Stackpole Co. 921 pp.
- Hall, L.C., and F.B. McGilvery. 1971. Nesting by a yearling Canada goose. Cited in Bellrose 1976.
- Headley, P.C. 1967. Ecology of the emperor goose. Cited in Bellrose 1976.
- Johnsgard, P.A. 1975. Waterfowl of North America. Don Mills, Ort; Fitshenry and Whiteside, Limited. 575 pp.
- Kiera, E.F. 1979. Feeding ecology of black brant on the North Slope of Alaska. M.S. Thesis, Western Washington Univ. 50 pp.
- Lebeda, C.S. 1980. Nesting and rearing ecology of the Vancouver Canada goose in Admiralty Island in Southeast Alaska. M.S. Thesis, S. Dak. State Univ. 77 pp.
- Lehnhausen, W.A., and S.E. Quinlan. 1981. Bird migration and habitat use at Icy Cape, Alaska. Unpubl. rept. USFWS, Anchorage, Alaska. 298 pp.
- Mickelson, P.G. 1973. Breeding biology of cackling geese (<u>Branta</u> <u>canadensis minima</u> Ridgway) and associated species on the Yukon-Kuskokwim delta, Alaska. Cited in Bellrose 1976.

- Rothe, T. 1985. Personal communications. Game Biologist, ADF&G, Div. Game, Anchorage.
- Seaman, G.A., G.F. Tande, D.L. Clausen, and L.L. Trasky. 1981. Mid Beaufort coastal evaluation study: Colville River to Kuparuk River. MCHM, ADF&G, Anchorage.
- Sellers, R.A. 1984. Personal communications. Game Biologist, ADF&G, Div. Game, King Salmon.
- Simpson, S.G., and R.L. Jarvis. 1979. Comparative ecology of several subspecies of Canada geese during winter in western Oregon. Pages 223-241 in R.L. Jarvis and J.C. Bartonek, eds. Management and biology of Pacific flyway geese. OSU Bookstore, Corvallis. 346 pp.
- Terres, J.K. 1980. The Audubon Society encyclopedia of North American birds. New York: Alfred A. Knopf. 1,109 pp.
- Timm, D. 1975. Northeast Gulf Coast waterfowl. Pages 264-343 in E.G. Klinkhart, ed. A fish and wildlife resource inventory of Prince William Sound. Vol. 1: Wildlife.
- . 1977. Waterfowl. CZM rept. on Cook Inlet-Kodiak.
- _____. 1982. Report of survey and inventory activities waterfowl. Fed. Aid in Wildl. Rest. Proj. W-19-2, Job 11.0. 48 pp.



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Map 1. Range of arctic char and Dolly Varden in Alaska (ADF&G 1978)

- I. NAME
 - A. Common Names: Dolly Varden, arctic char
 - B. Scientific Names: <u>Salvelinus malma</u> (Walbaum), <u>Salvelinus alpinus</u> (Linnaeus) Dolly Varden and arctic char are two closely related salmonids of the subfamily Salmoninae. Members of the genus <u>Salvelinus</u> are morphologically and ecologically very plastic species. Although this has allowed char to adapt to changing environmental conditions it has been a nightmare for taxonomists, who must attempt to compartmentalize a continuum of life history types and morphological forms into recognizable groups. Morrow (1980a) stated that both <u>Salvelinus malma</u> and <u>S. alpinus</u> are valid species in Alaska, with <u>S. malma</u> composed of <u>a</u> northern form and a southern form. McPhail (1961) divided the North

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American <u>S</u>. <u>alpinus</u> complex into an eastern arctic form and a western arctic-Bering Sea form. Morrow (1980a) concluded that the northern form of <u>S</u>. <u>malma</u> and the western arctic-Bering Sea form of <u>S</u>. <u>alpinus</u> are identical and should be called <u>S</u>. <u>malma</u>. The MacKenzie River is the dividing line between the distributions of anadromous populations of the two forms in North America (Craig 1977a), and where the eastern arctic form occurs west of the MacKenzie River it is generally a freshwater lake resident (ibid.). Within this narrative, we will circumvent the taxonomic problem by referring to all forms of <u>S</u>. <u>malma</u> and <u>S</u>. <u>alpinus</u> jointly as char.

Within each taxonomic form of char there are several different life history patterns. Char may be anadromous or nonanadromous stream residents or nonanadromous lake residents (Craig 1977a, Morrow 1980a). In the arctic area, there are also a few populations of nonanadromous spring-resident fish (Craig 1977a). Lake-resident char may be subdivided into dwarf- and normal-size forms (ibid.). Nonanadromous stream residents may be predominantly dwarf male populations that mate with anadromous females or self-perpetuating populations of male and female fish (Craig 1977a, Morrow 1980a).

II. RANGE

A. Statewide

Anadromous and nonanadromous populations are found from the arctic coast south along the western, southwestern, southcentral, and southeastern coastal areas of Alaska. Isolated populations of resident (landlocked) char are found in lakes and streams scattered throughout Interior and Arctic Alaska and on the Kenai Peninsula and Kodiak Island (ADF&G 1978, Morrow 1980b).

B. Regional Distribution Maps

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

- C. Regional Distribution Summary
 - 1. <u>Southwest</u>. Char are widely distributed throughout most systems in the Southwest Region. Important drainages of Bristol Bay include the Togiak River, the Wood River Lakes system, the Tikchik-Nushagak system, the Iliamna-Kvichak system, the Naknek River and Lake, and the Becharof and Ugashik rivers. Some important lake-river systems in the Kodiak region include Uganik, Little River, Karluk, Ayakulik (Red River), Akalura, Saltery, Buskin, and Barabara lakes. Char are also abundant in the Aleutian Islands (ADF&G 1976, 1977a, 1977b).

(For a more detailed narrative on char distribution in the Southwest Region, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)

- 2. Char are widely distributed throughout the Southcentral. Southcentral Region. They are found in the Klutina and Tonsina river drainages and small tributary streams of the Copper River (Williams, pers. comm.). In the Prince William Sound area, nearly all freshwater systems, with the possible exception of short glacial streams on the southeast side of the Kenai Peninsula, contain char. Char are found in lakes and streams on the Kenai Peninsula, most notably the Kenai River, Kasilof River, Deep Creek, Stariski Creek, Anchor River, and lakes in the Swanson River drainages. Char are also found in many streams draining into the west side of Cook Inlet and in the Susitna River drainage (ADF&G 1978). (For a more detailed narrative on char distribution in the Southcentral Region, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)
- 3. <u>Arctic</u>. Char are found in every major watershed in the northwest Alaska area, including the Selawik, Kobuk, Noatak, Wulik, and Kivalina rivers (ADF&G 1978, 1984). On the North Slope from Cape Lisburne to Demarcation Point, char are found in most rivers and many lakes. Char have not been reported from rivers or lakes on the arctic coastal plain west of Teshekpuk Lake (Hablett 1979, Bendock and Burr 1984); much of this area, however, has not been extensively surveyed. (For a more detailed narrative on char distribution in the Arctic Region, see volume 2 of the Alaska Habitat Management

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

Char are found in clear and glacial rivers and lakes, brackish deltas and lagoons (ADF&G 1977a), and nearshore marine waters (Morrow 1980b).

1. Water quality:

Guide for the Arctic Region.)

Recorded water temperatures during the Temperature. a. spawning period range from 0.5 to nearly 13°C (Morrow 1980b, Moore 1975). In Southeast Alaska, spawning occurs when water temperatures are 5.5 to 6.5°C (Morrow 1980b). Water temperatures on char spawning redds in the Wulik and Kivalina river drainages in northwest Alaska in August ranged from 6.5 to 11°C (Alt 1978). Egg hatching and alevin development are guite slow but appear to be dependent upon temperature, with do temperatures accelerating hatching warmer-than-normal and resulting in earlier-than-normal fry emergence. (1968) determined that Southeast Alaska Blackett anadromous char eggs held in a hatchery began hatching after 129 days in water with a temperature range of 8.3 to 0.6°C. No upper or lower temperature tolerance limits of char eggs or alevins were found in the literature; however, eggs are frequently exposed to temperatures from 0.0 to 2.2°C during incubation, and Scott and Crossman (1973) report significant egg mortality at temperatures above 7.8°C. Juvenile char have been observed burrowing into the substrate when water temperatures decreased to 2°C (Elliott and Reed Emigration of char from overwintering areas to 1974). 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 Vertical distribution in lakes appears to be 1977ь). temperature-dependent, with char preferring mid water and bottom depths with temperatures lower than 12.8°C (ADF&G 1976).

- b. <u>Dissolved oxygen (D.0)</u>. 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.0. 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.0. 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. <u>Turbidity</u>. 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. <u>Salinity</u>. Physiological changes for salinity tolerance of anadromous char probably begin before emigration from freshwater overwintering areas to marine summer feeding areas (Conte and Wagner 1965, Johnson 1980). Roberts (1971), who conducted experiments with a nonanadromous population of char that had been isolated from sea water for about 12,000 years, concluded that nonanadromous char retain a certain degree of salinity tolerance. In the Beaufort Sea in summer, char have been observed in salinities ranging from 2 to 32 parts per thousand (ppt).

- 2. Water quantity. Sufficient water velocity and depth are required to allow adequate water flow during egg and alevin development. Low flows and cold winter temperatures could cause redds to desiccate or freeze (Krueger 1981). Excessive velocities or flooding can cause egg dislodgement and/or displacement of juvenile (presmolt) char from rearing areas as well as hinder upstream fish migration (ibid.). Juvenile char in the Terror River on Kodiak Island are associated with relatively slow current velocities in pools, quiet side channels, and sloughs and tributaries (Wilson et al. 1981). Habitat preference studies for juvenile char in streams along the route of the Trans Alaska Pipeline System (TAPS) indicated that juvenile char prefer pools with low current velocities, generally below 0.3 m/sec, located adjacent to swift-flowing water (DenBeste and McCart 1984). Anadromous char juveniles and fry in the Sagavanirktok River and neighboring drainages are most abundant in the vicinity of spring water sources (McCart et al. 1972). Proximity to perennial sources of water is probably important in assuring their over-winter survival without having to undertake extensive migrations (ibid.). Char have been observed spawning in water depths of 0.15 to 4.5 m (Krueger 1981, ADF&G 1977b, Alt 1978) and in slow-to-moderate current velocities ranging from 0.3 to 1.2 m/sec (1.0 to 3.8 ft/sec) (Blackett 1968, Scott and Crossman 1973, Alt 1978).
- 3. Preferred spawning substrate is small-to-coarse Substrate. (walnut-size) gravel (Scott and Crossman 1973, McPhail and Lindsey 1970). Blackett (1968) found char in Southeast Alaska spawning primarily in small gravels, 6 to 50 mm in diameter. Wilson et al. (1981) found char on Kodiak Island spawning on gravels ranging from 2 to 32 mm in diameter. In the Wulik and Kivalina river drainages in northwest Alaska, char spawn over substrate that is predominantly medium and coarse gravel, with some fine gravel, sand, and boulders (Alt 1978). Char in the Anaktuvuk River also spawn over mixed substrate, ranging from sand to gravel up to three inches (8 cm) in diameter (Bendock 1981). A gravel layer over fertilized eggs in the redd protects eggs from sunlight and predation and reduces disturbance by ice and floods (Krueger 1981). In streams along the route of the TAPS, juvenile char prefer shallow pools with medium-to-coarse rock substrates (DenBeste and McCart 1984). Juvenile char burrow into substrate interstices and logging debris and slash to avoid cooling water temperatures (Elliott and Reed 1974).
- B. Cover Requirements

Rocks, logs, root balls, and undercut stream banks in pools, quiet side channels, and high-water overflow areas provide cover for young-of-the-year fish. Char seldom swim near the water surface, preferring to remain near the bottom (Krueger 1981; ADF&G 1977a, 1977b). Larger char are most abundant in deeper water in pools, under cutbanks and in quiet water on the downstream side of large boulders (McCart et al. 1972). In-stream vegetation, bank vegetation, shade, in-stream tundra slumps, and rock cover are the most important cover features for juvenile char in streams along the route of the TAPS (DenBeste and McCart 1984). Char overwintering in North Slope streams apparently prefer ice-covered areas even when open-water areas are available (Bendock 1982).

IV. NUTRITIONAL REQUIREMENTS

A. Preferred Foods

Fry begin active feeding as soon as they emerge. Juveniles feed on various winged insects, larvae of mayflies (Ephemeroptera) and midges (Chironomidae), and various small crustaceans (Karzanovskii In the Bristol Bay drainages, fish 1962, Krueger 1981). (sticklebacks, sculpins, blackfish, and salmon fry), fish eggs, and invertebrates (snails, leeches, clams, insects, and insect larvae) are major food sources (Alt 1977, Moriarity 1977, Greenback 1967). Rearing char from the Noatak and Wulik rivers consume fly (Diptera), mayfly, and stonefly (Plecoptera) larvae (DeCicco 1983). Russell (1980) found that char in the Lake Clark area of Bristol Bay consumed gastropods, pelycopods, caddis fly (Trichoptera) larvae and adults, ants and small wasps (Hymenoptera), midge pupae and adults, adult aquatic beetles (Coleoptera), and small crustaceans (amphipods, copepods, and cladocerans). In the Wood River Lakes system, char feed on sockeye salmon smolt during the smolt's summer migration to Nushagak Bay (Rogers 1972, Buklis 1979). Ruggerone and Rogers (1984) found that the number of smolt consumed in a 24-hour period increased when large smolt migrations occurred. When smolt migrations in excess of 80,000 smolts/24 hours took place, char consumption of smolts increased to 5.6 smolts/char per 24 hours. Palmisano (1971) studied the food habits of char in lakes on Amchitka Island. He found that in lakes with access to the sea crustaceans and aquatic insects were the major foods. Char in landlocked lakes on Amchitka fed primarily on aquatic insects, fish, and fish eggs (ibid.). Stream-resident (nonanadromous) char in the Sagavanirktok and Canning river drainages on the North Slope feed mainly on dipteran larvae (mostly chironomids), stonefly, nymphs, and caddis fly larvae (Craig 1977a, McCart et al. 1972). The diet of large fry in the Canning drainage is generally similar to that of older residents, although the fry feed on fewer kinds and smaller individuals (Craig 1977a). Craig (1977b) found that spring-resident char in Sadlerochit Spring in the Arctic National Wildlife Range fed primarily on larvae of stream-dwelling benthic invertebrates, which have high densities in the spring.

In marine waters, smelt, herring, juvenile salmon, sandlance, greenling, sculpins, flounder larvae, and cod are major food components. Amphipods, decapods, mysids, euphausiids, brachiopods, polychaetes, and isopods are also included in their diet
(Armstrong and Morrow 1980, Johnson 1980). Townsend (1942) found that char captured near the Shumagin Islands contained large numbers of flounder juveniles and larvae of the sand lance. 0ff Amchitka Island, char fed on a variety of items, mainly amphipods, mysids, and small fish (Neuhold et al. 1974). Once North Slope char enter coastal waters they feed on insects (chrironomid larvae and diptera pupae), crustaceans (Amphipods and mysids), and fish, especially juvenile arctic cod (Boreogadus saida) and fourhorn sculpin (Myoxocephalus quadricornis) (Craig and McCart 1976). Anadromous char feed little while in fresh water. Those that had fed in the Sagavanirktok drainage most frequently consumed arctic char eggs and small arctic char (McCart et al. 1972). Craig and Poulin (1974) found that some char in Weir Creek in the Shaviovik River drainage consumed grayling, and char taken in the Anaktuvuk River during the seaward migration fed on slimy sculpin (Cottus cognatus) and caddis fly larvae (Bendock 1981).

B. Feeding Locations

Juveniles feed primarily from the benthos in low-velocity areas along stream and lake margins (Armstrong and Morrow 1980, Johnson 1980). Older char move to deeper and faster stream reaches with higher densities of drifting invertebrates (Krueger 1981, ADF&G 1977b, ADF&G 1977a). Adult anadromous char appear to be equally capable of taking food from mid water or from the bottom (Johnson 1980). Resident char in lakes feed primarily on the lake bottom (Murray, pers. comm.; McCart et al. 1972). McBride (1979) estimated that 40% of the char population in the Wood River Lakes system feed at inlets and outlets of lakes or confluences of rivers and streams during sockeye smolt migrations. Morrow (1980b) states that adult anadromous char consume the majority of their annual diet of small fish and invertebrates in nearshore marine waters.

C. Factors Limiting Availability of Food

Excessive sedimentation may inhibit production of aquatic plants and invertebrate fauna (Hall and McKay 1983) and reduce visual references. While in fresh water, the char may compete directly for food and space with such fishes as grayling, whitefish, sculpins, 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 1980b, McCart et al. 1972, Craig 1977a). Stream-resident fish feed year-round (McCart et al. 1972, Craig 1977a). When leaving lakes in spring and early summer, char also appear to feed very little (Armstrong 1965).

- V. REPRODUCTIVE CHARACTERISTICS
 - A. Reproductive Habitat

Spawning site selection is influenced by current velocity, water depth, and substrate composition. Spawning sites are usually located in a fairly strong current near the center of the stream in riffles or spring areas at least 0.3 m deep or in gravelbottomed lakes (Krueger 1981, ADF&G 1977a).

In the Sagavanirktok River and neighboring drainages, all known spawning areas for anadromous char are either in the vicinity of spring sources of mountain streams originating in the Brooks Range or spring-fed tributaries of mountain streams (McCart et al. 1972). Spawning sites in the Anaktuvuk River are also closely associated with spring areas (Bendock 1981). The eggs cannot tolerate freezing, and these are the only stream areas in which winter flow is assured (ibid.). In the Canning River, almost all spawning sites are located in the main channels of the river or in springs originating within or near the Canning floodplain (Craig In the Noatak River system, some spawning takes place in 1977a). and around springs; however, most spawning occurs downstream of springs in the main channels of streams. The major spawning streams maintain limited flow throughout the winter and are under spring influence for much of their length (DeCicco 1982). Manv spawning areas in the Kivalina River are near spring areas; however, in the Wulik River most spawning grounds are not directly influenced by groundwater (Alt 1978).

B. Reproductive Seasonality

All races of char spawn between early July and the beginning of December (Meacham 1977, Alt 1977, DeCicco 1982).

Char have been observed spawning in the Terror and Kizhuyak rivers on Kodiak Island between late August and the end of September (Wilson et al. 1981). On Amchitka Island, Neuhold et al. (1974) observed char spawning from mid October to late November. Char in the Wood River Lakes system spawn in September and October (McBride 1980). Char in the Susitna River drainage also spawn in September and October (ADF&G 1981), and spawning peaks in the Anchor River on the Kenai Peninsula in mid October (Hammarstrom and Wallis 1981) and in Valdez area streams in October and November (Dames and Moore 1979).

The peak of spawning activity in Southeast Alaska occurs between September and November (Blackett 1968, Blackett and Armstrong 1965).

In North Slope rivers, the char spawning period apparently extends over several months; however, the peak of spawning activity probably occurs during late September or early October (McCart et al. 1972, Craig 1977a). In the Anaktuvuk River, spawning has been observed from early September through early November (Bendock 1981). In the Noatak drainage, char are found in the vicinity of the spawning grounds from early July to mid October (DeCicco 1982). In the Noatak and Wulik and Kivalina drainages, char spawners may be divided into two groups: summer spawners that remain in fresh water after overwintering and occupy spawning grounds from early July through mid September, and fall spawners that in-migrate in the fall and spawn from mid September through freeze-up (DeCicco 1982, Alt 1978). In the Wulik and Kivalina rivers, the peaks of spawning appear to be in mid August and mid September (Alt 1978).

Spring-resident char in most North Slope streams spawn in November and December (Craig 1977b).

C. Reproductive Behavior

Age at Sexual Maturity

Spawning behavior is similar to that of salmon. Fish are usually paired. The male usually takes no part in the nest-building and spends his time defending the redd from other male spawners. The female excavates the redd, often in typical salmonid fashion by turning on her side and thrashing the substrate with her tail. When the female is ready to deposit her eggs, the pair descend into the redd and press against each other laterally; sperm and eggs are released simultaneously into the redd. After completion of the spawning act, the female may move to the upstream end of the redd and repeat the digging process, washing gravel downstream over the fertilized eggs. The spawning act may be repeated up to five times; several days are usually required for a female to deposit all her eggs (Morrow 1980b). Morrow (1980b) described the redds as varying from a deep pit to a clean spot on large stones. The dimensions of the redd vary with the size of the female, the substrate, and the current velocities. Male spawners may mate with more than one female; occasionally a female will mate successively with two or more males (Fabricus 1953, Fabricus and Gustafson 1954, Krueger 1981, ADF&G 1977a).

D.

Char are an especially slow-growing fish and attain sexual maturity at different ages and sizes, varying with their life history and local environmental conditions. Three life forms of char occur in Alaska: resident lake char, resident stream char, and anadromous char. In general, resident stream char do not grow as large as resident lake or anadromous stream char. Resident stream char commonly occur in dwarf form (sexually mature and fully grown but only six to eight inches in length) (ADF&G 1977a, Russell 1980). Generally, northern populations grow slower, live longer, and reach a smaller maximum size than more southerly populations. Char populations in the south also attain sexual maturity earlier (Morrow 1980b). Males may mature before females. In Kuskokwim Bay drainages, char generally mature at 7 to 10 years (Alt 1977). In the Iliamna system, Metsker (1967) found mature char (life form unknown) as young as four years old. Russell (1980) noted that char in the Lake Clark area apparently become mature at 6 years of age. Most char in Southeast Alaska reach maturity by age 4 or 5 (Blackett and Armstrong 1965). Most anadromous char in the Sagavanirktok and Canning river tributaries spawn for the first time at age 7 or 8 (McCart et al. 1972, Craig 1977a). Female char in the Anaktuvuk River mature as early as age 6, males as early as age 7. Stream resident males in these tributaries may mature as early as age 2 or 3 (ibid.). Most anadromous char from the Wulik and Kivalina rivers in Northwest Alaska are mature at age 9 (Alt 1978).

Age at maturity for northern populations of lake resident char is variable, ranging from ages 2 to 9 (Craig 1977a). Males in North Slope spring resident char populations begin maturing at age 2, whereas the youngest mature females are ages 3 or 4 (ibid.). The longevity of char is variable. Char have been found as old as 24 years (Grainger 1953), but most in Southeast Alaska live 8 to 12 years (Armstrong 1963, Heiser 1966, ADF&G 1978).

E. Fecundity

The fecundity of char varies by stock, location, and size of Eggs of anadromous stocks are much larger than those of female. nonanadromous fish and increase in size with fish age and length (Blackett 1968, Morrow 1980b). The fecundity of anadromous char is also higher than that of nonanadromous stocks (McCart et al. 1972). In Alaska, the number of eggs generally ranges from 600 to 8,000 per female (ADF&G 1978, Morrow 1980b, McPhail and Lindsey 1970), though Russell (pers. comm.) has observed dwarf. prespawning females with as few as 20 mature eggs in the Tazimina Lakes in Southwest Alaska, and the fecundity of female lakeresident char from the Canning River drainage ranged from 54 to 1.600 eggs (Craig 1977a).

F. Frequency of Breeding

Though char do suffer a high postspawning mortality rate, a number live to spawn again in subsequent years. Armstrong (1974) found that in a Southeast Alaska population of char 73% spawned once, 26% twice, and 1% three times. Up to 50% of the females spawning for the first time survived to spawn again. In Southeast Alaska, males are much less likely to survive spawning than females. This may also be true of males in North Slope drainages (Armstrong 1974, Yoshihara 1975). Some char spawn in consecutive years; others spawn at two- or three-year intervals. Most anadromous char in northern Alaska spawn only every second year (Yoshihara 1975). Craig (1977a), in studies of char in the Canning River, noted that only a small number of char beyond age 9 were found in the population. Because most anadromous char on the North Slope do not mature until age 7 or 8, relatively few anadromous char may spawn more than twice during their lifetime. Stream-resident char, in contrast to the anadromous type, almost always spawn annually (Armstrong and Morrow 1980, Craig 1977a); however, lake-resident char from lakes in the Canning River drainage are not annual spawners (Craig 1977a).

- G. Incubation Period/Emergence
 - The time of development varies widely with temperature and stock. Embryo development is slow in cold water temperatures. Eaas incubate over winter, generally four to five months; however, periods of up to eight months have been documented on the North Slope of the Brooks Range (ADF&G 1977a, Yoshihara 1973). The incubation time for char eggs in streambed gravels in the Sagavanirktok and Canning rivers on the North Slope has been estimated to be seven to nine months, though fry in perennial springs may emerge sooner (McCart et al. 1972, Craig 1977a). Eggs hatch as 15-to-20-mm-long alevins (yolk sac fry) in March or Yoshihara (1973) observed preemergent fry in the April. Sagavanirktok River drainage that had probably hatched in April. Alevins remain in the gravel for approximately 18 days while absorbing their yolk sac before they emerge as free-swimming fry (20 to 25 mm) in April to July (ADF&G 1977a, McCart et al. 1972, DeCicco 1982).

In Valdez area streams, fry emerge from the gravel in April and May (Dames and Moore 1979). Peak emergence of fry in the Canning River on the North Slope occurs during the end of May and early June, though fry have been observed in early April (Craig 1977a). In the Noatak drainage, young-of-the-year fry probably emerge sometime in mid July (DeCicco 1982).

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

A. Anadromous

Out-migration. Juvenile anadromous char rear in streams and 1. lakes. After a variable number of years (usually at age 4 or 5), most char juveniles undergo a physiological change and, in the spring, migrate seaward as smolts (ADF&G 1977a, immature and mature char emigrate from 1977b). Most overwintering areas to marine summer feeding areas following ice breakup from April to June. In the Sagavanirktok and neighboring North Slope drainages, it is likely that seaward migration occurs during the spring flood in late May and June (McCart et al. 1972). In the Canning River, char begin to leave overwintering areas in May, with a large-scale emigration observed in late June and early July (Craig 1977a). In the Anaktuvuk River, char out-migrate in mid June Departure from overwintering habitats may (Bendock 1982). more closely coincide with breakup along the Beaufort Sea coast than with breakup near the overwintering site (ibid.) The char smolt migration in the Anchor River on the Kenai Peninsula takes place in late May and early June (Hammarstrom and Wallis 1983). Nonlake systems may support an additional 1965 out-migration (Armstrong autumn smolt and 1970, Armstrong and Kissner 1969. Dinneford and Elliott 1975, Elliott and Dinneford 1976). In the Noatak, Wulik, and Kivalina rivers, some fish that will spawn in the current year do not migrate seaward in the spring but rather go directly from overwintering to spawning grounds. Some of

these summer spawners that spawn in early-to-mid August probably do migrate to sea for a month or two after spawning (DeCicco 1982, Alt 1978). Alt (1978) estimated that in the Wulik and Kivalina rivers probably in excess of 50% of the prespawning fish do not go out to the ocean at breakup.

- 2. <u>Marine environment</u>. Individuals remain at sea feeding in the estuary and along the coast for a period of a few weeks to seven months (Morrow 1980b). While in the marine environment, char stay in coastal areas. In some cases, char in the Beaufort Sea may travel great distances along the coast (up to 300 km)(Craig and McCart 1976).
- 3. Spawning and overwintering. Char generally begin reentering fresh water in July and may continue through December, with spawners entering first, followed by immature fish and nonspawners (ADF&G 1977a). Mature anadromous char in the Sagavanirktok River have been taken in the vicinity of spawning tributaries as early as June 26. Mature migrants enter downstream spawning tributaries earlier than those further upstream (McCart et al. 1972). Immature migrants may make this return journey several times before they mature for the first time (ibid.). Although it appears that char return to their natal stream to spawn, nonspawners from Beaufort Sea drainages and from the Wulik and Kivalina river drainages may overwinter elsewhere in the same drainage or in nonnatal drainages (Craig 1977a, Craig and McCart 1976, DeCicco 1984). Radio-tagging studies of char in the Anaktuvuk River indicate that during the ice-covered months (October to May) char are confined residents of limited overwintering habitat, and movement at this time is minimal (Bendock 1982). In the Chignik River system on the Alaska Peninsula, char, which migrate to sea from April through June, return to Chignik Lake and Black Lake from late July through September to spawn and overwinter (Roos 1959). Emigration of spawned-out char to overwintering areas usually occurs within two weeks after completion of spawning, typically during late October and November. Immature char move to overwintering areas earlier, primarily in July, August, and September (Blackett and Armstrong 1965, Krueger 1981). Adult char usually remain in fresh water through the winter months to avoid the cooler water temperatures of the marine environment (ADF&G 1977a). Overwintering sites include deep lakes, deep river pools, and groundwater spring areas.
- B. Nonanadromous
 - 1. Lake residents. Lake-resident char move into streams for short periods of time. Studies in the Wood River Lakes system show that discrete subpopulations of resident lake char concentrate at inlets and outlets of the lakes during early summer to feed on out-migrating sockeye salmon smolt (McBride 1979). During late summer, char move to deeper lake waters, probably in

response to a declining availability of sockeye salmon smolt and to escape warming surface waters (Nelson 1966). Mature spawners usually move back to the lake margins to spawn in the fall. Resident lake char in the Sagavanirktok drainage do not undertake any long migrations, though they do sometimes enter streams (McCart et al. 1972).

2. Stream residents. Little is known about the life history of resident stream char. In the Sagavanirktok River and neighboring drainages, they are common in mountain and spring streams. Overwintering of stream residents occurs in deep pools of streams and rivers (Morrow 1980b). In the Sagavanirktok, Canning, Firth, and Babbage rivers, apparently all stream-resident char males; however, stream-resident females have are occasionally been found in Fish Creek, Yukon Territory (Craig and McCart 1976). A consequence of this pattern is that female char are significantly more abundant in nearshore areas than are males (ibid.).

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

Natural mortality is largely a result of limited winter habitat. Char that hatch in surface runoff streams must find suitable overwintering areas with open water. Studies in Southeast Alaska indicated that populations of juvenile char suffered 51% mortality in small surface-water streams, versus about 31% mortality in spring-fed streams, from November to June (Elliott and Hubartt 1977). Severe stream flooding can harm developing eggs and embryos and hinder upstream fish migration (Krueger 1981). Low flows and cold winter temperatures could cause redds to 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 substrate material and significantly reduce the imbed the available overwintering habitat for juvenile char (Bjornn et al. 1977, Krueger 1981). Postspawning mortality is high and may account for the natural removal of up to 50% of a spawning and population (Armstrong Kissner 1969. ADF&G 1977a). Lake-dwelling populations are often heavily parasitized with nematodes and cestodes (Russell, pers. comm.) There is no significant natural predation on char except for cannibalism (Scott and Crossman 1973, Armstrong and Morrow 1980, Craig 1977a).

B. Human-related

In the Arctic Region, char rely extensively on spring-fed habitats at particular stages in their life cycle. Springs are used as spawning grounds, summer rearing areas of fry and juveniles, and as overwintering areas (Craig 1978). In smaller North Slope drainages, which have few areas suitable for overwintering, it is conceivable that a single spring-fed site might harbor virtually all members of a particular char population, from eggs to mature adults, during the winter period (ibid.). Because stream beds are frozen solid both above and below overwintering sites, char cannot avoid disturbances in their winter habitat (Bendock 1983). Thus any disturbances to spring-fed areas, such as water removal or siltation due to gravel extraction, may have severe deleterious effects on char populations in the entire drainage. The introduction of organic materials under the ice in overwintering areas may reduce dissolved oxygen below the lethal level for any of the life history stages inhabiting the affected stream section (Craig and McCart 1974). A summary of possible impacts from human-related activities includes the following:

- Alteration of preferred water temperatures, pH, dissolved oxygen, and chemical composition
- [°] Alteration of preferred water velocity and depth
- * Alteration of preferred stream morphology
- ^o Increase in suspended organic or mineral material
- Increase in sedimentation and reduction in permeability of substrate
- ° Reduction in food supply
- Reduction in protective cover (e.g., overhanging stream banks or vegetation)
- Shock waves in aquatic environment
- ° Human harvest

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

VIII. LEGAL STATUS

A. Managerial Authority

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

IX. LIMITATIONS OF INFORMATION

Most life history information on char pertains to the sea-run variety. Little is known about the habits of nonmigratory char. There are very little data relating the various char life stages to the physical and chemical characteristics of their habitats.

REFERENCES

ADF&G. 1976. A fish and wildlife resource inventory of the Cook Inlet-Kodiak areas. Vol. 2: Fisheries. 434 pp.

_____. 1978. Alaska's fisheries atlas. Vol. 2 [R.F. Mclean and K.J. Delaney, comps.]. 43 pp. + maps.

______. 1981. Susitna Hydroelectric Project Subtask 7.10. Phase 1: final draft report resident fish investigation on the lower Susitna River. Susitna Hydro Aquatic Studies. 138 pp. + appendices. . 1984. An atlas to the catalog of waters important for spawning, rearing or migration of anadromous fishes. Arctic Region. Resouce Management Region V., Div. Habitat, Anchorage. 77 pp. + maps.

- ADF&G, comp. 1977a. A compilation of fish and wildlife resource information for the State of Alaska. Vol. 2: Sport fisheries. 337 pp.
- _____. 1977b. A fish and wildlife resource inventory of the Alaska Peninsula, Aleutian Islands, and Bristol Bay areas. Vol. 2: Fisheries. 556 pp.
- Alderdice, D., W. Wickett, and J. Brett. 1958. Some effects of temporary low dissolved oxygen levels on Pacific salmon eggs. J. Fish. Res. Bd. Can. 15(2):229-250.
- Alt, K.T. 1977. Inventory and cataloging of sport fish and sport fish waters of western Alaska. ADF&G, Fed. Aid in Fish Rest. Completion rept. Vol. 18. Proj. F-9-9, Job G-I-P.
- ______. 1978. Inventory and cataloging of sport fish and sport fish waters of western Alaska - Wulik-Kivalina rivers study. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol. 19. Proj. F-9-10, Job G-I-P.
- Armstrong, R. 1963. Investigations of anadromous Dolly Varden population in the Lake Eva-Hanus Bay drainages, southeastern Alaska. ADF&G, Fed. Aid in Fish Rest. Job completion rept. Vol. 4. Proj. F-5-R-4, Job 3-B. 44 pp.
- ______. 1965. Some migratory habits of the anadromous Dolly Varden <u>Salvelinus malma</u> (Walbaum) in southeast Alaska. ADF&G, Res. Rept. 3:1-26.
- _____. 1970. Age, food, and migration of Dolly Varden smolts in southeast Alaska. J. Fish. Res. Bd. Can. 27:991-1,004.
- _____. 1974. Migration of anadromous Dolly Varden (<u>Salvelinus malma</u>) in southeast Alaska. J. Fish. Res. Bd. Can. 31:435-444. Cited in Armstrong and Morrow 1980.
- Armstrong, R., and S. Elliott. 1972. A study of Dolly Varden in Alaska. ADF&G, Fed. Aid in Fish Rest. Ann. prog. rept. Vol. 13. Proj. F-9-4, Job R-IV-D.
- Armstrong, R., and P. Kissner. 1969. Investigations of anadromous Dolly Varden populations in Hood Bay, southeast Alaska. ADF&G, Fed. Aid in Fish Rest. Ann. prog. rept. Vol. 10. Proj. F-9-R-1, Job 2-B.
- Armstrong, R.H., and J.E. Morrow. 1980. The Dolly Varden char, Salvelinus malma. Pages 99-140 in E.K. Balon, ed. Chars: salmonid fishes of the

genus Salvelinus. The Hauge, the Netherlands: Dr. W. Junk bv Publishers. 928 pp.

- Bendock, T.N. 1981. Inventory and cataloging of arctic area waters. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol. 22. Proj. F-9-13, Job G-I-I.
- _____. 1982. Inventory and cataloging of arctic area waters. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol. 23. Proj. F-9-14, Job G-I-I.
- . 1983. Inventory and cataloging of arctic area waters. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol. 24. Proj. F-9-15, Job G-I-I.
- Bendock,T.N., and J. Burr. 1984. Inventory and cataloging of arctic area waters. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol. 25. Proj. F-9-16, Job G-I-I.
- Bjornn, T., M. Brusven, M. Molnau, J. Milligan, R. Klampt, E. Chacho, and C. Schaye. 1977. Transport of granitic sediment in streams and its effects on insects and fish. For Wildlife and Range Experimental Station, completion rept. Water Resource Res. Inst. Proj. B-036-IDA. Univ. Idaho, Moscow. 43 pp.
- Blackett, R.F. 1968. Spawning behavior and early life history of anadromous Dolly Varden, <u>Salvelinus malma</u> (Walbaum), in southeast Alaska. ADF&G, Res. Rept. 6:1-85
- Blackett R., and R. Armstrong. 1965. Investigations of anadromous Dolly Varden populations in the Lake Eva-Hanus Bay drainages, southeast Alaska. ADF&G, Div. Sport Fish, Fed. Aid in Fish Rest. Job completion rept. Vol. 6. Proj. F-5-R-6, Job 2-B.
- Buklis, L.S. 1979. Effects of confinement on arctic char in the Wood River Lakes system, Alaska. ADF&G, Informational Leaflet No. 182. 61 pp.
- Conte, F., and H. Wagner. 1965. Development of osmotic and ionic regulation in juvenile steelhead trout, <u>Salmo gairdneri</u> Comp. Biochem. Physiol. 14:603-620.
- Craig, P.C. 1977a. Ecological studies of anadromous and resident populations of arctic char in the Canning River drainage and adjacent coastal waters of the Beaufort Sea, Alaska. Chapter 1 in P. McCart, ed. Fisheries investigations along the North Slope and Beaufort Sea coast in Alaska with emphasis on the arctic char. Canadian Arctic Gas Study Ltd./Alaskan Arctic Gas Study Co. Biol. Rept. Ser. Vol. 41.

_____. 1977b. Arctic char in Sadlerochit Spring, Arctic National Wildlife Range. Chapter 2 <u>in</u> P. McCart, ed. Fisheries investigations along the North Slope and Beaufort Sea coast in Alaska with emphasis on arctic char. Canadian Arctic Gas Study Ltd./Alaskan Arctic Gas Study Co. Biol. Rept. Ser. Vol. 41.

. 1978. Movements of stream-resident and anadromous arctic char (<u>Salvelinus alpinus</u>) in a perennial spring on the Canning River, Alaska. J. Fish. Res. Bd. Can. 35:48-52.

- Craig, P.C., and P. McCart. 1974. Fall spawning and overwintering areas of fish populations along routes of proposed pipeline between Prudhoe Bay and the MacKenzie delta 1972-1973. Chapter 3 <u>in</u> P.J. McCart, ed. Fisheries research associated with proposed gas pipeline routes in Alaska, Yukon, and the Northwest Territories. Canadian Arctic Gas Study Co. Biol. Rept. Ser. Vol. 15.
- . 1976. Fish use of nearshore coastal waters in the western arctic: Emphasis on anadromous species. Pages 361-388 in D.W. Hood and D.C. Burrell, eds. Assessment of the arctic marine environment. Occasional Publ. No. 4, Inst. of Mar. Sci., Univ. Alaska, Fairbanks. 468 pp.
- Craig, P.C., and V. Poulin. 1974. Life history and movements of grayling (<u>Thymallus arcticus</u>) and juvenile arctic char (<u>Salvelinus alpinus</u>) in a small tundra stream tributary to the Kavik River, Alaska. Chapter 2 <u>in</u> P.J. McCart, ed. Life histories of anadromous and freshwater fish in the western arctic. Canadian Arctic Gas Study Ltd./Alaskan Arctic Gas Study Co. Biol. Rept. Ser. Vol. 20.
- Dames and Moore. 1979. Freshwater aquatic habitats of the Valdez area. Pages 263-288 in United States Environmental Protection Agency, environmental impact statement, Alaska petrochemical facility, Valdez, Alaska. Appendix, Vol. 1, EPA 910/9-79-064. 584 pp.
- DeCicco, A. 1982. Inventory and cataloging of sport fish and sport fish waters of western Alaska. Part A: Arctic char life history study. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol. 23. Proj. F-9-14, Job G-I-P-A.
- ______. 1983. Inventory and cataloging of sport fish waters of western Alaska. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol. 24. Proj. F-9-15, Job G-I-P-A.

. 1984. Inventory and cataloging of sport fish and sport fish waters of western Alaska with emphasis on arctic char life history studies. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol. 25. Proj. F-9-16, Job G-I-P-A.

DenBeste, J., and P. McCart. 1984. Overview of studies of the long-term effects of the Trans Alaska Pipeline System on fish and aquatic habitats. Vol. 1. Prepared for Alyeska Pipeline Service Co. by Aquatic Environments Inc., Anchorage, AK. 49 pp.

- Dinneford, W.B., and S.T. Elliott. 1975. A study of land use activities and their relationship to the sport fish resources in Alaska. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol. 16. Proj. F-9-7, Job D-I-B.
- Elliott, S.T., and W.B. Dinneford. 1976. A study of land use activities and their relationship to the sport fish resources in Alaska. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol. 17. Proj. F-9-8, Job D-I-B. 35 pp.
- Elliott, S.T., and D. Hubartt. 1977. A study of land use activities and their relationship to sport fish resources in Alaska. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol. 18. Study D-I-B.
- Elliott, S.T., and R.D. Reed. 1974. A study of land-use activities and their relationship to the sportfish resources in Alaska: ecology of rearing fish. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol. 15. Proj. F-9-6, Job D-I-B.
- Fabricius, E. 1953. Aquarium observations on the spawning behavior of the char, <u>Salmo alpinus</u>. Rept. Inst. Freshwater Res. Drottningholm 35:51-57.d. Cited in Morrow 1980.
- Fabricus, E., and K.J. Gustafson. 1954. Further aquarium observations on the spawning behavior of the char, <u>Salmo alpinus</u>. L. Rept. Inst. Freshwater Res. Drottningholm 35:58-104. Cited in Morrow 1980.
- Grainger, E.H. 1953. On the age, growth, migration, productive potential, and feeding habits of the arctic char (<u>Salvelinus alpinus</u>) of Frosbisher Bay, Baffin Island. J. Fish Res. Bd. Can. 10(6):326-370.
- Greenback, J. 1967. Sport fish survey, Katmai National Monument, Alaska. NMFS, Auke Bay Biological Laboratories Manuscript Rept. 35. 30 pp.
- Hablett, T.R. 1979. Fish inventories conducted within the National Petroleum Reserve on the North Slope of Alaska, 1977-78. Pages 337-406 in National Petroleum Reserve in Alaska Work Group 3. Studies of selected wildlife and fish and their use of habitats on and adjacent to the National Petroleum Reserve in Alaska. Vol. 2. USDI, National Petroleum Reserve in Alaska 105(c) Land Use Study, Anchorage. 423 pp.
- Hall J.E., and D. McKay. 1983. The effects of sedimentation on salmonids and macro-invertebrates - a literature review. ADF&G, Div. Habitat, Anchorage. 31 pp.

- Hammarstrom, S., and J. Wallis. 1981. Inventory and cataloging of Kenai Peninsula and Cook Inlet drainages and fish stocks. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol. 22. Proj. F-9-13, Job G-I-C.
- ______. 1983. Inventory and cataloging of Kenai Peninsula and Cook Inlet drainages and fish stocks. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol. 24. Proj. F-9-15, Job G-1-C.
- Heiser, D. 1966. Age and growth of anadromous Dolly Varden char, <u>Salvelinus malma</u> (Walbaum), in Eva Creek, Baranof Island, southeastern Alaska. ADF&G, Research Rept. 5:1-29.
- Johnson, L. 1980. The arctic char, <u>Salvelinus aplinus</u>. Pages 15-98 <u>in</u> E.K. Balon, ed. Chars: salmonid fishes of the genus Salvelinus. The Hauge, the Netherlands: Dr. W. Junk by Publishers. 928 pp.
- Karzanovskii, M.Y. 1962. Food of migrating fry of <u>Oncorhynchus gorbuscha</u> and <u>Salvelinus</u> <u>malma</u> in the rivers of Sakhalin. Ryhoe Khoz. 38(6):24-25.
- Koski, K. 1966. The survival of coho salmon (<u>Oncorhynchus kisutch</u>) from egg deposition to emergence in three Oregon coastal streams. M.S. Thesis, Oregon State Univ., Corvalis. 84 pp.
- Krueger, S.W. 1981. Freshwater habitat relationships: Dolly Varden char (<u>Salvelinus malma</u>) (Walbaum). ADF&G, Div. Habitat, Resource Assessment Branch. <u>38</u> pp.
- McBride, D.N. 1979. Homing of arctic char, <u>Salvelinus alpinus</u> (Linnaeus), to feeding and spawning sites in the Wood River Lake system, Alaska. M.S. Thesis, Univ. Alaska, Southeastern Senior College, Juneau.

. 1980. Homing of arctic char, <u>Salvelinus</u> <u>aplinus</u> (Linnaeus) to feeding and spawning sites in the Wood River Lake system, Alaska. ADF&G, Informational Leaflet No. 184. 23 pp.

- McCart, P., P. Craig, and H. Bain. 1972. Report on fisheries investigations in the Sagavanirktok River and neighboring drainages. Alyeska Pipeline Service Co. 170 pp.
- McPhail, J.D. 1961. A systematic study of the <u>Salvelinus</u> <u>alpinus</u> complex in North America. J. Fish. Res. Bd. Can. 18:793-816. Cited in Craig 1977.
- McPhail, J.D., and C.C. Lindsey. 1970. Freshwater fishes of northwestern Canada and Alaska. Bull. Fish. Res. Bd. Can. 173:381.
- Meacham, C.P. 1977. Arctic char predations assessment and control investigations within the Wood River System, Alaska, 1975 and 1976. Bristol Bay Data Rept. No. 75. ADF&G, Div. Commer. Fish, Anchorage.

- Metsker, H. 1967. Iliamna Lake watershed freshwater commercial fisheries investigation of 1964. ADF&G, Div. Commer. Fish. Informational Leaflet No. 95. 50 pp.
- Moore, J.W. 1975. Reproductive biology of anadromous arctic char, <u>Salvelinus alpinus</u> (L.), in the Cumberland south area of Baffin Island. J. Fish Biol. 7(2):143-151.
- Moriarity, D.W. 1977. Arctic char in the Wood River Lakes. Final report to Alaska Department of Fish and Game for period November 1, 1975 to October 31, 1976. Univ. Washington, College of Fisheries, Fisheries Research Institute.
- Morrow, J.E. 1980a. Analysis of the Dolly Varden char, <u>Salvelinus malma</u>, of northwestern North America and northeastern Siberia. Pages 323-338 <u>in</u> E.K. Balon, ed. Chars: salmonid fishes of the genus Salvelinus. The Hauge, the Netherlands: Dr. W. Junk by Publishers. 928 pp.

_____. 1980b. The freshwater fishes of Alaska. Anchorage, AK: Alaska Northwest Publishing Company. 248 pp.

- Murray, J.B. 1984. Personal communications. Area Mgt. Biologist, ADF&G, Div. Sport Fish, Kodiak.
- Nelson, M.O. 1966. Food and distribution of arctic char in Lake Aleknagik, Alaska during the summer of 1962. M.S. Thesis, Univ. Washington. 164 pp. Cited in Moriarty 1977.
- Neuhold, J.M., W.T. Helm, and R.A. Valdez. 1974. Amchitka Bioenvironmental Program: freshwater vertebrate and invertebrate ecology of Amchitka Island. Battelle Memorial Institute, Columbus Laboratories, USAEC Rept. BMI-171-154. 37 pp. Cited in Armstrong and Morrow 1980.
- Palmisano, J.F. 1971. Freshwater food habits of <u>Salvelinus malma</u> (Walbaum) on Amchitka Island, Alaska. M.S. Thesis, Utah State Univ., Logan. 76 pp. Cited in Armstrong and Morrow 1980.
- Reiser, D., and T. Bjornn. 1979. Habitat requirements of anadromous salmonids: influence of forest and rangeland management on anadromous fish habitat in the western United States and Canada. USDA Forest Service, Gen. Tech. Rept. PNW-96. Pacific Northwest Forest and Range Experimental Station, Portland, OR. 54 pp.
- Roberts, R.A. 1971. Prelimainary observations on the ionic regulations of the arctic char <u>Salvelinus alpinus</u>. J. Exp. Biol. 55:213-222. Cited in Johnson 1980.
- Rogers, D.E. 1972. Predator-prey relationship between arctic char and sockeye salmon smolts at the Agulowak River, Lake Aleknagik, in 1971. Fisheries Research Institute, Univ. Washington. Circular No. 72-7.

- Roos J.F. 1959. Feeding habits of the Dolly Varden, <u>Salvelinus malma</u> (Walbaum), at Chignik, Alaska. Trans. Am. Fish. Soc. 88:253-260.
- Ruggerone, G.T., and D.E. Rogers. 1984. Arctic char predation on sockeye salmon smolts at Little Togiak River, Alaska. Fish. Bull. 82:401-410.
- Russell, R. 1980. A fisheries inventory of waters in the Lake Clark National Monument Area. ADF&G, Div. Sport Fish, and USDI: NPS. 197 pp.
 - _____. 1983. Personal communications. Asst. Area Mgt. Biologist, ADF&G, Div. Commer. Fish., King Salmon.
- Scott, W.B., and E.J. Crossman. 1973. Freshwater fishes of Canada. Bull. Fish. Res. Bd. Can. 184:965 pp.
- Silver, S., C. Warren, and P. Doudoroff. 1963. Dissolved oxygen requirements of developing steelhead trout and chinook salmon embryos at different water velocities. Trans. Am. Fish. Soc. 92(4):327-343.
- Townsend, L.D. 1942. The occurrance of flounder post-larvae in fish stomachs. Copeia 1942:126-127. Cited in Armstrong and Morrow 1980.
- Vaux, W.A. 1962. Interchange of stream and intragravel water in a salmon spawning riffle. USFWS, Spec. Sci. Rept. Fish No. 405. 11 pp.
- Wickett, W. 1958. Review of certain environmental factors affecting the production of pink and chum salmon. J. Fish. Res. Bd. Can. 15(5):1,103-1,126.
- Williams, F.T. 1984. Personal communication. Area Mgt. Biologist, ADF&G, Div. Sport Fish, Glennallen.
- Wilson, W., E. Trihey, J. Baldrige, C. Evans, J. Thiele, and D. Trudgen. 1981. An assessment of environmental effects of construction and operation of the proposed Terror Lake hydroelectric facility, Kodiak, Alaska. Instream flow studies final report. Arctic Environmental Info. and Data Center. Univ. Alaska, Anchorage. 419 pp.
- Yoshihara, H.T. 1973. Monitoring and evaluation of arctic waters with emphasis on the North Slope drainages. ADF&G, Fed. Aid in Fish Rest. Ann. prog. rept. Vol. 13. Proj. F-9-5, Job G-III-A.
- . 1975. Inventory and cataloging of arctic area waters. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol. 16. Proj. F-9-7, Job G-I-I.



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

NAME Ι.

- Common Name: Arctic grayling Α.
- Scientific Name: <u>Thymallus arcticus</u> (Pallas) Β.

II. RANGE

Statewide Α.

Native arctic grayling are distributed throughout the Interior and Arctic regions of Alaska as well as in Southwest Alaska north of Port Heiden and west of the Aleutian Range. Stocking programs have produced self-sustaining populations in Southeast Alaska, Prince William Sound, the Kenai Peninsula, and Kodiak Island (ADF&G 1978).

B. Regional Distribution Maps

- To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for each region. Most of the maps in this series are at 1:250,000 scale, but some are at 1:1,000,000 scale. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of selected fish and wildlife species has been prepared and may be found in the Atlas that accompanies each regional guide.
- C. Regional Distribution Summary
 - 1. <u>Southwest</u>. Arctic grayling are found in clearwater streams of Bristol Bay and Alaska Peninsula drainages south to approximately Port Heiden. Grayling have been stocked in selected lakes on Kodiak Island (Murray, pers. comm.). Grayling are not present on the Aleutian Islands or in streams on the south side of the Alaska Peninsula (ADF&G 1978). Large grayling are found in the Ugashik, Becharof, Nuyakuk, and Togiak river drainages (ADF&G 1978; Russell, pers. comm.). (For more detailed narrative information, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)
 - 2. <u>Southcentral</u>. Arctic grayling are found in several clearwater tributaries and lakes within the upper Copper River and Susitna River drainages and in a few clearwater tributaries of the lower Copper River. Grayling are not found on the west side of Cook Inlet south of Tyonek (ADF&G 1978). They are also not native to the Kenai Peninsula but have been stocked in several Kenai Peninsula lakes, which now contain self-sustaining populations (Engel 1971). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Arctic Region.)
 - Grayling are widely distributed throughout the 3. Arctic. Arctic Region. On the arctic coast most of the freshwater drainages that have been surveyed contain grayling (USFWS 1982), and they are the principal species inhabiting foothill lakes and streams (Bendock 1982). Grayling are also found in lakes and streams on the Seward Peninsula and in lakes and streams draining into the Chukchi Sea between Kotzebue and (For (ADF&G 1978). more detailed narrative Barrow information, see volume 2 of the Alaska Habitat Management Guide for the Arctic Region.)
- III. PHYSICAL HABITAT REQUIREMENTS
 - A. Aquatic
 - 1. Water quality. Grayling prefer clear, cold lakes and streams (ibid.), with different life stages frequently occurring in different locations within a drainage. Grayling generally feed during the summer in rivers and streams that may freeze solid or dry up during the winter, and they may overwinter, therefore, in areas unsuitable for summer feeding (Tack

1980). The basic water chemistry of streams that support grayling varies by geographic area and reflects the character of mineral types in the area (ibid.).

Temperature. Increasing water temperatures and spring a. flooding appear to stimulate spawning (Armstrong 1982). A water temperature of around 4°C triggers spawning in the interior streams of Alaska (Tack 1973, ADF&G 1983) and in Western Alaska (Alt 1976); however, spawning activities have been observed at temperatures ranging from 3.3°C at the inlet to Fielding Lake in Interior Alaska (Wojcik 1954) to 16.7°C at Wier Creek in the western Arctic Region (Craig and Poulin 1975). Tack (1980) noted that grayling tend to spawn in the warmest areas of drainages, and that the use of bog or tundra streams for spawning is probably because of their favorable temperature regimes. Development of eggs to hatching is directly influenced by water temperatures. Bog and tundra streams warm rapidly, thus causing rapid development and early hatching of eggs spawned in these areas. Kratt and Smith (1977) and Bishop (1971) reported that centigrade degree days required for hatching grayling eggs ranging from 177 to 230.

Field observations indicate that juveniles and fry are tolerant of high temperatures but that small subadults and adults tend to avoid water temperatures above 16°C (Reed 1964, Schallock 1966, Wojcik 1955). Grayling in the Tangle Lakes area near Paxson displayed signs of discomfort and experienced unusually high mortality when taken in waters with a temperature of 17°C (Wojcik 1955, cited in Netsch 1975). LaPerriere and Carlson (1973), in laboratory experiments with grayling from the Chena River, concluded that the median tolerance limit (temperature that will kill 50% of the fish exposed) for grayling larger than 10 cm was 20.0 to 24.0°C. No reference to upper or lower lethal temperature data for eggs was found in the available literature.

- b. The pH factor. No optimum pH value was found in the literature. Measured values of several Interior Alaska 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. <u>Dissolved oxygen (D.O.)</u>. 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 Alaska streams. Measured D.O. concentrations during the summer months in several Southwest Alaska waters indicate an average D.O. of around 10 ppm (Russell 1980).

- d. Turbidity. High levels of turbidity may abrade and clog fish gills, reduce feeding, and cause fish to avoid some areas (Reiser and Bjornn 1979). Turbidity and sedimentation may smother food organisms and reduce primary productivity (Bell 1973, LaPerriere et al. 1983). Turbid water may absorb more solar radiation than clear water and may thus indirectly erect thermal barriers to migration (Reiser and Bjornn 1979, Van Nieuwenhuyse 1983). Stomach analyses of caged grayling held in mined and unmined streams (LaPerriere et al. 1983) indicated that gravling in the turbid, mined waters were not capable of locating invertebrate prey. This may be due to the observed reduction of invertebrate abundance in the mined stream or to the inability of the grayling to locate prey in the turbid water. Grayling in arctic environments do most of their feeding under conditions of continuous daylight and very clear water and have been exposed to little or no selective pressure to increase their ability to feed in turbid or low lightintensity conditions (Schmidt and O'Brien 1982). Studies conducted on the Susitna River indicate that gravling avoid high-turbidity waters (Suchanek et al. 1984).
- e. <u>Salinity</u>. Grayling have been taken in the spring from marine waters along the coastline adjacent to the Arctic National Wildlife Range around river mouths and behind barrier reefs (Roguski and Komarek 1971). The spring runoff from numerous rivers entering this area keeps the salinity at or below one part per thousand (ppt). No grayling were found in salinities exceeding 1 ppt. In the Nome area, there is some movement of grayling into tidal areas of the Nome River, but grayling do not enter the ocean (Alt 1978).
- 2. <u>Water quantity</u>. Sufficient water velocity and depth are required to allow adequate intragravel water flow during egg and alevin development. Low flows during incubation could result in desiccation of developing eggs and alevins (Wojcik 1954). High velocities or flooding could cause low fertilization, egg dislodgement, and/or displacement of young-ofthe-year (YOY) out of their rearing areas to less favorable sites, resulting in direct mortality (Nelson 1954; Tack 1971, 1974; Walker 1983). Holmes (1983, 1984) found a high correlation between numbers of grayling in an age class and the average rate of river discharge during May, June, and July of their natal years. As discharge increased, grayling

abundance decreased. Excessive velocities may also impede migrating fish (Hallberg 1977, MacPhee and Watts 1976). The upstream migration of gravling usually coincides with high flows resulting from spring breakup (Krueger 1981). In studies of Deadman Creek, tributary to the Susitna River, the upper reach, which is characterized by an abundance of large, pool-type habitats, contained а hiaher summer deen. population of grayling than the middle and lower reaches, which were more shallow (Sautner and Stratton 1984). Arctic grayling spawn in a wide range of current velocities and Wojcik (1954) reported spawning in "slow, shallow depths. backwaters" in an inlet stream to Fielding Lake. Warner (1955) observed gravling in the same stream spawning in surface-current velocities of about 1.2 m/sec in depths of 16 cm. Surface-current velocities measured in territories of 22 males in the outlet of Mineral Lake (Interior Alaska) ranged from 0.34 to 1.46 m/sec, and territorial depths ranged from 0.18 to 0.73 m (Tack 1971). Newly emerged fry are found in protected areas where current velocities are extremely low. Typical emergent fry-rearing areas include shallow back waters and flooded stream margins and side channels (Krueger 1981, Walker 1983). In studies of 27 streams along the route of the Trans Alaska Pipeline System (TAPS), it was found that juvenile gravling select habitats with the lowest possible velocity (often where there is no detectable current) and pools with an average depth of 0.65 m (Denbeste and McCart 1984). Adult grayling in the study streams also preferred near-zero-velocity water, with an average depth of 0.8 m (ibid.). Both juveniles and adults frequently were found in areas with adjacent swift water (greater than 0.5 m/sec) to provide a steady supply of stream drift for food (ibid.). Older YOY fish occupy progressively faster waters. Aquatic habitat occupied by rearing YOY fish in selected bog streams along the TAPS had mean-column velocities of 0 to 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). Preliminary results from winter tagging studies on the Chena and Salcha rivers indicate that grayling in Interior Alaska overwinter in areas of moderate current (Holmes, pers. comm.).

3. <u>Substrate</u>. Arctic grayling have been reported to spawn over a wide range of substrates, including mud, silt, and gravel up to 4 cm in diameter (Krueger 1981). Gravel substrate provides cover, decreases the chances of dislodgement, and lessens swimming stresses in early life history stages, probably resulting in higher alevin survival than for those hatching on exposed substrate (Kratt and Smith 1977). The following are examples of observed spawning substrates in Alaska:

- ° Fine (1 cm) gravel (Warner 1955)
- "Pea-size" gravel in the outlet of Mineral Lake (Tack 1971)
- Sand-to-small-cobble, with coarse sand and gravel to about 2.5 cm in diameter, in four inlet tributaries to Tyee Lake near Ketchikan (Cuccarease et al. 1980)
- Relatively fine (3.8 cm diameter) gravel, with most material less than 1.25 cm, in outlets of two Kenai Peninsula lakes (Krueger 1981)
- Sand and fine gravel substrate, about 0.6 cm in diameter, in the outlet of Tea Lake near the TAPS (McCart et al. 1972)
- Silt and fine sand overlaid by organic detritus in Million Dollar Creek, along the TAPS (Elliott 1980)
- Silt overlaying gravel in the main stem Colville River (Bendock 1979)
- [°] Gravel 0.5 to 7.6 cm in diameter (Kratt and Smith 1977)
- [°] Relatively uniform distribution of particle sizes from 0.75 mm to 28.1 mm at the outlet of Mineral Lake (Tack 1973)

Juvenile and adult grayling in 27 streams along the route of the TAPS were found to occupy pools with fine-grained substrates (DenBeste and McCart 1984), but adults also displayed a preference for coarse substrates, and both juveniles and adults used rocks as cover (ibid.). In the Susitna River, adult grayling use rocks with diameters over 8 cm for protective cover (Suchanek et al. 1984).

B. Cover Requirements

Newly emerged fry have limited swimming abilities, and they school in shallow, protected stream areas with cover, low current velocities, and an abundance of food items. Irregular banks, with shadows from boulders and overhanging vegetation, contribute important cover for these rearing fry. Juvenile fish (age one year and older) progressively move to faster and deeper stream reaches (Vascotto 1970). Older fish commonly use logs, boulders, and turbulence for in-stream cover (Krueger 1981, Sautner and Stratton 1984). In streams along the TAPS, juvenile grayling were found to use rock cover most extensively, but to a lesser extent they also use habitats with cutbanks or loose gravel or rock banks providing cover, overhanging vegetation, deep water, in-stream vegetation, and shade (DenBeste and McCart 1984). Adult grayling preferred habitats with cover features typically associated with banks, such as cutbanks, overhanging vegetation, in-stream vegetation, and shade, but also use rock cover and deep water to some extent (ibid.).

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

Grayling are opportunistic feeders, able to use a wide range of food items, but they prey primarily on immature and emerging aquatic insects (Armstrong 1982). Elliott (1980) found that immature midges (Chironomidae) were the most frequently consumed taxon by YOY grayling in spring, rapid-runoff, and bog streams crossed by TAPS. Jennings (1983) found that chironomid pupae were the most important food item for yoy grayling (length range 40-48 mm) stocked in ponds near Delta, Alaska. In the Chena River, chironomid pupae and larvae made up 94% by volume of yoy grayling (length range 11-16 mm) stomach contents (ibid.). Engel (1973) found that grayling eggs comprised the bulk of the diet of juvenile grayling found downstream of spawning adults in Crescent Creek on the Kenai Peninsula. Adults feed primarily on immature mayflies (Ephemeroptera), stoneflies (Plecoptera), dipterans, and caddis flies (Trichoptera) (Bishop 1971, Bendock 1980, Craig and Wells 1975, McCart et al. 1972). In lakes, zooplankton may make a significant contribution to the diet (Yoshihara 1972 and Wojcik 1954, cited in Armstrong 1983, Schmidt and O'Brien 1982). In three lakes in Southwest Alaska, Russell (1980) found caddis fly larvae and adults and cyclopoid copepods to be the most common Furniss (1974) found Diptera, stonefly, bettle food items. (Coleoptera), caddis fly, and Hymenoptera (bees and wasp) larvae and adults, gastropods, and nematodes to be important food items for grayling from four mountain lakes on the north side of the Salmon eggs, smelt eggs, and shrews have been Brooks Range. observed in grayling stomachs from the Naknek River in the Bristol In the Chena River near Bay area (Russell, pers. comm.). Fairbanks, grayling have been observed concentrating at the downstream end of chinook and chum salmon spawning redds, feeding on the salmon eggs that drift down during spawning activity (Hallberg 1981). Whitefish eggs and mayfly and stonefly larvae are dominant grayling food items in the Colville River during October (Bendock 1979, 1981). Other food items include isopods (ADF&G 1977), plant material (Craig and Wells 1975), fish (McCart et al. 1972, Williams 1969), and lemmings (Alt 1978, Reed 1964).

Β. Types of Feeding Areas Used Newly emerged fry have limited swimming abilities and spend the first summer near their hatch site (Tack 1980). They school and feed in shallow lotic habitats with low current velocities where production of aquatic invertebrates is high (Cuccarese et al. In the Arctic Region, YOY grayling rear in small tundra 1980). streams. The warm water and abundance of food in these small streams provide favorable conditions for growth. Grayling fry are able to equal the growth of char fry in the same river systems, although the char may emerge four to six weeks earlier and at a larger size (Craig and Poulin 1974). Immediately after spawning, adults and large juveniles move to upstream locations or into tributary streams or lakes rich in food (Tack 1980). Tack (1980)

found that in large, rapid-runoff rivers, grayling consistently home to their summer feeding streams and feeding locations. Vascotto (1970) observed that during the summer months grayling were found almost exclusively in pools, where they established feeding territories and, within each feeding territory, a feeding range where all feeding activities took place. In pools with a strong current, distribution was related to the strength of the current and the availability of food in the benthic drift, with the larger fish holding near the upstream end near the center and smaller fish distributed downstream and to the sides (Tack 1980, Vascotto and Morrow 1973, ADF&G 1983). Other literature also indicates that rearing grayling concentrate in the lower reaches of a stream and that larger (older) fish are found further upstream (Hallberg 1978, Tack 1971).

- C. Factors Limiting Availability of Food Grayling are visual feeders, relying primarily upon benthic drift for nutrition. During periods of high, muddy water, this drift is unavailable to them. Schallock (1966) suggested that grayling and slimy sculpin (<u>Cottus cognatus</u>) 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). Craig and Wells (1975) noted that grayling spawning in the Chandalar River drainage in Northeast Alaska tends to occur in small, clearwater tributaries with low stream gradients. These spawning tributaries tend to be warmer and less turbid than the main stem of the Chandalar River during the grayling spawning period (ibid.). Within rivers and streams, grayling usually spawn in riffles composed of gravel or rubble (See III.A.3., Substrate, this report). Grayling have also been reported spawning in slow, shallow backwater areas (Wojcik 1954, Bendock 1979), 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). Tack (1980) suggests that inasmuch as grayling adults home to the feeding stream annually they probably also home to their natal stream to spawn. Scale analysis indicates homing of grayling to Badger Slough on the Chena River for spawning (Holmes, pers. Tagging studies in the Susitna River drainage indicate comm.). that the majority of arctic grayling do return to the same stream year after year, in many cases returning to the same specific area within the stream (ADF&G 1983). Craig and Poulin (1975) also suggested that some grayling may return annually to a particular stream to spawn.

B. Reproductive Seasonality

Grayling populations in Alaska spawn between late April and early July, with most spawning taking place between mid May and mid June (Bendock 1979, Roguski and Tack 1970, Schallock 1966, Warner 1955, Wojcik 1954). In the Bristol Bay area, grayling generally spawn in May (Russell 1980). In 1982 and 1983, grayling in the Susitna River drainage spawned from late May to mid June (ADF&G 1983, Sundet and Wenger 1984). Grayling in the Chandalar River drainage in northeast Alaska enter tributaries and spawn during the latter half of May (Craig and Wells 1975). In Weir Creek, tributary to the Kavik River in the Shaviovik River drainage on the arctic coastal plain, grayling spawn in mid June (Craig and Poulin 1974). Spawning time is also mid June in Happy Valley Creek, tributary to the Sagavanirktok River (McCart et al. 1972). Grayling spawning in small tributaries of the Colville River is completed by the end of June (Bendock 1979). The spawning period often coincides with the rising water temperatures and flooding of spring breakup. Grayling typically ascend to spawning sites as soon as flow conditions permit passage (Krueger 1981).

- С.
- Reproductive Behavior

Males enter the spawning grounds and establish territories in riffle areas, which they vigorously defend against other males. Females remain in deep pools and enter the riffles only for short periods to spawn (Tack 1971). The spawning act involves intensive simultaneous body-arching and vibrating; no redd is dug, but small depressions usually result from the spawning activity. During the spawning act, the posterior portion of the female's body may be forced into the gravel by the male's tail working vertically (ibid.). Eggs are simultaneously fertilized and deposited 2 to 3 cm below the gravel surface (Kratt and Smith 1977, Van Wyhe 1962). The eggs are adhesive prior to water-hardening and have a slightly higher specific gravity, enabling them to sink to the bottom rapidly, where they are covered by settling material loosened during the spawning act (Brown 1938, Warner 1955). The female resumes her former resting position after spawning. Both

sexes may spawn more than once with various partners (Krueger 1981). The duration of spawning activity may range from four days to two weeks (Craig and Poulin 1975, McCart et al. 1972, Tack 1971, Warner 1955). Conflicting observations exist in the literature concerning an apparent diurnal pattern of spawning activity. Van Wyhe (1962) and Warner (1955) reported that most spawning activity occurred between 8:00 P.M. and 4:00 A.M. Russell (pers. comm.) has also observed grayling spawning at night in Lower Talarik Creek in Southwest Alaska. Other observations, however, indicate that spawning activity occurs only during daylight hours and probably ceases during the evening (Bishop 1971, Kruse 1959, MacPhee and Watts 1976, Scott and Crossman 1973, Tack and Fisher 1977). Williams (1968) noted that grayling from Tolsona Lake near Glennallen, Alaska, entered Bessie Creek to spawn only at dusk and after dark. In contrast, grayling from Moose Lake entered Our Creek during all hours (ibid). Williams hypothesized that the difference may be due to the lack of cover in Bessie Creek.

D. Age at Sexual Maturity

The point at which sexual maturity is reached varies and is probably more related to size than to age (Armstrong 1982). In the interior systems and the lower Kuskokwim River, lower Yukon River, Seward Peninsula, and Tanana River, grayling reach maturity by age 4, 5, or 6 (Alt 1977, 1978, 1980; Armstrong 1982; Wojcik 1955). Most grayling begin spawning in the Bristol Bay area at age 5 (Russell 1980). Grayling from Crescent Lake on the Kenai Peninsula mature at age 3 or 4 (Engel 1973).

Grayling in the upper Susitna River mature at age 4 or 5 (ADF&G 1983, Schmidt and Stratton 1984). In the North slope systems, most grayling appear to mature later, at ages 6 or 9 (Armstrong 1982). Craig and Wells (1975) noted that the age at which grayling reach sexual maturity in the Chandalar River drainage is highly variable, ranging from ages 5 to 10 in the Chandalar River, ages 6 to 8 in Monument Creek, and ages 4 to 9 in Strangle Woman Creek. Grayling in the Pilgrim River near Nome are nearly 100% mature by age 6 (Alt 1980). Grabacki (1981) found that upper Chena River (Interior Alaska) populations subject to heavy fishing pressure showed slower individual growth rates, younger average age, and lower natural mortality than populations in areas free of fishing pressure. Longevity is variable. with northern populations generally living longer than southern populations. In some unexploited populations, a high percentage live beyond age 8, with some surviving up to at least age 22 (deBruyan and McCart 1974, Craig and Poulin 1975, Craig and Wells 1975).

E. Frequency of Breeding

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

F. Fecundity Fecundity varies, apparently depending on the size of the fish and the stock. Williams (1968) sampled eight grayling from Bessie Creek, which connects Tolsona and Moose lakes, and found an average fecundity of 4,490 eggs per fish. Schallock (1966) found an average fecundity of 5,350 eggs from 24 Interior Alaska grayling. Individual fecundities ranged from 1,700 eggs for 267 mm-long fish (fork length) up to 12,350 for a 400 mm-long fish. An average fecundity of 8,968 was found for 20 grayling from the Yukon Territory (deBruyan and McCart 1974, cited in Armstrong 1982), with no significant correlation between fecundity and fish length.

G. Incubation Period and Time of Emergence Embryo development is rapid (13 to 32 days) and is directly correlated with water temperatures (Bishop 1971, Kratt and Smith 1977). Kratt and Smith (1977) found that arctic grayling eggs in northern Saskatchewan hatched in 32 days at a mean daily temperature of 5.8°C. Field studies in Interior Alaska by Warner (1955) and Wojcik (1954, 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 In another field study, eggs incubated at an average 8 days. water temperature of 8.8° C eyed at 10 days and began hatching in 13.7 days (Bishop 1971). Alevins remain in the gravel and almost completely absorb their yolk sacs before emerging (Kratt and Smith 1977). Young-of-the-year are present by June 5 in the Bristol Bay area (Russell 1980). Fry were first collected by Craig and Wells (1975) in the Chandalar River drainage during the last week of June, but the authors note that it is likely that the fry had emerged one to two weeks earlier.

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

A. Home Territory

All life phases, including the life functions of spawning, rearing of young, feeding, and overwintering, usually take place within the semiconfined environment of one drainage or watershed system. Usually some locations within a drainage are better suited than others for supplying seasonal life-function needs, and grayling therefore often exhibit complex migrational patterns and require unrestricted movement within a system (Armstrong 1982). Spawning territories vary in size, depending upon such factors as stream width, water depth, current velocity, channel configuration, and spawner density. Tack (1971) described 22 male territories as generally oval, 1.8 to 2.4 m wide and 2.4 to 3.0 m long.

B. Timing of Movements and Use of Areas The seasonal pattern of grayling movements within a system is affected by each river or stream's source of water (Tack 1980) and therefore varies from system to system. Tack (1980) and Armstrong (1982) provide detailed descriptions of grayling movements in several different stream types, which can serve as more complete references for the reader in need of extensive information on grayling movements. Generally, adults move from overwintering locations to begin an upstream prespawning migration under the ice in late winter or early spring. The prespawning migration typically lasts from two to six weeks, depending upon the distance traveled. In most cases, grayling move into bog streams or unsilted rapid-runoff streams to spawn (avoiding spring-fed streams and silted rapid-runoff streams) as soon as the ice is out and the water temperatures rise to about 1°C, usually in May or June (Tack 1980, Armstrong 1982, Sundet and Wenger 1984). Only in the case of large unsilted rapid-runoff rivers do grayling spawn in the same stream in which they overwinter, and even in these rivers there is a marked upstream migration to parts of the system not used for overwintering (Tack 1980). Immature fish generally follow closely behind adults. Immediately after spawning, many of the adults move to upriver summer feeding areas, but most juveniles remain in lower portions of unsilted rapid-runoff streams and associated tributaries until late August or September (Armstrong 1982). Young-of-the-year feed in the area near their hatch site and then migrate directly to overwintering areas (Tack 1980). From September through December, as temperatures drop and instream flow and food availability deteriorate, there is a general downstream movement of all age classes to more favorable overwintering areas (Grabacki 1981, Netsch 1975, Tack 1980). Common overwintering sites include intermittent pools, under the ice in large rivers, deep lakes, brackish river deltas, and spring or ground-fed areas (Bendock 1980, Tack 1980). In the arctic area, spring areas in rapid-runoff (mountain) streams and isolated deep pools in the largest rapid-runoff rivers provide the only overwintering habitat other than a few lakes (Tack 1980). Lake-dwelling populations move into tributaries to spawn in the spring and may return to the lakes shortly after spawning (Engel 1973), or they may remain in the tributaries until fall (Saunter and Stratton 1984). Grayling leave Deadman Lake in the upper Susitna River drainage in mid June and do not return until early September (ibid.).

C. Migration Routes

A river or stream's source of water affects the migrational pattern of grayling within that system. Glacier-fed systems in the interior tend to be used mainly for overwintering or as migration routes to other systems; spring-fed systems are used primarily for feeding, with some overwintering for those systems entering the Arctic Ocean; bog-fed systems may provide suitable spawning and feeding habitat; large unsilted runoff waters may be used for spawning, feeding, and overwintering (Tack 1980).

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

Excessive water velocities can cause low fertilization, egg dislodgement, and alevin displacement (Nelson 1954; Tack 1971, 1974; Holmes 1983, 1984). Low water during the summer months will concentrate grayling, making their population more available to fishing pressure (Tack 1975). High water temperatures (above

16°C) during the summer and low water and D.O. levels during the winter can be detrimental. Predation on gravling 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 (<u>Salvelinus alpinus</u> [Linnaeus]), round whitefish (<u>Prosopium cylindraceum</u> [Pallus]), northern pike (<u>Esox lucius</u> and longnose [Linnaeus]). suckers (Catostomus catostomus [Forster]), also consume arctic grayling eggs and alevins (Bishop 1971, MacPhee and Watts 1976, Alt 1977). Grayling fry are often trapped in shallow pools that are cut off from main-stream channels as water levels fall. Many fry perish as these shallow pools dry up or freeze with the onset of winter (McCart et al. Peterson (1968) suggested that grayling fry lack the 1972). behavioral mechanisms that prompt salmon and trout to escape entrapment.

B. Human-related

Any disturbances within a system that degrade grayling spawning, rearing, or feeding habitats, degrade water quality, or block fish migration routes may adversely affect population levels of grayling occupying that system. A summary of possible impacts from human-related activities includes the following:

- Control 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
- ^o Reduction in food supply
- ^o Reduction in protective cover (e.g., overhanging stream banks or vegetation)
- Shock waves in aquatic environment
- ° Human harvest

(For additional impacts information, see the Impacts of Land and Water Use volume of this series.)

VIII. LEGAL STATUS

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

IX. LIMITATIONS OF INFORMATION

A great amount of information has been collected on the life history of arctic grayling in Alaska, particularly in the Interior Region and along the TAPS, but there are still gaps in our knowledge critical to the future management of grayling as resource development (habitat alterations) and angler pressure continue to increase. A better understanding of the dynamics of exploitation, early life history, stock separation, feeding habits, grayling stocking, the validity of aging by scale analysis, and the effects of various habitat alterations is necessary. There are very few studies on the effects of environmental changes on arctic grayling in Alaska (Armstrong 1982, Grabacki 1981).

REFERENCES

- ADF&G, comp. 1977. A fish and wildlife resource inventory of the Alaska Peninsula, Aleutian Islands, and Bristol Bay areas [R.F. McLean, K.J. Delaney, and B.A. Cross, comps.]. Vol. 2: Fisheries. [Juneau.] 556 pp.
- ADF&G. 1978. Alaska's fisheries atlas. Vol. 2 [R.F. McLean and K.J. Delaney, comps.]. 43 pp. + 153 maps.
- _____. 1983. Susitna Hydro Aquatic Studies. Phase 2, basic data rept. Vol. 5. Upper Susitna River impoundment studies 1982. 150 pp. + appendices.
- Alt, K. 1976. Inventory and cataloging of North Slope waters. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol. 17. Proj. F-9-8, Job G-I-0.
- . 1977. Inventory and cataloging of arctic area waters. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol. 18. Proj. F-9-9, Job G-I-P.
- . 1978. Inventory and cataloging of sport fish waters of western Alaska. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol. 19. Proj. F-9-10, Job G-I-P.
- ______. 1980. Inventory and cataloging of sport fish and sport fish waters of western Alaska. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol. 21. Proj. F-9-12, Job G-I-P.
- Armstrong R.H. 1982. A review of arctic grayling studies in Alaska. Contrib. No. 6, Alaska Coop. Fish. Rest. Unit, Univ. Alaska, Fairbanks. 60 pp.
- Bell, M.C. 1973. Fisheries handbook of engineering requirements and biological criteria. Fisheries-Engineering Research Program Corps of Engineers. N. Pac. Div., Portland, OR.
- Bendock, T.N. 1979. Inventory and cataloging of arctic area waters. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol. 20. Proj. F-9-11, Job G-I-I.
- ______. 1980. Inventory and cataloging of arctic area waters. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol. 21. Proj. F-9-12, Job G-I-I.

_____. 1981. Inventory and cataloging of arctic area waters. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol. 22. Proj. F-9-13, Job G-I-I.

_____. 1982. Inventory and cataloging of arctic area waters. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol. 23. Proj. F-9-14, Job G-I-I.

- Bishop, F. 1971. Observations on spawning habits and fecundity of the arctic grayling. Prog. Fish Cult. 27:12-19.
- Brown, C.J.D. 1938. Observations on the life-history and breeding habits of the Montana grayling. Copeia (3):132-136.
- Craig, P.C., and V.A. Poulin. 1974. Life history and movements of grayling (<u>Thymallus arcticus</u>) and juvenile arctic char (<u>Salvelinus alpinus</u>) in a small tundra stream tributary to the Kavik River, Alaska. Chap. 2 in P.J. McCart, ed. Life histories of anadromous and freshwater fish in the western arctic. Canadian Arctic Gas Studies Ltd./Alaskan Arctic Gas Study Co., Biol. Rept. Series. Vol. 20.
- . 1975. Movements and growth of arctic grayling (<u>Thymallus</u> <u>arcticus</u>) and juvenile arctic char (<u>Salvelinus alpinus</u>) in a small arctic stream, Alaska. J. Fish. Res. Bd. Can. 32:689-697.
- Craig, P.C., and J. Wells. 1975. Fisheries investigations in the Chandalar River region, northeast Alaska. Pages 1-114 in P.C. Craig, ed. Fisheries investigations in a coastal region of the Beaufort Sea. Canadian Arctic Gas Study Ltd./Alaskan Arctic Gas Study Co., Biol. Rept. Ser. Vol. 34(1).
- Cuccarease, S., M. Floyd, M. Kelly, and J. LaBelle. 1980. An assessment of environmental effects of construction and operation of the proposed Tyee Lake hydroelectric project, Petersburg and Wrangell, Alaska. AEIDC, Univ. Alaska, Anchorage.
- deBruyan, M., and P. McCart. 1974. Life history of the grayling (<u>Thymallus arcticus</u>) in Beaufort Sea drainages in the Yukon Territory. Chap. 2 in P.J. McCart, ed. Fisheries research associated with proposed gas pipeline routes in Alaska, Yukon, and Northwest Territories. Canadian Arctic Gas Study Ltd./Alaskan Arctic Gas Study Co., Biol. Rept. Ser. Vol. 15.
- DenBeste, J., and P. McCart. 1984. Overview of studies of the long-term effects of the Trans-Alaska Pipeline System on fish and aquatic habitats. Vol. 1. Prepared for Alyeska Pipeline Service Co. by Aquatic Environments Inc., Anchorage. 49 pp.

- Elliott, G. 1980. First interim report on the evaluation of stream crossings and effects of channel modifications on fishery resources along the route of the trans-Alaska pipeline. USFWS, Special Studies. Anchorage, AK. 77 pp.
- Engel, L.J. 1971. Evaluation of sport fish stocking on the Kenai Peninsula-Cook Inlet areas. ADF&G, Fed. Aid in Fish Rest. Ann. prog. rept. Vol 12. Proj. F-9-3, Job G-11-F.
 - _____. 1973. Inventory and cataloging of Kenai Peninsula, Cook Inlet, and Prince William Sound drainages and fish stocks. ADF&G, Fed. Aid in Fish Rest. Ann. prog. rept. Vol 14. Proj. F-9-5, Job G-I-C.
- Furniss, R.A. 1974. Inventory and cataloging of arctic area waters. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol. 15. Proj. F-9-6, Job G-I-I.
- Grabacki, S. 1981. Effects of exploitation on the population dynamics of Arctic grayling in the Chena River Alaska. M.S. Thesis, Univ. Alaska, Fairbanks.
- Hallberg, J. 1977. Arctic grayling in the Tanana River drainage. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol 18. Proj. F-9-9, Job R-I.
- . 1978. Arctic grayling in the Tanana River drainage. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol. 19. Proj. F-9-10, Job R-I.
 - _____. 1981. Population structure, migratory patterns and habitat requirements of the arctic grayling. ADF&G, Fed Aid in Fish Rest. Ann. performance rept. Vol. 21. Proj. F-9-12, Job R-I-A.
- Holmes, R. 1983. Distribution, abundance and natural history of the arctic grayling in the Tanana drainage. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol. 24. Proj. F-9-15, Job R-I-A.
- . 1984. Population structure and dynamics of arctic grayling. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol. 25. Proj. F-9-16, Job R-I-A.
- _____. 1985. Personal communication. Fishery Biologist, ADF&G, Div. Sport Fish, Fairbanks.
- Jennings, T.R. 1983. Survival, growth and food habits of young-of-the-year Arctic grayling stocked in barren, subarctic lakes. M.S. Thesis, Univ. Alaska, Fairbanks. 69 pp.

- Kratt L., and J. Smith. 1977. A post-hatching sub-gravel stage in the life history of the arctic grayling, <u>Thymallus arcticus</u>. Trans. Am. Fish. Soc. 106(3):241-243.
- Krueger, S.W. 1981. Freshwater habitat relationships: arctic grayling (<u>Thymallus arcticus</u>). ADF&G, Div. Habitat, Resource Assessment Branch. 65 pp.
- Kruse, T. 1959. Grayling of Grebe Lake, Yellowstone National Park, Wyoming. Fish Bull. 149. USFWS 59:305-351.
- LaPerriere, J.D., D.M. Bjerklie, R.C. Simmons, E.E. Van Niewenhuyse, S.M Wagner, and J.B. Reynolds. 1983. Effects of gold placer mining on interior Alaskan stream ecosystems. In proceedings of the first annual meeting of the Alaska chapter of the Water Resources Association, Nov. 1983, Fairbanks. 34 pp.
- LaPerriere, J.D., and R.F. Carlson. 1973. Thermal tolerances of Interior Alaskan arctic grayling, <u>Thymallus arcticus</u>. Institute of Water Resources, Univ. Alaska, Fairbanks. Rept. No. IWR-46.
- McCart, P., P. Craig, and H. Bain. 1972. Report on fisheries investigations in the Sagavanirktok River and neighboring drainages. Alyeska Pipeline Service Company. 170 pp.
- MacPhee, C., and F. Watts. 1976. Swimming performance of arctic grayling in highway culverts. Final rept. to USFWS, Anchorage, Ak. 41 pp.
- Morrow, J. 1980. The freshwater fishes of Alaska. Anchorage, Ak.: Alaska Northwest Publishing Company. 248 pp.
- Moyle, P.B. 1977. In defense of sculpins. Fisheries 2:20-23.
- Murray, J.B. 1984. Personal communication. Area Mgt. Biologist, ADF&G, Div. Sport Fish, Kodiak.
- Nelson, P.H. 1954. Life history and management of the American grayling (<u>Thymallus signifer tricolor</u>) in Montana. J. Wildl. Manage. 18:324-342.
- Netsch, N. 1975. Fishery resources of waters along the route of the trans-Alaska pipeline between Yukon River and Atigun Pass in northcentral Alaska. USFWS. Resource Publication 124. 45 pp.
- Pearse, G. 1974. A study of a typical spring-fed stream of interior Alaska. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol. 15. Proj. F-9-6, Job G-III.

- Peterson, H.H. 1968. The grayling, (<u>Thymallus</u> <u>thymallus</u> [L]) of the Sundsvall Bay area. Institute of Freshwater Fisheries, Drottingholm, 48:36-56. Cited in McCart et al. 1972.
- Reed, R. J. 1964. Life history and migration patterns of arctic grayling, <u>Thymallus arcticus</u> (Pallas), in the Tanana River drainage of Alaska. ADF&G, Juneau. Res. Rept. No. 2. 30 pp.
- Reiser, D.W., and T.C. Bjornn. 1979. Influence of forest and rangeland management on anadromous fish habitat in western North America. Habitat requirements of anadromous salmonids, USDA, For. Serv., Pac. Northwest For. and Range Exper. Station. Gen. Tech. Rept. PNW-96. 54 pp.
- Roguski, E.A., and E. Komarek, Jr. 1971. Monitoring and evaluation of arctic waters with emphasis on the North Slope drainages: Arctic Wildlife Range Study. ADF&G, Fed. Aid in Fish Rest. Ann. prog. rept. Vol. 12. Proj. F-9-3, Job G-III-A.
- Roguski, E.A., and S.L. Tack. 1970. Investigations of the Tanana River and Tangle Lakes grayling fisheries: migratory and population study. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol 11. Proj. F-9-2, Job 16-B.
- Russell, R. 1980. A fisheries inventory of waters in the Lake Clark National Monument area. ADF&G, Div. Sport Fish, and USDI: NPS. 197 pp.
- _____. 1983. Personal communication. Asst. Area Mgt. Biologist, ADF&G, Div. Commer. Fish., King Salmon, AK.
- Sautner, J.S., and M.E. Stratton. 1984. Access and transmission corridor studies. Part 1 in D.C. Schmidt, C.C. Estes, D.L. Crawford, and D.S. Vincent-Lang, eds. ADF&G, Susitna Hydro Aquatic Studies. Rept. No. 4. Access and transmission corridor aquatic investigations (July-October 1983).
- Schallock, E.W. 1966. Investigations of the Tanana River and Tangle Lakes fisheries: migratory and population study. ADF&G, Fed. Aid in Fish Rest. Ann. prog. rept. Vol. 7. Proj. F-5-R-7, Job 16-B.
- Schmidt, D., and W.J. O'Brien. 1982. Planktivorous feeding ecology of arctic grayling (<u>Thymallus arcticus</u>). Can. J. Fish. Aquat. Sci. 39:475-482.
- Schmidt, D.C., and M.E. Stratton. 1984. Population dynamics of arctic grayling in the upper Susitna basin. Part 2 in D.C. Schmidt, C.C. Estes, D.L. Crawford, and D.J. Vincent-Lang, eds. ADF&G Susitna Hydro Aquatic Studies. Rept. 4. Access and transmission corridor aquatic investigations (July-October 1983).

- Scott, W. B., and E.J. Crossman. 1973. Freshwater fishes of Canada. Bull. Fish. Res. Bd. Can. 184:300-305.
- Sonnichsen, S.K. 1981. Ecology of slimy sculpin (<u>Cottus</u> <u>cognatus</u>) in the Chena River, AK. M.S. Thesis, Univ. Alaska, Fairbanks. 71 pp.
- Suchanek, P.M., R.L. Sundet, and M.N. Wenger. 1984. Resident fish habitat studies. Part 6 in D.C. Schmidt, S.S. Hale, D.L. Crawford, and P.M. Suchanek, eds. ADF&G, Susitna Hydro Aquatic Studies. Rept. 2: Resident and juvenile anadromous fish investigations (May-October 1983).
- Sundet, R.L., and M.N. Wenger. 1984. Resident fish distribution and population dynamics in the Susitna River below Devil Canyon. Part 5 in D.C. Schmidt, S.S. Hale, D.L. Crawford, and P.M. Suchanek, eds. ADF&G, Susitna Hydro Aquatic Studies. Rept. 2: Resident and juvenile anadromous fish investigations (May - October 1983).
- Tack, S.L. 1971. Distribution, abundance and natural history of the arctic grayling in the Tanana River drainage. ADF&G, Fed. Aid in Fish Rest. Ann. prog. rept. Vol. 12. Proj. F-9-3, Job R-I.
 - _____. 1973. Distribution, abundance and natural history of the arctic grayling in the Tanana River drainage. ADF&G, Fed. Aid in Fish Rest. Ann. prog. rept. Vol. 14. Proj. F-9-5, Job R-I.
 - _____. 1974. Distribution, abundance and natural history of the arctic grayling in the Tanana River drainage. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol. 15. Proj. F-9-6, Job R-I.
 - _____. 1975. Distribution, abundance, and natural history of the arctic grayling in the Tanana River drainage. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol 16. Proj. F-9-7, Job R-I.
- ______. 1980. Distribution, abundance and natural history of the arctic grayling in the Tanana River drainage. ADF&G, Fed. Aid in Fish Rest. Research project completion rept. Vol 21. Proj. F-9-12, Job R-I.
- Tack, S.L., and J.G. Fisher. 1977. Performance of arctic grayling in a twenty-foot section of Model "A" Alaska Steeppass Fish Ladder. Final rept. on Contract No. DAC-W85-77-C-0018, Army Corps of Engineers, Alaska Div., Anchorage. 19 pp.
- USFWS. 1982. Arctic National Wildlife Refuge coastal plain resource assessment. Initial baseline study of the fish, wildlife, and their habitats. USDI: USFWS, Region 7, Anchorage, AK. 507 pp.
- Van Nieuwenhuyse, E.E. 1983. The effects of placer mining on the primary productivity of interior Alaska streams. M.S. Thesis, Univ. Alaska, Fairbanks. 120 pp.

- Van Wyhe, G, 1962. Inventory and cataloging of sport fish and sport fish waters of the Copper River and Prince William Sound drainages. ADF&G, Fed. Aid in Fish Rest. Job completion rept. Vol 3. Proj. F-5-R-3, Job 11-A.
- Vascotto, G.L. 1970. Summer ecology and behavior of the grayling of McManus Creek, Alaska. M.S. Thesis, Univ. Alaska, Fairbanks. 132 pp.
- Vascotto, G.L., and J.E. Morrow. 1973. Behavior of the arctic grayling <u>Thymallus arcticus</u>, in McManus Creek, Alaska. Univ. Alaska, Biol. Papers 13:29-38.
- Walker, R.J. 1983. Growth of young-of-the-year salmonids in the Chena River, Alaska. M.S. Thesis, Univ. Alaska, Fairbanks. 147 pp.
- Warner, G. 1955. Spawning habits of grayling in interior Alaska. USFWS, Fed. Aid in Fish Rest. Q. prog. rept. (F-1-R-5).
- Williams, F.T. 1968. Grayling investigations on Tolsona and Moose lakes. ADF&G, Fed. Aid in Fish Rest. Ann. prog. rept. Vol. 9. Proj. F-5-R-9, Job 14-B.
- Williams, F.T. 1969. Grayling investigations on Tolsona and Moose lakes. ADF&G, Fed. Aid in Fish Rest. Ann. prog. rept. Vol. 10. Proj. F-9-1, Job 14-B.
- Williams, F.T., and W.D. Potterville. 1981. Inventory and cataloging of sport fish and sport fish waters of the Copper River, Prince William Sound, and the upper Susitna River drainages. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol 22. Proj. F-9-12, Job G-I-F.
- Wojcik, F. 1954. Spawning habits of grayling in Interior Alaska. Work Plan D., Job No. 1, Alaska Game Commission. USFSW. Q. Rept. No. 2.

_____. 1955. Life history and management of the grayling in Interior Alaska. Unpubl. M.S. Thesis, Univ. Alaska. 54 pp.

Yoshihara, H.T. 1972. Monitoring and evaluation of arctic waters with emphasis on the North Slope drainages. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol 13. Proj. F-9-4, 13 Job G-III-A.


Map 1. Range of broad whitefish (Morrow 1980)

- Ι. NAME
 - Common Names: Broad whitefish, round-nose whitefish, sheep-nose Α. whitefish, small-headed whitefish, Kennicott's whitefish
 - Β.
 - Scientific Name: <u>Coregnous nasus</u> Pallus, 1776 Due to taxonomic confusion in identifying broad whitefish, the following scientific names have been used since 1883 to describe <u>Coregonus nasus: Coregonus kennicottii, Coregonus nelsoni,</u> <u>Coregonus nasus kennicotti, Coregonus clupeaformis, Prosopium</u> cylindraceum, and Prosopium kennicotti.
- II. RANGE
 - Worldwide Α.
 - Broad whitefish are distributed in the fresh and brackish waters of the arctic and subarctic drainages of northwestern North

America and northern Eurasia, south to about 60° north latitude (Baxter 1973, Scott and Crossman 1973). The western limit of the range is the Pechora River, USSR (52° E), just west of the Ural Mountains, from which they occur east to the Bering Sea, south to the Bay of Korf, and in the Penzhia River on the northeastern corner of the Sea of Okhotsh (Baxter 1973, Scott and Crossman 1973, Morrow 1980). In North America, broad whitefish occur in fresh water from the Perry River, Northwest Territories, west in numerous river systems of arctic Canada (such as the Coppermine and MacKenzie rivers) and along the arctic and northwest coast of Alaska to the Kuskokwim River (Scott and Crossman 1973). Anadromous populations have been observed in nearshore brackish water along the Beaufort Sea and as far offshore as Herschel A nonanadromous population Island, Yukon Territory (ibid.). exists in Teslin Lake at the headwaters of the Yukon River (ibid.).

B. Statewide

Broad whitefish are found throughout Alaska from the Kuskokwim River north to the arctic coast (Alt 1971, Morrow 1980). They are present throughout the Yukon River drainage from the mouth to the headwaters in British Columbia, including the Innoko, Koyukuk, and Porcupine river tributaries in Alaska (Alt 1971). In the Tanana River drainage (part of the Yukon River system), they are widespread in the Minto flats and the lower Tolovana, Chatanika, and Tatalina rivers (Alt, pers. comm.). They are also found in most of the rivers draining into the Bering, Chukchi, and Beaufort seas (Alt 1971, Morrow 1980).

- C. Regional Distribution Maps To supplement the distribution information presented in the test, a series of blue-lined reference maps has been prepared for each region. Most of the maps in this series are at 1:250,000 scale, but some are at 1:1,000,000 scale. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of selected fish and wildlife species has been prepared and may be found in the Atlas that accompanies each regional guide.
- D. Regional Distribution Summary
 - 1. <u>Arctic</u>. Broad whitefish are widely distributed throughout the Arctic Region. They are frequently caught in nearshore waters of the Beaufort Sea. Anadromous runs occur in the Colville and Sagavanirktok rivers (Alt 1971, 1972; Bendock 1977, 1982). Small numbers were observed at stream and lake sites on the arctic coastal plain, including Teshekpuk Lake (Hablett 1979, Bendock 1982, Bendock and Burr 1985). Broad whitefish were observed in the lower Canning River and may possibly use other drainages to the east, although none have been reported in the Arctic National Wildlife Range (USFWS 1982).

In northwest Alaska, they are present in the Kobuk River (Alt 1971) as well as in the Imuruk Basin proper and the lower reaches of the major rivers flowing into the basin: the Agiapuk, Kuzitrin, and Pilgrim rivers (Alt 1972).

Western-Interior. Broad whitefish are found in most major 2. drainages where there is 1) summer access to tundra lakes and ponds, 2) suitable sand or fine gravel in moving water for spawning, and 3) adequate oxygenated water for winter survival (Baxter 1973). They are widely distributed in the Yukon River drainage from the mouth to the headwaters (Scott and Crossman 1973). Alt (1983) reported that broad whitefish were very abundant in the Innoko River system. They were taken in early September 1982 in all surveyed areas of the Iditarod River. They were also taken 7 mi up the Yentna River, near the mouth of the Dishna River, and 8 mi up the North Fork of the Innoko River (Alt 1983). Broad whitefish are found in the Porcupine and Kovukuk rivers and are widespread in the Minto flats region of the Tanana River drainage but apparently are rare farther upstream (Alt 1977). A single broad whitefish was captured in the Tanana River 14 km upstream from its confluence with the Chena River in September 1971 (Alt 1972). This represents the farthest upstream penetration of this species documented in the Tanana drainage (ibid.). They are also common in the entire Kuskokwim River system (Alt 1971, Baxter 1973). Alt (1972) reported that broad whitefish exist in Highpower Creek, 1,350 km up the Kuskokwim River.

III. PHYSICAL HABITAT REQUIREMENTS

- A. Water Quality
 - 1. <u>The pH factor</u>. In the Yukon-Kuskokwim delta, broad whitefish have been observed in tundra ponds containing a pH in the range of 5.5 to 6.0 (Hale 1981). They have been observed in the central arctic coastal plain lakes, where pH values ranged from 7.5 to 9.0 (Bendock and Burr 1985). Broad whitefish also were observed at stream survey sites in the Topagoruk and Ikpikpuk river drainages within the central arctic coastal plain, where pH values ranged from 8.0 to 9.0 (ibid.). However, the exact range they can tolerate or prefer is unknown (ibid.).
 - 2. Dissolved oxygen (D.O.). Little information is available on the dissolved oxygen requirements of broad whitefish. Baxter (1973) reports that broad whitefish in the Kuskokwim River drainage appear to need at least 2 mg/l at a water temperature of 0°C to survive. Bendock (1980) found broad whitefish overwintering in deeper pools and depressions of the Colville River, where D.O. levels ranged from 1.4 to 4.6 mg/l. Fish found at the lower D.O. level appeared healthy. Bendock (1977) also found late winter under-ice D.O. readings in the

Sagavanirktok River that varied between 7 mg/l and saturation (in excess of 15 mg/lat 0°C).

3. Turbidity. Little information is available on the effects of turbidity on broad whitefish populations in Alaska. Craig and Haldorson (1980) report that Simpson Lagoon waters are turbid to varying degrees for almost the entire open-water Because of wind-generated turbulence of period. bottom sediments, nearshore turbidity readings fluctuated widely (1-146 NTU recorded 80 m from shore) from day to day. Divers observed that a vertical stratification of water currents occurred in the center of the lagoon even though the water depth was only 2 m. Currents were slower at the bottom, and thus the flocculent detrital layer often remained in place despite relatively high velocities of overlying water. Kogl (1971) reported turbidity readings taken during July 1970 in the Colville River drainage that ranged from 0 to 20 ppm. The highest reading occurred at the outlet of Nanuk Lake on the Nechelik Channel of the Colville River delta.

Most experimental work has shown that many species of fish can survive high concentrations of suspended matter for short periods. Prolonged exposure to some types of materials in most species, however, results in a thickening of the cells of the respiratory epithelium and the eventual fusion of adjacent gill lamellae, which definitely interferes with respiration. Fish do not have gill cleaners for removing foreign matter and rely on the flow of water through the gill chambers (Bell 1973).

Excess turbidity in the form of settleable solids can kill buried eggs and alevins by denying water interchange and can smother food organisms. Primary food production is lowered above levels of 25 NTU (ibid.). Alaska turbidity standards for anadromous waters are set at no more than 25 NTU over background levels (ADEC 1979).

- 4. Salinity. Broad whitefish have been caught in waters with salinities as high as 30 ppt during summer conditions and O ppt during winter conditions in the Beaufort Sea (Craig and Haldorson 1980). Bendock (1977) captured broad whitefish in open-water leads of Prudhoe Bay with a salinity of less than 2.5 ppt during the early spring when fresh river water mixes with the more saline water of the ocean. In the arctic, broad whitefish are confined to fresh or slightly brackish water near coastal areas (Berg 1948, Muth 1969). Alt (1976) reports that broad whitefish are seldom taken in water with salinities greater than 20 ppt. Thus the Bering, Chukchi, and Beaufort seas should act as isolating between fish of the Kuskokwim, barriers Yukon, and
- B. Water Quantity Broad whitefish in Alaska generally occur in streams where the gradient is less than 0.75 m/km (Kogl 1971). Current velocities

Sagavanirktok river systems (Alt 1976).

for several bodies of water on the North Slope, where broad whitefish occur, range from 0 to approximately 180 cm/sec (ibid.). Hale (1981), based on information from Jones (n.d.), states that upstream migration might be inhibited by stream reaches longer than 100 m with velocities in the range of 40 cm/sec.

C. Water Temperature

Broad whitefish were captured in the Arctic Region and northwest Canada in water temperatures ranging from 0 to 16°C (Muth 1969, Bendock 1977). They overwinter at 0°C, with no apparent ill effects (Baxter 1973). They may also tolerate summer temperatures in shallow ponds of the Kuskokwim River delta up to about 20°C (Hale 1981).

There is little information on preferred temperatures, but fish from the MacKenzie River (0 to 15.5°C annual range) have a greater growth rate than fish from the Coppermine River (0 to 10°C annual range) (Muth 1969). The environmental factors (water temperature, longer ice-free period, and food availability) are suggested as the primary causes of growth differences between Coppermine and MacKenzie river fish (ibid.). Alt (1976) suggests that the slower growth rate of broad whitefish from the Sagavanirktok River and Imuruk Basin as compared to populations from the Yukon-Kuskokwim drainage may be the result of the shorter ice-free period in the Arctic Region. Food availability and genetic differences could be secondary factors (Alt 1976).

D. Substrate

Little information was found relating to the substrate required by broad whitefish. The lacustrine stock of broad whitefish in Lake Minchumina, northwest of Denali National Monument, evidently spawns on gravel and cobble along the lakeshore (Hale 1981). Baxter (1973) notes that they were found spawning in areas with sand and fine gravel in the Yukon-Kuskokwim delta. Broad whitefish were taken by Bendock (1985) in rivers draining the central arctic coastal plain, which were characterized by an unvegetated substrate of silt and mixed sand. He also captured broad whitefish in thaw lakes, with typically unvegetated or sparsely vegetated silt bottoms and in deflation lakes characterized by vegetated sandy bottoms (ibid.).

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

Broad whitefish are opportunistic feeders able to use a wide range of food items. Percy (1975) captured broad whitefish fry along the arctic coast, in streams, and in delta lakes, and the stomach contents were analyzed. He noted a distinct difference in the diets of these three groups. Coastal fry were principally feeding on chironomids (midges) and copepods. Stream specimens had fed on plecopterans (stoneflies), crustaceans, and oligocheates. Lake specimens had fed on mysids.

Stomach analysis of 136 broad whitefish (399 to 516 mm fork length) captured during the summers of 1974 and 1975 in the outer

MacKenzie River delta revealed that 130 were empty. The stomach contents of the remainder included 60% plant remains, 35% gastro-5% trichopterans (caddisflies) (ibid.). pods. and Stomach contents of broad whitefish sampled in Prudhoe Bay during late July revealed that 58% (n = 12) were empty; the remainder included 80% amphipoda, 20% pelecypoda, and 40% dipteran larvae and adults (Furniss 1973). From stream surveys, Hablett (1979) found that 76% (n = 83) of the broad whitefish sampled in the Colville River had empty stomachs. Food items found in the remaining fish included snails, aerial insects, chironomid larvae, and zooplankton. Fifteen percent (n = 35) of the Innoko River broad whitefish stomachs sampled during the spring upstream migration contained food (Alt 1983). Food items of fish captured on summer feeding grounds were clams, caddisflies, snails, diptera larvae, and beetles (ibid.). Bendock (1982) reports that 46% (n = 66) of the broad whitefish stomachs examined from coastal plain lakes contained food. Prey items in descending frequency of occurrence included clams, snails, chironomid larvae, and zooplankton (Bendock 1982).

Β. Types of Feeding Areas Used

As is suggested by their short gill rakers and blunt snouts, broad whitefish are apparently bottom feeders (McPhail and Lindsey 1970).

Upon entering the Beaufort Sea when the larger rivers break up in early June, anadromous broad whitefish forage along the mainland coastline, inhabiting shallow bays and lagoons (Bendock 1977). In the Sagavanirktok and Colville river deltas, young-of-the-year and age 1 broad whitefish seldom travel beyond the waters adjacent to the rivers (ibid.). Overflow channels and oxbows connected to the Colville River are used extensively by young-of-the-year and immature broad whitefish (Hablett 1979).

In the Kuskokwim drainage, the nonanadromous broad whitefish usually feed in lakes that connect with river channels. The adult and young broad whitefish leave the tundra lakes, ponds, and sloughs in the fall to overwinter in the deeper river channels (Baxter 1973).

Alt (1983) reports that nonanadromous broad whitefish migrate upstream in early summer and move into the lake and slough environment to feed along the lower 140 mi of the Innoko River and lower Iditarod River. In 1982, they were captured in shallow lakes that in 1981 had been dry because of low water levels (ibid.).

C. Factors Limiting Availability of Food

Little documentation was found that discussed factors limiting the availability of food. In the Beaufort Sea, the primary food source of anadromous fish are marine-derived organisms (mysids, amphipods, etc.). This is because of the low input of terrestrially derived carbons to the brackish water nearshore zone. The availability of suitable feeding habitat in the nearshore zone is limited by the thermoregulatory and osmoregulatory abilities of

the anadromous broad whitefish. Therefore, the suitable feeding habitat for anadromous broad whitefish in the Beaufort Sea would be defined by high temperatures (less than 15°C), low salinity (15 ppt), and the availability of prey organisms recruited from the marine waters offshore (Johnson 1984).

D. Feeding Behavior

Broad whitefish do not feed in the Kuskokwim River from the time they leave their summer feeding areas in the fall until the next spring, when they return to the tundra lakes (Baxter 1973). For spawners, this is a period of eight to nine months without feeding. Baxter (1973) found no food in hundreds of broad whitefish that he examined during fall and winter months. Bendock (1977) reports that all of the spawning broad whitefish captured in the Sagavanirktok River during the last week of September had empty stomachs. Innoko River broad whitefish (in the Western Region) do not feed during the spring upstream migration (Alt 1983).

During the summer open-water season, the anadromous fish emerge from the overwintering areas and disperse along the coast of the Beaufort Sea. Their summer dispersal is predominantly for feeding purposes; in excess of 80% of the annual food budget is obtained during the summer open-water season (Johnson 1984).

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Little documentation was found on reproductive habitat characteristics. In the Yukon-Kuskokwim river drainages, with the possible exception of Lake Minchumina, all broad whitefish spawning areas reported by Baxter (1973) have been in moving water. Baxter (1973) states that adult broad whitefish require flowing water for their eggs to develop to the final stages before spawning.

Both anadromous and nonanadromous populations of broad whitefish travel up the main stem of larger rivers to spawn, sometimes traveling several hundred miles (Baxter 1973, Bendock 1977). Bendock 1977 also reports that anadromous adult broad whitefish reenter the Sagavanirktok River in late August and spawn in deep pools throughout the lower reaches of the delta. (Additional information on spawning substrate is discussed in the Physical Habitat Requirements section.)

B. Reproductive Seasonality In the fall, broad whitefish leave their summer feeding areas and move toward the spawning grounds. Broad whitefish apparently move upstream in small groups, and the run is spread over several months. The peak catch at Umiat on the Colville River occurred at the end of July (Kogl 1971). An annual upstream spawning migration, peaking during September and October in the inner delta, has been documented in the MacKenzie River (DeGraaf and Machniak 1977, Percy 1975). Adults apparently move downstream after spawning and overwinter in deeper parts of the rivers or in estuaries (Morrow 1980, Baxter 1973). Tag-return data indicate that the downstream run of spent fish in the MacKenzie River occurs during the first two weeks of November (Percy 1975).

All broad whitefish (n = 12) captured near the mouth of the Pilgram River, Imuruk Basin, on 19 September were in spawning condition (Alt 1980). Bendock (1977) captured ripe broad whitefish in the Sagavanirktok River during the last week in September. Baxter (1973) reported the following seasonal distribution for broad whitefish in the Kuskokwim River drainage:

- 1. <u>June and July</u>. The entire population spends summers feeding as a mixed-age-and-sex group on the tundra in the lakes and ponds and, to a lesser extent, in the tundra sloughs.
- 2. <u>August</u>. Sexually mature females that will spawn in the fall start their out-migration from summer feeding areas and slowly ascend the Kuskokwim River, 5 to 10 mi per day. The earlier ripening fish spawn farthest upriver.
- 3. <u>September</u>. Sexual development of males occurs more rapidly, and the males join the females in the upstream migration.
- 4. <u>Late September through October</u>. The nonspawning adults leave the tundra feeding areas and apparently mill in the Kuskokwim River generally below the spawning population.
- 5. <u>October to December</u>. The immature fish leave the tundra and mill with the nonspawning adults. The youngest fish leave last.
- 6. October to early December. The only area surveyed in the main Kuskokwim River during the spawning season was at river mile 89. Spawning starts about the time the Kuskokwim River freezes over in this area.
- 7. <u>Mid December to May</u>. After spawning, the entire broad whitefish population moves downstream and appears to be mixed for the rest of the winter in deeper pools of the lower Kuskokwim River.
- 8. Late May or early June. As soon as the melting snow and ice flushes the Kialik River and it becomes oxygenated, broad whitefish populations enter the river and proceed upstream to their summer feeding areas. This migration occurs before the ice is out of the tundra lakes, ponds, and sloughs and will proceed above the anchor ice in the sloughs. The older fish appear in the upper reaches of the rivers first, with no apparent differences between spent and developing fish. In the Nizhnyaya and Tungusky rivers in the USSR, broad whitefish spawn from the end of October to the beginning of November at water temperatures close to 0°C (Berg 1948).
- D. Age at Sexual Maturity

Limited data on the sexual maturity of Sagavanirktok River fish indicate that males mature at ages 7 to 9 and females at ages 8 to 10 (Alt 1976). Age at maturity for both sexes from the Colville River samples was 7 to 8 years (Alt and Kogl 1973). Fifty percent (n = ?) of the age 9 broad whitefish sampled from the Colville River and the eastern margin of Foggy Bay in the Beaufort Sea during 1975 and 1976 were mature (Bendock 1977). Twenty-three (n = ?) of those fish between ages 11 and 13 had redeveloping gonads and would not spawn in the year of capture (ibid.). Broad whitefish captured from arctic coastal plain lakes ranged from 5 to 20 years. The age of sexual maturity was 10 years for both sexes (Bendock 1982).

In Imuruk Basin samples, males mature between ages 6 and 8, whereas females mature between ages 7 and 8 (n = 53) (Alt 1976). Gonad examinations of specimens from the Innoko River suggest that all age 6 and older fish, except for a 376 mm female, were mature (Alt 1983).

Data indicate a somewhat earlier age at maturity for Porcupine River broad whitefish. Males reach sexual maturity at age 5 and females at age 5 or 6 (n = 32) (Alt 1976). Minto flats samples (n = 79) ranged from ages 5 to 11, and all were mature except one age 5 400-mm male (ibid.).

Holitna River specimens ranged from age 4 to 8 (n = 73). Examinations of the gonads of these fish indicate that males mature at ages 5 and 6 and females mature at ages 6 and 7 (ibid.).

The maximum age reported by Craig and Haldorson (1980) for broad whitefish from Simpson Lagoon in the Beaufort Sea was 22 years. Longevity is generally greater for broad whitefish of the arctic coastal plain lakes than for either their anadromous counterparts (from Prudhoe Bay) or Interior Alaska broad whitefish (Bendock 1982).

E. Frequency of Breeding

In the Kuskokwim and Yukon river systems, larger broad whitefish do not spawn every year after they become adults (Baxter 1973). During the winter, part of the population consists of large adult fish that have immature gonads. These fish are quite fat in physical condition, especially in the nuchal hump. The other part of the adult population consists of those that have spawned recently. These fish have lost almost all their abdominal fat, and the nuchal hump is lower than that of the nonspawning adults (ibid.).

Females in the Minto flats area are apparently nonconsecutive spawners because many large fish were found during the summer that contained tiny undeveloped eggs and residual eggs from the previous year's spawning (Alt 1972). Other investigators have noted the nonconsecutive spawning of northern fishes. Baxter (1973) presumes that it is possibly caused by the paucity of the food supply and the lack of trace elements and vitamins in the food.

Based on field examinations of fish in the Innoko River, consecutive spawning is probably the rule for broad whitefish in that system (Alt 1983).

F. Fecundity

An exceptionally large broad whitefish for the Kuskokwim River, fork length (FL) = 590 mm, had an estimated egg number of 127,700; a large fish, FL = 522 mm, had an estimated 71,480 eggs; and an average fish, FL = 476 mm, had an estimated 46,220 eggs (Baxter 1973). Age was not given for these fish. Berg (1948) reported the fecundity of broad whitefish up to age 8 in the Kara River, USSR. The fecundity of the fish varied from 14,000 to 29,000 eggs. The fecundity of a sample (n = 11) from the MacKenzie River ranged from 26,922 to 65,798 eggs/female, with a mean of 39,721 eggs/female (DeGraaf and Machniak 1977).

G. Incubation Period/Emergence The timing and requirement for egg and fry development is largely unknown, but young-of-the-year fish have been documented in coastal waters in the summer (Bendock 1977, Craig and Haldorson 1980), indicating early movement away from spawning areas (USFWS 1982). Morrow (1980) states that the young hatch in the spring and move downstream.

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

Most of the natural mortality apparently occurs during the winter months that follow spawning (Baxter 1973). The exact cause of mortality was not given but may be any of several factors, including low D.O. or freezing (ibid.). Predation is also a major cause of mortality (Berg 1948). In the Kolyma River, Russia, the eggs of broad whitefish were found in the intestines of grayling, round whitefish, Siberian whitefish, dace, longnose sucker, and sturgeon (ibid.).

1. <u>Overwintering</u>. During the winter, the critical habitats are freshwater pools located under the ice that are fed by springs or the interstitial flow of the major rivers (Johnson 1984). As the river ice increases in thickness, it freezes into the substrate in shallow areas and riffles (Bendock 1977). By mid winter, this process has effectively created a series of discontinuous pools of water under the ice. This constitutes the only overwinter habitat for fish occupying the lower reaches of these rivers (ibid.). Overwinter locations have been reported in pools from the

lower Sagavanirktok River and from the Colville River in the vicinity of Umiat (Bendock 1977, 1980). Overwintering broad whitefish were also netted in several lakes in the inner MacKenzie delta (Percy 1975).

B. Human-related

Significant loss or reduction of overwintering habitats could result in populationwide reductions in numbers. Access to the overwintering pools is also essential if the populations are to be maintained (Johnson 1984). The overwintering and fall spawning areas within river deltas are extremely sensitive to disruption because concentrated numbers of fish are restricted to small pockets of under-ice water in these areas (Bendock 1977). Largescale gravel mining in river deltas can disrupt their hydrologic regime, thus affecting the availability of fall spawning and overwintering habitat (ibid.). The start of intensive fishing may lead to sharp successional changes. From studies in Russia, Reshetnikov (1979) states that fishing usually reduces the abundance of large and old fishes and that at least 10 years are needed to allow the population to return to its original state. He also notes that overfishing leads to a change in the composition of the ichthyofauna and that valuable commercial fishes with a long life cycle (inconnu, whitefishes, trout) are replaced by species with a short life cycle. Such changes in the compositions of the ichthyofauna, attributed to fishing and the eutrophication processes, were recorded in Lake Imandra, Syamozero, and the Pskov-Chudskoye body of water in Siberia, USSR (Reshetnikov 1979).

- Drilling fluids. An intensive investigation was conducted in the vicinity of Prudhoe Bay, Alaska, in early and mid 1979 to examine the environmental implications of offshore drilling fluid disposal in the arctic. Components of this investigation included measurement of environmental parameters, test discharges of freshwater drilling effluents (above and below ice), benthic studies, acute toxicity testing, and long-term biological effects studies. Ninety-six-hour LC50s values (concentrations at which 50% of the test organisms died over a ninety-six-hour period) for broad whitefish varied from 6.4% for XC-Polymer drilling fluids (from mid-well depth) to greater than 20.0% for CMC/Gel drilling fluids (from upper portions of the well)(Tornberg et al. 1980).
- 2. Barriers. To date, the primary coastal development activity in the Alaskan Beaufort Sea is the 13,000-ft-long West Dock Causeway extending into the brackish nearshore zone of Prudhoe Bay (Johnson 1984). Baker (1985) states that the Prudhoe Bay Waterflood Studies have obtained sufficient data to clearly establish the negative effect of the West Dock Causeway on four species of anadromous fishes. The study of the effects of the West Dock Causeway on anadromous fish has been ongoing for over four years (Johnson 1984). Baker (1985) reports that it has been established that the causeway has degraded habitat and blocked the movement of anadromous fishes by creating thermal and salinity gradient barriers. A sharp decrease in temperature accompanied by an increase in salinity blocks the movement of fishes. It is the presence of these gradients, not the physical presence of the causeway, that results in the barrier to fish movement (Johnson 1984). These gradients may present a barrier that could delay the arrival of the anadromous fish to their overwintering habitat, resulting in high overwintering mortality (ibid.).

A summary of potential impacts from human-related activities in the Beaufort Sea estuary includes the following (Bendock 1977):

A large-scale reduction in invertebrate fauna may have a profound effect on the fishery.

- Overwintering and fall spawning areas within river deltas are extremely sensitive to disruption because of the concentrated number of fish restricted to small pockets of under-ice water.
- [°] Large-scale gravel mining in river deltas can disrupt their hydrologic regime, thus affecting the availability of fall spawning and overwintering habitat.
- The following are other possible impacts:
- ° Changes in biological oxygen demand, nutrient loading
- ° Changes in chemical composition of water
- [°] Changes in dissolved oxygen, temperature, pH, salinity
- ° Changes in flow or water level, entrapment
- ^o Changes in sedimentation rates, turbidity, suspended solids
- Changes in substrate composition and location
- ° Competition with introduced species
- Increased susceptibility to harvest or predation
- [°] Inducement of impingement or entrainment
- ° Physical barriers to movement
- [°] Shock waves and blasting in aquatic environments

(For additional impacts information, see the Impacts of Land and Water Use volume of this series.)

VIII. LEGAL STATUS

Broad whitefish stocks in Alaska are managed by the Alaska Department of Fish and Game.

IX. LIMITATIONS OF INFORMATION

There are major gaps in our current knowledge critical to the future management of broad whitefish and their habitat requirements. More extensive information is needed on velocity, depth, temperature, and salinity requirements. Little information was found on the effects of environmental changes. A better understanding of early life history, population dynamics, population genetics, species identification, and spawning populations is necessary.

Russian scientists have conducted research on broad whitefish, including studies on hatchery production, that have been published in Russian language journals for which translations are not readily available.

REFERENCES

ADEC. 1979. Water quality standards. Juneau. 34 pp.

Alt, K.T. 1971. Distribution, movements, age, and growth, and taxonomic status of whitefish (<u>Coregonus</u> sp.) in the Tanana-Yukon drainage and North Slope. ADF&G, Fed. Aid in Fish Rest. Ann. prog. rept. Vol. 12. Proj. F-9-3, Study R-11, Job R-11-F. . 1972. Distribution, movements, age and growth, and taxonomic status of whitefish (<u>Coregonus</u> sp.) in the Arctic-Yukon-Kuskokwim area. ADF&G. Fed. Aid in Fish Rest. Ann. prog. rept. Vol. 13. Proj. F-9-4, Job R-11-G.

_____. 1976. Age and growth of Alaskan broad whitefish, <u>Coregonus</u> nasus. Trans. Am. Fish Soc. 105:526-528.

_____. 1980. Inventory and cataloging of sport fish and sport fish waters of western Alaska. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol. 21. Proj. F-9-12, Job G-I-P.

_____. 1983. Inventory and cataloging of sport fish and sport fish water of western Alaska. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol. 24. Proj. F-9-15, Job G-I-P-B.

_____. 1985. Personal communication. Area Mgt. Biologist, ADF&G, Div. Sport Fish, Fairbanks.

- Alt, K.T., and D.R. Kogl. 1973. Notes on the whitefish of the Colville River, Alaska. J. Fish. Res. Bd. Can. 30(4):554-556.
- Baker, B.H. 1985. Monthly report, March. ADF&G, Div. Habitat, Juneau.
- Baxter, R. 1973. <u>Coregonus</u> <u>nasus</u> (Pallas). ADF&G, Div. Commer. Fish., Bethel.
- Bell, M.C. 1973. Fisheries handbook of engineering requirements and biological criteria. Fisheries-Engineering Research Program, Corps of Engineers, North Pacific Division. Portland, OR. Approx. 500 pp.
- Bendock, T.N. 1977. Beaufort Sea estuarine fishery study. Final rept., OCS Contract No. 03-5-022-69. ADF&G, Fairbanks.

_____. 1980. Inventory and cataloging of arctic area waters. ADF&G, Fed. Aid in Fish Rest., Study No. G1, Job No. G-I-I.

. 1982. Inventory and cataloging of arctic area waters. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol. 23. Proj. F-9-14, Job G-I-I.

- Bendock, T.N., and J.M. Burr. 1985. Freshwater fish distribution in the central arctic coastal plain. ADF&G, Div. Sport Fish, Fairbanks.
- Berg. L.S. 1948. Freshwater fishes of the USSR and adjacent countries. Guide to the fauna of the USSR. No. 27. Vol. 1, 4th ed. Akad. Nauk USSR Zool. Inst., Moscow. Translated from Russian by Israel Prog. for Sci. Transl., 1962. Office of Technical Services, USDC. Washington, DC. 504 pp.

- Craig, P.C., and L. Haldorson. 1980. Beaufort Sea Barrier Island-Lagoon ecological process studies; final report, Simpson Lagoon studies. Part 4: Fish. OCS ann. rept. Contract No. 03-6-022-35193, LGL Limited, Sidney, British Columbia, Can. 259 pp.
- DeGraaf, D., and K. Machniak. 1977. Fishery investigations along the Cross delta pipeline route in the MacKenzie delta. Chapter IV, pages 1-169 <u>in</u> P. McCart, ed. Studies to determine the impact of gas pipeline development on aquatic ecosystems. Arctic Gas Biol. Rept. Ser., Vol. 39. Prepared by Aquatic Environments Limited.
- Furniss, R.A. 1975. Inventory and cataloging of arctic area waters. ADF&G, Fed. Aid in Fish Rest. Vol. 16. Proj. F-9-7, Study G-I-I.
- Hablett, T.R. 1979. Fish inventories conducted within the National Petroleum Reserve on the North Slope of Alaska, 1977-78. Pages 337-406 in National Petroleum Reserve in Alaska Work Group 3. Studies of selected wildlife and fish and their use of habitats on and adjacent to the National Petroleum Reserve in Alaska 105(c) Land Use Study, Anchorage.
- Hale, S.S. 1981. Freshwater habitat relationships: broad whitefish (<u>Coregonus nasus [Pallus]</u>). ADF&G, Div. Habitat, Resource Assessment Branch. 16 pp.
- Johnson, C. 1984. Effects of coastal development for oil and gas on anadromous fisheries in the Beaufort Sea. NMFS rept.
- Jones, D.R. N.d. An evaluation of the swimming performance of several fish species from the Mackenzie River. Univ. British Columbia, Department of Zool., Vancouver, B.C. 53 pp. Cited in Hale 1981.
- Kogl, D.R. 1971. Monitoring and evaluation of arctic waters with emphasis on the North Slope drainages: Colville River study. ADF&G, Fed. Aid in Fish Rest. Vol. 12. Proj. F-9-3, Job G-III-A.
- McPhail, J.D., and C.C. Lindsey. 1970. Freshwater fishes of Northwestern Canada and Alaska. Fish. Res. Bd. Can. Bull. 173. 381 pp.
- Morrow, J.E. 1980. The freshwater fishes of Alaska. Anchorage: Alaska Northwest Publishing Co. 248 pp.
- Muth, K.M. 1969. Age and growth of broad whitefish (<u>Coregonus nasus</u>), in the Mackenzie and Coppermine rivers, N.W.T. J. Fish. Res. Bd. Can. 26(8):2,252-2,256.
- Percy, R. 1975. Fishes of the outer Mackenzie delta. Beaufort Sea Tech. Rept. No. 8. Dept. of Environment, Beaufort Sea Project. Victoria, B.C. 114 pp.

- Reshetnikov, Y.S. 1979. Whitefishes in northern ecosystems. J. Ichthyol. 19(3):31-44.
- Scott, W.B., and E.J. Crossman. 1973. Freshwater fishes of Canada. Fish. Res. Bd. Can. Bull. 184. Ottawa. 966 pp.
- Tornberg, L.D., E.D. Thielk, R.E. Nakatani, R.C. Miller, and S.O. Hillman. 1980. Toxicity of drilling fluids to marine organisms in the Beaufort Sea, Alaska. The joint government-industry symposium research on environmental fate and effects of drilling fluids and cuttings.
- USFWS. 1982. Initial report baseline study of the fish, wildlife, and their habitats. USFWS, Section 1002c. Anchorage. 507 pp.



Lake Trout Life History and Habitat Requirements

Map 1. Range of lake trout (Morrow 1980, ADF&G 1978b, Bendock and Burr 1985, Pearse 1978)

- Ι. NAME
 - Α. Common Name: Lake trout
 - Β. Scientific Name: Salvelinus namaycush

II. RANGE

Statewide-Α.

Lake trout are distributed throughout highland lakes of the Brooks Range, the arctic coastal plain, Bristol Bay, and the Kenai, upper Susitna, and Copper river drainages (ADF&G 1978b). They are generally absent from lakes of the North Slope lowlands and the lower Yukon-Kuskokwim river basins (Morrow 1980, McPhail and Lindsey 1970) and are not found in the Wood River system or in Alaska Peninsula systems south of Mother Goose Lake (Alt 1977).

B. Regional Distribution Map

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

- C. Regional Distribution Summary
 - Southcentral. Lake trout are most abundant in the upper 1. Susitna and Copper River drainages, occurring in most large area lakes and some smaller ones (e.g., Lake Louise, Paxson, Crosswind, Fielding, and Susitna lakes and Klutina Lake and They are found in several lakes on the Kenai River). Peninsula (e.g., Tusteumena, Skilak, Hidden, Swan, Juneau, and Kenai lakes; also Trail Lake and River). They also occur in a few lakes on the west side of Cook Inlet (e.g., Chelatna, Chakachamna, and Beluga lakes) and in the Matanuska Valley (e.g., Byers and Lucy lakes). In the Cordova area, Little Tokun Lake near Bering Glacier contains the only known population (ADF&G 1976, 1978a, 1978b; Redick 1967). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)
 - Arctic. Lake trout are widely distributed across the North 2. Slope, primarily inhabiting lakes, but also occurring in streams within the Colville, Sagavanirktok, and Canning river drainages (Bendock 1982). They have been found in most of the glacial lakes that lie within the Brooks Range and in the southern foothills adjacent to the mountain front (McCart et al. 1972). Waters within the foothills region and the western margin of the coastal plain have few lake trout, but the species is well represented in the central coastal plain. which marks the northernmost distribution of this species in Alaska (Bendock 1982). Lake trout are present in the Kobuk drainage as far west as Selby and Narvak lakes (ADF&G 1978b). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Arctic Region.)

III. PHYSICAL HABITAT REQUIREMENTS

- A. Water Quality
 - 1. <u>Temperature</u>. Temperature is probably the most important single factor determining the movements of lake trout (Martin and Olver 1980). In most cases, lake trout inhabit waters with a temperature range of about 6 to 13°C (ibid.) in the shallows during winter and in deeper waters below the thermocline during summer. The species has been found in temperatures as low as -0.8°C in marine situations in arctic Canada (Boulva and Simard 1968) and up to 18°C in Ontario lakes and Cayuga Lake in New York State (Martin 1952,

Straight 1969, Galligan 1962). Reported upper lethal temperatures have ranged from 17.8°C (Seguin 1957) to 23.5°C (Gibson and Fry 1954).

- 2. <u>The pH factor</u>. Little information was found in the available literature on the influence of pH levels on the survival and development of lake trout. Waters of the western North Slope inhabited by lake trout, among many other species of fish, are characteristically soft, having low values for alkalinity and hardness and a neutral pH (Bendock 1979). Experimental studies conducted in Whitepine Lake near Sudbury, Canada, indicate that under natural conditions most lake trout sac fry could tolerate short periods of substantial pH depression (five days at pH less than 5.0), though they show obvious signs of stress under these conditions (Gunn and Keller 1984).
- 3. Dissolved oxygen (D.O.). Lake trout eggs and fry have a low tolerance for reduced oxygen concentrations. From the results of laboratory experiments, Carlson and Siefert (1974) concluded that, assuming poor larval survival and development indicate poor conditions for lake trout, the oxygen concentrations for eggs and fry should be no less than 50% saturation at 7°C. At 10°C the effect of lowered oxygen concentrations was more pronounced. Martin and Olver (1976) concluded that 4 mg/l is about the minimal acceptable level of oxygen for adult lake trout. Studies examining the eutrophication (organic enrichment) of the Great Lakes that, especially during periods of concluded thermal stratification, oxidation of organic matter can cause widespread hypolimnetic oxygen depletion, which is probably detrimental to this species (Leach and Nepsky 1976).
- 4. <u>Turbidity</u>. Turbidity and resultant sedimentation from either runoff material or eutrophication could degrade inshore spawning areas used by lake trout (ibid.). Rayner (1941) suggested that mud brought down to Cayuga Lake by a flood may have had a deleterious effect on lake trout eggs. Webster et al. (1959) noted that a mantle of silt over the deeper spawning areas in Cayuga Lake has resulted in the complete absence of natural reproduction in that lake.
- 5. <u>Salinity</u>. Boulva and Simard (1968) found lake trout to be the least tolerant of salt water of all the chars and reported that the upper limit of salinity tolerance appears to be around 11 to 13 parts per thousand (ppt), though they are common in water with salinity values between 6 and 9 ppt. Rounsefell (1958) noted that lake trout have been caught at the head of tidewater in the Naknek River.
- B. Water Quantity

Lake trout in temperate areas require lakes deep enough to thermally stratify during periods of hot, calm weather. They prefer the cooler water below the thermocline. Rawson (1961) found that lake trout required depths of at least 15 and usually 20 m in Lac La Ronge, Saskatchewan (55 north latitude), during the months of July and August. In arctic areas, where water temperatures may not rise far above 10°C even during summer, lake trout may be found in more shallow lakes. In these areas, lakes must be deep enough to not freeze to the bottom in winter, but they may not thermally stratify in summer. For instance, lake trout are found in Teshekpuk Lake, on the North Slope west of Harrison Bay, which has a maximum depth of 15 m (Bendock 1979).

C. Substrate

Spawning typically occurs over a clean, rocky, or rubble bottom (Morrow 1980, ADF&G 1978b, Rawson 1961). More details of spawning substrate requrements are given in the Reproductive Habitat section of this narrative, below.

- D. Cover Requirements Protective cover is provided for adults by deep pools and swift riffles in rivers and sometimes by undercut banks (Alt 1977). Rocky bottom areas in lakes provide cover from predation for juveniles. In far northern waters, juveniles may spend several years hiding in the rubble of a lake bottom (Machniak 1975, Miller and Kennedy 1948).
- IV. NUTRITIONAL REQUREMENTS
 - A. Food Species Used
 - Preferred foods vary with the age and size of the fish and in response to availability. Juvenile lake trout feed on small crustaceans, particularly Mysis relicta, when present, plankton, detritus, Diptera (fly) larvae, and some small fish (Morrow 1980, ADF&G 1978b). As lake trout mature, they generally begin to eat more fish and fewer invertebrates; however, some feed on plankton throughout their lives (Martin 1966). Lake trout populations in systems where forage fish are not available do not grow as large as those that feed on fish (Martin 1966, Sautner and Stratton 1984). Furniss (1974) examined the stomach contents of lake trout from four mountain lakes on the north side of the Brooks Range in Mosquito larvae (Diptera: Culicidae), caddis July. fly (Trichoptera) pupae, detritus, and snails were frequently consumed food items. The lake trout stomachs also contained remains of sculpin (Cottidae), round whitefish (Prosopium cylindraceum), lake trout, and arctic char (Salvelinus alpinus). Bendock (1982) found that lake trout from eight coastal plain lakes consumed ninespine stickleback (Pungitius pungitius); other fish, including least cisco (Coregonus sardinella), slimy sculpin (Cottus cognatus), and lake trout; and snails and clams. Lake trout from Old John Lake near Arctic Village consumed snails, slimy sculpin, juvenile lake trout, pike (Esox lucius), and burbot (Lota lota). Surface insects and benthic invertebrates other than snails were also found in the stomachs, although these organisms were not commonly eatern (Craig and Wells 1975). Snails (Lymnaea sp.) were the major food item in lake trout over 400 mm in length from Itkillik Lake in the Colville River drainage (McCart et al. 1972). Hablett

(1979) reported that lake trout captured during summer in the western arctic had consumed least cisco, snails, aerial insects, round whitefish, slimy sculpin, and voles.

- B. Types of Feeding Areas Used
 - Juvenile lake trout in northern waters may spend several years near the bottom, seeking protection from predators and feeding. In the spring, older lake trout feed inshore and near the surface. As the water termperatures in the lakes rise, lake trout move deeper and finally reside beneath the thermocline (Martin and Olver 1980). Lake trout were generally more abundant near inlet and outlet streams of lakes studied in the lower Kuskokwim River and Kuskokwim Bay area in July 1978, because of cooler water temperatures and greater food abundance (Alt 1977).
- C. Factors Limiting Availability of Food

Nutrient loading, or eutrophication, of a system leads to changes in the quality and species types of phytoplankton, zooplankton, and benthic organisms available to lake trout (Leach and Nepsky 1976). Excessive sedimentation may inhibit production of aquatic invertebrate fauna (Hall and McKay 1983).

During periods of thermal stratification, lake trout are restricted to food items available below the thermal barrier (Scott and Crossman 1973, Eck and Wells 1983).

As lake trout are top predators in most situations and also found in deeper waters, food competition is generally not too extensive (Martin and Olver 1980). Instances have been recorded, however, of competition between lake trout and burbot, northern pike, and longnose suckers (<u>Catostomus catostomus</u>) (ibid.). Alevins or juveniles may have to compete with the young or adults of other species, particularly for invertebrate foods (ibid.). Competition may also be more significant in northern lakes where lake trout do not enter deep water away from other species during the summer.

D. Feeding Behavior

Lake trout are opportunistic feeders able to take advantage of an abundance of almost any food. They are particularly voracious in the spring (Scott and Crossman 1973). Studies of lake trout food habits from northern lakes have shown, however, that at any given time a large percentage of lake trout in these lakes may have empty stomachs. Fifty-one percent of lake trout sampled during the summer from the western North Slope by Bendock (1979) had Among lake trout sampled from arctic coastal empty stomachs. plain lakes during the summer, 38% had empty stomachs, and Craig and Wells (1975) found that 35% of lake trout taken from Old John Lake near Arctic Village had empty stomachs. Furniss (1974), however, found that lake trout taken from Chandler, Itkillik, Elusive, and Shainin lakes on the north side of the Brooks Range in July had only 4.0 to 7.1% empty stomachs. The feeding rate of adult lake trout decreases immediately preceeding and during spawning; however lake trout do continue to feed to some extent during the spawning season (Machniak 1975).

- V. REPRODUCTIVE CHARACTERISTICS
 - A. Reproductive Habitat

Most lake trout are lake spawners, but river-spawning populations are known to exist. Spawning typically occurs on reefs or shoal areas at depths of less than 12 m (40 ft) but sometimes in depths of less than a meter to as deep as 61 m (200 ft) (Morrow 1980, ADF&G 1978b). Redick (1967) reported that all spawning in Susitna Lake appeared to occur between depths of from 2 to 5 m. Lake trout spawning grounds are generally restricted to areas with clean gravel or rubble substrate free of sand and mud (Machniak 1975). Eggs are broadcast over the bottom and settle into cracks and crevices between rocks. Areas that tend to accumulate heavy bottom sediments are thus rendered useless for lake trout spawning (Redick 1967). The presence of rubble of such a size as to permit the eggs to drop between and receive protection from predators and light is essential to egg and fry survival (Paterson 1968). It is also essential that water percolate between the rubble to provide adequate aeration for the eggs and freedom from silt (ibid.). Though lake trout have been known to spawn over areas with smooth and soft substrate, egg and fry survival in these cases is not good (Hacker 1957, Dorr et al. 1981). The location of suitable areas of bottom in a lake is primarily determined by currents or winds that keep spawning areas clear of mud and debris (Redick 1967, Machniak 1975). Spawning reefs and shoals frequently face the prevailing winds and are close to deep water (Martin and Olver 1980).

B. Reproductive Seasonality

Generally, lake trout spawn in late summer and early autumn. with many factors such as cyclic weather changes, physiological characteristics of certain populations or races, and physical and biological peculiarities of individual lakes playing roles resulting in variations in spawning times in different areas (Machniak 1975). Spawning occurs as early as late August and early September in northern Alaska (McCart et al. 1972) to as late as November in southern Canada (Scott and Crossman 1973). Temperature plays an important part in the initiation and length of the spawning period (Martin and Olver 1980). Spawning begins with falling water temperatures, and in many of the more temperate lakes, at about 10°C (Martin and Olver 1980, Royce 1951). Wind is also important in triggering spawning activity (Martin and Olver Heavy onshore winds of several days duration may induce 1980). Lake trout from Paxson and Summit lakes spawning (ibid.). probably spawn from mid to late September (VanWhye and Peck Lake trout in Itkillik Lake spawn in early September 1968). (McCart et al. 1972).

- C. Reproductive Behavior
 - Evidence indicates that in many populations lake trout, having once spawned at a particular ground, will return to the same spot to spawn in subsequent years (Machniak 1975, Martin and Olver 1980).

Several authors have reported that male lake trout clean the spawning area of mud and silt by brushing it with their body or tail fin or by digging with their jaws (Martin 1957, Royce 1951, DeRoche and Bond 1957). Martin and Olver (1980), however, concluded that in most situations wave action and currents effectively keep the spawning area clean.

Lake trout do not dig a redd. One or two males may spawn with one female, or a group of males and females may spawn in mass, broadcasting eggs and sperm over the bottom to settle into crevices between rocks. The spawning act may be repeated many times before a female has voided her eggs (Morrow 1980, Scott and Crossman 1973). Lake trout reproductive studies conducted in New York and Ontario found that spawning activity occurred only at night. During the day, the fish were dispersed but returned to the spawning beds in great numbers, with peak activity occurring between dusk and 9 or 10 P.M. (Royce 1951, Martin 1957). No information on circadian spawning activity in Alaskan waters was found in the available literature.

D. Age at Sexual Maturity

Lake trout are slow-growing and late-maturing. Sexual maturity is more closely correlated with size than with age; however, it is usually attained by age 5 to 7 but may not be achieved until as late as age 13 (Morrow 1980, ADF&C 1978b, Scott and Crossman 1973). In the lower Kuskokwim River and Kuskokwim Bay area, age at first maturity is generally 9 to 10, and most fish are mature by age 12 (Alt 1977). Males usually mature a year earlier than females (Morrow 1980). In Paxson Lake in Interior Alaska, lake trout mature at ages 7 to 8. In Summit Lake, a less productive lake close to Paxson Lake, lake trout mature at ages 8 to 10 (VanWhye and Peck 1968). Lake trout in the arctic area mature at an older age than those from more southern populations. Lake trout in Old John Lake near Arctic Village reach sexual maturity between ages 10 and 15 (Craig and Wells 1975). Male lake trout in Itkiliik and Campsite lakes on the Alaskan North Slope may mature as early as age 11 (McCart, Craig and Bain 1972). The youngest female with maturing eggs was age 13 in Campsite Lakes and age 14 in Itkillik Lake (ibid.). Lake trout from North Slope coastal plain lakes, including Teshekpuk Lake, mature at age 11 (Bendock 1982), and all lake trout over age X from an unnamed lake at the headwaters of the Kuparuk River were mature (Alt 1976). Longevity of lake trout is variable, with the oldest on record

estimated to be 42+ from Chandler Lake, Alaska (Furniss 1974). Most individuals caught in the lower Kuskokwim River/Kuskokwim Bay area are 9 to 11 years old (Alt 1977). Alt (1977) also reports that the growth of lake trout from the Kuskokwim study area is generally slower than that reported from other waters in Interior Alaska and Great Slave Lake in Canada but more rapid than growth of lake trout in lakes of the Brooks Range, Alaska, and Great Bear Lake, Northwest Territories. Lake trout from the Kuskokwim area of Alaska generally do not live as long as slower-growing populations in northern Alaska and Great Bear Lake (Alt 1977).

- E. Frequency of Breeding Spawning frequency may vary from annually to about once in three years (Morrow 1980, ADF&G 1978b, Rawson 1961). Lakes in which lake trout spawn less than once in every year are typically northern, oligotrophic lakes (Machniak 1975). Lake trout in Great Bear Lake spawn about once in every three years (Miller and Kennedy 1948). Kogl (1971) found three nonspawners in a sample of 11 lake trout from the Colville River, indicating nonconsecutive spawning in this population. Furniss (1974) also found nonconsecutive spawners in lake trout from Chandler, Shainin, and Itkillik lakes.
- F. Fecundity

Fecundity varies with the size and condition of the female and may range from a few hundred up to 18,000 eggs (Morrow 1980, ADF&G 1978b, Scott and Crossman 1973). Fecundity of eight lake trout from Chandler Lake ranged rom 1,088 eggs for a 420 mm-long female to 6,371 for a 748 mm female (Furniss 1974).

Incubation Period and Time of Emergence G. Incubation period and time of hatching varies considerably throughout the lake trout range (Machniak 1975, Martin and Olver Paterson (1968) suggested that the critical period 1980). determining time of emergence is that between egg disposition and the time that stream temperatures drop to their minimum. During this time, higher temperatures may accelerate incubation, causing the hatching period to be significantly shortened (ibid.). In most populations, hatching occurs in March or April (Machniak 1975), but in Great Bear Lake, Northwest Territories, it is delayed until June (Miller and Kennedy 1948). The alevins may remain near the spawning area in shallow water for one to two months after emergence if the water temperature does not exceed 15°C for an extended period (Peck 1982). In far northern waters, young lake trout may remain among the boulders near shore for several years. Miller and Kennedy (1948) noted that fry and oneto-three-year-old lake trout were found in shallow waters of Great Bear Lake. This tendency of fry to inhabit warm shallow areas may be a local adaptation to stimulate growth and aid juvenile survival in this rigorous environment (Redick 1967).

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

Whole populations of lake trout do not undertake movements in definite directions; they are solitary wanderers that move freely throughout lakes between seasonal feeding areas and spawning grounds, limited in movement chiefly by the size of the body of water (Morrow 1980, Scott and Crossman 1973). Larger fish tend to travel greater distances (Morrow 1980).

Depth distribution and seasonal movements of lake trout are primarily related to changing water temperatures. Lake trout typically move into shallow water in the spring during ice break-up and remain there until the surface water warms to above 10° C. As surface waters approach 10° C, lake trout tend to move to cooler (deeper) waters, eventually congregating below the thermocline during the summer months, preferring temperatures between 4.4 and 10° C (Martin 1952, ADF&G 1978b, Rawson 1961, Scott and Crossman 1973).

In the fall, when cooling surface waters destroy the thermal stratification, lake trout return to the rocky shallows to spawn. There is evidence of homing to prior spawning grounds (Martin 1960, Rawson 1961). After spawning, lake trout disperse throughout the lake at various depths and remain dispersed throughout the winter months (Rawson 1961, Scott and Crossman 1973).

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

A low water table and cold winter temperatures could cause eggs deposited at lake margins to desiccate or to freeze. Lake trout eggs may be dislocated from spawning beds by winter storms and washed onto shore or to areas unsuitable for development (Dorr et al. 1981). Extensive bottom scouring by winter storms may also injure developing eggs (ibid.). High water temperatures (above 10°C) and resultant deep heating during the summer could be detrimental to lake trout.

Occasionally, lake trout become cannibalistic, eating their own eggs and young (Furniss 1974, Bendock 1982). Martin and Olver (1980) stated that cannibalism may be most common in arctic lakes where there is not a diversity of forage species. Small lake trout are also preyed upon by burbot and northern pike (Redick 1967). Round whitefish have been reported consuming eggs of river-spawning lake trout (Loftus 1958); burbot are reported to eat lake trout eggs (Anon. 1960); and suckers (Catostomidae) have been found to prey on lake trout eggs in many areas (Martin and Olver 1980).

B. Human-related

Freshwater habitat is critical to lake trout populations. Each system is a semiconfined environment in which the population spends all life phases, including the most sensitive life functions of spawning, rearing of young, and feeding. These activities frequently are undertaken in different locations within a lake or tributary or outlet stream and therefore require movement within the system. Disturbances that degrade lake trout spawning, rearing, or feeding habits or that degrade water quality may adversely affect the population levels of lake trout that use the disturbed system (ADF&G and USFWS 1984). Martin and Olver (1980) stated that lake trout are extremely sensitive to exogenous, man-induced perterbations, and that it is essential that pristine conditions be maintained for the well-being of this species. Domestic and industrial pollution, mining, agricultural and forestry practices, power development schemes, and shoreline development all may have a deleterious effect on lake trout and other salmonids found in North American oligotrophic lakes (Ryder

and Johnson 1972). Lake trout are slow-growing and late-maturing fish and so are also very susceptible to overfishing (Martin and Oliver 1980).

In arctic areas, where many of the lakes and streams freeze to the bottom in winter months, overwintering habitat is limited, and lake trout populations become concentrated into small open-water areas. These overwintering areas are critical, and any disturbance in or near them would be very detrimental to arctic lake trout populations. A summary of possible impacts from human-related activities includes the following:

- Alteration of preferred water temperatures, pH, dissolved oxygen, and chemical composition
- [°] Alteration of preferred water velocity and depth
- ^o Alteration of preferred lake and stream morphology
- ° Increase in suspended organic or mineral material
- Increase in sedimentation and reduction in permeability of substrate
- ^o Reduction in food supply
- ^o Reduction in protective cover
- Shock waves in aquatic environment
- ° Human harvest

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

VIII.LEGAL STATUS

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

IX. LIMITATIONS OF INFORMATION

Most of the information available on lake trout has been collected in Canada and the Great Lakes region; very little life history information specific to Alaska has been collected. There are major gaps in our knowledge critical to the future management of lake trout and their habitat. Little information was found on the effects of environmental changes. A better understanding of early life history, population dynamics, and river-spawning populations is necessary.

REFERENCES

ADF&G, comp. 1976. A fish and wildlife resource inventory of the Cook Inlet-Kodiak areas. Vol. 2: Fisheries. Juneau. 434 pp.

_____. 1978a. A fish and wildlife resouce inventory of the Prince William Sound area. Vol. 2: Fisheries. Juneau. 241 pp.

ADF&G. 1978b. Alaska's fisheries atlas. Vol. 2 [R.F. McLean and K.J. Delaney, comps.]. 43 pp. + 153 maps.

- ADF&G and USFWS. 1984. Life histories and harvest information for selected species of fish and wildlife of the Bristol Bay region. Prepared for the Bristol Bay Cooperative Management Plan.
- Alt, K.T. 1976. Inventory and cataloging of North Slope waters. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol. 17. Proj. F-9-8, Job G-I-0.

______. 1977. Inventory and cataloging of sport fish and sport fish waters of Western Alaska. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol. 18. Proj. F-9-9, Job G-I-P.

- Anonymous. 1960. Maria eat eggs. Fishing. Fish. Br. Prov. Manitoba 1(4):13. Cited in Scott and Crossman 1973.
- Bendock, T.N. 1979. Inventory and cataloging of arctic area waters. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol. 20. Proj. F-9-11, Job G-I-I.

. 1982. Inventory and cataloging of arctic area waters. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol. 23. Proj. F-9-14, Job G-I-I.

- Bendock, T.N., and J. Burr. 1985. Catalog of North Slope lake and stream surveys. ADF&G, Div. Sport Fish, Fairbanks. 34 pp.
- Boulva, J., and A. Simard. 1968. Presence due <u>Salvelinus</u> <u>namaycush</u> (Pisces: Salmonidae) dans les eaux marine de l'arctique occidental Canadian. J. Fish. Res. Bd. Can. 25(7):1,501-1,504.
- Carlson, A.R., and R.E. Siefert. 1974. Effects of reduced oxygen on the embryos and larvae of lake trout (<u>Salvelinus namaycush</u>) and largemouth bass (<u>Micropterous salmoides</u>). J. Fish. Res. Bd. Can. 31:1,393-1,396.
- Craig, P.C., and J. Wells. 1975. Fisheries investigations in the Chandalar River region, northeast Alaska. Chap. 1 <u>in</u> P.C. Craig, ed. Arctic gas biological report series. Vol. 34. 387 pp.
- DeRoche, S.E., and L.H. Bond. 1957. The lake trout of Cold Stream Pond, Enfield, Maine. Trans. Am. Fish. Soc. 85:257-270. Cited in Machniak 1975.
- Dorr, J.A., III, D.V. O'Connor, N.R. Foster, and D.J. Jude. 1981. Substrate conditions and abundance of lake trout eggs in a traditional spawning area in southeastern Lake Michigan. N. Am. J. Fish. Mgt. 1:165-172.
- Eck, G.W., and L. Wells. 1983. Biology, population structure, and estimated forage requirements of lake trout in Lake Michigan. Tech. Pap. USFWS 111. 18 pp.

- Furniss, R.A. 1974. Inventory and cataloging of arctic area waters. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol. 15. Proj. F-9-5, Job G-I-I.
- Galligan, J.P. 1962. Depth distribution of lake trout and associated species in Cayuga Lake, New York. N.Y. Fish and Game J. 9:44-68. Cited in Martin and Olver 1980.
- Gibson, E.S., and F.E.J. Fry. 1954. The performance of the lake trout, <u>Salvelinus</u> <u>namaycush</u>, at various levels of temperature and oxygen pressure. Can. J. Zool. 32:252-260. Cited in Martin and Olver 1980.
- Gunn, J.M., and W. Keller. 1984. Spawning site water chemistry and lake trout (<u>Salvelinus namaycush</u>) sac fry survival during snowmelt. Can. J. Fish. and Aquatic Sci. 41:319-329.
- Hablett, T. 1979. Fish inventories conducted within the National Petroleum Reserve on the North Slope of Alaska, 1977-78. Rept. by USFWS for BLM. 89 pp.
- Hacker, V.A. 1957. Biology and management of lake trout in Green Lake, Wisconsin. Trans. Am. Fish. Soc. 86:71-83. Cited in Machniak 1975.
- Hall, J.E., and D.O. McKay. 1983. The effects of sedimentation on salmonids and macro-invertebrates: literature review. ADF&G, Div. Habitat, unpubl. rept. 31 pp.
- Kogl, D.R. 1971. Monitoring and evaluation of arctic waters with emphasis on the North Slope drainages: Colville River study. Fed. Aid in Fish Rest. Ann. prog. rept. Vol. 12. Proj. F-9-3, Job G-III-A.
- Leach, J.H., and S.J. Nepsky. 1976. The fish community in Lake Erie. J. Fish. Res. Bd. Can. 33:622-638.
- Loftus, K.H. 1958. Studies on river spawning populations of lake trout in eastern Lake Superior. Trans. Am. Fish. Soc. 87:259-277.
- Machniak, K. 1975. The effects of hydroelectric development on the biology of northern fishes (reproduction and population dynamics) IV. Lake trout <u>Salvelinus namaycush</u> (Walbaum). Environment Canada, Fisheries and Marine Service Tech. Rept. 530. 52 pp.
- Martin, N.V. 1952. A study of the lake trout, <u>Salvelinus namaycush</u>, in two Algonquin Park, Ontario, lakes. Trans. Am. Fish. Soc. 81:111-137.

_____. 1957. Reproduction of lake trout in Algonquin Park, Ontario. Trans. Am. Fish. Soc. 86:231-244. Cited in Scott and Crossman 1973, Morrow 1980, and Martin and Olver 1980. . 1960. Homing behavior in spawning lake trout. Canadian Fish Culturist 26:3-6.

_____. 1966. The significance of food habits in the biology, exploitation, and management of Algonquin Park, Ontario, lake trout. Trans. Am. Fish. Soc. 95:415-422. Cited in Scott and Crossman 1973.

- Martin, N.V., and C.H. Olver. 1976. The distribution and characteristics of Ontario lake trout lakes. Ont. Min. Natur. Resour. Res. Rept. 97:1-30. Cited in Martin and Olver 1980.
 - . 1980. The lake charr, <u>Salvelinus</u> <u>namaycush</u>. Pages 205-277 <u>in</u> E.K. Balon, ed. Charrs: salmonid fishes of the genus Salvelinus. The Hauge, Netherlands: Dr. W. Junk by Publishers. 925 pp.
- McCart, P., P. Craig, and H. Bain. 1972. Report on fisheries investigations in the Sagavanirktok River and neighboring drainages. Alyeska Pipeline Service Company. 170 pp.
- McPhail, J.D., and C.C. Lindsey. 1970. Freshwater fishes of northwestern Canada and Alaska. Bull. Fish. Res. Bd. Can. 173. 381 pp.
- Miller, R.B., and W.A. Kennedy. 1948. Observations on the lake trout of Great Bear Lake. J. Fish. Res. Bd. Can. 7:176-189. Cited in Machniak 1975, Martin and Olver 1980.
- Morrow, J.E. 1980. The freshwater fishes of Alaska. Anchorage, Ak: Alaska Northwest Publishing Company. 248 pp.
- Paterson, R.J. 1968. The lake trout (<u>Salvelinus namaycush</u>) of Swan Lake, Alberta. M.S. Thesis, Univ. Alberta. 149 pp. Cited in Machniak 1975.
- Pearse, G.A. 1978. Inventory and cataloging of interior waters with emphasis on the upper Yukon and Haul Road area. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol. 19. Proj. F-9-10, Job G-I-N.
- Peck, J.W. 1982. Extended residence of young-of-the-year lake trout in shallow water. Trans. Am. Fish. Soc. 111:775-778.
- Rawson, D.S. 1961. The lake trout of Lac La Ronge, Saskatchewan. J. Fish. Res. Bd. Can. 18:423-462.
- Rayner, H.J. 1941. The development of a management policy for the rainbow trout of the Finger Lakes. Ph.D. Thesis, Cornell Univ., Ithaca, NY. 66 pp. Cited in Martin and Olver 1980.
- Redick, R.R. 1967. A review of literature on lake trout life history with notes on Alaskan management. ADF&G Informational Leaflet 111. 19 pp.

- Rounsefell, G.A. 1958. Anadromy in North American Salmonidae. USFWS. Fish. Bull. 58:171-185. Cited in Martin and Olver 1980.
- Royce, W.F. 1951. Breeding habits of lake trout in New York. USFWS Bull. 52:59-76.
- Ryder, R.A., and L. Johnson. 1972. The future of salmonid communities in North American oligotrophic lakes. J. Fish. Res. Bd. Can. 29:617-628. Cited in Martin and Olver 1980.
- Sautner, J.S., and M.E. Stratton. 1984. Access and transmission corridor studies. Part 1 in D.C. Schmidt, D.L. Crawford, and D.S. Vincent-Lang, eds. ADF&G, Susitna Hydro Aquatic Studies. Rept. 4: Access and transmission corridor aquatic investigations (July-October 1983).
- Scott, W.B., and E.J. Crossman. 1973. Freshwater fishes of Canada. Bull. Fish. Res. Bd. Can. 184. 965 pp.
- Seguin, L.R. 1957. Scientific fish culture in Quebec since 1945. Trans. Am. Fish. Soc. 86:136-143. Cited in Martin and Olver 1980.
- Straight, W.J. 1969. Depth distribution of splake of known ability to retain swimbladder gas. M.S. Thesis, York Univ., Toronto, Ont. 45 pp. Cited in Martin and Olver 1980.
- VanWhye, G.L., and J.W. Peck. 1968. A limnological survey of Paxson and Summit Lakes in Interior Alaska. ADF&G Informational Leaflet 124. 39 pp.
- Webster, D.A., W.G. Bentley, and J.P. Galligan. 1959. Management of the lake trout fishery of Cayuga Lake, New York, with special reference to the role of hatchery fish. Mem. Cornell Univ. Agr. Sta. 357:1-83. Cited in Martin and Olver 1980.

1



Map 1. Range of least cisco

- NAME Ι.
 - Common Name: Least cisco, lake herring
 - Α. Scientific Name: <u>Coregonus sardinella</u> Valenciennes
 - The least cisco is a member of the family Salmonidae, subfamily Coregoninae, the whitefishes. Whitefishes are common throughout Β. С. the north, inhabiting both lakes and rivers, and some species exhibit anadromous characteristics. There are many species of whitefish and cisco recognized, but because of extensive intraspecific variation and interspecific similarities the taxonomic structure of this group of fishes has changed often. The least cisco Coregonus sardinella is known to occur in several forms with uncertain relationships and has been referred to as a "species complex" (McPhail and Lindsey 1970). Various distribution and

local population characteristics have contributed to changes in classification of least cisco in past years.

- II. RANGE
 - A. Worldwide

Least cisco are found in northern Europe, Siberia, and western North America. The species occurs in coastal regions from Bristol Bay throughout Alaska and eastward along the arctic coast into Canada, at least to Bathurst Inlet. Least cisco are present on St. Lawrence Island in the Bering Sea and north to Victoria and Banks islands in the Arctic Ocean (McPhail and Lindsey 1970, Scott and Crossman 1973).

B. Statewide

The least cisco is a resident of many inland waters throughout Interior Alaska and is anadromous in streams and rivers draining into the Bering, Chukchi, and Beaufort seas (Bendock 1979). The species spawn and overwinter in the Colville and MacKenzie river deltas and migrate in the nearshore coastal waters of the Beaufort Sea during the open-water period. Apparently, the general limits to which they can migrate are east to Prudhoe Bay (for the Colville River population) and west to Herschel Island (for the MacKenzie River population) (Bendock 1979, Craig and Haldorson 1981, Mann 1974). Thus, the species is rarely found in the region between Prudhoe Bay and Herschel Island, and these two major populations are geographically isolated (Bendock 1979).

C. Regional Distribution Maps

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

D. Regional Distribution Summary

In the Arctic, Western, and Interior regions, least cisco are present in most streams and lakes north of the Alaska Range and in the nearshore zone of the marine coastal environment. Least cisco are present and abundant throughout the Colville, Kuskokwim, and Yukon river drainages (Morrow 1980). They ascend the Yukon River upstream at least as far as Circle (McPhail and Lindsey 1970). In the arctic, least cisco apparently do not penetrate very far inland (ibid.).

- III. PHYSICAL HABITAT REQUIREMENTS
 - A. Aquatic
 - 1. Water quality:
 - a. <u>Dissolved oxygen (DO) and pH</u>. No information exists on the DO and pH requirements of least cisco. Craig and

Haldorson (1981) reported an average DO level of 9.8 ml/l during the open-water period in 1977 in Simpson Lagoon, Beaufort Sea (range = 7.0 to 12.0 ml/l, n = 40). Least cisco were widely distributed and abundant in this area.

- b. <u>Turbidity</u>. Little information is available on the turbidity requirements of least cisco. Craig and Haldorson (1981) defined a narrow band of water immediately adjacent to the shoreline in the Beaufort Sea where wind-generated turbidity fluctuated widely from day to day (1-146 NTU, recorded 80 m from shore). This band of coastal water was inhabitated throughout the summer by anadromous fishes, of which least cisco was one of the most abundant species.
- Salinity. Anadromous least cisco inhabit brackish с. waters throughout the summer, at which time they make extensive migrations along the coast (at least 100 mi Haldorson (1981) distance). Craig and measured salinities in Simpson Lagoon, Beaufort Sea, during the open-water period, in which anadromous least cisco are present. Salinities ranged from nearly fresh to saline. In late June and early July, melting ice and riverflooding caused low salinities (1-10 ppt) in the lagoon. Between mid July and September, brackish conditions existed (18-25 ppt). In fall, least cisco migrate back into freshwater rivers and lakes to spawn and over-Presumably, their coastal environment becomes winter. uninhabitable in winter because of thick nearshore ice and hypersaline conditions, which are common in winter. Alt (1971) reported a high abundance of least cisco in the Imuruk Basin-Grantly Harbor-Port Clarence (Norton Salinity values there ranged from 23 ppt Sound) area. in Grantly Harbor and 29 ppt in Port Clarence to 3.8 ppt in the upper Imuruk Basin (ibid.).
- 2. Water velocity and depth. Least cisco inhabit a wide variety of habitats: shallow, slow-moving lakes and sloughs; large, deep, fast-moving rivers; and shallow tributary streams. Migratory forms of least cisco spend the winter in freshwater rivers and river deltas and the summer and early fall in coastal regions immediately adjacent to the shoreline. 0n the Beaufort Sea coast, Craig (1984) found least cisco abundant in the nearshore brackish-water zone. The depth of this zone fluctuated widely with freshwater input, nearshore currents, prevailing winds, and topographic features (ibid.). In the Chatanika River, near Fairbanks, least cisco spawning sites have been defined. Water depths range between 1.3 and 2.6 m at these sites, and the average velocity is about .5 m/s (Kepler 1973). Water depth and stream velocity appeared to be important for spawning, because males and

females move toward the surface, perpendicular to the current, while the eggs are released and fertilized (ibid.). In connection with building roads and culverts along the gas pipeline route, Jones et al. (1974) studied the critical velocities of 17 species of fish in the Mackenzie River. They determined that flow rates in culverts (100 m long) should be kept below .3 to .4 m/s to allow successful passage of the majority of mature individuals of migratory species.

- 3. Water temperature. Least cisco are apparently tolerant of a wide range of temperatures. Alt (1971) reported July temperatures of 12 to 13°C in shallow, slow-moving waters of the Imuruk Basin area. Kepler (1973) reported surface temperatures of 0 to 3°C during the spawning period (late September) in the Chatanika River. Craig and Haldorson (1981) reported temperatures of 0 to 6°C during the spring and fall and 7 to 10°C during the summer in Simpson Lagcon on the arctic coast. Craig and Griffiths (1981) attributed the nearshore distribution of anadromous fishes to an association with the band of relatively warm and brackish water that flows along the Beaufort Sea coast. Walters (1955) suggested that the habits of feeding during summer in the sea and moving up rivers and into lakes for the winter might be an arctic adaptation to escape the low winter temperatures (below 0°C) in sea water yet also take advantage of higher food abundance in coastal waters during the short arctic summer.
- 4. <u>Substrate</u>. Little is known about substrate requirements for least cisco. Adults are known to spawn over sand and gravel bottoms in shallow areas of lakes and streams. The eggs are simply scattered over the bottom (McPhail and Lindsey 1970). Alt (pers. comm.) found them spawning over a gravel bottom in the upper Innoko River in 4 to 8 ft of water.
- IV. NUTRITIONAL REQUIREMENTS
 - A. Foods Species Used

Least cisco are generalists in their food habits. They consume a wide variety of the secondary producers (invertebrates) in both marine and freshwater environments. Composition of food items is largely dependent upon the specific location at which least cisco species are sampled. Primary food items recorded are various species of copepods, cladocerans, mysiids, amphipods, and isopods; some fish (fourhorn sculpin and nine-spine stickleback); and some surface-dwelling insects (Plecoptera nymphs and adults, hemiptera adults) (Mann and McCart 1980, Bendock 1979, Griffiths et al. 1975, Scott and Crossman 1973, Morrow 1980, Mann 1974, Russell 1980).

B. Types of Feeding Areas Used

Least cisco are primarily planktonic feeders, utilizing the mid-water column in lakes, sloughs, and coastal marine waters. Populations of least cisco that inhabit rivers apparently feed also on aquatic and terrestrial insects (Scott and Crossman 1973).

- C. Factors Limiting Availability of Food
 - Availability of food is undoubtedly related to seasonal abundance in marine coastal regions in the arctic and in coldwater rivers and lakes throughout the Arctic, Western, and Interior regions in Alaska. In arctic habitats, there is no productivity throughout most of the year, and an outburst of exceedingly high productivity occurs in the short summer season (Russell-Hunter 1970). Similarly, productivity in winter in the inland freshwater environments is much reduced because of cold temperatures, icecover, and reduced light availability. However, least cisco captured in winter have been known to be feeding (Mann 1975).
- V. REPRODUCTIVE CHARACTERISTICS
 - A. Reproductive Habitat

Least cisco spawn in freshwater rivers, river deltas, tributary streams, and lakes. Adults spawn over sand and gravel bottoms in shallow areas (McPhail and Lindsey 1970).

- B. Reproductive Seasonality Least cisco spawn in the fall, as is characteristic of many coregonids. Some variation in spawning time occurs between geographically isolated populations, but spawning typically takes place in late September and October (Scott and Crossman 1973, McPhail and Lindsey 1970, Morrow 1980, Kepler 1973, Mann and McCart 1980). In the Chatanika River near Fairbanks, the peak spawning period was the last week of September (Kepler 1973).
- C. Reproductive Behavior

During the upstream spawning migration, least cisco generally move at night and rest in quiet pools during daylight hours. Kepler (1973) caught only small groups of least cisco in gill nets during overnight sampling, indicating that they migrate in small groups. Observations of least cisco in the Chatanika River revealed that least cisco spawn at night, with most spawning activity occurring from 10 P.M. to midnight (Kepler 1973). Alt (1983), however, observed least cisco actively spawning at 1 P.M. in the Innoko River, a tributary of the Yukon River.

During spawning, a female swims almost vertically toward the surface, with her ventral side upstream. As many as five males may join her (but usually only one or two) and swim vertically and close to her (Morrow 1980). As they approach the surface, eggs and milt are released. The fish break the surface, fall over backward, and swim to the bottom of the pool. It is not known whether a female deposits all her eggs in one night or whether more nights are required (ibid.).

D. Age at Šexual Maturity

Age at sexual maturity apparently varies among different geographically isolated populations of least cisco, as well as among different life history types of least cisco that occur sympatically. In the Minto flats area, Interior Alaska, Kepler (1973) determined that some least cisco males mature at two years and that most mature by three years of age; some females mature at three years, but most mature at four years. On the Colville River, in the Arctic Region, Alt and Kogl (1973) found that individual least cisco mature at four years, whereas the majority were mature at five years. In the Yukon Territory, North Slope, and eastern MacKenzie River delta drainages, Mann (1974) found differences in age at sexual maturity between sympatric "dwarf" and "normal" populations of least cisco. Dwarf individuals matured at three to four years, and 100% of the normal individuals were mature at seven years (freshwater population) and eight years (anadromous population).

E. Frequency of Breeding

Information regarding frequency of breeding in least cisco populations is inconsistent. Isolated geographic populations vary in behavior and life functions because of the different environmental conditions present. Kepler (1973) examined least cisco ovaries from specimens captured during July and August in the Minto flats area. The presence of retained eggs plus those that could develop fully by mid September indicated that all individuals sampled were consecutive spawners. In Trout Lake, Yukon Territory, Mann and McCart (1981) determined that least cisco spawn consecutively after reaching maturity. In contrast, several other authors have reported alternate-year spawning of least cisco in localized populations: Mann (1974) for least cisco captured in the Mackenzie River delta, Furniss (1975) for least cisco captured in Prudhoe Bay, and Alt and Kogl (1973) for least cisco captured in the Colville River delta. Mann (1974), however, points out that a great deal of subjectivity may be inherent in the methods used to determine mature spawners (i.e., eggs have the potential to ripen for the upcoming spawning season) and mature nonspawners (eggs are in resting stage).

F. Fecundity

Kepler (1973) found that fecundity in least cisco was more closely correlated with age than with length. In samples (from the Chatanika River) of individual least cisco ranging from 2+ to 7+ years, fecundity ranged from 27,825 to 93,500 eggs. Mann (1974) found that fecundity varied greatly between local populations of least cisco in the Yukon Territory's north slope and the eastern Mackenzie River delta drainages. In sympatric "normal" and "dwarf" populations, fecundity of normal least cisco exceeded that of dwarf least cisco by nearly 30 times (Mann and McCart 1981). Fecundity of normal, nonmigratory populations in Trout Lake, Yukon Territory, ranged from 7,886 to 19,261 eggs (mean = 12,059, s.d. = 3,330, n = 13). The dwarf populations from the same lake had a lower fecundity, ranging from 223 to 1,080 eggs (mean = 412, s.d. = 105, n = 33) (Mann 1974). Egg diameter at time of spawning for normal individuals was consistently 1.5 mm. Egg diameter for dwarf individuals at time of spawning exceeded that for normal individuals by an average of 0.3 mm diameter (Mann and McCart 1981).

G. Incubation Period/Emergence
Eggs are demersal and lodge in crevices between gravel where they incubate and overwinter (late September to late May or early June) (McPhail and Lindsey 1970). In Siberia, larvae of the migratory forms move downstream toward the sea soon after hatching (Scott and Crossman 1973). Alt (1983) also reported that young-of-theyear least cisco undertake a slow downstream migration to rearing areas in slower, deeper waters of the lower Yukon River.

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

Least cisco are characterized by several life history types. Mann (1974) defined three types: anadromous, freshwater migratory, and freshwater nonmigratory. Anadromous forms of least cisco generally spend the summer months feeding in the nearshore coastal marine zone and migrate into the lower reaches of coastal rivers and river deltas in the fall. In the Beaufort Sea, this movement is associated with the ice-free period; in Prudhoe Bay, e.g., ice-out generally occurs in the first two weeks of June, and least cisco first appear during the first week of July (1975 and 1976) (Bendock 1979). Moulton et al. (1985) reported high catches of large (greater than 250 mm) least cisco in Gwydyr Bay in early July in 1984; a major movement occurred about 20 July through Gwydyr Bay and Prudhoe Bay. Craig and Haldorson (1981) reported least cisco movements through Simpson Lagoon in the last week Tagging studies indicate that the Colville River is the of June. primary freshwater source of these fish. Tagged individuals showed an eastward movement through Simpson Lagoon, followed by a build-up in Prudhoe Bay from breakup through mid August, and then a westward movement until freeze-up (Bendock 1979, Craig and Haldorson 1981, Moulton et al. 1985). Mann (1975) reported similar findings in the Mackenzie River delta population of least cisco. In September, the nearshore brackish water zone freezes over and least cisco move into the freshwater deltas to spawn and overwinter. The presence of shore-fast ice and hypersaline conditions prevent least cisco from utilizing the marine environment until breakup occurs again in the spring (Bendock 1979, Craig and Haldorson 1981). Utilization of the more productive marine environment for feeding generally fosters greater growth rates and greater maximum age in these migratory least cisco than in the nonmigratory forms (Scott and Crossman 1973).

Mann (1974) defined a second migratory form of least cisco that remains in fresh water rather than migrating to sea. He concluded from seasonal sampling results that least cisco migrated into Peter Lake, Yukon Territory, in September to spawn. This population had direct access to the Mackenzie River delta and the Beaufort Sea, but growth rates (similar to other lake-resident populations) indicated they resided in fresh water throughout the year (Mann 1974).

Alt (1983) reports that in the Innoko River, a tributary of the lower Yukon River, least cisco begin an upstream migration in late spring, or soon after ice-out. They move into lakes and sloughs to feed along the migration route. This feeding migration is composed mainly of mature fish, although immature individuals of ages I and II are present (ibid.). In late summer (August), the mature fish continue the upstream movement towards spawning areas. After spawning occurs, they apparently move downstream again to the Yukon River. It is not known whether this population is anadromous or not (Alt 1983). Similar movements were recorded in the Chatanika River near Fairbanks (Kepler 1973).

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

It is apparent that natural environmental factors influence nearly all local populations of least cisco. Lindsey (1981) documented the fact that a significant amount of plasticity occurs in morphological characteristics of whitefish genera because of coinhabitation of certain species. In least cisco, this may be sympatric "dwarf" and "normal" related to the populations documented by Mann and McCart (1980). Lindsey and Kratt (1982) reported a jumbo spotted form of least cisco in lakes of the southern Yukon Territory. They identified a variety of natural factors that could cause such distinct differentiation from other least cisco: glacial isolation, high levels of dissolved solids in the lakes, high lacustrine productivity and summer temperatures, lack of significant competition, and the migratory nature of the population.

Predation presumably has some influence on least cisco populations. Craig and Haldorson (1981) suggest that anadromous fish species use the nearshore coastal marine zone because there is a low predator density in that environment. Freshwater predators of least cisco include pike, burbot, lake trout, and sheefish. Eggs and young least cisco are very important in the diets of these predators (Alt 1977).

B. Human-related

Anadromous least cisco would potentially be vulnerable to disturbances from construction and/or oil development in the nearshore marine zone during the summer feeding migrations. The presence of a solid-fill causeway in the nearshore coastal zone of the Beaufort Sea (Prudhoe Bay) has been shown to cause temperature and salinity gradients that affect least cisco movements (Moulton et al. 1985). In freshwater streams, construction of roads, culverts, dams, etc., would create unnatural barriers (either physical or due to water velocity) and possibly cause a loss of spawning habitat.

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

- Alteration of preferred water temperatures, pH, dissolved oxygen, and chemical composition
- ° Introduction of water-soluble substrates
- [°] Increase in suspended organic or mineral material
- [°] Increase in sedimentation
- Reduction in food supply
- ° Human harvest
- Seismic shock waves

(See the Impacts of Land and Water Development volume of this series under the category Freshwater Fish for additional impacts information.)

VIII. LEGAL STATUS

The Alaska Department of Fish and Game has managerial authority over least cisco throughout its freshwater and coastal marine range. Because only localized harvesting by commercial, subsistence, and sport fishermen occurs, no statewide management plan has been formulated.

IX. LIMITATIONS OF INFORMATION

Least cisco inhabit much of Interior Alaska in the Yukon and Kuskokwim river drainages and coastal Alaska from Bristol Bay through the Bering, Chukchi, and Beaufort seas. Because of the variations in local populations, apparently caused by geographic isolation and numerous natural environmental factors, it is difficult to generalize about the life history characteristics of the species. Information on least cisco is available primarily in areas where studies actually targetted on other species. Thus, there is a general data gap for least cisco distribution and abundance in many portions of its range, particularly uninhabited areas and/or areas not yet proposed for development.

REFERENCES

- Alt, K.T. 1971. A life history study of sheefish and whitefish in Alaska. ADF&G, Div. Sport Fish, Fed. Aid in Fish Rest. Vol. 12, F-9-3, R-11. 31 pp.
- ______. 1983. Inventory and cataloging of sport fish and sport fish waters of western Alaska. ADF&G, Div. Sport Fish, Fed. Aid in Fish Rest. and Anad. Fish Studies. Study G-I-P-B. 38 pp.

_____. 1985. Personal communication. ADF&G, Div. Sport Fish, Fairbanks.

- Alt, K.T., and D.R. Kogl. 1973. Notes on the whitefish of the Colville River, Alaska. J. Fish. Res. Bd. Can. 30:554-556.
- Bendock, T.N. 1979. Beaufort Sea estuarine fishery study. Pages 670-729 in Environmental assessment of the Alaskan continental shelf. Final reports of principal investigators. Vol. 4: Biological studies. BLM, NOAA, OCSEAP. 59 pp.
- Craig, P.C. 1984. Fish use of coastal waters of the Alaskan Beaufort Sea: a review. Trans. Am. Fish. Soc. 113(3):265-282.
- Craig, P.C., and W.G. Griffiths. 1981. Passage of large fish around a causeway in Prudhoe Bay, Alaska, USA. Arctic 34(4):314-317.

- Craig, P.C., and L. Haldorson. 1981. Beaufort Sea barrier island-lagoon ecological process studies: final report, Simpson Lagoon. Part 4: Fish. Pages 384-678 in Environmental assessment of the Alaskan continental shelf. Final reports of principal investigators. Vol. 7. BLM, NOAA, OCSEAP. 294 pp.
- Furniss, R.A. 1975. Inventory and cataloging of arctic area waters. ADF&G, Div. Sport Fish, Fed. Aid in Fish Rest. Vol. 16, F-9-7, G-1-1. 47 pp.
- Griffiths, W.B., P.C. Craig, G. Walder, and G.J. Mann. 1975. Fisheries investigations in a coastal region of the Beaufort Sea (Nunaluk Lagoon, Yukon Territory). Biol. Rept. Ser. 34(2):1-219.
- Jones, D.R., J.W. Kiceniuk, and O.S. Bamford. 1974. Evaluation of the swimming performance of several fish species from the Mackenzie River. J. Fish. Res. Bd. Can. 31:1,641-1,647.
- Kepler, P. 1973. Population studies of northern pike and whitefish in the Minto Flats complex with emphasis on the Chatanika River. ADF&G, Div. Sport Fish, Fed. Aid in Fish Rest. F-9-5, G-II-J, Vol. 14:59-81.
- Lindsey, C.C. 1981. Stocks are chameleons: plasticity in gill rakers of corgonid fishes. Can. J. Fish. Aquat. Sci. 38:1,497-1,506.
- Lindsey, C.C., and L.F. Kratt. 1982. Jumbo spotted form of least cisco <u>Coregonus sardinella</u> in lakes of southern Yukon Territory. Can. J. Zool. 60(11):2,783-2,786.
- Mann, G.J. 1974. Life history types of the least cisco (<u>Coregonus</u> <u>sardinella</u> Valenciennes) in the Yukon Territory north slope and eastern Mackenzie River delta drainages. M.S. Thesis, Univ. Alberta, Edmonton. Also, Biol. Rept. Ser. 18(3):1-416.

_____. 1975. Winter fisheries survey across the Mackenzie delta. Biol. Rept. Ser. 34(3):1-54.

- Mann, G.J., and P.J. McCart. 1981. Comparison of sympatric dwarf and normal populations of least cisco (<u>Coregonus sardinella</u>) inhabiting Trout Lake, Yukon Territory. Can. J. Fish. Aquat. Sci. 38:240-244.
- McPhail, J.D., and C.C. Lindsey. 1970. Freshwater fishes of northwestern Canada and Alaska. Fish Res. Bd. Can., Bull. No. 173. 381 pp.
- Morrow, J.E. 1980. The freshwater fishes of Alaska. Anchorage, AK: Alaska Northwest Publishing Co. 248 pp.
- Moulton, L.L., B.J. Galloway, M.H. Fawcett, W.B. Griffiths, K.R. Critchlow, R.G. Fechhelm, D.R. Schmidt, and J.S. Baker. 1985. 1984 Central

Beaufort Sea Fish Study, Waterflood Monitoring Program fish study. Envirosphere Co., Anchorage, AK.

- Russell, R. 1980. A fisheries inventory of waters in the Lake Clark National Monument area. ADF&G, Div. Sport Fish. USDI: NPS.
- Russell-Hunter, W.D. 1970. Aquatic productivity: an introduction to some basic aspects of biological oceanography and limnology. New York: MacMillan Publishing Co. 306 pp.
- Scott, W.B., and E.J. Crossman. 1973. Freshwater fishes of Canada. Fish. Res. Bd. Can., Bull. No. 184. 966 pp.
- Walters, V. 1955. Fishes of western arctic America and eastern arctic Siberia, taxonomy and zoogeography. Bull. Am. Mus. Nat. Hist. 106(5):261-368.

Sheefish Life History and Habitat Requirements Arctic Region



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

- I. NAME
 - A. Common Name
 - Inconnu is the accepted common name for this species (Robins et al. 1980); however, in Alaska, sheefish is the most frequently used common name.
 - B. Scientific Name: Stenodus leucichthys

II. RANGE

A. Statewide

Sheefish in Alaska have been separated into five major populations (Alt 1969a, Alt 1977). The Minto flats and upper Yukon River populations are year-round residents in the eastern part of Interior Alaska (ADF&G 1978). The lower Yukon and Kuskokwim populations overwinter in the delta areas of these two rivers and

move upstream as far as the middle Yukon River above Rampart and the upper Koyukuk River near Hughes and in the lower Alatna River to spawn (Alt 1975, 1981; Alt, pers. comm.) in the fall. The Selawik-Kobuk population overwinters in Hotham Inlet and Selawik Lake and travels to spawning grounds approximately 200 km up the Selawik River and in the Kobuk River 38-100 km above Kobuk Village (Alt 1967; Alt, pers. comm.).

B. Regional Distribution Maps

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

- C. Regional Distribution Summary
 - Sheefish are found in the Selawik and Kobuk rivers Arctic. 1. but are absent north of Kotzebue Sound across the arctic slope until they are again encountered in rivers east of Demarcation Point (Alt 1969b). The Kobuk-Selawik population overwinters in Selawik Lake, Hotham Inlet, and Kotzebue Sound and travels upstream to spawning grounds approximately 200 km up the Selawik River and in the Kobuk River 40-50 km above Kobuk Village (ibid.). Rearing immature sheefish of ages 4 to 10 are found in Hotham Inlet, Selawik Lake, and in estuarine areas around Kotzebue and Sheshalik (Alt 1980; Alt. pers. comm.). Rearing sheefish are also found in the lower Kobuk, lower Selawik, and Tuklomarak rivers (Alt 1980). A small population of sheefish is also found in the Koyuk River, which drains into Norton Bay (ADF&G 1978). These fish are found up the Koyuk River to its confluence with the Peace River (ibid.). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Arctic Region.)

III. PHYSICAL HABITAT REQUIREMENTS

- A. Water Quality
 - 1. <u>Temperature</u>. Surface water temperatures in areas where sheefish feed range from 22°C in July to 0°C during the winter (Alt 1973). Water temperatures at time of spawning in the Kobuk River ranged from 1.4 to 4.6°C in 1965 and 1966 (Alt 1967). In 1967 in the Koyukuk River, water temperatures at time of spawning ranged from 4.8 to 4.3°C (Alt 1968), and in 1971 in Highpower Creek (Kuskokwim drainage) spawning began at 3°C and peaked at 1°C (Alt 1972). Spawning temperatures vary from watershed to watershed, and time of spawning is apparently more related to gonad development than to water temperature (Alt 1969a).

- 2. <u>The pH factor</u>. PH readings from areas in Alaska where sheefish are found range from 6.7 to 7.9; however, a comprehensive study relating chemical values and sheefish distribution has not been conducted (Alt 1973).
- 3. <u>Dissolved oxygen (D.O.)</u>. Little information is available on the D.O. requirement of sheefish. Alt (1981) noted that in 1980 sheefish stocked in Island Lake had good overwinter survival though surface D.O. readings from the lake were quite low (2 to 2.5 ppm) during both February and March. No fish were recovered in the lake in 1981 and 1982, however, indicating that they may have perished from low D.O. conditions in late winter (Alt, pers. comm.).
- 4. <u>Turbidity</u>. Little information is available on the effects of turbidity on sheefish populations in Alaska. Alt (1969b) notes that eggs carried to areas with slow-moving water may be covered with silt and thus have reduced chances of survival.
- 5. <u>Salinity</u>. Sheefish are generally not found in salt water, and saltwater barriers may limit their range expansion into the Seward Peninsula area and from Kotzebue Sound into northwestern Alaska and northern Alaska (Alt 1973). Sheefish rear and overwinter in brackish water in Hotham Inlet and in Norton Sound. Local fishermen in the Kotzebue area, however, have said that extremely high tides tend to bring about mass movements of sheefish into river mouths or into Selawik Lake (Arthur D. Little, Inc. 1963). Kirilov (1962) stated that sheefish inhabited areas of the Lena River delta in Siberia with a salinity not exceeding 6 to 7 ppt (parts per thousand).
- B. Water Velocity and Depth Sheefish are not strong swimmers, and both Russian and Alaskan studies indicate that they will not ascend streams with rapid current or even small falls (Alt 1973).

Water velocity is a very important factor in successful sheefish spawning. Spawning in the Kobuk River occurs in the relatively swift main current, both where it moves along the cut bank and also in the center of the channel as the current swings to the opposite shore (Alt 1969b). No spawning was observed on gravel bars on the inside curve of the river where the current is slower. Water velocity in spawning areas of Highpower Creek was measured at less than 100 cm/sec (Alt, pers. comm.). The Big River spawning area in the Kuskokwim drainage, which Alt (1981) considered to be far superior to the Highpower Creek spawning area, had a water velocity of 100 to 130 cm/sec.

The depth of water in spawning areas is also important. In the Yukon River above Rampart, sheefish must spawn in water deeper than 5 m to prevent the eggs from freezing when the Yukon water level drops over the winter (Alt 1975). In other areas, sheefish may successfully spawn in shallower water. Spawning in the Kobuk River in 1965 and 1966 occured at depths of 1.2 to 2.7 m, with the major spawning in waters 1.5 to 1.8 m deep (Alt 1967). Spawning in Highpower Creek in 1971 took place at depths of 1.3 to 2.7 m and in Big River in 1980 at depths of 0.6 to 1.5 m (Alt 1981). In Great Slave Lake, sheefish are seldom found in depths greater than 30 m (Fuller 1955).

C. Substrate

Alt (1969b) noted that in optimum sheefish spawning habitat the substrate is composed of differentially sized coarse gravel, with no silt and some sand present. Apparently, the presence of differentially sized gravel is neccessary to ensure lodging of the egas. With a bottom of uniformly sized gravel, Alt (1969b) speculated that the eggs might fail to lodge because of the swift current and be carried out into the slow-moving water where there is more silt, thus reducing chances for survival. In a study on the lower Volga River in Russia, it was found that sheefish eggs laid over a substrate where suitable shelter was available had better survival than those laid over an open sandy substrate (Letichevskiy 1981). Other fishes intensely prey on the sheefish eggs on the open sandy spawning grounds, and practically none survive to the completion of embryogenesis (ibid.). Alt (1981) described the sheefish spawning ground substrate in Big River as generally composed of 5% sand, 15% gravel less than 0.5 inches (1.3 cm), 30% gravel 0.5 to 1 inches (1.3 to 2.5 cm), and 50%coarse gravel and rocks.

Sheefish stocked in Four Mile Lake near Tok, Alaska, successfully spawn in the lake over a mud and silt bottom (Alt 1980, 1981). This is the only record of sheefish spawning in a lake or over such substrate (Alt 1980).

- D. Cover Requirements In Big River, sheefish use small eddies created by downed timber and log jams as holding or resting areas during their upstream spawning migration (Alt 1981).
- IV. NUTRITIONAL REQUIREMENTS
 - A. Food Species Used

Adult sheefish are piscivorous (Fuller 1955, Alt 1965). Sheefish fry feed on plankton but are feeding actively on crustaceans and insects by the summer of their first year of life (Alt 1973). By July and August, they also begin feeding on fry of other fish and by the second year of life are almost entirely piscivorous (ibid.). Sheefish introduced into lakes barren of fish show excellent growth during the first four years of life on a diet of insects and freshwater shrimp but must switch to feeding on fish after three or four years to maintain a good growth rate (Alt 1973, 1980). Sheefish mouth configuration prevents them from consuming prey larger than about 30 cm in length (Alt 1973). In the middle Yukon River, sheefish seldom eat prey over 15 cm in length (Alt 1975).

Sheefish are opportunistic feeders, and their diet varies from place to place, depending on food availability. In the Selawik

area, sheefish feed on least cisco (Coregonus sardinella), Mysis relicta (a small pelagic crustacean), Mesidotea entomon (an isopod), ninespine stickleback (Pungitius pungitius), humpback whitefish (Coregonus pidschian), broad whitefish (C. nasus), burbot (Lota lota), and blackfish (Dallia pectoralis), herring, smelt, and lamprey (Alt 1969b, 1979). In estuarine areas around Kotzebue, sheefish captured in June and September had consumed ninespine stickleback, shrimp, smelt, and fish remains (Alt 1979). In the Holitna River (Kuskokwim drainage), summer foods include fingerlings of chum, coho, and chinook salmon, and Pacific lamprey (Entosphenus tridentatus) (Alt 1972). Nonspawning and immature sheefish that spend the summer and fall in the lakes and streams of the lower Kuskokwim drainage feed very little on salmon fingerlings but rather use ninespine stickleback, pike, and whitefish (ibid.). In the winter on the lower Kuskokwim River, least cisco are the main food item (ibid.).

In the middle Yukon River from May to September, sheefish feed on arctic lamprey (Lampetra japonica), humpback whitefish, least cisco, and suckers (Catostomus catostomus) (Alt 1975). In the upper Yukon River, chinook salmon fingerlings and broad whitefish are the major food items, with sheefish near mouths of tributary rivers feeding mainly on salmon and those in adjacent quiet water of the Yukon feeding mainly on whitefish (Alt 1965). Finally, in the Minto flats area sheefish feed heavily on northern pike (Esox lucius) during the summer (Alt 1968).

Fuller (1955) reported that adult sheefish in the Big Buffalo River taken before their downstream run into Great Slave Lake were gorged with young sheefish; however, Alt has reported only one case of cannibalism in Alaska. The stomach of one sheefish taken from the middle Yukon River contained 14 other sheefish up to 14 cm in length (Alt 1975).

B. Types of Feeding Areas Used

Sheefish from the Selawik and Kobuk drainages overwinter and feed in Hotham Inlet, Selawik Lake, Inland Lake, and the lower reaches of the Selawik and Kobuk rivers (Alt 1977). In early June, sheefish in these areas feed close to the surface, jumping almost completely out of the water as they pursue least cisco (Alt 1969b). In late June, as air and water temperatures increase, most sheefish are found at depths of 2 to 3 m (ibid.).

The lower Yukon River sheefish population feeds in the lower reaches of tributaries of the lower and middle Yukon such as Hess Creek and Ray River and in slack-water areas of the main Yukon (Alt 1975, 1981). The two main feeding areas of upper Yukon River sheefish are the mouths of tributary rivers and the adjacent quiet- water areas (Alt 1965). In the Kuskokwim River, feeding sheefish are widely distributed in lakes and sloughs of the lower Kuskokwim River and the Holitna River, with smaller concentrations along the Kuskokwim River and its tributaries (Alt 1981). The Holitna River is a major feeding area, and sheefish arrive there in early June, with smaller sheefish arriving first (ibid.). Minto flats is the main summer feeding and rearing area for the Minto flats sheefish population. Sheefish move into these flats in May (Alt 1977).

- C. Factors Limiting Availability of Food Little information could be found in the available literature on factors limiting availability of food. Sheefish stocked in Four Mile Lake near Tok apparently competed with landlocked coho salmon and rainbow trout, which were also stocked in the lake (Alt 1978, 1979). Fuller (1955) noted that in Great Slave Lake sheefish probably do not compete with lake trout for food because the lake trout are found in deeper areas than the sheefish.
- D. Feeding Behavior
 - Sheefish generally cease feeding some time prior to spawning. In the Kuskokwim drainage, sheefish that will spawn in October cease feeding in July (Alt 1981). In the middle Yukon, fish that would spawn in the fall were feeding in June, but nearly all spawning fish examined in August and September had empty stomachs (Alt 1975). Thirteen sheefish taken approximately 100 mi up the Chatanika River in late September had empty stomachs, but four had digested food in the intestine (Alt 1965). In 1973, Alt found one prespawning sheefish in the upper Porcupine River to have been actively feeding on fingerlings of humpback whitefish (Coregonus pidschian) (Alt, pers. comm.), suggesting that at least some feeding takes place during the spawning migration (Alt 1965). In Russia, sheefish that leave the Caspian Sea to spawn in the lower reaches of the Volga River do not feed after they enter the river, and their body wieght decreases by 15 to 20% during the spawning period (Letichvskiy 1981). Sheefish fry held in darkened aquaria during a rearing experiment ceased feeding and appeared to enter a state of sleep (LaPerriere 1973). When light was allowed to enter the aquaria the fish slowly revived (ibid.).
- V. REPRODUCTIVE CHARACTERISTICS
 - A. Reproductive Habitat

Sheefish spawn in the relatively swift main current of rivers in areas with substrate composed of differentially sized coarse gravel.

B. Reproductive Seasonality

Alaskan sheefish spawn in late September and early October. Kobuk River sheefish spawn during the last week of September (Alt 1969b); Koyukuk River sheefish spawn from the last days of September to the first days of October (Alt 1968); Kuskokwim sheefish spawn during the first days of October (Alt 1972); and middle Yukon River sheefish spawn sometime in early October (Alt 1975).

C. Reproductive Behavior

Morrow (1980) summarized sheefish reproductive behavior as follows:

Spawning takes place in the evening, usually beginning about dusk and continuing well into the night. In the spawning act a female accompanied by a male (in rare cases by two or more males) rises to the surface near the upstream end of spawning grounds. She moves rapidly across the current . . . extruding eggs as she goes. This activity lasts for 1 to 3 seconds. The male, meanwhile, stays below the female. The eggs sink to the bottom through the cloud of sperm released by the male and are fertilized as they sink . . .

After completing a spawning pass the female drifts downstream. She may repeat the spawning act over the downstream portion of the spawning area or move upstream to the head of the grounds before releasing more eggs.

Several spawning passes are needed for a female to release all of her eggs (Morrow 1980).

D. Age at Sexual Maturity

Sheefish from the fast-growing Minto flats and Kuskokwim populations become sexually mature at an earlier age than the longer-living, slower-growing Kobuk-Selawik fish (Alt 1973). Males reach maturity at an earlier age and smaller size than do females (ibid.). Males in the Minto flats population mature at ages 5 to 7, in the Holitna River spawning group of the Kuskokwim population at ages 6 to 8, and in the upper Yukon population at ages 6 to 7 (ibid.). Females in these populations mature at ages 7 to 9 (ibid.). Males in the lower Yukon population mature at age 6 to 9, females at ages 8 to 10 (ibid.). Males in the Kobuk-Selawik population mature at ages 7 to 11, females at ages 9 to 14 (Alt 1973, 1978). Kuskokwim population sheefish at the Big River spawning grounds in 1980 matured at 4 to 13 years for males and 6 to 9 years for females (Alt 1981).

- E. Frequency of Breeding Sheefish are nonconsecutive spawners. The majority of females spawn once every two years and possibly once every three years for older fish (ibid.).
- F. Fecundity

Fecundities recorded for Alaskan sheefish range from 27,000 eggs for a 1.6 kg female from the Salmon Fork River in the middle Yukon drainage (Alt 1978) to 286,840 eggs for a 11.9 kg female from Big River in the Kuskokwim drainage (Alt 1981). Geiger (1969) estimated from a sample of 13 Kobuk River females that ovary weight averaged 20% of body weight and that there were 9,000 eggs per pound of body weight. Ovaries from the 11.9 kg Big River female contributed 27% of her body weight (Alt 1981).

G. Incubation Period and Time of Emergence Eggs collected from sheefish in the Koyukuk and Kobuk rivers and Highpower Creek in the Kuskokwim drainage from September 29 to October 3 hatched at the Fire Lake Hatchery from late January through March 15 (Alt 1968, 1970, 1972). Vork (1948) mentioned that sheefish from the Ob River in Russia had an average incubation period of 182 days.

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

Sheefish in the Kobuk-Selawik, lower Yukon, and Kuskokwim populations overwinter and feed in the brackish inlets, deltas, and lower reaches of these rivers. In the summer months, they move far upstream to reach spawning areas in the fall. After spawning in September and October, sheefish rapidly move back downstream to overwintering areas. Immature and nonspawning sheefish do not migrate as far upstream as spawning adults. Sheefish fry are swept downstream from spawning areas by spring floods and remain in the lower reaches of large rivers and brackish inlets to feed year-round.

In the middle Yukon, there are local sheefish populations that may mix with fish from the anadromous lower Yukon population during the summer but that are not themselves anadromous (Alt 1981).

The Minto flats sheefish population spawns in the Chatanika River, migrates downstream to overwinter in the lower Tolovana and Tanana rivers, and enters the Minto flats area to feed in late May after breakup (Alt 1977).

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

Fuller (1955) reports that adult sheefish from Great Slave Lake feed heavily on immmature sheefish; Alt, however, has recorded only one Alaskan example of cannibalism.

Sheefish are not strong swimmers (Alt 1973), and their migrations may be affected by velocity barriers created by periods of high water (Alt 1983).

B. Human-related

Any disturbances within a system that degrade sheefish spawning, rearing, or feeding habitats, degrade water quality, or block migration routes may affect population levels of sheefish occupying that system. Sheefish have stringent spawning requirements, and whole populations spawn in relatively few areas. Any disturbances of spawning areas would have the potential to strongly affect the entire population.

Sheefish are not as strong swimmers as salmon. Because of this, developments that increase water velocity along migration routes may be especially detrimental to sheefish stocks.

The sheefish spawning and overwintering migration behavior makes them available for harvest by commerical, subsistence, and sport fisheries throughout their life cycle and increases their vulnerability to overharvest (ADF&G 1983). In addition, the sheefish's slow maturation rate increases the time required to restore depleted populations (ibid.).

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

- ° Changes in biological oxygen demand, nutrient loading
- ° Changes in chemical composition of water
- ° Changes in dissolved oxygen, temperature, pH, salinity
- Changes in flow or water level, entrapment
- ° Changes in riparian or aquatic vegetation

- [°] Changes in sedimentation rates, turbidity, suspended solids
- ° Changes in substrate composition and location
- ^o Competition with introduced species
- ^o Increased susceptibility to harvest or predation
- Inducement of impingement or entrainment
- Physical barriers to movement
- ^o Shock waves, blasting

(For additional impacts information, see the Impacts of Land and Water Use volume of this series.)

VIII. LEGAL STATUS

Sheefish stocks in Alaska are managed by the Alaska Department of Fish and Game.

IX. LIMITATIONS OF INFORMATION

Kenneth Alt has contributed over 20 years of research on sheefish stocks in Alaska. As a result of his efforts, a great deal of information is available on Alaskan sheefish, especially with respect to distribution and movements. Information on habitat requirements, however, remains incomplete. More extensive information is needed on velocity, depth, temperature, and salinity requirements, for example. Russian scientists have conducted a great deal of sheefish research, including many studies on hatchery production, which have been published in Russian language journals for which translations are not readily available.

REFERENCES

ADF&G. 1978. Alaska's fisheries atlas. Vol. 2 [R.F. McLean and K.J. Delaney, comps.]. 43 pp. + 153 maps.

_____. 1983. Annual management report 1983 Norton Sound-Port Clarence-Kotzebue. Div. Commer. Fish., Nome. 156 pp.

Alt, K.T. 1965. Food habits of inconnu in Alaska. Trans. Am. Fish. Soc. 94:272-274.

_____. 1967. Taxonomy and ecology of the inconnu, <u>Stenodus leucichthys</u> nelma, in Alaska. M.S. Thesis, Univ. Alaska, Fairbanks. 106 pp.

. 1968. Sheefish and pike investigations of the upper Yukon and Kuskokwim drainages with emphasis on Minto flats drainages. ADF&G, Fed. Aid in Fish Rest. 1967-1968 prog. rept. Vol. 9. Proj. F-5-R-9, Job 17-B.

. 1969a. Sheefish and pike investigations of the upper Yukon and Kuskokwim drainages with emphasis on Minto flats drainages. ADF&G, Fed. Aid in Fish Rest. 1968-1969 prog. rept. Vol. 10. Proj. F-9-1, Job 17-B. . 1969b. Taxonomy and ecology of the inconnu, <u>Stenodus leucichthys</u> nelma, in Alaska. Univ. Alaska, Biol. Pap. No. 12. 63 pp.

- . 1970. Sheefish and pike investigations of the upper Yukon and Kuskokwim drainages with emphasis on Minto flats drainages. ADF&G, Fed. Aid in Fish Rest. Ann. prog. rept. Vol. 11. Proj. F-9-2, Job 17-B.
- . 1972. A life history study of sheefish and whitefish in Alaska. ADF&G, Fed. Aid in Fish Rest. Ann. prog. rept. Vol. 13. Proj. F-9-4, Study R-II.
- _____. 1973. A life history study of sheefish and whitefish in Alaska. ADF&G, Fed. Aid in Fish Rest. Ann. prog. rept. Vol. 14. Proj. F-9-5, Study R-II.
- ______. 1975. A life history study of sheefish and whitefish in Alaska. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol. 16. Proj. F-9-7, Study R-II.
- . 1977. Inconnu, <u>Stenodus leucichthys</u>, migration studies in Alaska 1961-74. J. Fish. Res. Bd. Can. 34:129-123.
- ______. 1978. A life history study of sheefish and whitefish in Alaska. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol. 19. Proj. F-9-10, Study R-II.
- ______. 1979. A life history study of sheefish and whitefish in Alaska. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol. 20. Proj. F-9-11, Study R-II.
 - _____. 1980. Life history study of sheefish in Alaska. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol. 21. Proj. R-II, Jobs R-II-A and R-II-B.
- _____. 1981. Life history study of sheefish in Alaska. ADF&G, Fed. Aid in Fish Rest. and Anadromous Fish Studies. Ann. performance rept. Vol. 22. Proj. F-9-13, Jobs R-II-A and R-II-B.
 - _____. 1983. Inventory and cataloging of sport fish and sport fish water of Western Alaska. ADF&G, Fed. Aid in Fish Rest. Ann. performance rept. Vol. 24. Proj. F-9-15, Job G-I-P-B.

_____. 1985. Personal communication. Area Mgt. Biologist, ADF&G, Div. ______Sport Fish., Fairbanks.

Arthur D. Little, Inc. 1963. An evaluation of the feasibility of native industry in northwestern Alaska. Rept. C-64870. Prepared in cooperation with Bureau of Indian Affairs.

- Fuller, W.A. 1955. The inconnu (<u>Stenodus leucichthys</u> mackenziei) in Great Slave Lake and adjoining waters. J. Fish. Res. Bd. Can. 12:768-780.
- Geiger, M. 1969. Kotzebue Sound sheefish study. ADF&G, Div. Commer. Fish, Ann. research rept, AYK Area, Anchorage. Cited in Alt 1978.
- Kirilov, F.H. 1962. Fauna ryb i bespozvonochynkh basseina velyuya. Isdat. Akad. Nauk. USSR. Moskva. 163 pp. Cited in Alt 1967.
- LaPerriere, J.D. 1973. Laboratory rearing experiments on artificially propagated inconnu (<u>Stenodus leucichthys</u>). Univ. Alaska Institute of Water Resources. Rept. IWR-40. 28 pp.
- Letichevskiy, M.A. 1981. Prospects of increasing the artificial and natural reproduction of the inconnu, <u>Stenodus leucichthys</u>, in the lower course and delta of the Volga. J. Ichthyology 21(5):103-107.
- Morrow, J.E. 1980. The freshwater fishes of Alaska. Anchorage, AK: Alaska Northwest Publishing Company. 248 pp.
- Robins, C.B., R.M. Bailey, C.E. Bond, J.R. Brooker, E.A. Lachner, R.N. Lea, and W.B. Scott. 1980. A list of common and scientific names of fishes from the United States and Canada. Fourth ed. Am. Fish. Soc. Special Publ. 12. Bethesda, MD. 174 pp.
- Vork, F.I. 1984. Nel'ma (<u>Stenodus leucichthys nelma</u>) reki Ob. Trudy Sib. Otd. VNIORX. Krasnoyarsk. 7(2):80-109. Cited in Alt 1969b.



Chinook Salmon Life History and Habitat Requirements Southwest, Southcentral, and Arctic Alaska

- I. NAME:
 - A. Common Names: Chinook salmon, king salmon, spring salmon, tyee, tule, quinnat, blackmouth
 - B. Scientific Name: <u>Oncorhynchus tshawytscha</u>

II. RANGE

A. Worldwide

Chinook salmon are native to the Pacific coasts of Asia and North America, and, except for areas immediately adjacent to the coast, it is possible that they do not occur on the high seas south of about 40°N (Major et al. 1978). In North America, spawning populations range from the Ventura River, California, northward to the Wulik River, Kotzebue Sound, Alaska. Along the Asian coast, they are found from the Anadyr River, Siberia, south to the Amur River, and they occur in the Komandorskie Islands, USSR, and at Hokkaido Island, Japan (Hart 1973, Major et al. 1978).

- B. Statewide Chinook salmon are found in major river drainages from Southeast Alaska to the Wulik River, Kotzebue Sound, Alaska (Major et al. 1978). During an Aleutian Islands salmon study, Holmes (1982) found that there were no systems in the Aleutian Islands (from Unimak Pass to Attu Island) that would provide for spawning and rearing of chinook salmon.
- C. Regional Distribution Maps To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for each region. Most of the maps in this series are at 1:250,000 scale, but some are at 1:1,000,000 scale. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of selected fish and wildlife species has been prepared and may be found in the Atlas that accompanies each regional guide.
- D. Regional Distribution Summary
 - 1. <u>Southwest</u>. In the Kodiak area, major chinook salmon spawning and rearing drainages include the Karluk and Red river systems (ADF&G 1977b).

In the Bristol Bay area (for waters from Cape Newenham to Cape Menshikof and north side Alaska Peninsula streams south to Cape Sarichef), major chinook-producing drainages include the Togiak, Wood, Nushagak, Mulchatna, Alagnak (Branch), and Naknek rivers. Other Bristol Bay drainages supporting lesser runs of chinook salmon include the Egegik, Ugashik, Meshik, Cinder, and Sapsuk rivers (ADF&G 1977a).

Streams on the Alaska Peninsula (south and west of Moffet Bay) and the Aleutian Islands appear to be unsuitable for supporting chinook salmon (ADF&G 1977a, Holmes 1982). Chinook salmon are found in one drainage on the south side of the Alaska Peninsula: the Chignik River system (ADF&G 1977a). (For more detailed narrative information, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)

- 2. <u>Southcentral</u>. In the Cook Inlet area, major chinook spawning and rearing drainages include the Susitna, Kenai, and Kasilof river drainages. In the Prince Williams Sound area, the Copper River drainage accounts for most of the chinook salmon production (ADF&G 1977b, ADF&G 1978). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)
- 3. Arctic. The presence of chinook salmon has been documented in 13 first-order streams (those with mouths at salt water) within the Norton Sound District (ADF&G 1984). Although other important chinook salmon-producing systems exist in the area, the Unalakleet River drainage and the Shaktoolik River

are considered the major chinook salmon producers in the district (Schwarz, pers. comm.).

Within the Port Clarence District, chinook salmon have been documented in the Kuzitrin River system (ADF&G 1984).

In the Kotzebue District, chinook salmon have been documented in the Buckland, Kobuk, Noatak, Wulik, and Kivalina rivers (ibid.).

Within the Northern District, chinook salmon have been documented in the Kuk and Colville rivers; however, in these systems they are considered as strays (Hablett 1979, Bendock and Burr 1984). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Arctic Region.)

III. PHYSICAL HABITAT REQUIREMENTS

a.

- A. Aquatic
 - 1. Water quality:
 - <u>Temperature</u>. Water temperature requirements play an important role in the chinook salmon life cycle and encompass an extremely wide range of temperatures, 0 to 25°C. The ability to survive within this temperature range and specific requirements, however, vary by life stage (i.e., egg, alevin, juvenile, and adult), the temperature to which the fish have been acclimated, and adaptations that specific stocks have made over the course of their evolutionary history. The results of several field and laboratory studies are provided in the following paragraphs.

Egg hatching and alevin development have occurred under variety of temperature regimes in hatchery and а laboratory conditions. Combs and Burrows (1957) found 100% mortality of eggs occurred when water that temperatures in laboratory tests remained constantly at $1.7^{\circ}C$; and they established a temperature range of 5.8to 14.2°C for normal development if the temperatures remained constant throughout incubation, a situation not likely to occur under natural conditions. In later experiments, Combs and Burrows (1965) found that chinook salmon eggs that had developed to the 128-cell, or early blastula stage, in 5.8°C water could tolerate 1.7°C water for the remainder of the incubation period, with only normal losses. The 128-cell stage was attained after eggs had been incubated for 144 hours in 5.8°C water.

Alderdice and Velson (1978) assembled data from the literature and analyzed the relations between incubation temperature and rate of development from fertilization to 50% hatch of the eggs. They found that early imposition of low (below 6 to 7°C), constant (having a range around a mean not greater than 2° C) temperatures appears

to slow egg development below those rates occurring at ambient (average daily temperatures with ranges around a mean greater than 2° C) temperatures having the same mean values. Information in these analyses included constant temperature values ranging from 1.6 to 18.1° C and ambient temperature values ranging from 2.3 to 16.4° C (ibid.).

The juvenile (including fry, fingerling, and parr stages of development) upper lethal limit was found to be 25.1°C under laboratory conditions (Brett 1952). During the same experiment, Brett found that young chinook salmon were very sensitive to low temperatures. The temperature, however, lower lethal 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 Burrows (1960) indicates that Columbia River 1951). female chinook salmon in holding ponds apparently lost all inclination to spawn naturally when the water

- temperature dropped abruptly below 4.4°C.
 b. <u>The pH factor</u>. 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. <u>Dissolved oxygen (D.O)</u>. Silver et al. (1963), during Taboratory studies, found that low (1.6 ppm) dissolved

oxygen concentrations caused total mortality of chinook embryos in 11°C waters flowing at rates of 82, 570, and 1,310 cm/hr. They also found that oxygen concentrations of 2.5 ppm and more (3.5, 5.6, and 8.0 ppm) resulted in low prehatching mortalities similar to controls reared at 11.7 ppm. Further, embryos reared to hatching at low and intermediate (2.5 to 8.0 ppm) concentrations produced smaller sacfry than did embryos reared at high (11.7 ppm) concentrations.

Whitmore et al. (1960) noted that juvenile chinook salmon showed marked avoidance of mean oxygen concentrations near 1.5, 3.0, and 4.5 ppm in laboratory experiments when summer water temperatures were high (means of 18.4 to 22.8°C). They also noted that juvenile chinook salmon showed little avoidance of concentrations near 4.5 ppm in the fall when water temperatures were low (means of 8.1 to 13.2°C) and that no avoidance of concentrations near 6.0 ppm occurred regardless of the temperature range.

Adult swimming performance is adversely affected by reduction of D.O. concentrations below air saturation level. Bell (1973) states that it is desirable that D.O. concentrations be at or near saturation and that it is especially important in spawning areas where D.O. levels must not be below 7 ppm at any time. State of Alaska water quality criteria for growth and propagation of fish state that "D.O. shall be greater than 7 mg/l in waters used by anadromous and resident fish. Further, in no case shall D.O. be less than 5 mg/l to a depth of 20 cm in the interstitial waters of gravel utilized by anadromous or resident fish for spawning. In no case shall D.O. above 17 mg/l be permitted. The concentration of total dissolved gas shall not exceed 110% of saturation at any point of sample collection."

d. Turbidity. Sedimentation causes high mortality in eggs and alevin by reducing water interchange in the redd. If 15 to 20% of the intragravel spaces become filled with sediment, salmonid eggs have suffered significant (upwards of 85%) mortality (Bell 1973). Prolonged exposure to turbid water causes gill irritation in juveniles that can result in fungal and pathogenic bacterial infection. Excess turbidity from organic materials in the process of oxidation may reduce oxygen below safe levels, and sedimentation may smother food organisms and reduce primary productivity (ibid.). Turbid water will absorb more solar radiation than clear water and may thus indirectly raise thermal barriers to migration (Reiser and Biornn 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 Juveniles are closely wastes are removed (ibid.). 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 of 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 of 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 Cregon and 0.381 to 1.983 m in Columbia River tributaries (ibid.). Burger et al. (1983), in a Kenai River tributary stream, found redds at depths from 61.0 to 70.2 cm. Their velocity measurements at 0.6 of total depth had mean values of 39.6 to 94.5 cm/sec pit velocity and 70.2 to 115.9 cm/sec tailspill velocity. Burger et al. (1983) also suggest that mainstream spawning might occur in depths from 1.0 to 2.8 m, with velocities near the bottom (0.2 total depth) ranging from 0.3 to 1.4 m/sec.

3. <u>Substrate</u>. Egg incubation and alevin development occur in substrates ranging widely in size and composition. Successful growth and emergence has been recorded in areas with the following bottom materials:

- 1.9 to 10.2 cm diameter materials (Bell 1973)
 5% mud/cilt/cand 80% 15 2 cm in diameter to 1
 - 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)
- ^o 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 of 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 Substrate is important to juveniles during areas (ibid.). 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 to remain close to cover such as log debris and/or surface ice, if these were present (Burger et al. 1983).

- B. Terrestrial
 - 1. <u>Conditions providing security from predators or other</u> <u>disturbances</u>. 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. <u>Protection from natural elements</u>. 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 eqgs, and spiders (Scott and Crossman 1973, McLean et al. 1977). They are characterized as opportunistic drift and benthic feeders (Beauchamp et al. 1983). Upon migration to the sea, young chinook salmon eat crab larvae. amphipods, copepods, euphasiids. cladocerans, barnacles, and a variety of small fish such as sand lance, eulachon, herring, rockfish, and smooth tongue (Hart 1973). Adults eat fish, squid, euphasiids, shrimps, and crab larvae (Major 1978). Fishes make up the bulk (97%) of the food of marine adults, with herring and sand lance being the most frequently eaten (Scott and Crossman 1973). Crustaceans (composed dominantly of euphasiids but including young crabs, crab megalops, and other miscellaneous forms) are eaten in considerable numbers in the spring months (May and June), as documented by Prakash (1962) in studies off the coast of British Columbia. Merkel (1957) made a similar finding for chinook salmon in the marine waters near San Francisco, California, where euphasiids dominated the diet during April and May. Major (1978) suggests that the diet of adult chinook salmon at sea is related to the types and abundance of food items available.

- B. Types of Feeding Areas Used Juveniles feed in low-velocity areas of streams and rivers, such as riverbank pools formed by bank irregularities (Burger et al. 1983) and in the pools below riffles where drifting invertebrate material provides a ready food supply. During the first year at sea, the young fish stay near shore. During the second and subsequent years, chinook salmon are far-ranging, undertake extensive migrations, and are found over a wide range of depths, from surface waters to depths exceeding 100 m. It is not unusual to encounter them at depths ranging from 20 to 110 m (Major 1978).
- C. Factors Limiting Availability of Food Sedimentation is one of the major factors that affect freshwater food availability. Excessive sedimentation may inhibit production of aquatic plants and invertebrate fauna (Hall and McKay 1983). Bell (1973) states that primary food production is lowered above levels of 25 JTU (Jackson Turbidity Unit) and visual references lost above levels of 30 JTU.
- D. Feeding Behavior Chinook salmon are opportunistic feeders. Food consumption is related directly to the types and abundance of items available (Major 1978), although juvenile chinook salmon in fresh water do not seem to utilize fish as food (Scott and Crossman 1973, Morrow 1980). Upon returning to fresh water, adult salmon no longer feed but live off the fat stored up in the ocean (Netboy 1974).
- V. REPRODUCTIVE CHARACTERISTICS

Α.

Breeding Habitat The general nature of the spawning ground, which may be located from just above tidal limits to great distances upstream (over 3,200 km in the Yukon River), varies considerably (Mayor 1978). Main channels and tributaries of larger rivers serve as the major chinook spawning areas (Scott and Crossman 1973). Normally, the spawning grounds are characterized by stream underflow (downwelling currents or intragravel flow) created by the depth and velocity of the water rather than being associated with the emergence of groundwater (Vronskiy 1972, Burner 1951). Vronskiy found that 95% of the redds in the Kamchatka River, USSR, were situated precisely at the transition between a pool and a riffle. Burger (1983) found that many chinook salmon redds were located near the upstream tips of vegetated islands in the Kenai River gravels aggraded where loose. clean and where predominant substrates ranged from 1.6 to 6.4 cm diameter materials. Areas just below log jams, where flow through the gravel is increased as a consequence of reduced surface flow, are also favorite spawning sites (Major 1978).

Exceptions to what may be considered normal breeding habitat and behavior have been documented. During late October and early November 1965, approximately 50 chinook salmon from University of Washington hatchery stocks spawned in groundwater seepage areas of gravel and sand beaches in Lake Washington (Roberson 1967). This behavior is believed to have resulted from crowding and high water temperatures, both unfavorable conditions, at the hatchery homing pond. Although the returns were similar in 1964, 1965, and 1966, the biomass in 1965 was 1.81 and 1.82 times that in 1964 and 1966, respectively. A decline in the rate of entry was noted in 1965, when water temperatures rose to about 14.4°C during peak entry. In 1965 and 1966, the water temperature dropped from about 14.4 to 11.1°C during the entry period. Also, during the 1965 return, the water temperatures remained .6 to 1.4° C warmer for the remainder of the run than during the same time frames in 1964 and 1966. A sample of several redds, approximately two weeks after spawning had occurred, revealed that, of all eggs recovered, most had been fertilized, but all were dead (ibid.).

B. Breeding Seasonality

In Alaska, mature chinook salmon ascend the rivers from May through July. Generally, fish that appear at the river mouth earliest migrate farthest (Scott and Crossman 1973). Peak spawning occurs from July through September (Morrow 1980).

C. Breeding Behavior

As with other salmon, adult chinook salmon return from the sea and normally move into their natal freshwater streams to spawn. The female selects the spawning site and digs the redd (nest) by turning on her side and thrashing her tail up and down. The current washes loosened substrate material downstream, and a depression 35 to 60 cm deep is formed in the river bottom (Burner 1951, Morrow 1980, Major 1978). Eggs and sperm (milt) are released simultaneously and deposited in the redd. After egg deposition, the female moves to the upstream margin of the redd and repeats the digging process. Dislodged substrate is washed over the eggs. In this manner, the eggs are covered and prevented from washing away. The process is repeated many times, and the redd appears to move upstream (Burner 1951). As a result of the continued digging, the redd may grow to become 1.3 to 5.6 m in length and 1.5 to 3.3 m wide (Morrow 1980, Burger et al. 1983). A female may dig several redds and spawn with more than one male (McPhail and Lindsey 1970). Males may also spawn with several females (ADF&G 1977, Morrow 1980).

- D. Age at Sexual Maturity The age at which chinook salmon reach sexual maturity ranges from two to eight years (generally zero to two years in fresh water and one to seven years at sea), although the vast majority of the fish mature in their third to sixth year. Age at maturity, like freshwater age and ocean age, tends to be greater in the north than in the south because more northern populations spend a longer time at sea (Major 1978, Scott and Crossman 1973). From California northward to Cook Inlet, Alaska, for example, three, four, and five-year-old fish prevail (there are significant numbers of six-year-olds in some areas, but few if any seven- or eight-year-olds). Five- and-six-year-olds dominate runs from Bristol Bay northward, but seven- and eight-year-olds are not uncommon (Major 1978).
- E. Fecundity

Chinook 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 - $32^{\circ}F$ + $1^{\circ}F$ if the mean temperature is $32^{\circ}F$. 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 tail spill) and the average of several equidistant widths (Reiser and Bjornn 1979). Burger et al. (1983) list mean measurements for a Kenai River tributary stream indicating that chinook salmon redds are about 4.37 m² in size. Mean values for mainstream Kenai River chinook salmon redds, however, are 6.38 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). Out-migrating smolt bound for the sea depart fresh water in the springtime. Major and Mighell (1969), during studies on the Yakima River, Washington, noted that smolt out-migrations tended to be nocturnal.

Adults return to fresh water during the period of May through July. Studies on the Kenai River (Burger et al. 1983) indicate that of all radio-tagged adults returning to the spawning grounds, most moved between 1400 and 2200 hours. Neave (1943), during studies of the Cowichan River, Vancouver Island, British Columbia, found that adult chinook salmon moved upstream mainly in the daytime.

C. Migration Routes

Large rivers serve as corridors for smolt out-migration. Barriers to adult upstream movement include excess turbidity, hiah temperatures (20.0°C or more), sustained high-water velocities, and blockage of streams (log jams, waterfalls) (Reiser and Bjornn 1979). While in the marine environment, first-year ocean fish are confined primarily to coastal areas and are much less abundant in the open ocean (Major 1978). During the second and subsequent year of ocean life, they are found widely distributed in the North Pacific Ocean and Bering Sea. Morrow (1980) states that chinook salmon from Alaskan streams enter the Gulf of Alaska gyre and move extensively across the North Pacific. In the spring, they seem to be scattered across the northern Pacific and in the Bering Sea, and during the summer their numbers increase in the area of the Aleutian Islands and in the western Gulf of Alaska. Many of the inshore fish of Southeast Alaska, however, appear to be of local origin (Morrow 1980).

Major (1978) suggests that except for areas immediately adjacent to the coast it is possible that chinook salmon do not occur in

the high seas south of 40° N. The central Bering Sea is a feeding ground and migration path for immature chinook salmon in Western Alaska (defined as the area from and including Bristol Bay northward to Point Hope). Tag recoveries are known to occur in the Bering Sea as far west as $172^{\circ}12'$ E (at $59^{\circ}03'$ N), whereas scalepattern and maturity studies, combined with seasonal distribution and Japanese mothership and research vessels information, push the range further west, to probably at least 160° to 165° E (Major 1978). These same stocks have been found as matures in the North Pacific Ocean just south of Adak at $176^{\circ}18'$ W (at $51^{\circ}36'$ N). Scale-pattern analysis shows tentatively that they may extend from $160^{\circ}-170^{\circ}$ 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
- ^o Alteration of preferred stream morphology
- Increase in suspended organic or mineral material
- Increase in sedimentation and reduction in permeability of substrate
- Reduction in food supply
- [°] Reduction in protective cover (e.g., overhanging stream

- banks, vegetation, or large rocks)
- ° Obstruction of migration routes
- Shock waves in aquatic environment
- ° Human harvest

(For additional impacts information, see the Impacts of Land and Water Use volume of this series.)

- VIII. LEGAL STATUS
 - A. Managerial Authority
 - 1. The Alaska 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 JNPFC has also prepared conservation measures that limit the location, time, and number of fishing days that designated high seas (beyond the 200-mi limit) areas may be fished by Japanese nationals and fishing vessels.
- IX. SPECIAL CONSIDERATIONS Caution must be used when extending information from one stock of chinook salmon to another stock. Environmental conditions for one area must not be treated as absolute; the stocks (races) have acclimated/evolved over time and space to habitat conditions that can vary greatly.
- X. LIMITATIONS OF INFORMATION Very little life history and habitat information concerning Alaskan chinook salmon has been collected/published. Most of the available information has been documented from Pacific Northwest and Canadian field and laboratory studies.

ADEC. 1979. Water quality standards. Juneau. 34 pp.

ADF&G, comp. 1977. A compilation of fish and wildlife resource information for the State of Alaska. Vol. 3: Fisheries. [Juneau.] 606 pp.

_____. 1977a. A fish and wildlife resource inventory of the Alaska Peninsula, Aleutian Islands, and Bristol Bay areas. Vol. 2: Fisheries. [Juneau.] 557 pp.

_____. 1977b. A fish and wildlife resource inventory of the Cook Inlet-Kodiak areas. Vol. 2: Fisheries. [Juneau.] 443 pp.

- ______. 1984. An atlas to the catalog of waters important for spawning, rearing, and migration of anadromous fishes, Arctic Resource Management Region V. Div. Habitat, Anchorage. 5 pp. + maps.
- Alderdice, D.F., and F.P.J. Velsen. 1978. Relation between temperature and incubation time of eggs of chinook salmon (<u>Oncorhynchus tshawytscha</u>). J. Fish. Res. Bd. Can. 35:69-75.
- Beauchamp, D.A., M.F. Shepard, and G.B. Pauley. 1983. Species profiles: life histories and environmental requirements (Pacific Northwest): Chinook salmon. National Coastal Ecosystems Team, Div. Biol. Ser., USDI, USFWS, Rept. FWS/OBS-83/1. 16 pp.
- Bell, M.C. 1973. Fisheries handbook of engineering requirements and biological criteria. Fisheries-Engineering Research Program, Corps of Engineers, North Pacific Div. Portland, OR. Approx. 500 pp.
- Bendock, T.N., and J. Burr. 1984. Index to North Slope stream and lake surveys. ADF&G, Div. Sport Fish.
- Bjornn, T.C. 1971. Trout and salmon movements in two Idaho streams as related to temperature, food, stream flow, cover, and population density. Trans. Am. Fish. Soc. 100(3):423-438.
- Brett, J.R. 1952. Temperature tolerance in young Pacific salmon, genus Oncorhynchus. J. Fish. Res. Bd. Can. 9(6):265-322.
- Burger, C.V., D.B. Wangaard, R.L. Wilmot, and A.N. Palmisano. 1983. Salmon investigations in the Kenai River, Alaska, 1979-1981. USFWS, Nat. Fish. Res. Can. Seattle, Alaska Field Station. Anchorage, AK. 178 pp.
- Burner, C.J. 1951. Characteristics of spawning nests of Columbia River salmon. USFWS Fish. Bull. 61(52):97-110.

- Burrows, R.E. 1960. Holding ponds for adult salmon. USFWS special scientific rept. Fisheries No. 357. 13 pp. Cited in Combs 1965.
- Combs, B.D. 1965. Effect of temperature on the development of salmon eggs. Progressive Fish-Culturist 27(3):134-137.
- Combs, B.D., and R.E. Burrows. 1957. Threshold temperatures for the normal development of chinook salmon eggs. Progressive Fish-Culturist 19(1):3-6.
- Edmundson, E., F.E. Everest, and E.W. Chapman. 1968. Permanence of station in juvenile chinook salmon and steelhead trout. J. Fish. Res. Bd. Can. 25(7):1,453-1,464.
- Everest, F.H., and D.W. Chapman. 1972. Habitat selection and spatial interaction by juvenile chinook salmon and steelhead trout in two Idaho streams. J. Fish. Res. Bd. Can. 29(1):91-100.
- Gusey, W.F. 1979. The fish and wildlife resources of the Bering Sea region. Shell Oil Company Environmental Affairs. 368 pp.
- Hablett, R.R. 1979. Fish investigations conducted within the National Petroleum Reserve on the North Slope of Alaska, 1977-1978. Pages 337-406 in Studies of selected wildlife and fish and their use of habitats on and adjacent to the National Petroleum Reserve in Alaska (105)c, Field Study 3. USDI, Anchorage, AK.
- Hall, J.E., and D.O. McKay. 1983. The effects of sedimentation on salmonids and macro-invertebrates: a literature review. ADF&G, Div. Habitat, Anchorage. Unpubl. rept. 31 pp.
- Hart, J.L. 1973. Pacific fishes of Canada. Fish. Res. Bd. Can. Bull. 180. Ottawa, Can. 739 pp.
- Holmes, P.B. 1982. Aleutian Islands salmon stock assessment study special report to the Alaska Board of Fisheries. ADF&G. 82 pp.
- Kissner, P.D. 1976. A study of chinook salmon in Southeast Alaska. ADF&G, Div. Sport Fish, AFS 41-4, Juneau.
- _____. 1977. A study of chinook salmon in Southeast Alaska. ADF&G, Div. Sport Fish, AFS 41-5, Juneau.
- Major, R.L., and J.L. Mighell. 1969. Egg-to-migrant survival of spring chinook salmon (<u>Oncorhynchus tshawytscha</u>) in the Yakima River, Washington. USFWS Fish. Bull. 67(2):347-359.
- Major, R.L., J. Ito, S. Ito, and H. Godfry. 1978. Distribution and origin of chinook (<u>Oncorhynchus tshawytscha</u>) in offshore waters of the North Pacific Ocean. INPFC Bull. 38. Vancouver, Can. 54 pp.

- McPhail, J.D., and C.C. Lindsey. 1970. Freshwater fishes of northwestern Canada and Alaska. Fish. Res. Bd. Can. Bull. 173. Ontario, Can. 381 pp.
- Merkel, T.J. 1957. Food habits of the king salmon, <u>Oncorhynchus</u> <u>tshawytscha</u> (Walbaum), in the vicinity of San Francisco, California. Calif. Fish and Game 43(4):249-270.
- Morrow, J.E. 1980. The freshwater fishes of Alaska. Anchorage, AK: Alaska Northwest Publishing Co. 248 pp.
- Neave, F. 1943. Diurnal fluctuations in the upstream migration of coho and spring salmon. J. Fish. Res. Bd. Can. 6(2):158-163.
- Netboy, A. 1974. The salmon: their fight for survival. Boston, MA: Houghton Mifflin Company. 613 pp.
- Och, R.S. 1983. Personal communication. Fish Culturist, ADF&G, Div. FRED, Kasilof.
- Prakash, A. 1962. Seasonal changes in feeding of coho and chinook (spring) salmon in southern British Columbia waters. J. Fish. Res. Bd. Can. 19(5):851-864.
- Reiser, D.W., and T.C. Bjornn. 1979. Influence of forest and rangeland management on anadromous fish habitat in western North America habitat requirements of anadromous salmonids. USDA Forest Service gen. tech. rept. PNW-96, Pacific Northwest Forest and Range Experiment Station. Portland, OR. 54 pp.
- Roberson, K. 1967. An occurrence of chinook salmon beach spawning in Lake Washington. Tran. Am. Fish. Soc. 96(4):423-424.
- Schwarz, L. 1985. Personal communication. Area Mgt. Biologist, ADF&G, Div. Commer. Fish., Nome.
- Scott, W.B., and E.J. Crossman. 1973. Freshwater fishes of Canada. Fish. Res. Bd. Can. Bull. 184. Ottawa, Can. 966 pp.
- Silver, S.J., C.E. Warren, and P. Doudoroff. 1963. Dissolved oxygen requirements of developing steelhead trout and chinook salmon embryos at different water velocities. Trans. Am. Fish. Soc. 92(4):327-343.
- Smith, A.K. 1973. Development and application of spawning velocity and depth criteria for Oregon salmonids. Trans. Am. Fish. Soc. 102(2):312-316.
- Straty, R.R. 1981. Trans-shelf movements of Pacific salmon. Pages 575-595 in D.W. Hood and J.A. Calder, eds. The eastern Bering Sea shelf: oceanography and resources, Vol. I. USDC: NOAA, OMPA.

- Thompson, K. 1972. Determining stream flows for fish life. Pages 31-50 in Proceedings, Instream Flow Requirement Workshop, Pacific Northwest River Basin Commission, Vancouver, WA.
- Vronskiy, B.B. 1972. Reproductive biology of the Kamchatka River chinook salmon (<u>Oncorhynchus tschawytsha</u> [Walbaum]). J. of Icth. 12(2):259-273.
- Whitmore, C.M., C.E. Warren, and P. Doudoroff. 1960. Avoidance reactions of the salmonid and centrarchid fishes to low oxygen concentrations. Trans. Am. Fish. Soc. 89(1):17-26.


I. NAME

A. Common Names: Chum salmon, dog salmon, keta salmon

B. Scientific Name: Oncorhynchus keta

II. RANGE

A. Worldwide

Chum salmon have the widest distribution of any of the Pacific salmon. In North America, the chum salmon ranges from the Sacramento River in California (and as far south as Del Mar, about 50 km north of the Mexican border) north to the arctic and east at least as far as the Mackenzie and Anderson rivers in northern Canada. In Asia, they range from the Lena River on the arctic coast of Siberia east and south along the coast to near Pusan, Korea, and Honshu Island, Japan. They are also found in the Aleutian, Commander, and Kurilei islands (Morrow 1980, McPhail and Lindsey 1970, Hart 1973).

- Statewide Chum salmon generally occur throughout Alaska except for certain streams in the Copper River drainage upstream of Miles Lake (Roberson, pers. comm.) and in the eastern Brooks Range (Hale 1981). Relatively few streams north of the Kotzebue Sound drainage support runs of chum salmon (ibid.).
- C. Regional Distribution Maps To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for each region. Most of the maps in this series are at 1:250,000 scale, but some are at 1:1,000,000 scale. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of selected fish and wildlife species has been prepared and may be found in the Atlas that accompanies each regional guide.
- D. Regional Distribution Summary

Β.

1. <u>Southwest</u>. In the Kodiak area, very little escapement information for chum salmon is available. They utilize many of the same streams as pink salmon for spawning (ADF&G 1977b).

In the Bristol Bay area (for waters from Cape Newenham to Cape Menshikof and north-side Alaska Peninsula streams south to Cape Sarichef), the Nushagak, Togiak, and Naknek-Kvichak districts are the major producers of chum salmon (Middleton 1983). Other important runs are also found in the Egegik and Ugashik systems (Russell, pers. comm.) and at Izembek-Moffet lagoons, Bechevin Bay, the Sapsuk River (Nelson Lagoon), Herendeen Bay, Moller Bay, Frank's Lagoon, Port Heiden, and Cinder River (Shaul, pers. comm.).

In south-side Alaska Peninsula streams, chum salmon are found at Canoe Bay and in every other major bay east of False Pass (ADF&G 1977a). Unga Island in South Peninsula waters is a moderate chum salmon producer (Shaul, pers. comm.). In the Chignik area, the Chignik Lagoon, Amber Bay, Ivanof Bay, Kuikukta Bay, Ivan River, Kujulik Bay, Chiginagak Bay, Agripina Bay, Aniakchak River, Hook Bay, and Nakalilok River support runs averaging several thousand fish each (ibid.). Small runs of chum salmon occur sporadically throughout the Aleutian Islands chain, but few of these would ever be expected to be of commercial importance (Holmes 1984). (For more detailed narrative information, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)

2. <u>Southcentral</u>. In the Upper Cook Inlet (UCI) area, chum salmon survey and escapement data are limited. Production areas for chum have been identified as Chinitna Bay, west-shore river systems of UCI, and the Susitna River (ADF&G 1982). In Lower Cook Inlet (LCI), chum salmon production areas include Port Graham, Tutka Bay, Dogfish (Koyuktolik) Bay, Island Creek (in Port Dick), Tonsina and Clear creeks in Resurrection Bay, and Port Chatham (ADF&G 1981a). In addition, all streams in the Kamishak Bay District are chum salmon producers. They include the McNeil, Douglas, Big Kamishak, Little Kamishak, Bruin, and Iuiskin rivers and Cottonwood, Sunday, and Ursus Lagoon creeks (Schroeder, pers. comm.).

In the Prince William Sound area, chum salmon stocks exhibit an early, middle, and late run pattern that is linked to geographic distribution and is related to stream temperature regimes. Early run (early and mid July) stocks spawn in major, non-lake-fed mainland streams of all districts. Middle-run (late July-mid August) stocks spawn in lake-fed streams of the mainland and most chum salmon streams of the outer island complex. Included is these stocks are the Coghill and Duck river (in Galena Bay) runs, which are the two largest stocks of the middle run. The late-run (mid August-late September) stocks spawn almost exclusively in small spring-fed creeks at the upper ends of Port Fidalgo and Valdez Arm (ADF&G 1978). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)

3. <u>Arctic</u>. Major chum salmon-producing systems in the Norton Sound District include the Unalakleet and Fish river drainages, and the Shaktoolik, Egavik, Inglutalik, Ungalik, Koyuk, Tubutulik, Kwiniuk, Kachavik, Bonanza, Eldorado, Flambeau, Nome, Snake, and Sinuk rivers (Schwarz, pers. comm.).

Within the Port Clarence District, chum salmon have been documented in the Bluestone, Cobblestone, Agiapuk, and Kuzitrin river systems (ADF&G 1984).

Major chum salmon-producing systems in the Kotzebue District are the Kobuk and Noatak rivers (ADF&G 1977). Important spawning areas in the Kobuk River system are found in the Squirrel, Salmon, and Tutuksuk rivers and the headwaters of the main Kobuk River (ADF&G 1983). Important spawning areas in the Noatak River system are found in the Eli and Kelly rivers, Eli Lake, and in the main Noatak River (ibid.).

The Northern District of the Arctic Region represents the most northern range of chum salmon in North America. Populations in the area are existing at the outer limits of their environmental tolerances, and their numbers are extremely limited (ADF&G 1977c). First-order streams (those with mouths at salt water) in which chum salmon have been documented include the Pitmegea, Kukpowruk, Kokolik, Utukok, Kuk, Meade, Fish, Colville, Sagavanirktok, and Canning (ADF&G 1984). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Arctic Region.)

III. PHYSICAL HABITAT REQUIREMENTS

- A. Aquatic
 - 1. Water quality:
 - a. <u>Temperature</u>. Egg hatching and alevin development have occurred in Alaska at temperatures ranging from 0.2 to 6.7°C during the winter months (Hale 1981). Optimal incubation temperatures, however, appear to range between 4.4 and 13.3°C (Bell 1973).

Emergence from the gravel and downstream migration to the sea have occurred at temperatures between 3.0 and $5.5^{\circ}C$; peak movements, however, occur at warmer temperatures (i.e., 5.0 to $15^{\circ}C$) (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 $0.1^{\circ}C$.

In Alaska, adult chum salmon have migrated upstream in temperatures ranging from 4.4 to $19.4^{\circ}C$ (ibid.), with peaks of migration occurring between 8.9 to $14.4^{\circ}C$. Bell (1973) suggests water temperature criteria for successful upstream migration of 8.3 to $15.6^{\circ}C$, with an optimum of $10^{\circ}C$.

Spawning has occurred in Alaskan waters at temperatures from 6.9 to 12.8°C, with preferred temperature ranges of 7.2 to 12.8°C (ibid.).

- b. <u>The pH factor</u>. 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).
- Dissolved oxygen (D.O.). Laboratory experiments show с. 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. These same tests tend to indicate a slow but 1958). 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).

- 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 infection. High suspended sediment loads bacterial 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:

d.

a. <u>Instream flow</u>. Hale (1981) states, "The flow of water in the stream channel is important to incubating embryos in promoting an adequate intragravel flow and in protecting the substrate from freezing temperatures. Heavy mortality of embryos can occur during periods when there is a relatively high or a relatively small discharge. Flooding can cause high mortality by eroding eggs from the redds or by depositing fine sediments on the surface of the redds which can reduce permeability or entrap emerging fry. Low discharge periods can lead to dessication of eggs, low oxygen levels, high temperatures, or, during cold weather, freezing."

During laboratory tests, juveniles when presented with a choice between two channels with "laminar" flows preferred 350, 500, 600, and 700 ml/min flows to a flow of 200 ml/min, and the greatest response was toward the 500 ml/min flow (Mackinnon and Hoar 1953). In another experiment with "turbulent" water flow, they found that fry seemed to prefer flows of about 5,000 to 12,000 ml/min over either lesser or greater flows. Levanidov (1954) stated that optimum stream velocities to support the feeding of fry in the Amur River, USSR, are less than 20 cm/sec.

There is little information available on the maximum sustained swimming velocity of which adult chum salmon are capable. Chum salmon have less ability than other salmon to surmount obstacles (Scott and Crossman 1973) and in general show less tendency to migrate upstream beyond rapids and waterfalls (Neave 1966).

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

- Egg incubation and alevin development occur in 3. Substrate. substrates ranging widely in size and composition. Hale (1981) summarizes redd sites by stating that, "in general, chum salmon excavate redds in gravel beds with a particle size of 2 to 4 cm diameter, but they will also construct redds in substrates with particles of a greater size and will even use bedrock covered with small boulders (Morrow 1980, Scott and Crossman 1973). Generally, substrates with a percentage of fine particles (less than 0.833 mm in diameter) greater than 13% are of poor quality because of reduced permeability (Thorsteinson 1965). Chum salmon, however, often spawn in areas of upwelling ground water and may therefore be able to tolerate higher percentages of fines than would seem desirable if some of the fines are kept in suspension by the upwelling water." The ADF&G (1977) observed that spawning usually occurs in riffle areas and that chum salmon generally avoid areas where there is poor circulation of water through the stream bed.
- B. Terrestrial
 - 1. <u>Conditions providing security from predators or other</u> <u>disturbances</u>. 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. <u>Conditions providing protection from natural elements</u>. A gravel substrate was found to prevent yolk sac malformations of alevins reared at 12°C and water velocities of 100/cm/hr (Emadi 1973). Alevins reared on a smooth substrate with identical temperature and water velocities were susceptible to yolk sac malformation. Because 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 Those that must spend several days to weeks on their 1980). journey, however, feed actively on chironomid larvae, cladocerans (water fleas), copepods, nematodes, and a variety of mature and immature insects (Morrow 1980, Scott and Crossman 1973). Stomach contents of chum salmon fry caught in the main stem of the Noatak River, its tributaries, and its backwaters during the period May through early August 1980 reveal that the fry had fed mainly on the larvae, pupae, and adult forms of insects. Only 4% of the stomach contents were of other types of organisms and, of these, most were zooplanktors (Merritt and Raymond 1983). The primary insect prey species were of the order Diptera and the order Plecoptera. Other types of insects were represented and included specimens from the orders Ephemeroptera (mayflies), Homoptera, and Zooplanktors included specimens from the order Hymenoptera. Cyclopoid and Harpacticoid forms of the subclass Cladocera. Copepoda were also represented. Some chum salmon fry had also consumed roundworms (Nematoda) (ibid.). During their early sea life they feed on a wide variety of

During their early sea life they feed on a wide variety of organisms, such as diatoms, many small crustaceans (e.g., ostracods, cirripeds, mysids, cumaceans, isopods, amphipods, decapods), dipterous insects, chaetognaths, and fish larvae (Morrow 1980, Scott and Crossman 1973). The food of chum salmon fry caught in the brackish water areas in Kotzebue Sound during June and early July 1980 consisted largely of insects (58%). Zooplankton, which made up most of the remainder, were mostly copepods. During early August of 1981, chum salmon fry caught near Cape Blossom in Kotzebue Sound in more saline water than the 1980 samples were found to be feeding primarily on cladocerans (<u>Chydorinea</u>) and copepods (Merritt and Raymond 1983). Copepods, tunicates, and euphausiids dominate the diet at sea (Morrow 1980, Scott and Crossman 1973). Other items eaten at sea include other fishes, pteropods, squid, and mollusks.

- B. Types of Feeding Areas Used Because chum salmon spend such a short time in natal water following emergence from the gravel, no data are available on freshwater feeding locations. At sea, the fish are found from close to the surface down to at least 61 m. There is some indication of vertical movement according to the time of day, with the fish tending to go toward the surface at night and deeper during the day (Manzer 1964). This is probably a response to movements of food organisms (Morrow 1980).
- C. Factors Limiting Availability of Food Chum salmon juveniles that feed while in fresh water eat benthic organisms. Excessive sedimentation may inhibit production of aquatic plants and invertebrate fauna (Hall and McKay 1983) and thereby decrease available food.
- D. Feeding Behavior

Juvenile daily food intake while in fresh water increases as water temperatures increase. Levanidov (1955), using aquaria, found that at 4 to 10°C the weight of food eaten daily was 5 to 10% of the body weight; at 12 to 20°C it was 10 to 19% of the body weight. Juveniles appear to be benthic feeders, relying on aquatic insects to supply the bulk of their food (Bakkala 1970). Adult feeding seems to be opportunistic and is based on availability of, rather than preference for, certain kinds of food (Le Brasseur 1966). Upon returning to fresh water to spawn, adults cease feeding and obtain energy from body fat and protein (Morrow 1980, Bakkala 1980).

- V. REPRODUCTIVE CHARACTERISTICS
 - A. Reproductive Habitat

Chum salmon spawn in waters ranging from short coastal streams, where the adults may spawn within the tidal zone, to large river systems, such as the Yukon River, where they are known to migrate upstream over 2,500 km. Most, however, spawn above the reaches of salt water and within 200 km of the sea (Bakkala 1970). Spawning grounds must provide suitable substrate as well as suitable stream conditions. Many stocks of chum salmon (particularly fall chum) select areas with springwater or 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 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 Dislodged margin of the redd and repeats the digging process. substrate is washed over the eggs. In this manner, the eggs are covered and prevented from washing away. The process is repeated, and the redd appears to move upstream (Burner 1951). As a result of the continued digging, the redd may grow to become 1.6 to 3.2 m long and 1.1 to 2.1 m wide (Bakkala 1970). A female may spawn with several males, and a male may mate with more than one female (Morrow 1980).

D. Age at Sexual Maturity

The age at which chum salmon mature sexually ranges from two to seven years, although most mature in their third to fifth year. In general, fish from the southern part of the range return to streams during their third and fourth years, whereas those from the Yukon (and probably other far north rivers) return mostly in their fourth and fifth years (Bakkala 1970, Morrow 1980). In Alaska Peninsula waters, fourth-year chum salmon are normally predominant, followed by significant numbers of third and fifth-year fish (Shaul, pers. comm.). Fish in their fourth year are usually most common in Southeast Alaska. Fifth-year fish predominate from Prince William Sound northward, with fourth and sixth-year fish being next in abundance. Seventh and eighth-year fish are rare (Hale 1981).

E. Fecundity

Fecundity varies by stock and the size of the female and ranges from 1,000 to 8,000 eggs. In Alaska, 2,000 to 3,000 are most common (ibid.). Samples taken from the lower Noatak River north of Kotzebue on September 1, 1981, ranged from 1,860 to 4,190 eggs and averaged 3,120 eggs, which is larger than fecundities reported for other Alaskan chum salmon (Merritt and Raymond 1983).

F. Frequency of Breeding As with all Pacific salmon, the spawning cycle for chum salmon is terminal. Both male and female die after spawning.

G. Incubation Period/Emergence

The time required for eggs to hatch is dependent upon many interrelated factors, including 1) dissolved oxygen, 2) water temperature, 3) apparent velocity in gravel, 4) biological oxygen demand, 5) substrate size (limited by percentage of small fine material), 6) channel gradient and 7) configuration, 8) water depth, 9) surface water discharge and velocity, 10) permeability, 11) porosity, and 12) light (Reiser and Bjornn 1979, Hale 1981). Generally speaking, factors 4 through 12 influence/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, although studies of spawning grounds in the Noatak River in northwestern Alaska suggest that egg hatching occurs from late December through January (Merritt and Raymond 1983). The alevins remain in the gravel until the yolk sac is absorbed, 60 to 90 days after hatching, then make their way through the gravel and begin migration to the sea (Morrow 1980). Although rare, chum salmon that have spent at least a year in freshwater lakes and grown to lengths of 160 to 170 mm have been captured at Lake Aleknagik in the Wood River system of Bristol Bay (Roberson, pers. comm.).

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

A. Sizes of Use Areas

From studies of Columbia River tributaries, Burner (1951) suggests that a conservative figure for the number of pairs of salmon that can satisfactorily utilize a given area of spawning gravel may be obtained by dividing the area by four times the average size of the redds. Redd area can be computed by measuring the total length of the redd (upper edge of pit to lower edge of tailspill) and the average of several equidistant widths (Reiser and Bjorrn 1979).

The average size of the redd area has been reported to range from 1.0 m² to 4.5 m² (Hale 1981). The ADF&G (1977) states that the optimum size is considered to be 3 m^2 .

B. Timing of Movements and Use of Areas

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

In their first year at sea, chum salmon migrate to offshore waters of the North Pacific Ocean and Bering Sea.

Adults return to fresh water during the period from June through September. Rates of movement during upstream migration vary greatly. Bakalla (1970) gives the following examples: "Yukon River chum salmon migrated at 80 km per day for the first 1,300 km and 56 km per day for the next 1,100 km. In the Amur River, USSR, the average rate of migration was 115 km per day. In some rivers of Japan where spawning grounds are much closer to the sea, the average rate of travel was 1.9 to 4.2 km per day." C. Migration Routes

Rivers serve as corridors for smolt outmigration. Adult upstream migration may be hindered or prevented by excess turbidity, high temperatures (20.0°C or more), sustained high water velocities (greater than 2.44m/sec), and blockage of streams (e.g., log jams and waterfalls) (Reiser and Bjornn 1979).

Once in the sea, the young chum salmon remain close to shore (within 37 to 55 km of the shoreline) during July, August, and September before dispersing into the open ocean (Morrow 1980, Neave et al. 1976). During this time, stocks found along the northern coast of the Gulf of Alaska and south of the Alaska Peninsula probably migrate westward. Stocks found north of the Alaska Peninsula probably move to the southwest (Neave et al. 1976).

From tagging studies, Neave et al. (1976) summarize maturing Alaskan chum salmon movements as follows: "Maturing chums of western Alaskan origin occupy the entire Gulf of Alaska in spring and were found westward along the Aleutians to 179°E. There was no tagging evidence of the presence of Alaskan chums in the Bering Sea before June. The recovery in the Yukon River of a maturing fish tagged in July at 60°N, 174°E, not far from the U.S.S.R. coast, constitutes the westernmost record of a north American chum salmon, as revealed by tagging. Other chums, tagged in the Gulf of Alaska, were found to travel as far north as the Arctic Ocean. The direction of movement in the Gulf of Alaska is westward in April-June. In the latter month most of the fish pass through the eastern part of the Aleutian Chain and migrate rapidly northward in the Bering Sea. No significant penetration of the Bering Sea by immature fish was disclosed.

Maturing chum salmon originating in central and southeastern Alaska occupy a large part of the Gulf of Alaska in spring but were rarely found west of 155°W. From May to July the fish tend to shift northward into waters from which western Alaska chums have largely withdrawn. Some immature fish move westward along the Aleutians to at least 177°W. No significant penetration of the Bering Sea by immature or maturing fish was indicated."

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

The period the eggs and alevin spend in the gravel is a time of heavy mortality. The survival rate from eggs to fry in natural streams averages less than 10% (Hale 1981).

Scott and Crossman (1973) state that "young chum salmon on the spawning grounds and during downstream migration are preyed upon by cutthroat and rainbow trout, Dolly Varden, coho salmon smolts, squawfish, and sculpins. . . . Kingfisher, merganser, other predaceous birds, and mammals are also responsible for a small loss. Even stonefly larvae and possibly other predaceous insects may prey on eggs and alevins. Water temperature, floods, droughts, other fluctuations in water level, spawning competion, and poor returns of adults, control number of young to a far greater extent." At sea, chum salmon are preyed upon by man, marine mammals, lampreys, and, in the early sea life, possibly by large fishes. Upon returning to fresh water to spawn, adults fall prey to bears, eagles, osprey, and other mammals (Scott and Crossman 1973).

B. Human-related

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

- Alteration of preferred water temperatures, pH, dissolved oxygen, and chemical composition
- * Alteration of preferred water velocity and depth
- ^o Alteration of preferred stream morphology
- [°] Increase in suspended organic or mineral material
- Increase in sedimentation and reduction in permeability of substrate
- ^o Reduction in food supply
- Reduction in protective cover (e.g., overhanging stream banks or vegetation)
- Shock waves in aquatic environment
- ° Human harvest

(For additional impacts information see the Impacts of Land and Water Use volume of this series.)

- VIII. LEGAL STATUS
 - A. Managerial Authority
 - 1. The Alaska 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 nonvoting members. The 11 are divided as follows: 5 from Alaska, 3 from Washington, and 3 from state fishery agencies (Alaska, Washington, Oregon). The four nonvoting members include the director of the Pacific Marine Fisheries Commission, the director of the U.S. Fish and Wildlife Service, the commander of the 17th Coast Guard District, and a representative from the U.S. Department of State. The council prepares fishery managment plans that become federal law and apply to marine areas between the 3-mi limit and the 200-mi limit. With regard to salmon, the only plan prepared to date is the Salmon Power Troll Fishery Management Plan.
 - 3. The International North Pacific Fisheries Commission is a convention comprised of Canada, Japan, and the United States established to provide for scientific studies and for coordinating the collection, exchange, and analysis of scientific data regarding anadromous species.

With regard to salmon, the INPFC has also prepared conservation measures that limit the location, time, and number of fishing days that designated high seas (beyond the 200-mi limit) areas may be fished by Japanese nationals and fishing vessels.

- IX. LIMITATIONS OF INFORMATION Limited life history and habitat information concerning Alaskan chum salmon has been collected/published. Most of the available information has been documented from Pacific Northwest and Canadian field and laboratory studies.
- X. SPECIAL CONSIDERATIONS

Caution must be used when extending information from one stock of chum salmon to another stock. Environmental conditions from one area must not be treated as absolute; the stocks (races) have acclimated/evolved over time and space to habitat conditions that can vary greatly. The distribution and abundance narrative for the salmon species, presented by ADF&G commercial fisheries management areas, follows the aggregated salmon life histories.

REFERENCES

ADEC. 1979. Water quality standards. Juneau. 34 pp.

- ADF&G, comp. 1977. A compilation of fish and wildlife resource information for the State of Alaska. Vol. 3: Commercial fisheries. [Juneau.] 606 pp.
- _____. 1977a. A fish and wildlife resource inventory of the Alaska Peninsula, Aleutian Islands, and Bristol Bay areas. Vol. 2: Fisheries. [Juneau.] 557 pp.

_____. 1977b. A fish and wildlife inventory of the Cook Inlet-Kodiak areas. Vol. 2: Fisheries. [Juneau.] 443 pp.

_____. 1977c. A fish and wildlife resource inventory of Western and Arctic Alaska. Vol. 2: Fisheries. [Juneau.] 340 pp.

_____. 1978. A fish and wildlife resource inventory of the Prince William Sound area. Vol. 2: Fisheries. [Juneau.] 241 pp.

ADF&G. 1981. Lower Cook Inlet annual management report: salmon. ADF&G, Div. Commer. Fish., Homer. 97 pp.

______. 1982. Stock separation feasibility report. Phase 1: Final draft. ADF&G, Su-Hydro Adult Anadromous Fisheries Project, Anchorage. 74 pp.

_____. 1983. Annual management report - 1982 - Norton Sound-Port Clarence-Kotzebue area. Div. Commer. Fish., Nome. 166 pp. _____. 1984. An atlas to the catalog of waters important for spawning, rearing, or migration of anadromous fishes, Arctic Resource Management Region V. Div. Habitat, Anchorage. 5 pp. + maps.

- Alderdice, D.F., W.P. Wickett, and J.R. Brett. 1958. Some effects of temporary exposure to low dissolved oxygen levels on Pacific salmon eggs. J. Fish. Res. Bd. Can. 15(2):229-259.
- Bakkala, R.G. 1970. Synopsis of biological data on the chum salmon, <u>Oncorhynchus keta</u> (Walbaum) 1792. FAO Species Synopsis No. 41. USFWS, Bureau Commer. Fish., Circular 315. Wash., DC. 89 pp.
- Bell, M.C. 1973. Fisheries handbook of engineering requirements and biological criteria. Fisheries-Engineering Research Program, Corps of Engineers, North Pacific Division. Portland, OR. Approx. 500 pp.
- Brett, J.R. 1952. Temperature tolerance in young Pacific salmon, genus Oncorhynchus. J. Fish. Res. Bd. Can. 9(6):265-322.
- Brett, J.R., and D.F. Alderice. 1958. The resistance of cultured young chum and sockeye salmon to temperatures below zero degrees C. J. Fish. Res. Bd. Can. 15(5):805-813. Cited in Hale 1981.
- Burner, C.J. 1951. Characteristics of spawning nests of Columbia River salmon. USFWS Fish. Bull. 61(52):97-110.
- Emadi, H. 1973. Yolk-sac malformation in Pacific salmon in relation to substrate, temperature, and water velocity. J. Fish. Reg. Bd. Can. 30(8):1,249-1,250.
- Hale, S.S. 1981. Freshwater habitat relationships: chum salmon (<u>Oncor-hynchus keta</u>). ADF&G, Div. Habitat, Resource Assessment Branch, Anchorage. 81 pp.
- Hall, J.E., and D.O. McKay. 1983. The effects of sedimentation on salmonids and macro invertebrates: literature review. ADF&G, Div. Habitat, Anchorage. Unpubl. rept. 31 pp.
- Hart, J.L. 1973. Pacific fishes of Canada. Fish. Res. Bd. Can. Bull. 180. Ottawa, Can. 739 pp.
- Hoar, W.S. 1956. The behavior of migrating pink and chum salmon fry. J. Fish. Reg. Can. 13(3):309-325.
- Hunter, J.G. 1959. Survival and production of pink and chum salmon in a coastal stream. J. Fish. Res. Bd. Can. 16(6):835-886. Cited by Hale 1981.

- Kogl, D.R. 1965. Springs and ground-water as factors affecting survival of chum salmon spawn in a sub-arctic stream. M.S. Thesis, Univ. Alaska, Fairbanks. 59 pp. Cited in Hale 1981.
- LeBrasseur, R.J. 1966. Stomach contents of salmon and steelhead trout in the northeastern Pacific Ocean. J. Fish. Res. Bd. Can. 23:85-100. Cited in Bakkala 1970.
- Levanidov, V.Y. 1954. Ways of increasing the reproduction of Amur chum salmon. (Transl. from Russian.) Akademiya. Nauk USSR, Ikhtiologicheskaya Komissya, Trudy Soveschanii, No. 4:120–128. Israel Prog. Sci. Transl. Cat. No. 8. Office of Tech. Serv., USDC, Wash., DC. 12 pp. Cited in Hale 1981.
- ______. 1955. Food and growth of young chum salmon in fresh water. Zool. Zh. 34:371-379 Transl. Fish. Res. Bd. Can. Biol. Sta., Nanaimo, Brit. Col. Transl. Ser. 77. Cited in Bakkala 1970.
- Levanidov, V.Y., and I.M. Levanidova. 1951. The food of young Amur chum salmon in fresh water. (Transl. from Russian). Izv. Tikh. Nauch. – Issled. Inst. Ryb. Khoz. Okeanog. 35:41–46. Fish. Res. Bd. Can. Transl. Ser. 102. Cited in Hale 1981.
- MacKinnon, D., and W.S. Hoar. 1953. Responses of coho and chum salmon fry to current. J. Fish. Res. Bd. Can. 10(8):523-538. Cited in Hale 1981.
- Manzer, J.I. 1964. Preliminary observations on the vertical distribution of Pacific salmon (Genus <u>Oncorhynchus</u>) in the Gulf of Alaska. J. Fish. Res. Bd. Can. 21(5):891-903. Cited in Morrow 1980.
- Merritt, M.F., and J.A. Raymond. 1983. Early life history of chum salmon in the Noatak River and Kotzebue Sound. ADF&G, Div. FRED. Juneau. 56 pp.
- Middleton, K.R. 1983. Bristol Bay salmon and herring fisheries status report through 1982. Informational Leaflet No. 211. ADF&G, Div. Commer. Fish. Homer. 81 pp.
- McPhail, J.D., and C.C. Lindsey. 1970. Freshwater fishes of northwestern Canada and Alaska. Fish Res. Bd. Can. Bull. 173. Ontario, Can. 381 pp.
- Morrow, J.E. 1980. The freshwater fishes of Alaska. Anchorage, AK: Alaska Northwest Publishing Company. 248 pp.
- Neave, F. 1955. Notes on the seaward migration of pink and chum salmon fry. J. Fish. Res. Bd. Can. 12(3):369-374. Cited by Hale 1981.

_____. 1966. Salmon of the North Pacific Ocean: Part 3. INPFC Bull.18. Vancouver, B.C. Can.

- Neave, F., T. Yonemori, and R.G. Bakkala. 1976. Distribution and origin of chum salmon in offshore waters of the North Pacific Ocean. INPFC Bull. 35. Vancouver, Can. 79 pp.
- Reiser, D.W., and T.C. Bjornn. 1979. Influence of forest and rangeland management on anadromous fish habitat in western North America: habitat requirements of anadromous salmonids. USDA Forest Service Gen. Tech. Rept. PNW-6. Pacific Northwest Forest and Range Experiment Station, Portland, OR. 54 pp.
- Roberson, K. 1985. Personal communication. Research Project Leader, ADF&G, Div. Commer. Fish., Glennallen.
- Schroeder, T. 1985. Personal communication. LCI Area Mgt. Biologist, ADF&G, Div. Commer. Fish., Homer.
- Schwarz, L. 1985. Personal communication. Area Mgt. Biologist, ADF&G, Div. Commer. Fish., Nome.
- Scott, W.B., and E.J. Crossman. 1973. Freshwater fishes of Canada. Fish. Res. Bd. Can. Bull. 184. Ottawa, Can. 966 pp.
- Shaul, A. 1984. Personal communication. Alaska Peninsula-Aleutian Island Area Fisheries Mgt. Biologist, ADF&G, Div. Commer. Fish., Kodiak.
- Smith, D.W. 1978. Tolerance of juvenile chum salmon (<u>Oncorhynchus keta</u>) to suspended sediments. M.S. Thesis, Univ. Wash., Seattle. 124 pp. Cited in Hale 1981.
- Straty, R.R. 1981. Trans-shelf movements of Pacific salmon. Pages 575-595 in W.D. Head and J.A. Calder, eds. The eastern Bering Sea shelf: oceanography and resources. Vol. 1. USDC: NOAA, OMPA.
- Thorsteinson, F.V. 1965. Effects of the Alaska earthquake on pink and chum salmon runs in Prince William Sound. Pages 267-280 <u>in</u> G. Dahlgren, ed. Science in Alaska, 1964. Proc. 15th Alaska Science Conf. AAAS, College, AK. Cited in Hale 1981.



Coho Salmon Life History and Habitat Requirements Southwest, Southcentral, and Arctic Alaska

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

I. NAME

A. Common Names: Coho salmon, coho, silver salmon, sea trout

B. Scientific Name: Oncorhynchus kisutch

II. RANGE

A. Worldwide

The coho salmon occurs naturally in the Pacific Ocean and its tributary drainages. In North America, it is found from Monterey Bay, California, north to Point Hope, Alaska. In Asia, it occurs from the Anadyr River in northeastern Siberia south to Hokkaido, Japan (Scott and Crossman 1973).

B. Statewide In Alaska, coho salmon are abundant from Dixon Entrance (Southeast Alaska) north to the Yukon River. Evidence suggests that coho are rare north of Norton Sound (ADF&G 1977).

- C. Regional Distribution Maps
 - To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for each region. Most of the maps in this series are at 1:250,000 scale, but some are at 1:1,000,000 scale. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of selected fish and wildlife species has been prepared and may be found in the Atlas that accompanies each regional guide.
- D. Regional Distribution Summary
 - Southwest. In the Kodiak area, many streams have runs of coho salmon; however, the runs are late in the season, and escapement figures are incomplete (ibid.). In the Bristol Bay area (for waters from Cape Newenham to Cape Menshikof and northside Alaska Peninsula streams south to Cape Sarichef), major coho salmon-producing drainages include the Togiak and Nushagak systems, with smaller runs

found in the Kulukak, Naknek, Kvichak, Egegik, and Ugashik systems (Middleton 1983). Further south on the Alaska Peninsula, important north-side coho salmon-producing systems are found at Nelson Lagoon, Port Heiden, and Cinder River. Smaller fisheries also exist at Swanson Lagoon and Ilnik (Shaul, pers. comm.).

For south-side Alaska Peninsula streams and the Aleutian Islands, data are scarce concerning coho salmon production. The best-known runs on the South Peninsula occur in Russel Creek, Mortensen Lagoon, and Thin Point Cove at Cold Bay (ADF&G 1977a). A few streams on Unalaska Island and several small drainages in the Aleutian Islands contain coho salmon, but the size of the run is unknown (Holmes, pers. comm.). It is known that the Chignik River system produces most of the coho salmon utilized by the commercial fishery in the Chignik area. Other streams in the Chignik area also contain coho salmon, although the size of the runs is not known (ADF&G 1977a). (For more detailed narrative information, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)

2. Southcentral. In the upper Cook Inlet area, major coho salmon spawning and rearing drainages include the Susitna, Kenai, and Kasilof river systems (McLean et al. 1977a). In the lower Cook Inlet area, coho salmon are found in the English Bay lakes system, Clearwater Slough, and the Douglas, Big Kamishak, Little Kamishak, and McNeil river systems (ADF&G 1983b). In the Prince William Sound area, coho salmon are the dominant species in the Bering River (ADF&G 1978). They are also found in numbers in the Copper and Katalla river drainages (ADF&G 1978, 1983c). (For more detailed

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

3. <u>Arctic</u>. In the Norton Sound District, coho salmon have been documented in 19 first-order streams (those with mouths at salt water) (ADF&G 1984). Although not the only significant coho salmon-producing systems, the Unalakleet River drainage and the Shaktoolik River are considered to be the most important coho salmon producers in the district (Schwarz, pers. comm.).

Within the Port Clarence District, coho salmon have been documented in the Agiapuk and Kuzitrin first-order river systems (ibid.).

Within the Kotzebue District, first-order systems known to sustain populations of coho salmon include the Buckland, Noatak, Wulik, and Kivalina rivers (ibid.).

Coho salmon are documented in only one stream in the Northern District: Kuchiak Creek, northeast of Cape Lisbourne (ibid.).

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

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

- 1. Water quality:
 - a. <u>Temperature</u>. 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. <u>The pH factor</u>. 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).
- Dissolved oxygen (D.O.). The groundwater that is С. typical of coho salmon spawning beds is usually highly oxygenated (Godfrey 1965). Davis et al. (1963), during laboratory tests of sustained swimming speeds of juvenile coho salmon, found that the reduction of oxygen concentration from air saturation levels to 7, 6, 5, 4, and 3 mg/l usually resulted in reduction of the maximum sustained swimming speed by about 5, 8, 13, 20, and 30%, respectively. Adult swimming performance is also adversely affected by reduction of D.O concentrations below air saturation level. Bell (1973) states that it is desirable that D.O. concentrations be at or near saturation and that it is especially important in spawning areas, where D.O. levels must not be below 7 ppm at any time. State of Alaska water quality criteria for growth and propagation of fish state that "D.O. shall be greater than 7 mg/l in waters used by anadromous and resident fish. Further, in no case shall D.O. be less than 5 mg/l to a depth of 20 cm in the interstitial waters of gravel utilized by anadromous or resident fish for spawning. . . . In no case shall D.O. above 17 mg/l be permitted. The concentration of total dissolved gas shall not exceed 110 percent of saturation at any point of sample collection."
- d. Turbidity. Sedimentation causes high mortality to eggs and alevin by reducing water interchange in the redd. If 15 to 20% of the intragravel spaces become filled with sediment, salmonid eggs have suffered significant (upwards of 85%) mortality (Bell 1973). Prolonged exposure to turbid water causes gill irritation in juveniles, which can result in fungal and pathogenic bacterial infection. Excess turbidity from organic materials in the process of oxidation may reduce oxygen below safe levels, and sedimentation may smother food organisms and reduce primary productivity (ibid.). From investigation of the Susitna River in Southcentral Alaska during 1982, turbid water was found to be a

strong factor that influenced juvenile fish distributions. This study indicates that rearing coho salmon apparently avoid turbid water (ADF&G 1983a). Turbid water will absorb more solar radiation than clear water and may thus indirectly raise thermal barriers to adult upstream spawning migration (Reiser and Bjornn 1979).

2. Water quanitity:

а.

Instream flow. Sufficient water velocity and depth are needed to allow proper intragravel water movement (apparent velocity) so that dissolved oxygen is transported to eggs and alevins and in turn metabolic wastes are removed (ibid.). Juveniles after emerging from the gravel stay almost entirely in pools, avoiding riffle areas (Morrow 1980). Burger et al. (1983), during studies on the Kenai River, Alaska, and its tributaries, found that recently emerged juveniles (less than 50 mm long) in the main stem of the river were close to banks and often in reaches where the river had flooded terrestrial areas. Most of these juveniles were found in zones of zero water velocity, and almost 80% were captured in areas of less than 6.1 cm/sec mean water-column velocity. Larger juvenile coho salmon (51 to 71 mm) were typically captured in creek mouth basins, backwater pools, and man-made canals. Ninety percent of these fish were in habitat having no measurable water velocity. In contrast to these findings, the juveniles in Kenai River tributary streams were found in pool-riffle habitat. Burger et al. (1983) suggest that sooner-emerging chinook salmon juveniles may be displacing main stem spawned coho salmon into tributaries, canals, and basins. He also suggests that since the main stem age 0 coho salmon do not appear to be attaining the same growth as similar age fish in the Deshka or Susitna rivers, the areas to which they have been forced are probably not their preferred habitats and may not supply the drift food items that are a major contributor to salmonid diets. Competition with stickleback may also play a role in the lower coho salmon growth rates.

Bovee (1978) suggests that an optimum water velocity for coho salmon fry is from 15.2 to 18.3 cm/sec.

Stream water velocity is important to juveniles because it is the most important parameter in determining the distribution of aquatic invertebrates (food sources) in streams (Reiser and Bjornn 1979).

Excess velocities and shallow water may impede migrating fish. Thompson (1972) indicates that Pacific Northwest coho salmon require a minimum depth of 0.18 m, with velocities less than 2.44 m/sec. for migration. No measurements of Alaska waters for adult migration criteria are available.

Velocity is also important in redd construction because the water carries dislodged substrate materials from the nesting site. Measured flow rates at 0.12 m above the streambed include 19.2 to 69.2 cm/sec in Oregon and 7.6 to 61.0 cm/sec in the Columbia River and tributaries (Smith 1973). Minimum water depths at these spawning sites ranged from 0.122 to 0.153 m in Oregon and from 0.305 to 0.458 m in the Columbia River and tributaries. Smith (1973) recommended the following spawning velocity (as measured 0.12 m above streambed) and minimum depth criteria for Oregon coho salmon as 21.0 to 70.0 cm/sec and 0.15 m, respectively. Burger et al. (1983) list 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 tail-spill velocity (measurement taken at 0.6 total depth). The pit depths at these redds were 54.5 to 76.3 cm, and the tail-spill depths were 25.0 to 45.0 cm.

3. <u>Substrate</u>. Egg incubation and alevin development occur in substrates ranging widely in size and composition. The ADF&G (1977) states that optimum substrate composition is small-to-medium gravel. Generally, sediments less than .64 cm in diameter should comprise less than 20 to 25% of the incubation substrate (Reiser and Bjornn 1979).

Substrate composition regulates production of invertebrates, which are food sources for juveniles. Highest invertebrate production is from gravel and rubble-size materials associated with riffle areas (ibid.).

- B. Terrestrial
 - 1. <u>Conditions providing security from predators or other</u> <u>disturbances</u>. Emergent terrestrial vegetation was the dominant cover type used by juvenile coho in their backwater pool-rearing areas in the main stem Kenai River (Burger et al. 1983).

Undercut banks and deep water pools provide protection for adults.

2. Conditions providing protection from natural elements. Bustard and Narver (1975), working in Vancouver, British Columbia, noted that the juvenile coho salmon were associated with water velocities of less than 15 cm/sec when the water temperature was 7°C or less. They also noted that as the temperature dropped from 9 to 2°C young coho salmon moved closer to cover provided by such things as logs, uprooted trees, debris accumulations, overhanging banks, and overhanging brush.

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

Upon hatching, young alevin remain in the gravel for two or three weeks until the yolk sack has been absorbed. Following emergence from the gravel, the juveniles begin feeding at or near the surface (Morrow 1980). Major food items at this time are terrestrial insects, especially species of flies (Diptera) and wasps and bees (Hymenoptera) and perhaps also aphids and thrips (ibid.). Burger et al. (1983) found that midges (chironomids) were dominant in stomach samples of juvenile coho salmon in the Kenai River, Alaska. The diet can also include mites, beetles. springtails (Collembola), spiders, and small zooplankton. As the young fish grow they consume larger food items and often consume young sockeye salmon. In Chignik Lake, Alaska, young coho salmon have been found to eat seven times as many sockeye salmon as do Dolly Varden, and in other localities coho salmon may be equally serious predators (Morrow 1980). Scott and Crossman (1973) state that large numbers of chum and pink salmon are also taken by coho salmon.

Upon entering the sea, young coho salmon feed on various planktonic crustaceans, pink and chum salmon fry, herring, sand lance, other fishes, and squid (ibid.).

The food of marine adults is more pelagic and more varied than that of many Pacific salmon. Fishes make up 70 to 80% of the coho salmon's food, invertebrates 20 to 30%, and include the following: pilchard, herring, anchovy, coho salmon, capelin, lanternfish, Pacific saury, hake, whiting, rockfishes, black cod, sculpins, sand lance, squid, barnacles, isopods, amphipods, euphausiids, crab larvae, and jelly fish (Morrow 1980, Scott and Crossman 1973). Herring and sand lance make up 75% of the volume (Pritchard and Tester 1944). Some populations, however, remain on the crustacean diet, such coho generally not growing as big as those that eat fish (Prakash and Milne 1958).

B. Types of Feeding Areas Used

Young juveniles feed in low-velocity areas along streambanks and in backwater pools and current eddies. Feeding is generally near the surface, with drifting invertebrates the prey; young coho salmon feed infrequently on bottom-dwelling organisms (Morrow 1980). As they grow in size, the juveniles may become serious predators of other small fish, including other salmon species. When the young coho salmon migrate to the sea, they tend to stay fairly close to shore at first. The oceanic movements of coho in the southern part of the range (i.e., Washington, Oregon, British Columbia) seem to be chiefly along the coast, with some fish apparently never venturing far from the coast. By contrast, northern fish, particularly those from Alaskan streams, spread out all across the North Pacific and into the Bering Sea (ibid.). Available evidence from commercial fisheries and research vessels indicates that while at sea coho salmon occur most frequently near the surface. Individuals have been taken at greater depths, but

most coho salmon have been caught in the upper 10 m (Godfrey 1965).

- C. Factors Limiting Availability of Food Sedimentation is one of the major factors affecting freshwater food availability. Excessive sedimentation may inhibit production of aquatic plants and invertebrate fauna (Hall and McKay 1983). Bell (1973) states that primary food production is lowered above levels of 25 JTU (Jackson Turbidity Unit) and visual references lost above levels of 30 JTU.
- D. Feeding Behavior Food varies from place to place and with time (Scott and Crossman 1973). While on the high seas, schools may become involved in a feeding frenzy and have been found to be eating blue lanternfish and sauries (Hart 1973). Upon entering fresh water, adult salmon no longer feed but live off the fat they stored up while in the ocean (Netboy 1974).
- V. REPRODUCTIVE CHARACTERISTICS
 - A. Reproductive Habitat

Short coastal streams are usually preferred, but coho salmon are known to spawn in spring-fed tributaries of the Yukon River system from the Bonasila River at least as far upstream as the Tanana (Morrow 1980). Although spawning may occur in main channels of large rivers, locations at the head of riffles in shallow tributaries or narrow side channels are preferred (ADF&G 1977).

B. Reproductive Seasonality

In Alaska, coho salmon enter freshwater streams from mid July through November (Russell, pers. comm.). Actual spawning occurs between September and January (ADF&G 1977). As a rule, fish in the northern part of the range enter fresh water earlier in the season, with runs occurring progressively later to the south (Morrow 1980).

C. Reproductive Behavior

As with other salmon, adult coho salmon return from the sea and move into their natal freshwater streams to spawn. The female selects the spawning site and digs the redd (nest) by turning on her side and thrashing her tail up and down. The current washes loosened substrate material downstream, and a depression 8 to 51 cm (average about 20 to 25 cm) deep is formed in the river bottom (Burner 1951, Morrow 1980). Eggs and sperm (milt) are released simultaneously and deposited in the redd. After egg deposition, the female moves to the upstream margin of the redd and repeats the digging process. Dislodged substrate is washed over the In this manner, the eggs are covered and prevented from eaas. The process is repeated many times, and the redd washing away. 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 m² for Columbia River basin redds (ibid.). A female may dig several redds and spawn with more than one male (McPhail and Lindsey 1970).

D. Age at Sexual Maturity

The age at which coho salmon reach sexual maturity ranges from two to six years, although most usually return from marine waters to spawn at ages 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
 - Frequency of Breeding As with all Pacific salmon, the spawning cycle is terminal. Both male and female die after spawning.
- G. Incubation Period/Emergence

The amount of time required for eggs to hatch is dependent upon many interrelated factors, including 1) dissolved oxygen, 2) water temperature, 3) apparent velocity in gravel, 4) biological oxygen demand, 5) substrate size (limited by percentage of small fine material), 6) channel gradient and 7) configuration, 8) water depth, 9) surface water discharge and velocity, 10) permeability, 11) porosity, and 12) light (Reiser 1979, Hart 1973). Generally speaking, factors 4 through 12 influence/regulate the key factors 1, 2, and 3.

In Alaska, hatching usually takes place from mid winter to early spring, the amount of time varying with the water temperature. Scott and Crossman (1973) indicate that hatching times have ranged from 38 days at 10.7°C to 48 days at 8.9° in California, and they postulate that it might take 42 to 56 days farther north. Morrow (1980) states that incubation takes six to nine weeks and may require as long as five months. After hatching, the alevin remain in the gravel for 2 to 3 weeks (some may take up to 10 weeks) and emerge from the gravel sometime from April to June (ADF&G 1978 Morrow 1980, Godfrey 1965).

- VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS
 - A. Size of Use Areas

Juvenile coho salmon after emerging from the gravel take up residence not far from redds, especially near the banks, where they tend to congregate in schools. As they grow they disperse and become aggressive and territorial. Laboratory experiments by Chapman (1962) show that juveniles are aggressive and territorial or hierarchical in behavior. Hierarchies and territories were organized on the basis of fish size, and smaller fish tended to move downstream because of the continuous harassment by the larger fish.

From studies of Columbia River tributaries, Burner (1951) suggests that a conservative figure for the number of pairs of salmon that can satisfactorily utilize a given area of spawning gravel may be obtained by dividing the area by four times the average size of the redds. Redd area can be computed by measuring the total length of the redd (upper edge of pit to lower edge of tail spill) and the average of several equidistant widths (Reiser and Bjornn 1979). Burner (1951) states that Columbia River basin coho salmon redds averaged 2.8 m². Burger et al. (1983) measured three redds (two in the Kenai River main stem, one in a tributary stream) and listed their sizes. Main stem redds were 1.5 and 0.9 m long x 1.2 and 0.6 m wide, respectively. The tributary redd was 1.8 m long x 1.0 m wide.

Timing of Movements and Use of Areas Β. The young coho salmon normally spend a year in fresh water before going to sea, although some may go to sea at the end of their first summer. Others, as in the Karluk River on Kodiak Island, Alaska, may stay two, three, or even four years in fresh water (Morrow 1980). Middleton (1983) states that in Bristol Bay streams coho juveniles stay in fresh water mainly two or more years. The same is said for the Chignik and Nelson Lagoon systems by Shaul (pers. comm.), who postulates that most coho salmon on the Alaska Peninsula probably spend two winters in fresh water. In the Taku River of Southeast Alaska, downstream movement of juveniles bound for the sea is usually at night (Meehan and Siniff 1962), and the trip is completed during the period mid April through mid June. Studies of smolt outmigration in the Bear Lake system, near Seward, indicate that very few smolts migrate prior to stream temperatures attaining $3.9^{\circ}C$ (Logan 1967), and for this system the seaward movement of natural stocks commences during mid May and continues through late September, with 50% of the migration passing the sampling weir by mid June (Logan 1967, 1968, 1969). Burger et al. (1983) suggest that the Kenai River seaward migration occurs probably from July to November.

Having spent two or three years in the ocean, mature coho salmon first arrive in appreciable numbers in coastal waters of central and southeastern Alaska early in July, and the runs extend into August or September. Alaska Peninsula coho salmon spend only one year in salt water (Shaul, pers. comm.). Few details are known regarding the times of arrival of coho salmon off western Alaska streams, except that again they are late in the season and follow the runs of the sockeye and pink salmon (Morrow 1980, Godfrey 1965).

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

C. Migration Routes

Rivers and streams serve as corridors for smolt out-migration. Barriers to adult upstream movement include excess turbidity, high temperatures (20.0°C or more), sustained high-water velocities (greater than 2.44 m/sec), and blockage of streams (log jams, waterfalls) (Reiser and Bjornn 1979).

Alaskan coho salmon enter the Alaskan gyre (a generally counterclockwise flow of water moving westerly near the south side of the Alaska Peninsula and Aleutian Islands) and travel "downstream," making one complete circuit per year (Morrow 1980).

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

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

Scott and Crossman (1973) state that "coho juveniles especially when aggregated and abundant, are preyed on by a variety of fishes (e.g., coho smolts, cutthroat and rainbow trout, Dolly Varden, squawfish and sculpins), mergansers, loons, kingfishers, other birds, and some small mammals. The adults during their spawning run are taken by bears, other mammals, and large birds. In the ocean, man, lampreys, and aquatic mammals (e.g., seals and killer whales) are the chief predators."

The greatest natural mortality occurs in fresh water during the early life stages and is greatly influenced by environment (Straty 1981); therefore, deleterious changes in the freshwater quality, quantity, or substrate are most detrimental.

B. Human-related

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

- Alteration of preferred water temperature, pH, dissolved oxygen, and chemical composition
- ° Alteration of preferred water volocity and depth
- ° Alteration of preferred stream morphology
- ° Increase in suspended organic or mineral material
- Increase in sedimentation and reduction in permeability of substrate
- [°] Reduction in food supply
- Reduction in protective cover (e.g., overhanging stream banks or vegetation)
- Shock waves in aquatic environment
- ° Human harvest

(For additional impacts information, see the Impacts of Land and Water Use volume of this series.)

VIII. LEGAL STATUS

A. Managerial Authority

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

The North Pacific Fishery Management Council is composed of 15 members, 11 voting and 4 nonvoting members. The 11 are divided as follows: 5 from Alaska, 3 from Washington, and 3 from state fishery agencies (Alaska, Washington, Oregon). The four nonvoting members include the director of the Pacific Marine Fisheries Commission, the director of the U.S. Fish and Wildlife Service, the commander of the 175th Coast Guard District, and a representative from the U.S. Department of State. The council prepares fishery management plans, which become law and apply to marine areas between the 3-mi limit and the 200-mi limit. With regard to salmon, the only plan prepared to date is the Salmon Power Troll Fishery Management Plan.

The International North Pacific Fisheries Commission (INPFC), a convention comprised of Canada, Japan, and the United States, has been established to provide for scientific studies and for coordinating the collection, exchange, and analysis of scientific data regarding anadromous species.

With regard to salmon, the INPFC has also prepared conservation measures that limit the location, time, and number of fishing days that designated high seas (beyond the 200-mi limit) areas may be fished by Japanese nationals and fishing vessels.

- IX. LIMITATIONS OF INFORMATION Very little life history and habitat information concerning Alaskan coho salmon has been collected/published. Most of the available information has been documented from Pacific Northwest and Canadian field and laboratory studies.
- X. SPECIAL CONSIDERATIONS Caution must be used when extending information from one stock of coho salmon to another stock. Environmental conditions for one area must not be treated as absolute; the stocks (races) have acclimated/evolved over time and space to habitat conditions that can vary greatly.

REFERENCES

- ADEC. 1979. Water quality standards. Juneau. 34 pp.
- ADF&G, comp. 1977. A compilation of fish and wildlife resource information for the State of Alaska. Vol. 3: Commercial fisheries. [Juneau.] 606 pp.

______. 1977a. A fish and wildlife resource inventory of the Alaska Peninsula, Aleutian Islands, and Bristol Bay areas. Vol. 2: Fisheries. [Juneau.] 557 pp.

_____. 1977b. A fish and wildlife inventory of the Cook Inlet-Kodiak areas. Vol. 2: Fisheries. [Juneau.] 443 pp.

_____. 1978. A fish and wildlife inventory of the Prince William Sound area. Vol. 2: Fisheries. [Juneau.] 241 pp.

- ADF&G. 1983a. Susitna Hydro Aquatic Studies phase II report; synopsis of the 1982 aquatic studies and analysis of fish and habitat relationships-appendices ADF&G, Susitna Hydro Aquatic Studies, Anchorage. 355 pp.
 - _____. 1983b. Annual finfish management report-1982-Lower Cook Inlet. Div. Commer. Fish., Homer. 96 pp.
 - _____. 1983c. Prince William Sound area annual finifsh management report-1983. Div. Commer. Fish., Cordova. 135 pp.
- . 1984. An atlas to the catalog of waters important for spawning, rearing, or migration of anadromous fishes, Arctic Resource Management Region V. Div. Habitat, Anchorage. 5 pp. + maps.
- Bell, M.C. 1973. Fisheries handbook of engineering requirements and biological criteria. Fisheries-Engineering Research Program Corps. of Engineers, N. Pac. Div. Portland, OR. Approx. 500 pp.
- Bovee, K.D. 1978. Probability-of-use criteria for the family salmonidae. Instream Flow Information Paper No. 4. FWS/OBS-78/07, Ft. Collins, CO. Cited by Burger et al. 1983.
- Brett, J.R. 1952. Temperature tolerance in young Pacific salmon, genus Oncorhynchus. J. Fish. Res. Bd. Can. 9(6):265-322.
- Burger, C.B., D.B. Wangaard, R.L. Wilmot, and A.N. Palmisano. 1983. Salmon investigations in the Kenai River, Alaska, 1979-1981. USFWS, Natl. Fish. Res. Cen., Seattle; Alaska Field Station, Anchorage. 178 pp.
- Burner, C.J. 1951. Characteristics of spawning nests of Columbia River salmon. USFWS Fish. Bull. 61(52):97-110.
- Bustard, D.R., and D.W. Narver. 1975. Aspects of the winter ecology of juvenile coho salmon (<u>Oncorhynchus kisutch</u>) and steelhead trout (<u>Salmo</u> <u>gairdneri</u>). J. Fish. Res. Bd. Can. 35(5):667-680.
- Chapman, D.W. 1962. Aggressive behavior in juvenile coho salmon as a cause of emigration. J. Fish. Res. Bd. Can. 19(6). Cited in Godfrey 1965.
- Davis, G.E., J. Foster, D.E. Warren, and P. Doudoroff. 1963. The influence of oxygen concentration on the swimming performance of juvenile Pacific salmon at various temperatures. Trans. Am. Fish. Soc. 92(2):111-124.
- Godfrey, H. 1965. Coho salmon in offshore waters. Pages 1-40 in Salmon of the North Pacific Ocean, Part 9. INPFC. Vancouver, Can.

- Gribanov, V.I. 1948. Coho (<u>Oncorhynchus kisulch Walb.</u>) (General Biology). Izvestia TINRO, Vol. 28. Transi. W.E. Ricker, Fish. Res. Bd. Can., Transl. Ser. 370. Cited in Godfrey 1965.
- Hall, J.E., and D.O. McKay. 1983. The effects of sedimentation on salmonids and macro invertebrates: literature review. ADF&G, Div. Habitat, Anchorage. Unpubl. rept. 31 pp.
- Hart, J.L. 1973. Pacific fishes of Canada. Fish Res. Bd. Can. Bull. 180. Ottawa, Can. 739 pp.
- Logan, S.M. 1967. Silver salmon studies in the Resurrection Bay area. Pages 83-102 in Annual report of progress 1966-1967. ADF&G, Fed. Aid in Fish Rest. Vol. 8. Proj. F-5-R-8, Job 7-B-1, Sport Fish Invest. of Alaska. Juneau.
- . 1968. Silver salmon studies in the Resurrection Bay area. Pages 117-134 in Annual report of progress 1967-1968. ADF&G, Fed. Aid in Fish Rest. Vol. 9. Proj. F-5-R-9, Job 7-B-1, Sport Fish Invest. of Alaska. Juneau.
- . 1969. Silver salmon studies in the Resurrection Bay area. Pages 131-149 in Annual report of progress 1978-1969. ADF&G, Fed. Aid in Fish Rest. Vol. 10. Proj. F-9-1, Job 7-B-1, Sport Fish Invest. of Alaska. Juneau. 383 pp.
- McPhail, J.D., and C.C. Lindsey. 1970. Freshwater fishes of northwestern Canada and Alaska. Fish. Res. Bd. Can. Bull. 173. Ontario, Can. 381 pp.
- Meehan, W.R., and D.B. Siniff. 1962. A study of the downstream migrations of anadromous fishes in the Taku River, Alaska. Trans. Am. Fish. Soc. 91(4):399-407.
- Middleton, K.R. 1983. Bristol Bay salmon and herring fisheries status report through 1982. Informational Leaflet No. 211. ADF&G, Div. Commer. Fish. 81 pp.
- Morrow, J.E. 1980. The freshwater fishes of Alaska. Anchorage, AK: Alaska Northwest Publishing Company. 248 pp.
- Neave, F. 1943. Diurnal fluctuation in the upstream migration of coho and spring salmon. J. Fish. Res. Bd. Can. 6(2):158-163.
- Netboy, A. 1974. The salmon: their fight for survival. Boston: Houghton Mifflin Company. 613 pp.
- Prakash, A., and D.J. Milne. 1958. Food as a factor affecting the growth of coho salmon off the east and west coast of Vancouver Island, B.C.

Fish. Res. Bd. Can., prog. rept. Pacific Coast Sta. 112:7-9. Cited in Morrow 1980.

- Pritchard, A.L., and A.L. Tester. 1944. Food of spring and coho salmon in British Columbia. Fish. Res. Bd. Can. Bull. 65. 23 pp. Cited in Scott and Crossman 1973.
- Reiser, D.W., and T.C. Bjornn. Influence of forest and rangeland management on anadromous fish habitat in western North America: habitat requirements of anadromous salmonids. USDA For. Serv. Gen. Tech. Rept. PNW-6, Pacific Northwest and Range Experiment Station, Portland, OR. 54 pp.
- Russell, R.B. 1984. Personal communication. Egegik-Ugashik Area Fisheries Mgt. Biologist, ADF&G, Div. Commer. Fish., King Salmon.
- Schwarz, L. 1985. Personal communication. Area Mgt. Biologist, ADF&G, Div. Commer. Fish., Nome.
- Scott, W.B., and E.J. Crossman. 1973. Freshwater fishes of Canada. Fish. Res. Bd. Can. Bull. 184. Ottawa, Can. 966 pp.
- Shaul, A. 1984. Personal communication. Alaska Peninsula-Aleutian Islands Area Fisheries Mgt. Biologist, ADF&G, Div. Commer. Fish., Kodiak.
- Smith, A.K. 1973. Development and application of spawning velocity and depth criteria for Oregon salmonids. Trans. Am. Fish. Soc. 102(2):312-316.
- Thompson, K. 1972. Determining stream flows for fish life. Pages 31-50 in Proceedings, instream flow requirement workshop. Pacific Northwest River Basin Comm., Vancouver, WA.



I. NAME

A. Common Names: Pink salmon, pinks, humpback salmon, humpy
 B. Scientific Name: Oncorhynchus gorbuscha

II. RANGE

A. Worldwide

Pink salmon are the most abundant of the Pacific salmon (Krueger 1981). In North America, pink salmon range from the Russian River, California, north through the Bering Strait, and east to the Mackenzie River in the Northwest Territories, Canada. In Asia, pink salmon occur from the Tumen and North Nandai rivers of North Korea and the island of Hokkaido, Japan, north to the Lena River, Siberia. They also occur in the Kurile, Commander, and Aleutian islands (Neave 1967).

B. Statewide

Pink salmon are widely distributed along coastal Alaska, with only a few in the Copper River delta and none in the upper Copper River drainage (ADF&G 1978; Roberson, pers. comm.). They typically ascend streams only short distances (65 km or less), and some spawn in the intertidal areas of short coastal streams (Bailey 1969. Scott and Crossman 1973). In larger river systems such as the Kuskokwim and Yukon, some may go as much as 160 km (Morrow 1980). They are known to move great distances in the Nushagak River drainage. Measuring from Picnic Point at the Wood River confluence with the Nushagak River, pink salmon have been documented about 230 km upstream in the Nuvakuk River and approximately 410 km upstream in the Mulchatna River (ADF&G 1984a). Studies on the Susitna River in Southcentral Alaska have found spawning pink salmon at least 223 km upstream (ADF&G 1981a). Regional Distribution Maps

- C. Regional Distribution Maps To supplement the distribution information presented in the text, a series of bluelined reference maps has been prepared for each region. Most of the maps in this series are at 1:250,000 scale, but some are at 1:1,000,000 scale. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of selected fish and wildlife species has been prepared and may be found in the Atlas that accompanies each regional guide.
- D. Regional Distribution Summary
 - 1. <u>Southwest</u>. In the Kodiak area, there are approximately 300 streams that produce pink salmon, although 60 to 85% of the total escapement is usually contained in 35 major river systems during odd-numbered years and in 47 of the major river systems during even-numbered years (Prokopowich, pers. comm.). These systems comprise the Kodiak area's index streams.

In the Bristol Bay area (for waters from Cape Newenham to Cape Menshikof and north-side Alaska Peninsula streams south to Cape Sarichef), the Nushagak District is the major pink salmon producer. Within the district, pink salmon spawn almost entirely in the Nuyakuk River, with smaller populations also found in the Wood, Igushik, Nushagak, and Mulchatna rivers. Occasionally, strong runs occur in the Kvichak, Alagnak (Branch), and Naknek rivers (Middleton 1983). Bechevin Bay streams occasionally produce strong pink salmon runs during even-numbered years (Shaul, pers. comm.). In south-side Alaska Peninsula streams and the Aleutian Islands, pink salmon are abundant and are found in manv drainages. In the Chignik area, there are approximately 75 salmon streams. In the south peninsula area, Mino Creek, Point, and Southern Creek on Deer Settlement Island occasionally produce one-half the total pink salmon run to the area. Two other streams (Apollo Creek and Middle Creek)

have the combined potential of producing another 500,000 to 62 million pink salmon in a good year, if waterfalls on these streams could be bypassed with fish-passage structures (ibid.). (For more detailed narrative information, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)

2. <u>Southcentral</u>. In the Northern and Central districts of the Upper Cook Inlet area the majority of the pink salmon are produced in the Lake Creek, Deshka, Talachulitna, Kenai, and Kasilof river drainages (ADF&G 1977b). In the Southern, Outer, and Kamishak districts of the Lower Cook Inlet area, the majority of the pink salmon are produced in the following locations: Humpy Creek, Tutka Lagoon, Seldovia Creek, Port Graham River, Windy Left River, Windy Right River, Rocky River, Port Dick Creek, Bruin Bay River, Big Kamishak River, Little Kamishak River, Amekedori Creek, Sunday Creek, and Brown's Peak Creek (ADF&G 1981b).

In Prince William Sound (PWS), the genetically unrelated odd-year and even-year pink salmon stocks have adapted differently to the use of the same spawning streams. The odd-year stocks use primarily upstream spawning sites, with 43 to 65% (average of 25.6%) selecting spawning sites above the high tide line, while even-year stocks are more oriented toward intertidal spawning areas, with only 23 to 28% (average of 25.6%) selecting spawning sites above high tide. With regard to spawning areas, PWS pink salmon may be generally catagorized as early, middle, and late spawning stocks, which are distributed by geographic zones associated with different temperature regimes. Early runs (about July 20 to August 5) are found in relatively few streams, primarily in the major fiords of the northern main land, Port Wells, Valdez Arm, Port Fidalgo, Port Gravina, and Sheep Bay. Middle runs (about August 6 to August 20) utilize most of the larger, cold, clear streams of the mainland districts and a few cold mountain streams of Knight and LaTouche islands. Late runs (about August 21 to September 10) occupy the majority of the streams used and include nearly all the island streams, mainland lake-fed streams, and mainland streams in which only intertidal zones are accessible to migrants (ADF&G 1978). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)

3. Arctic. In the Norton Sound area, pink salmon do not exhibit strong even-odd year fluctuations in abundance as they do in more southerly latitudes (ADF&G 1977c). Major pink salmon-producing systems in the Norton Sound District include the Unalakleet and Fish river drainages, and the Shaktoolik, Egavik, Inglutalik, Ungalik, Koyok, Tubutulik, Kwiniuk, Kachavik, Bonanza, Eldorado, Flambeau, Nome, Snake, Sinuk, Solomon, Kwik rivers (Schwarz, pers. comm.). Within the Port Clarence District, pink salmon have been documented in the Bluestone, Agiapuk, and Kuzitrin river systems (ADF&G 1984b).

Within the Kotzebue District, pink salmon have been documented in the Pinguk, Inmachuk, Kugruk, Buckland, Kobuk, Noatak, Tasaychek, Wulik, and Kivalina rivers and Fish Creek (ibid.).

The Northern District of the Arctic Region represents the most northern range of pink salmon in North America. Populations in the area are existing at the outer limits of their environmental tolerances, and their numbers are extremely limited (ADF&G 1977c). First-order streams (those whose mouths are at salt water) in which pink salmon have been documented include the Kukpuk, Pitmegea, Kukpowruk, Utukok, Kokolik. Chipp, Ikpikpuk, Fish, Colville. Sagavanirktok, Staines, and Canning rivers (ADF&G 1984b). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Arctic Region.)

III. PHYSICAL HABITAT REQUIREMENTS

- A. Aquatic
 - 1. Water quality:
 - a. <u>Temperature</u>. Pink salmon in Southeast Alaska have been observed to spawn in water temperatures ranging from 7.4 to 18.3°C (Sheridan 1962). The preferred range appears to be 7.2 to 12.8°C (Krueger 1981).

Egg hatching rates are influenced by water temperature; abnormally warm or cold water can accelerate or depress developmental rates and cause premature or delayed fry Laboratory tests have shown that eggs emergence. 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, juveniles 14°C that preferred 12 however. to temperatures.

- b. <u>The pH factor</u>. 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. <u>Dissolved oxygen (D.O.)</u>. From laboratory experiments, Bailey et al. (1980) recommend that for successful
development of pink salmon eggs and alevins the D.O. level should exceed 6.0 mg/l. Dissolved oxygen levels below 6.0 mg/l apparently cause premature emergence, decreased size, and low survival (ibid.).

State of Alaska water quality criteria for growth and propagation of fish state that "D.O. shall be greater than 7 mg/l in waters used by anadromous and resident fish. Further, in no case shall D.O. be less than 5 mg/l to a depth of 20 cm in the interstitial waters of gravel utilized by anadromous or resident fish for spawning . . . In no case shall D.O. above 17 mg/l be permitted. The concentration of total dissolved gas shall not exceed 110% of saturation at any point of sample collection" (ibid.).

- d. Turbidity. Sedimentation causes high mortality to eggs and alevin by reducing water interchange in the redd. If 15 to 20% of the intragravel spaces become filled with sediment, salmonoid eggs have suffered significant (upwards of 85%) mortality (Bell 1973). Prolonged exposure to turbid water causes gill irritation in juveniles, which can result in fungal and pathogenic bacterial infection. Excess turbidity from organic materials in the process of oxidation may reduce oxygen below safe levels, and sedimentation may smother food organisms and reduce primary productivity (ibid.). Turbid water will absorb more solar radiation than clear water and may thus indirectly raise thermal barriers to the adult's upstream spawning migration (Reiser and Bjornn 1979).
- 2. Water quantity:
 - a. <u>Instream flow</u>. 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. <u>Substrate</u>. Pink salmon spawn over a variety of substrates ranging widely in size and composition. Adults generally select areas with a relatively low gradient combined with beds of small-to-medium-size gravel (1.3 to 10 cm diameter) (Neave 1966, Scott and Crossman 1973, Krueger 1981). Egg and alevin development is influenced by substrate composition because increased amounts of small material (fines) can reduce intragravel water flow. McNeil and Ahnell (1964), from studies in Southeast Alaska, concluded that productive pink salmon streams generally contained fines (0.833 mm diameter) contributing less than 5% of the volume of the substrate. They also found that less productive streams were characterized by 15% or more fines in the substrate.
- B. Terrestrial
 - 1. <u>Conditions providing security from other predators or</u> <u>disturbances</u>. 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. <u>Conditions providing protection from natural elements</u>. Because pink salmon remain in fresh water for a very short time after emergence from the substrate, no data are available concerning protection from natural elements for free-swimming juveniles.
- IV. NUTRITIONAL REQUIREMENTS
 - A. Food Species Used

Upon hatching, young alevin remain in the gravel for several weeks until the yolk sac has been absorbed. Immediately upon emerging from the gravel, juveniles begin migrating downstream (Scott and Crossman 1973). Migrating juveniles generally do not feed; if the distance to the sea is great, however, they may feed on nymphal and larval insects (ibid.). Studies in Lake Aleknagik and Tikchik Lake in the Bristol Bay area, however, indicate differences in the early life history of pink salmon that spawn in a lake system from those that spawn in coastal rivers. Rogers and Burgner (1967) state that "in coastal rivers, the fry migrate to salt water upon emergence from the gravel. They are then about 30 mm long. The young fry obtain little food from the freshwater environment and subsist largely on the yolk. In the Wood River lakes and Tikchik Lake, the fry must travel some distance to reach the outlet rivers (96 km in the case of Agulukpak River fry); and it is guite apparent that they feed actively during the course of their travel." In addition, it was found that some of the juvenile pink salmon remained in Lake Aleknagik long after emergence, were

caught in tow net samples as late as September 10, and had grown to mean lengths of 89 mm (ibid.). An examination of stomach contents taken from Lake Aleknagik fry during July 1-8, 1967, revealed that zooplankton (i.e., <u>Bosmina</u>, <u>Daphnia</u>, <u>Holopedium</u>, Cyclopoida, and Calanoida) made up the bulk of the food (ibid.). In nearshore salt water, the juveniles consume small crustaceans (e.g., copepods, euphausiids, amphipods, ostracods), larvae of decapods, cirripeds and tunicates, and dipterous insects (Neave 1966). As they grow, the diet consists of larger items until, during their final summer in the high seas, the diet consists of many organisms, the most important being euphausiids, amphipods, fish, squid, copepods, and pteropods (ibid.).

B. Types of Feeding Areas Used

Because pink salmon spend such a short time in natal waters following emergence from the gravel, little data are available on freshwater feeding locations. Samples of pink salmon fry in Lake Aleknagik indicate that although they were caught in the lake littoral zone (inshore), their stomach contents indicated that they had foraged mainly in the pelagic zone of the lake (Rogers and Burgner 1967). Juvenile pink salmon school in estuarine waters and frequent the water's edge along mainland and inland shores (Neave 1966). They remain in nearshore areas for about a month, and when they have attained a length of 6 to 8 cm they begin a gradual, irregular movement to offshore waters. On the high seas, pink salmon vertical distribution has been found to range from 10 to 23 m (Takagi et al. 1981), although a few have been caught at depths from 24 to 36 m (Neave 1966).

- C. Factors Limiting Availability of Food Because pink salmon feed very little if at all in fresh water, the major factors limiting food availability would be those found in the estuarine environment. Variations in weather patterns and ocean currents, which affect dispersal of planktonic organisms, could influence food sources for juvenile pink salmon.
- D. Feeding Behavior

Pink salmon select their food by sight and swallow it whole (Bailey 1969). In offshore marine waters, pink salmon appear to have a vertical feeding pattern, with light intensity the major factor. Studies by Shimazaki and Mishima (1969) show that feeding indices of pink salmon near surface waters began to increase before sunset, attained a maximum two to three hours after sunset, and thereafter decreased to a minimum before sunrise. The feeding indices again became large in daytime. Whereas the dominant organisms of the stomach contents before sunset were large prey animals such as squids and fish larvae, the percentage of amphipods (whose numbers increased in surface waters with darkness), as well as feeding indices, increased after sunset, when amphipods became the main item of diet. Shimazaki and Mishima (ibid.) concluded that darkness prevented pink salmon from seeing and feeding on amphipods.

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Pink salmon spawning takes place in a variety of locations. Neave (1966) states: "In some instances spawning takes place in stream mouth areas where water levels change with the tides and where varying degrees of salinity are experienced. In small coastal streams the upstream limit is usually defined by a waterfall situated within a few miles of the sea. In larger rivers without major obstructions, the end-point may be less definite. The grounds that are intensively occupied by pink salmon tend to have a relatively low gradient."

B. Reproductive Seasonality

In Alaska, pink salmon ascend freshwater streams from June to late September, depending largely on location. Spawning takes place in mid July in the lower Yukon but generally not until late August to October in areas to the south (Morrow 1980).

C. Reproductive Behavior

As with other salmon, adult pink salmon return from the sea and move into their natal freshwater streams to spawn. There is, however, a degree of wandering. Adults have been taken in spawning streams as much as 643 km from their original stream. The female selects the spawning site and digs the redd (nest) by turning on her side and thrashing her tail up and down. The current washes loosened substrate material downstream, and a depression up to 45.7 cm deep is formed in the river bottom (ibid.). Eggs and sperm (milt) are released simultaneously and deposited in the redd. After egg deposition, the female moves to the upstream margin of the redd and repeats the digging process. Dislodged substrate is washed over the eggs. In this manner the eggs are covered and prevented from washing away. The process is repeated many times, and the redd appears to move upstream (Burner 1951). As a result of the continued digging, the redd may grow to become 0.9 m in length (Morrow 1980). A female may dig several redds and spawn with more than one male (McPhail and Lindsey 1970). Males may also spawn with several females (Neave 1966).

- D. Age at Sexual Maturity Unlike the other Pacific salmon, the pink salmon matures in two years. Though rare three-year-old fish have been found, it is probable that they are sterile (Morrow 1980).
- E. Fecundity

The number of eggs carried by pink salmon entering the spawning area varies with the size of the female, the area, and the year (Scott and Crossman 1973). Each female may produce as few as 800 or as many as 2,000 eggs (Morrow 1980), with the average estimated at 1,500 to 1,900 (Scott and Crossman 1973). In general, larger fish have more eggs, but fish from small runs are said to be more fecund than those of the same size from large populations (Nikolskii 1952).

- F. Frequency of Breeding As with all Pacific salmon, the spawning cycle is terminal. Both male and female die after spawning.
- G. Incubation Period/Emergence
 - The amount of time required for eggs to hatch is dependent upon many interrelated factors, including 1) dissolved oxygen, 2) water temperature, 3) apparent velocity in gravel, 4) biological oxygen demand, 5) substrate size (limited by percentage of small fine material), 6) channel gradient, 7) channel configuration, 8) water depth, 9) surface water discharge and velocity, 10) permeability, 11) porosity, and 12) light (Reiser and Bjornn 1979, Hart 1973). Generally speaking, factors 4 through 12 influence/regulate the key factors 1, 2, and 3.

Egg development requires from 61 to about 130 days, depending largely on temperature (Morrow 1980). The young hatch from late December through February and remain in the gravel until April or May.

- VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS
 - A. Size of Use Areas

From studies of Columbia River tributaries, Burner (1951) suggests that a conservative figure for the number of pairs of salmon that can satisfactorily utilize a given area of spawning gravel may be obtained by dividing the area by four times the average size of the redds. The redd area can be computed by measuring the total length of the redd (upper edge of pit to lower edge of tailspill) and the average of several equidistant widths (Reiser and Bjornn 1979). No documented information on the average size of pink salmon redds in Alaska was found in the preparation of this report.

B. Timing of Movements and Use of Areas

Pink salmon fry emerge from the gravel at night and begin their downstream migration to the sea (Bailey 1969). During July of 1967, small schools of pink salmon fry were observed migrating upstream along shore through the narrows between Tikchik Lake and Nuyakuk Lake in company with larger sockeye fry and yearlings. This behavior is unusual for pink salmon (Rogers and Burgner When the distance to the sea is short, they reach the 1967). 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

Southeastern, Southcentral, and Southwestern (south-side Alaska Peninsula) stocks. The oceanic migrations of stocks of pink salmon originating in Southeast, Southcentral, and Southwest Alaska (south-side Alaska Peninsula) are similar enough to be treated as one. Generally speaking, these stocks are found in the North Pacific and Gulf of Alaska in an area bounded on the west by about longititude 165°W, on the south by latitude 42°N, and on the east and north by the North American continent. Juveniles from Southeast Alaska in their first marine summer and fall move generally northwestward but likely do not move far offshore. Juveniles from Southcentral and Southwest Alaska (south of the Alaska Peninsula) in their first marine summer and fall move southwestward along the Alaska Peninsula. Some juveniles from Southeast Alaska may move west and join the Southcentral and Southwestern stocks in this area.

Juvenile pink salmon are distributed farther offshore in the north Gulf of Alaska than they are off Southeast Alaska, which may indicate that offshore dispersion begins in the north-central Gulf of Alaska. No adequate measurements of offshore dispersion have been made south of the Alaska Peninsula.

Assumed migrations during the late fall and winter of their first year at sea indicate that the young pink salmon are farther 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.

 Southwestern (north-side Alaska Peninsula). Very little information is available concerning pink salmon marine migrations from stocks in Western and Southwest Alaska (north of the Alaska Peninsula). No data are available on seaward migrations of the juveniles during their first summer. From small numbers of tag returns of maturing adults it is supposed that these stocks are found in an area bounded on the west by 180° in the Bering Sea. They may also be found south of the eastern and central Aleutian Islands south to about latitude 50°N and thence southeasterly to about longitude 140°W at latitude 48°N. They probably do not extend beyond 54°N in the North Pacific.

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

The greatest natural mortality of pink salmon occurs during the early life stages. Bailey (1969) states that, in streams, less than 25% of the eggs survive from the time of spawning to the time of emergence from the gravel; he lists the principle causes of death of the eggs as 1) digging in the redds by other females, 2) low oxygen supply because of low stream flows or impairment of water circulation within the streambed, 3) dislodgement of eggs by floods, 4) freezing of eggs during periods of severe and prolonged cold, and 5) predation by other fish.

Juveniles are preyed upon by a variety of fishes (e.g., cutthroat and rainbow trout, Dolly Varden, coho salmon smolts, squawfish, and sculpins), kingfisher, mergansers, and other predaceous birds and mammals. Morrow (1980) states that mortality during early sea life (first 40 days) is fairly high at 2 to 4% per day, where predation by birds, fishes, and various invertebrates may be an important factor in mortality at this time. Adults at sea are preyed upon by man, marine mammals, Pacific and arctic lamprey, and to a lesser extent by large fish (Scott and Crossman 1973). Sea survival rates are highly variable and have been computed at about 2 to 22% and probably average 5% (Morrow 1980).

B. Human-related

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

- Alteration of preferred water temperature, pH, dissolved oxygen, and chemical composition
- ° Alteration of preferred water velocity and depth
- ° Alteration of preferred stream morphology
- [°] Increase in suspended organic or mineral material
- Increase in sedimentation and reduction in permeability of substrate
- ° Reduction in food supply
- Reduction in protective cover (e.g., overhanging stream banks or vegetation)
- Shock waves in aquatic environment
- Human harvest

(For additional impacts information, see the Impacts of Land and Water Use volume of this series.)

VIII. LEGAL STATUS

A. Managerial Authority

The Alaska Department of Fish and Game manages fresh waters of the state and marine waters to the 3-mi limit. The North Pacific Fishery Management Council is composed of 15 members, 11 voting and 4 nonvoting members. The 11 are divided as follows: 5 from Alaska, 3 from Washington, and 3 from state fishery agencies (Alaska, Washington, Oregon). The four nonvoting members include the director of the Pacific Marine Fisheries Commission, the director of the U.S. Fish and Wildlife Service. commander of the 17th Coast the Guard District. and a representative from the U.S. Department of State. The council prepares fishery management plans, which become federal law and apply to marine areas between the 3-mi limit and the 200-mi limit. With regard to salmon, the only plan prepared to date is the Salmon Power Troll Fishery Management Plan. The International North Pacific Fisheries Commission (INPFC) а convention comprised of Canada, Japan, and the United States, has been established to provide for scientific studies and for coordinating the collection, exchange, and analysis of scientific data regarding anadromous species. With regard to salmon, the INPFC has also prepared conservation measures that limit the location, time, and number of fishing days that designated high seas areas (beyond the 200-mi limit) may be fished by Japanese nationals and fishing vessels.

IX. LIMITATIONS OF INFORMATION

Limited life history and habitat information concerning Alaskan pink salmon has been collected/published. Most of the available information has been documented from Pacific Northwest and Canadian field laboratory studies.

X. SPECIAL CONSIDERATIONS

Neave (1966) states: "Schools of adult pink salmon often frequent bays and estuaries for days and even weeks before entering the streams. Fish tagged at this stage still show movements away from, as well as towards, the nearest spawning grounds. It appears, therefore, that spawning populations are not necessarily well segregated until actual entrance into the spawning streams."

Because of the two-year life cycle, returns of spawning adults are predictable by highly segregated even-numbered year and odd-numbered year runs. Both types of runs, or races, may use the same stream, or one or the other may predominate in a particular river (Scott and Crossman 1973). Some streams with a dominant run of one type have a very much smaller off-year run of the other race; they often utilize different tributaries as spawning grounds. There may be a significant difference in the date of return and in the length and weight of individuals of the two races or of the same race in different spawning rivers (ibid.). In addition, caution must be used when extending information from one stock of pink salmon to another stock. Environmental conditions for one area must not be treated as absolute; the stocks (races) have acclimated/evolved over time and space to habitat conditions that can vary greatly. The distribution and abundance narrative for the salmon species,

presented by ADF&G commercial fisheries management areas, follows the aggregated salmon life histories.

REFERENCES

ADEC. 1979. Water quality standards. Juneau. 34 pp.

ADF&G, comp. 1977a. A fish and wildlife resource inventory of the Alaska Peninsula, Aleutian Islands, and Bristol Bay areas. Vol. 2: Fisheries. [Juneau.] 557 pp.

_____. 1977b. A fish and wildlife inventory of the Cook Inlet-Kodiak areas. Vol. 2: Fisheries. [Juneau.] 443 pp.

_____. 1977c. A fish and wildlife resource inventory of western and arctic Alaska. Vol. 2: Fisheries. [Juneau.] 340 pp.

_____. 1978. A fish and wildlife resource inventory of the Prince Willam Sound area. Vol. 2: Fisheries. [Juneau.] 241 pp.

ADF&G. 1981a. Juvenile anadromous fish study on the lower Susitna River. ADF&G Susitna Hydro Aquatic Studies. Phase 1: Final draft rept. Anchorage, AK.

. 1981b. Lower Cook Inlet annual management report. Div. Commer. Fish. 99 pp.

_____. 1984a. An atlas to the catalog of waters important for spawning, rearing, and migration of anadromous fishes, Southwestern Resource Management Region III. Div. Habitat, Anchorage. 5 pp. + maps.

______. 1984b. An atlas to the catalog of waters important for spawning, rearing, and migration of anadromous fishes, Arctic Resource Management Region IV. Div. Habitat, Anchorage. 5 pp. + maps.

- Bailey, J.E. 1969. Alaska's fishery resources the pink salmon. USFWS, Bureau Commer. Fish., Fishery Leaflet No. 619. 8 pp.
- Bailey, J.E., and D.R. Evans. 1971. The low temperature threshold for pink salmon eggs in relation to a proposed hydroelectric installation. USFWS, Fish. Bull. 69(3):487-593. Cited in Krueger 1981.
- Bailey, J.E., S. Rice, J. Pella, and S. Taylor. 1980. Effects of seeding density of pink salmon, <u>Onchorhynchus gorbuscha</u>, eggs on water

chemistry, fry characteristics and fry survival in gravel incubators. USFWS, Fish. Bull. 78:649-658. Cited in Krueger 1981.

- Bell, M.C. 1973. Fisheries handbook of engineering requirements and biological criteria. Fisheries Engineering Research Program, Corps of Engineers, North Pacific Div. Portland, OR. Approx. 500 pp.
- Brett, J.R. 1952. Temperature tolerance in young Pacific salmon, genus Oncorhynchus. J. Fish. Res. Bd. Can. 9(6):265-322.
- Burner, C.J. 1951. Characteristics of spawning nests of Columbia River salmon. USFWS, Fish. Bull. 61(52):97-110.
- Hart, J.L. 1973. Pacific fishes of Canada. Fish. Res. Bd. Can. Bull. 180. Ottawa, Can. 739 pp.
- Hoar, W.S. 1956. The behavior of migrating pink and chum salmon fry. J. Fish. Res. Bd. Can. 13(3):309-325. Cited in Morrow 1980.
- Krueger, S.W. 1981. Freshwater habitat relationships pink salmon (<u>Oncorhynchus gorbuscha</u>). ADF&G, Div. Habitat, Resource Assessment Branch, Anchorage. 45 pp.
- McPhail, J.D., and C.C. Lindsey. 1970. Freshwater fishes of northwestern Canada and Alaska. Fish. Res. Bd. Can. Bull. 173. Ontario, Can. 381 pp.
- Middleton, K.R. 1983. Bristol Bay salmon and herring fisheries status report through 1982. Informational Leaflet No. 211. ADF&G, Div. Commer. Fish. 81 pp.
- Morrow, J.E. 1980. The freshwater fishes of Alaska. Anchorage, AK: Alaska Northwest Publishing Company. 248 pp.
- Neave, F. 1955. Notes on the seaward migration of pink and chum salmonfry. J. Fish. Res. Bd. Can. 12(3):369-374. Cited in Morrow 1980.
- _____. 1966. Chum salmon in British Columbia. INPFC Bull. 18. Vancouver, Can. 86 pp.
- Nikolskii, G.V. 1952. O tipe dinauriki stada i kharaktere neresta gorbushi o.g. (walb.): keti o.k. (walb) v Amure. Doklady Adad. Nauk USSR 86(4). Israel Prog. Sci. Transl. 538 pp. Cited in Morrow 1980.
- Prokopowich, D. 1983. Personal communication. Kodiak Area Asst. Fisheries Mgt. Biologist, ADF&G, Div. Commer. Fish., Kodiak.
- Reiser, D.W., and T.C. Bjornn. 1979. Influence of forest and rangeland management on anadromous fish habitat in western North America habitat requirements of anadromous salmonids. USDA, Forest Service

Gen. Tech. Rept. PNW-6, Pacific Northwest Forest and Range Experiment Station. Portland, OR. 54 pp.

- Rogers, D.E., and R.L. Burgner. 1967. Nushagak district salmon studies.
 Pages 12-14 in J.R. Matches and F.B. Taub, eds. Research in fisheries
 1967. Contribution No. 280. College of Fisheries, Fisheries
 Research Institute, Univ. Wash., Seattle, WA. 82 pp.
- Schwarz, L. 1985. Personal communication. Area Mgt. Biologist, ADF&G, Div. Commer. Fish., Nome.
- Scott, W.B., and E.J. Crossman. 1973. Freshwater fishes of Canada. Fish. Res. Bd. Can. Bull. 184. Ottawa, Can. 966 pp.
- Shaul, A. 1984. Personal communication. Alaska Peninsula-Aleutian Island Area Fisheries Mgt. Biologist, ADF&G, Div. Commer. Fish., Kodiak.
- Sheridan, W.L. 1962. Relation of stream temperatures to timing of pink salmon escapements in Southeast Alaska. Pages 87-102 in N.J. Wilimovsky, ed. H.R. MacMillian lectures in fisheries: symposium on pink salmon. 1962. Institute of Fisheries, Univ. Brit. Col., Vancouver. 226 pp.
- Shimazaki, K., and S. Mishima. 1969. On the diurnal change of the feeding activity of sockeye salmon in the Okhotsk Sea. Hokkaido Univ., Facul. Fish., Bull. 20(2):82-93. (In Japanese, English summary.) Cited in Takagi et al. 1981.
- Takagi, K., K.V. Aro, A.C. Hartt, and M.B. Dell. 1981. Distribution and origin of pink salmon (<u>Oncorhynchus gorbuscha</u>) in offshore waters of the North Pacific Ocean. INPFC. Bull. 40. Vancouver, Can. 195 pp.
- Thompson, K. 1972. Determining stream flows for fish life. Pages 31-50 in Proceedings, instream flow requirement workshop. Pacific Northwest River Basin Commission, Vancouver, WA.



Sockeye Salmon Life History and Habitat Requirements Southwest, Southcentral, and Arctic Alaska

Map 1. Range of sockeye salmon (Morrow 1980)

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, sockeye salmon are found from northern Hokkaido, Japan, to the Anadyr River in northeastern Siberia (Scott and Crossman 1973).

B. Statewide

The sockeye salmon is found in stream and river drainages from Southeast Alaska to Point Hope, Alaska. Spawning rivers are usually those with lakes in their systems (Hart 1973).

C. Regional Distribution Maps

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

D. Regional Distribution Summary

1. <u>Southwest</u>. In the Kodiak area, major sockeye salmon spawning and rearing waters include the Karluk, Red (or Ayakulik) River, and Upper Station systems. The Fraser Lake and Akalura Lake systems are growing in productivity (ADF&G 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 salmon-producing waters include the Togiak, Igushik, Snake, Wood, Nushagak, Kvichak, Alagnak (or Branch), Naknek, Egegik, Ugashik, and Bear river systems. Other important runs are located at Nelson Lagoon, Sandy River, Ilnik, and Urilla Bay (ADF&G 1977b).

In the waters draining the south side of the Alaska Peninsula and the Aleutian Islands are found numerous small runs of sockeye salmon. On the south peninsula, Thin Point and Orzinski lakes are important producers of sockeye salmon (Shaul, pers. comm.). The most significant Aleutian Island run is at Kashega on Unalaska Island. In the Chignik area, almost all are found in the Chignik River system (ADF&G 1977b), although there are several other minor systems in the area (Shaul, pers. comm.). (For more detailed narrative information, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)

- 2. <u>Southcentral</u>. In the Northern and Central districts of Cook Inlet, the majority of the sockeye salmon are produced in the Kasilof, Kenai, Susitna, and Crescent rivers and Fish Creek (Big Lake) systems (ADF&G 1982). In Lower Cook Inlet, systems producing smaller runs of sockeye salmon are the English Bay Lakes, Leisure Lake, Amakdedori, and Mikfik creeks, and Aialik, Delight, and Desire lakes (ADF&G 1981; Shroeder, pers. comm.). In the Prince William Sound area, the Copper River drainage is the major producer of sockeye salmon, with runs also found in the Bering, Eshamy, and Coghill systems (ADF&G 1978). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)
- 3. <u>Arctic</u>. Sockeye salmon are rare in the Norton Sound District and have been documented in only two first-order systems

(those with mouths at salt water). These are the Cripple and Sinuk (Sinrock) river systems (ADF&G 1984).

In the Port Clarence District, sockeye salmon are found in the Pilgrim River-Salmon Lake-Grand Central River complex of the Kuzitrin River system (ADF&G 1977d, 1984).

Within the Kotzebue District, sockeye salmon have been found in the Noatak and Kivalina rivers, Rabbit Creek, and Kelly Lake (ADF&G 1984).

The presence of sockeye salmon has not been documented in Northern District waters.

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

- III. PHYSICAL HABITAT REQUIREMENTS
 - A. Aquatic
 - 1. Water quality:
 - a. <u>Temperature</u>. 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 out-migration from freshwater nursery lakes takes place between 4 to 7°C (Hart 1973). Adult spawning has occurred in temperatures ranging from

3 to 10°C (McLean et al. 1977, Scott and Crossman 1973.) Water temperatures of 20°C and more have caused death in upstream-migrating adult sockeye (Foerster 1968).

- b. <u>The pH factor</u>. 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. <u>Dissolved oxygen (D.O.)</u>. 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."

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. <u>Instream flow</u>. 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. <u>Substrate</u>. 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. <u>Conditions providing security from predators or other dis-</u> turbances. No information was found in the literature.
 - 2. <u>Conditions providing protection from natural elements</u>. Gravel over fertilized eggs provides protection from surface ice and sunlight.
- **IV. NUTRITIONAL REQUIREMENTS**
 - A. Food Species Used

Upon hatching, young alevin remain in the gravel for several weeks until the yolk sac is absorbed. After emerging from the gravel, they usually swim to a lake to begin feeding. Juveniles, during their first few weeks in the nursery lake, feed largely on ostracods, cladocerans (water fleas), insects, and insect larvae (Morrow 1980, Hart 1973, Foerster 1968). After moving to deeper water, the young sockeye salmon become pelagic and feed on plankton in the upper 20 m or so. The major summer food items are copepods (Morrow 1980).

While in salt water, young sockeye salmon near shore eat insects, small crustaceans or zooplanktons (e.g., copepods, amphipods, decapods, barnacle larvae, ostracods, and euphausiids), and such young fishes and larvae as sand lance, bigeye whiting, rockfishes, eulachon, starry flounder, herring, prickle backs, and hake (Hart 1973).

On the high seas, the growing fish consume ever larger prey, which includes such crustaceans as euphausiids, amphipods, and copepods and also includes squids and young fishes (ibid.).

B. Types of Feeding Areas Used

When they first enter the nursery lake, sockeye salmon juveniles feed along the shore for a few weeks but soon move out over the deeper water in the body of the lake, where they are concentrated in the top 10 or 20 m but may be found as deep as 40 m or more (ibid.). In the Wood River system, Bristol Bay area, Alaska, Burgner (1958) reports that "while the fry do leave the rivers between lakes soon after emergence, downstream migration of fry in most of the tributary creeks is not completed for some time after breakup of the lake ice. In many creeks a portion of the fry population remains to feed and sometimes the fry acquire considerable growth before entering the lake. Sockeye fry in the Wood River lakes are observed in abundance along the lake shores for at least a month after breakup of the lake ice. When the lake level is high early in the season they are to be found in droves in flooded grass along protected areas of the lake shore." After migrating to salt water, the young sockeye salmon at first stay fairly close to shore (within 50 km) (Morrow 1980, Hart 1973, French et al. 1976), although they are not seen regularly near shore for several weeks during the summer, as young pink salmon and chum salmon are (Ricker 1966).

As the young sockeye salmon get bigger and stronger, they head out to sea. Vertical distribution studies discussed by French et al. (1976) show that sockeye salmon occupy depths to at least 61 m and may go deeper; most catches (90%), however, were within 15 m of the surface. These studies also suggest that the thermocline may limit the depth to which sockeye salmon descend.

Morrow (1980) states that the area bounded on the north by the Aleutians, on the south by 50° north latitude, on the west by 165 to 170° east longitude, and on the east by 160° west longitude is an important late spring, summer, and autumn feeding area. By late winter, the sockeye salmon have left this area and are found in a broad band across the north Pacific south of 50°N.

C. Factors Limiting Availability of Food

The well-being and growth of young sockeye salmon depend primarily on 1) the abundance of the food organisms on which they subsist, 2) the numbers of young sockeye present, and 3) the numbers of other species of fish in the lake that compete with sockeye for food (Foerster 1968). Further, temperature conditions, water transparency, and chemical conditions (particularly the amounts of nitrates, nitrites, phosphates, and silicates) all have a direct influence on the production of plankton populations, which are the main food of the young fish (ibid.).

D. Feeding Behavior Juveniles in nursery lakes feed in schools (Hartman 1971). Maturing sockeye salmon stop feeding as they near fresh water, and the spawning fish derive nourishment from oils and proteins of their flesh, skeletal structures, and scales (ibid.).

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Spawning occurs primarily in streams that connect with lakes (Morrow 1980), although some populations spawn along lake shore beaches and island beaches in lakes (Morrow 1960, McPhail 1966), and other populations spawn in streams with slow-moving reaches but no lakes in the system (Morrow 1980; Roberson, pers. comm.). Factors determining the selection of spawning sites are variable and include stream gradient, water depth and velocity, and the size of the streambed materials (substrate). Spawning sites are usually selected where there is a good waterflow through the gravel (ADF&G 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."

During 1965, a study of Iliamna Lake revealed that island beaches used for spawning showed no evidence of upwelling water; apparently the eggs are washed by means of wind-caused lake currents (McPhail 1966).

B. Reproductive Seasonality

In Alaska, adult sockeye salmon ascend their natal streams from early May to October, depending on the geographic location (Morrow 1980; ADF&G 1977a; Roberson, pers. comm.). Region-specific runtiming and spawning-time information is presented in the salmon Distribution and Abundance narratives prepared for each of the regions addressed in this series of publications.

In general, fish breeding in lakes and their outlet streams spawn later than those spawning in streams (ADF&G 1977a). This breeding characteristic, however, is by no means universal (Morrow 1980). Roberson (pers. comm.) notes that several factors affect the periods that have evolved to become the spawning times of different populations of sockeye salmon. Among these factors are the average water temperatures during egg incubation and alevin development, the feeding potential upon emergence from the gravel, and water temperature and velocity during adult migration.

A few exceptions to the general spawning-time characteristics mentioned above are found in Upper Mendeltna Creek (outlet stream of Old Man Lake), where spawning occurs early and spawners are dead by June 30; in Dickey Lake (at the headwaters of the Middle Fork of the Gulkana River), where spawning occurs early and spawners are dead by July 30; and in the Gulkana River Springs, where spawning occurs late and spawners are dead by late November (ibid.). Likewise, the general timing characteristics do not hold true for Bear Lake on the north side of the Alaska Peninsula or for Chignik Lake on the south side of the Alaska Peninsula (Shaul, pers. comm.).

C. Reproductive Behavior

As with other salmon, adult sockeye return from the sea and move into their natal freshwater streams or lakes to spawn. The female selects the spawning site and digs the redd (nest) by turning on her side and thrashing her tail up and down. The current washes loosened substrate material downstream, and a depression 35 to 41 cm deep is formed in the river bottom (Hartman 1971, Morrow 1980). Eggs and sperm (milt) are released simultaneously and deposited in the redd. After eqq 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 tail spill) and the average of several equidistant widths (Reiser and Bjornn 1979). Information obtained by Mathisen (cited in Foerster 1968) from observations in Pick Creek, Wood River system, Bristol Bay area, Alaska, shows that under competitive conditions for space each female usually manages to average $3.7~m^2$ as spawning territory. When competition for space is eliminated, each female occupies an average area of 6.97 m². The ADF&G (1977a) states that a redd (presumably in Alaska) generally averages 1.75 m² in stream-spawning areas. No specific data on redd size in Alaskan lake-spawning areas was found during literature review.

Β. Timing of Movements and Use of Areas In Alaska, alevins emerge from the gravel during the period April to June (Morrow 1980) and are light-sensitive, tending to hide in the stones and gravel of the stream bottom by day and coming out at night. In a few populations, the fry go to sea during their first summer, but the vast majority spend one or two years (in rare cases three or four years) in a lake (ibid.). After the juveniles emerge from the gravel in lake tributaries, those in inlet streams go downstream to the lake, and those in outlet streams swim upstream to the lake. They migrate singly at night and thus minimize the dangers of predation (Hartman 1971). Once in the lake, the juveniles move about in schools and stay close to shore for the first few weeks before moving to deeper water. In over 30 streams of the Copper River drainage, young sockeye salmon stay in the stream and move to slow-moving sections of the river because no lake is available in the system (Roberson, pers. comm.) After a year in the lake, often two years and sometimes three years in many Bristol Bay areas (Bucher, pers. comm.), smoltification occurs (the young fish lose their parr marks and turn silvery), and they migrate downstream. Most of the migrants move at night (Morrow 1980), the migration apparently being triggered when the nursery lake's temperature approaches 4°C. The peak of the Bristol Bay out-migration occurs during June. 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-towest 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 $(2-3^{\circ})$ north of their first year's southern limit. In June, the spawning migration toward Bristol Bay occurs over a broad front from about 166°E to near 140°W.

Sockeye salmon stocks from the Alaska Peninsula (south-side streams), Southcentral, and Southeast Alaska generally mix during their residence in the northeastern Pacific Ocean. Depending on origin, they move northward, westward, or southward in a general counter-clockwise pattern along the coast as age .0 juveniles. By January, the age .1 fish have moved generally west and south into feeding grounds well offshore. In the spring (June), a northerly movement begins, and by July they are widely spread throughout the northeastern Pacific Ocean. By late summer, migration is westward and southwestward until their distribution lies probably west of 145°W and north of 49°N (some may go as far west as 177°E during their second summer at sea). In the fall, the fish turn southward and eastward and by mid winter occupy an area from near 140°W to 165°W. There is some separation of age groups of fish at this time: the maturing fish age .2, the ones that will spawn the next season, tend to be in more northern areas of the winter range in the northeastern Pacific Ocean. In the spring, the maturing fish migrate northerly, easterly, and westerly from an area generally east of 160°W and north of 46°N towards their respective spawning streams. The circuit is repeated for those sockeye that remain in the marine environment for three and, rarely, four years.

VII. FACTORS INFLUENCING POPULATIONS

Natural Α.

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.).

Β. 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)
- ² Shock waves in aquatic environment
- Human harvest

(For additional impacts information see the Impacts of Land and Water Use volume of this series.)

VIII. LEGAL STATUS

A. Managerial Authority

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

The North Pacific Fishery Management Council is composed of 15 members, 11 voting and 4 nonvoting members. The 11 are divided as follows: 5 from Alaska, 3 from Washington, 3 from state fishery agencies (Alaska, Washington, Oregon). The four nonvoting members include the director of the Pacific Marine Fisheries Commission, the director of the U.S. Fish and Wildlife Service, the commander of the 17th Coast Guard District, and a representative from the U.S. Department of State. The council prepares fishery management plans, which become federal law and apply to marine areas between the 3-mi limit and the 200-mi limit. With regard to salmon, the only plan prepared to date is the Salmon Power Troll Fishery Management Plan.

The International North Pacific Fisheries Commission (INPFC), a convention comprised of Canada, Japan, and the United States, has been established to provide for scientific studies and for coordinating the collection, exchange, and analysis of scientific data regarding anadromous species.

With regard to salmon, the INPFC has also prepared conservation measures that limit the location, time, and number of fishing days that designated high seas (beyond the 200-mi limit) areas may be fished by Japanese nationals and fishing vessels.

IX. LIMITATIONS OF INFORMATION

The physical habitat requirements for sockeye salmon are less well documented than other aspects (timing and movement patterns, e.g.) of this species' freshwater residency in Alaska.

X. SPECIAL CONSIDERATIONS A freshwater form of this species exists and is known as the kokanee. The kokanee is generally very similar to the anadromous sockeye salmon except that it is smaller in ultimate length and weight and spends its entire life in fresh water. It, too, dies after spawning. 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.

REFERENCES

ADEC. 1979. Water quality standards. Juneau. 34 pp.

- ADF&G, comp. 1977a. A compilation of fish and wildlife resource information for the State of Alaska. Vol. 3: Commercial fisheries. [Juneau.] 606 pp.
- ______. 1977b. A fish and wildlife resource inventory of the Alaska Peninsula, Aleutian Islands, and Bristol Bay area. Vol. 2: Fisheries. [Juneau.] 557 pp.

_____. 1977c. A fish and wildlife inventory of the Cook Inlet-Kodiak areas. Vol. 2: Fisheries. [Juneau.] 443 pp.

______. 1977d. A fish and wildlife resource inventory of western and arctic Alaska. Vol. 2: Fisheries. [Juneau.] 340 pp.

ADF&G. 1981. Lower Cook Inlet annual management report. Div. Commer. Fish. 97 pp.

. 1982. Stock separation feasibility report. Phase I: Final draft. ADF&G, Susitna Hydro Adult Anadromous Fish Proj. 75 pp.

. 1984. An atlas to the catalog of waters important for spawning, rearing, or migration of anadromous fishes, Arctic Resource Management Region V. Div. Habitat, Anchorage. 5 pp. + maps.

- Bell, M.C. 1973. Fisheries handbook of engineering requirements and biological criteria. Fisheries-Engineering Research Prog. Corps. of Engineers, N. Pac. Div., Portland, OR. Approx. 500 pp.
- Brett, J.R. 1952. Temperature tolerance in young Pacific salmon, genus Oncorhynchus. J. Fish. Res. Bd. Can. 9(6):265-322.
- Bucher, W.A. 1984. Personal communication. Asst. Area Fisheries Biologist, ADF&G, Div. Commer. Fish., Bristol Bay.
- Burgner, R.L. 1958. A study of the fluctuations in abundance, growth, and survival in the early life stages of red salmon (<u>Oncorhyndrus nerka</u>,

1

Walbaum) of the Wood River lakes, Bristol Bay, Alaska. Ph.D. Thesis, Univ. Washington, Seattle. 200 pp. Cited in Forester 1968.

- Burner, C.J. 1951. Characteristics of spawning nests of Columbia River salmon. USFWS Fish. Bull. 61(52):97-110.
- Foerster, R.E. 1968. The sockeye salmon, <u>Oncorhynchus</u> <u>nerka</u>. Fish. Res. Bd. Can. Bull. 162. Ottawa, Can. 422 pp.
- French, R., H. Bilton, M. Osako, and A. Hartt. 1976. Distribution and origin of sockeye salmon (<u>Oncorhynchus nerka</u>) in offshore waters of the North Pacific Ocean. INPFC Bull. 34. Vancouver, Can.
- Hart, J.L. 1973. Pacific fishes of Canada. Fish. Res. Bd. Can. Bull. 180. Ottawa, Can. 739 pp.
- Hartman, W.L. 1971. Alaska's fishery resources the sockeye salmon. NOAA, NMFS, Fishery Leaflet No. 636. Seattle, WA. 8 pp.
- McPhail, J.D., ed. 1966. Studies of salmon in freshwater in Alaska-Kvichak sockeye. Pages 9-11 in Research in fisheries-1965. Contribution No. 212. College of Fisheries, Fisheries Research Institute, Univ. Wash., Seattle. 40 pp.
- Morrow, J.E. 1980. The freshwater fishes of Alaska. Anchorage, AK: Alaska Northwest Publishing Company. 248 pp.
- Reiser, D.W., and T.C. Bjornn. 1079. Influence of forest and rangeland management on anadromous fish habitat in Western North America habitat requirements of anadromous salmonids. USDA Forest Serv. Genl. Tech. Rept. PNW-6, Pacific Northwest Forest and Range Experiment Station. Portland, OR. 54 pp.
- Ricker, W.E. 1966. Salmon of the North Pacific Ocean. Part 3: A review of the life history of the North Pacific salmon. INPFC Bull. 18. Vancouver, Can.
- Roberson, K. 1985. Personal communication. Research Project Leader, ADF&G, Div. Commer. Fish., Glennallen.
- Schroeder, T. 1985. Personal communication. LCI Area Mgt. Biologist, ADF&G, Div. Commer. Fish., Homer.
- Scott, W.B., and E.J. Crossman. 1973. Freshwater fishes of Canada. Fish. Res. Bd. Can. Bull. 184. Ottawa, Can. 966 pp.
- Shaul, A. 1984. Personal communication. Alaska Peninsula-Aleutian Island Area Fisheries Mgt. Biologist, ADF&G, Div. Commer. Fish., Kodiak.



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Arctic Cod Life History and Habitat Requirements

Map 1. Range of arctic cod (Morrow 1980, NWAFC 1985)

NAME Ι.

- Α. Common Name: Arctic cod
- Β. Scientific Name: Boreogadus saida
- Cods (family Gadidae) reach their greatest diversity and abundance С. in north temperate seas. The arctic cod is the only species of the family that is common throughout its circumpolar range (Sekerak 1982a).

II. RANGE

Α. Worldwide

The arctic cod has a circumpolar distribution in most of the Arctic Ocean, being absent only from the region just north of Scandinavia. On the Atlantic side of North America it has been found as far south as the Saint Lawrence River in Newfoundland.

It ranges throughout the Arctic Ocean across the arctic coast of Canada and Alaska and south to the Bering Sea (Morrow 1980, NWAFC 1985). The existence of three or more separate stocks of arctic cod is responsible for the circumpolar distribution in arctic seas. These stocks have different feeding and spawning areas and migration routes and mix in the boundary areas (Ponomarenko 1968). Statewide

- B. Statewide The general distribution of arctic cod off Alaska is from the Bering Sea to the Beaufort Sea (map 1) (Sekerak 1982a, Morrow 1980).
- C. Regional Distribution Maps

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

- D. Regional Distribution Summary
 - 1. <u>Arctic</u>. The range of arctic cod extends from the Bering Sea throughout the Arctic Region (Morrow 1980, NWAFC 1985). Lowry and Frost (1981) found that arctic cod were most widespread and abundant in the northeastern Chukchi and western Beaufort seas and least abundant in the northern Bering and central Beaufort seas. Arctic cod is probably the most abundant fish in the Alaskan Beaufort and northeastern Chukchi seas (Sekerak 1982a). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Arctic Region.)
- III. PHYSICAL HABITAT REQUIREMENTS
 - A. Aquatic
 - 1. Water quality. No information is available on the pH and dissolved oxygen requirements of arctic cod. Arctic cod occurs in areas between the limits of pack ice and drift ice in waters that are less saline, with salinities from 15 to 30 parts per thousand (ppt) (Andriyashev 1954, Morrow 1980). Arctic cod in Simpson Lagoon, on the Beaufort Sea, were tolerant of widely ranging salinities and turbidities during the open-water season. For at least short periods of time, fish were able to cope with conditions ranging from nearly fresh to salt water (3-28 ppt) and from clear to very turbid water (1-146 Nephelometric Turbidity Units)(Craig et al. 1982).
 - 2. Water depth:
 - a. <u>Juvenile</u>. Quast (1974) found young-of-the-year (yoy) arctic cod in the eastern Chukchi Sea to be much more numerous at depths from 20 to 40 m than they are above

those depths. Quast speculated that this depth preference may be in order to avoid predation by sea birds. Sekerak (1982b) found that the densities of yoy arctic cod were related to season, depth, year, and location. From June to mid August, arctic cod near Greenland in Sekerak's samples were most abundant at 10 to 20 m depths and rare at the surface. Densities decreased below 20 m, and no yoy were caught at depths greater than 250 m. Thus, it appears that yoy are concentrated in the upper 40 to 50 m of water.

- The maximum depths to which adult or subadult b. Adult. arctic cod can be found are unknown, as is their preferred depth range. The bottom of shallow seas, such as the northern Bering, Chukchi, and southern Beaufort seas are within the depth range of arctic cod. Thev have been collected at depths of 300 m in the Canadian high arctic, 930 m in Baffin Bay, and 400 m in the northern Chukchi and Beaufort seas (Sekerak 1982a). Lowry and Frost (1981) sampled depths from 40 to 100 m in the northeastern Chukchi and Beaufort seas and to 50 m in the Bering Sea and found no relationship between depth of water and catches of arctic cod. In Norton Sound and the southeastern Chukchi Sea, arctic cod were found in high abundance at depths greater than 20 m (Wolotira et al. 1977).
- 3. <u>Water temperature</u>. Adult arctic cod usually inhabit waters with temperatures of 0 to -1.8°C (Andriyashev 1954, Morrow 1980, Hognestad 1968). Adults have been found in waters with temperatures up to 3 or 4°C (Hognestad 1968). In Simpson Lagoon, in the Beaufort Sea, arctic cod were found in waters ranging from 0 to 13.5°C during the open-water season (Craig et al. 1982). Egg development occurs when the water temperature is less than 0 to 2°C; larval development and growth occur at 2 to 5°C; and fry development and growth occur from 5 to 7°C and possibly higher (Rass 1968).
- B. Substrate and Cover Requirements

Arctic cod are widely assumed to associate with the ice undersurface (Andriyashev 1954, Sekerak 1982a, Ponomarenko 1968); however, they can also occur near the bottom (Hognestad 1968, Morrow 1890) and in open water (Craig et al. 1982, Lowry and Frost 1981). Near the ice edge, the mass development of phytoplankton and zooplankton occurs, and arctic cod are plankton feeders (Ponomarenko 1968). In a study near Greenland, arctic cod were more abundant in areas where the under-ice surface was rough than in areas where it was smooth; this difference may be related to the better protection from predators offered by the rough under-ice areas (Bradstreet 1982). Bradstreet (1982) found that cod captured offshore tended to be smaller and younger than those taken inshore. At the end of their first summer, larval cod leave the water column and become associated with a substrate, usually the ice undersurface (ibid.).

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

The diet of yoy arctic cod consists of phytoplankton and very small or early stages of zooplankton. After the first summer, phytoplankton are of minor importance as food, and the older cod prey on zooplankton, substrate and ice-associated crustaceans, and young fish (Sekerak 1982a).

Several studies have indicated that the diet of adult arctic cod may be influenced by the food availability or the habitat. Arctic cod in offshore waters and near offshore ice edges eat primarily copepods and some pelagic amphipods (Lowry et al. 1978, Bradstreet and Cross 1982, Lowry and Frost 1981, Craig et al. 1982, Hognestad 1968). Arctic cod in nearshore, shallower water habitats feed on benthic or epibenthic mysids, amphipods, shrimps, and some copepods (Craig and Haldorson 1981, Lowry and Frost 1981, Craig et al. 1982). Mysids, which are the primary food in nearshore areas, are nearly absent from the diet of arctic cod in offshore waters. Craig et al. (1982) indicated that arctic cod prefer to eat mysids rather than amphipods when both are available. Some amphipod species burrow into the substrate, thus becoming less accessible to arctic cod.

B. Types of Feeding Areas Used

Arctic cod are often found near the ice edge, where the mass development of phytoplankton and zooplankton occurs. Arctic cod is the main plankton feeder in this habitat, which has resulted in its great abundance (Ponomarenko 1968). The diet of cod in both inshore and offshore waters is apparently influenced by the presence of ice. Certain copepod, mysid, and amphipod species are closely associated with the ice undersurface, and cod collected near ice had these species in their stomachs (Bradstreet and Cross 1982).

C. Factors Limiting Availability of Food

The diet of arctic cod, especially in offshore areas, is dominated by copepods and amphipods, which in turn feed on diatoms (Bradstreet 1982). Thus the food available to arctic cod is closely dependent upon primary production. In polar waters, there is no productivity throughout most of the year, and an outburst of exceedingly high productivity occurs in the short summer season. Primary production in arctic waters is usually limited by available sunlight and, less often, by the availability of nutrients for phytoplankton (Pussell-Hunter 1970).

- V. REPRODUCTIVE CHARACTERISTICS
 - A. Reproductive Habitat

Arctic cod move inshore to warmer coastal waters and mouths of rivers for spawning, often forming large concentrations (Andriyashev 1954, Morrow 1980). Spawning usually occurs under ice cover (Andriyashev 1954, Rass 1968). On the basis of their widespread distribution, arctic cod are assumed to spawn in many areas of the arctic. The only identified spawning area in the North American arctic is in Stefansson Sound in the Alaskan Beaufort Sea (Craig et al. 1982).

B. Reproductive Seasonality

In Soviet waters, arctic cod spawn from December through March, mainly in January and February (Andriyashev 1954, Rass 1968). In coastal waters of the Beaufort Sea, arctic cod spawn between late November and early February (Craig et al. 1982).

C. Reproductive Rehavior Arctic cod spawn under the ice, and little information on spawning areas exists. Spawning behavior has not been observed.

D. Age at Sexual Maturity

Andriyashev (1954) reported that arctic cod attain sexual maturity at 4 years of age. Hognestad (1968) reported maturity at age 2 in the Barents Sea. Craig et al. (1982) found that in nearshore waters of the Beaufort Sea most mature males were ages 2 and 3 and females age 3.

E. Frequency of Breeding

The arctic cod is a relatively small fish that rarely attains a length of over 300 mm or an age of five years (Sekerak 1982a). With a reported age at maturity of from two to four years, arctic cod would not be expected to spawn more than several times in their lifetime.

F. Fecundity

Arctic cod produce the largest and fewest eggs of all species in the cod family. Fecundity varies from 9,000 to 21,000, with an average of 12,000 eggs (Andriyashev 1954). The egg diameter ranges from 1.5 to 1.9 mm, and the membrane is very thin and easily damaged (Rass 1968). Rass notes that fish species in low water temperatures usually produce large eggs and that a thin membrane is an adaptation to a calm spawning habitat such as one under ice cover without waves.

G. Incubation Period

Rass (1968) reports that the egg stage of arctic cod lasts from one-and-one-half to three months and that larvae appear in the sea from May through July. The larval stage lasts about two months in the Barents and Siberian seas, from June through July. Transition to the juvenile stage occurs at 3 to 5 cm in August.

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

Arctic cod make onshore-offshore migrations, which are associated both with spawning and the movements of ice (Morrow 1980). Arctic cod are usually found near the ice edge and descend to greater depths when the ice melts or breaks and the sea surface temperatures rise. The migration paths and areas of concentration depend mainly on the distribution of ice (Ponomarenko 1968).

The circumpolar distribution of arctic cod consists of separate stocks, which have different feeding and spawning areas and migration routes (ibid.). The stock in the Barents Sea, north of Norway, moves inshore in mass concentrations from June through August. When the water temperature rises in August and September, the cod move to deeper water.

Prespawning and spawning concentrations form in open northeastern areas of the Barents Sea from September-October to the end of February (ibid.). A local stock of arctic cod in the Laptev Sea, north of Siberia, feeds in the open sea and spends the winter, probably spawning, in the coastal zone (ibid.). In the southern Chukchi and northern Bering seas, the abundance of cod increases in winter and decreases in summer (ibid.).

In the Beaufort Sea, arctic cod were abundant in the nearshore waters of Simpson Lagoon in August and September (Craig and Haldorson 1981). Some cod remained in Simpson Lagoon in early winter, but all apparently vacated the shallow waters by February. The nearby deeper coastal areas of Stefansson Sound, however, were inhabited by arctic cod throughout the winter (ibid.).

The distribution and abundance of yoy arctic cod varies annually and geographically. In spring and most of the summer, yoy are planktonic and are found primarily in surface waters (Sekerak 1982b). The planktonic yoy become highly dispersed and can probably be transported considerable distances from the spawning areas. In surveys done in Norton Sound and the southeastern Chukchi Sea, either cold, deep waters or regions north of the Bering Strait provided the areas of highest density of young fish (Wolotira et al. 1977).

VII. FACTORS INFLUENCING POPULATIONS

Arctic cod are key species in the arctic marine ecosystem, which Α. channels the energy flow from plankton to high-level consumers through a few key links. Arctic cod may influence the distribution and movements of marine mammals and seabirds in arctic waters (Craig et al. 1982). Lowry et al. (1978) found arctic cod to be an important summer food source of spotted seals in the Chukchi Sea and a fall and winter food of ringed seals in the Beaufort Sea. Arctic char in the Canning River area of the Beaufort Sea eat juvenile arctic cod (Craig and McCart 1976), and arctic char in the Prudhoe Bay area were found with arctic cod in their stomachs (Furniss 1975). Fulmars, kittiwakes, murres, guillemots, ringed seals, and narwhals feed on arctic cod along the ice edges in Baffin Bay near Greenland (Bradstreet 1982, Bradstreet and Arctic and saffron cod are probably the most Cross 1982). important prey of belukha whales during autumn and winter in Norton Sound and the Chukchi Sea (Seaman et al. 1982). Nevertheless, populations of a small, early maturing, highly fecund species such as arctic cod may be influenced more strongly by physical factors in the environment than by predation (Craig et In the autumn or winter, when the fish have moved al. 1982). close to shore along the USSR, they are often washed ashore in great quantities by gales (Ponomarenko 1968). On islands and on the coast of the Kara Sea, heaps of dead arctic cod from 5 to 10 m wide and 3 to 5 m high, extending over tens of kilometers, accumulate after storms (ibid.). Polar bears, arctic foxes, and the local human population rely on beached arctic cod as a winter food source (Craig et al. 1982). Little evidence of the effects of competition on populations of arctic cod exists. However, in Newfoundland the distribution and diets of arctic cod and capelin overlap (Vesin et al. 1981). The recent dramatic increase of arctic cod in that area could be a response to a large reduction in zooplankton consumption by capelin in the region that has occurred since 1976 (ibid.).

B. Human-related

Arctic cod eggs are buoyant, and yoy are planktonic. These characteristics make them vulnerable to potential toxicants, such as hydrocarbons, formation waters, disinfectants, algicides, heavy metals, heated waters, drilling muds, and other chemicals that may be released during drilling and production. Arctic cod inhabit and feed at the ice edge where mass plankton blooms occur, and any perturbation of the ice edge environment could have negative effects on the population. The habit of arctic cod of using small cracks in the ice could make them prone to being entrapped where they would be unable to avoid lethal substances. Some arctic cod spawn in nearshore waters, and the same spawning areas are used by the cod every year (Sekerak 1982a). These regions coincide with areas delineated for hydrocarbon development, and the potential exists for disruption of spawning activities through acoustical disturbances, exposure to contaminants, unnatural ice movements, thicknesses or clearances, and shock waves due to explosives (ibid.).

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

[°] Changes in biological oxygen demand or nutrient loading

° Changes in chemical composition of water

- [°] Changes in dissolved oxygen, temperature, pH, salinity
- ° Entrapment
- [°] Changes in sedimentation rates, turbidity, suspended solids
- Physical barriers to movement
- Shock waves, blasting
- Increased susceptibility to harvest or predation

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

VIII. LEGAL STATUS

The Alaska Department of Fish and Game has managerial authority over arctic cod extending to 3 mi offshore. However, because harvesting of arctic cod is minimal, no management plan has been formulated.

IX. LIMITATIONS OF INFORMATION

Little information has been collected on populations of arctic cod in Alaska; most studies have concentrated on populations near Greenland, Siberia, and Norway. Information is needed on migrations of Bering and Beaufort sea populations, distribution of yoy, preferred depth range, spawning areas, egg and larval requirements, and the influence of physical factors and competition on population size.

REFERENCES

- Andriyashev, A. 1954. Fishes of the northern seas of the USSR. (Transl. Israel Prog. Sci. Transl., Jerusaleum, 1964). 617 pp.
- Bradstreet, M. 1982. Occurrence, habitat use, and behavior of seabirds, marine mammals, and arctic cod at the pond inlet ice edge. Arctic 35(1):28-40.
- Bradstreet, M., and W. Cross. 1982. Trophic relationships at high arctic ice edges. Arctic 35(1):1-12.
- Craig, P., W. Griffiths, L. Haldorson, and H. McElderry. 1982. Ecological studies of arctic cod (<u>Boreogadus saida</u>) in Beaufort Sea coastal waters, Alaska. Can. J. Fish and Aquatic Sci. 39:395-406.
- Craig, P., and L. Haldorson. 1981. Beaufort Sea barrier island-lagoon ecological process studies: final report, Simpson Lagoon. Part 4: Fish. Pages 384-678 in Environmental assessment of the Alaskan continental shelf. Vol. 7. BLM, NOAA, OCSEAP. Final rept. 678 pp.
- Craig, P., and P. McCart. 1976. Fish use of nearshore waters in the western arctic: emphasis on anadromous species. Pages 361-388 in D. Hood and D. Durrell, eds. Assessment of the arctic marine environment. Occ. Publ. No. 4, IMS, Univ. Alaska, Fairbanks. 468 pp.
- Frost, K., L. Lowry, and J. Burns. 1978. Trophic relationships among ice-inhabiting phocid seals. Appendix I, Offshore demersal fishes and epibenthic invertebrates of the northeastern Chukchi and western Beaufort seas. Vol. 1. Ann. rept. by ADF&G to NOAA/OCSEAP, Boulder, CO.
- Furniss, R. 1975. Inventory and cataloging of arctic area waters. ADF&G, Fed. Aid in Fish Rest. Ann rept. Vol. 16. Proj. F-9-7, Job G-I-I, Part B.
- Hognestad, P. 1968. Observations on polar cod in the Barents Sea. Rapp. Proc. Verb. Cons. Perm. Int. Explor. Mer. 158:126-130.
- Lowry, L., and K. Frost. 1981. Distribution, growth, and foods of arctic cod (<u>Boreogadus saida</u>) in the Bering, Chukchi, and Beaufort seas. Can. Field Nat. 95:186-191.
- Lowry, L., K. Frost, and J. Burns. 1978. Trophic relationships among ice-inhabiting phocid seals. Vol. 1. Ann. rept. by ADF&G for NOAA/OCSEAP.
- Morrow, J.E. 1980. The freshwater fishes of Alaska. Anchorage: Alaska Northwest Publishing Co. 248 pp.
- NWAFC (Northwest and Alaska Fisheries Center). 1985. Distribution information from bottom trawls, data through 1984. Resource Assessment and Conservation Engineering Division. USDC: NOAA, NMFS. Seattle. 1 p. computer map.
- Ponomarenko, V.P. 1968. Some data on the distribution and migrations of polar cod in the seas of the Soviet Arctic. Rapp. Proc. Verb. Cons. Perm. Int. Explor. Mer. 158:131-135.
- Quast, J.C. 1974. Density distribution of juvenile arctic cod, <u>Boreogadus</u> <u>saida</u>, in the eastern Chukchi Sea in the fall of 1970. Fish. Bull. 72:1,094-1,105.
- Rass, T. 1968. Spawning and development of polar cod. Rapp. Proc. Verb. Cons. Perm. Int. Explor. Mer. 158:135-137.
- Russell-Hunter, W. 1970. Aquatic productivity: an introduction to some basic aspects of biological oceanography and limmology. New York: MacMillan Pub. Co. 306 pp.
- Seaman, G., L. Lowry, and K. Frost. 1982. Foods of beluga whales (Delphinapterus leucas) in western Alaska. Cetology 44:1-19.
- Sekerak, A. 1982a. Summary of the natural history and ecology of arctic cod (<u>Boreogadus saida</u>). Rept. by LGL, Ltd., BLM and NOAA, OCSEAP. 10 pp.

. 1982b. Young-of-the-year cod (<u>Boreogadus</u>) in Lancaster Sound and Western Baffin Bay. Arctic 35(1):75-87.

- Vesin, J., W. Leggett, and K. Able. 1981. Feeding ecology of Capelin (<u>Mallotus villosus</u>) in the estuary and western Gulf of St. Lawrence and its multispecies interactions. Can. J. Fish Ag. Sci. 38(3):257-267.
- Wolotira, R., T. Sample, and M. Morin. 1977. Demersal fish and shellfish resources of Norton Sound, the southeastern Chukchi Sea, and adjacent waters in the baseline year 1976. NOAA, NMFS processed rept. Seattle, WA. 292 pp.



Map 1. Range of capelin (Hart 1973)

- I. NAME
 - A. Common Name: Capelin
 - B. Scientific Name: Mallotus villosus
 - C. Species Group Representation Capelin belong to the smelt family, Osmeridae. The Pacific capelin and the Atlantic capelin were formerly considered to be two separate species; however, they are now regarded as the same

II. RANGE

A. Worldwide

species.

Capelin has a circumpolar distribution and can be found in the northern regions of the Atlantic, Pacific, and Arctic oceans, but they are not reported from eastern Siberia. They are found along the Atlantic coast of North America from Labrador northwards and near Greenland, Ireland, and Norway. They are found throughout the Canadian mainland arctic and along the Pacific coasts of British Columbia, Alaska, the Bering Strait, Kamchatka Peninsula, Sea of Japan, and the Sea of Okhotsk as far south as Korea (Hart 1973, Jangaard 1974, Pahlke 1981a).

B. Statewide

Capelin are distributed along the entire coastline of Alaska and extending south along British Columbia to the Strait of Juan de Fuca (map 1)(Hart 1973).

C. Regional Distribution Map

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

- D. Regional Distribution Summary
 - 1. Arctic. Capelin are found along the coast of the entire Arctic Region (ibid.). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Arctic Region.)

III. PHYSICAL HABITAT REQUIREMENTS

A. Water Quality

No information is available on the pH, dissolved oxygen, or turbidity tolerances of capelin. Capelin in the Canadian arctic have been reported spawning in warm, brackish water (Ellis 1962). Frank and Leggett (1982a) hypothesize that onshore winds initiate capelin spawning in Newfoundland, because the winds cause the nearshore waters to be warmer and less saline. Capelin larvae have been found over a wide range of salinities from 4.8 to 32.6 parts per thousand, generally moving to cooler, less saline water below the thermocline in the fall (Jacquaz et al. 1977).

B. Water Depth

Andriyashev (1954) reports that Pacific capelin were collected at depths of 65-75 m in the fall and that Atlantic capelin inhabit depths to 200 m. Studies in eastern Canada and Norway have shown that capelin move from deeper water during the day to shallower water at night. Bailey et al. (1977) found that capelin in Canada disperse in the upper 20 m of water during the night and school mostly above 50 m but sometimes as deep as 100 m during the day. There was no difference in the vertical distribution of adult and juvenile capelin. In Norway, capelin moved from 150 m depth during the day to between 50 and 100 m at night (Pearcy et al. 1979). Offshore spawning has been reported to depths of 280 m but usually occurs in the upper 75 m of the water column. Capelin larvae are mainly concentrated in the upper 50 m during the summer in eastern Canada and move to slightly deeper water in September as the surface waters cool (Jacquaz et al. 1977). Yolk-sac larvae were most abundant in the upper 25 m of the water column. No evidence of vertical migration of the capelin larvae was seen during the summer months (ibid.).

C. Water Temperature

Beach-spawning capelin found along the Newfoundland and Labrador coasts in June and July generally spawned in water temperatures of 5.5 to 8.5° C, although spawning has been reported in temperatures as high as 10°C (Jangaard 1974). In the Canadian arctic near Baffin Island, the surface water temperatures during the spawning period varied from about 13 to 15°C (Ellis 1962), while temperatures in southern British Columbia are about 10 to 12.5°C (Hart 1973). Water temperatures at the time of spawning of Bering Sea capelin are between 5.3 and 10.5°C (Whitmore, pers. comm.). Temperatures for offshore spawning range from 2 to 4.2°C (Bakke and Bjorke 1971, Pitt 1958, Andriyashev 1954). Adult capelin have been trawled at depths of 70 m at a temperature of -1.7 to 1.3°C in the fall (Andriyashev 1954). Capelin larvae in northeastern Canada were collected at temperatures ranging from 0.2 to 14.4°C (Jacquaz et al. 1977).

D. Substrate

Adult and larval capelin are pelagic fish. Capelin spawn either offshore in deep water or on sand and gravel beaches (Anadriyashev 1954, Pahlke 1981a).

- IV. NUTRITIONAL REQUIREMENTS
 - A. Food Species Used

Capelin are filter feeders, consuming euphausiids, copepods, amphipods, and a variety of planktonic invertebrates (Jangaard 1974). Adult capelin north of Norway feed mainly on copepods and euphausiids (Pearcy et al. 1979), whereas both juveniles and adults in eastern Canada feed primarily on copepods, euphausiids, and appendicularians (Vesin et al. 1981). Bjorke (1976) found that the diet of first-feeding capelin larvae consisted mainly of copepod eggs and nauplii. Vesin et al. (1981) also noted that a shift in diet occurred during growth, with early larval capelin consuming invertebrate eggs, copepods, and diatoms. The diets of juvenile and adult capelin overlapped, with a shift from small copepods to adult euphausiids as the capelin reached a total length of 140 mm.

B. Factors Limiting Availability of Food The diet of capelin is dominated by zooplankton, which, in turn, feed on phytoplankton. In polar waters, there is no productivity throughout most of the year, and an outburst of exceedingly high productivity occurs in the short summer season. Primary production in arctic waters is usually limited by available sunlight and, less often, by the availability of nutrients for phytoplankton (Russell-Hunter 1970).

C. Feeding Behavior

Winters (1969) found that capelin's feeding is highly seasonal. Feeding intensity increases before spawning in late winter and early spring and declines with the spawning migration. Feeding ceases during spawning and proceeds again at high intensity until early winter, when zooplankton becomes less abundant. Daily feeding peaks occur in mornings and evenings between May and August in eastern Canada, and a single midday feeding occurs in October and November (Vesin et al. 1981).

- V. REPRODUCTIVE CHARACTERISTICS
 - A. Reproductive Habitat
 - 1. Offshore spawning. Offshore spawning has been reported to depths of 280 m but usually occurs in water less than 75 m deep (Saetre and Gjosaetre 1975, Templeman 1948). Pitt (1958) stated that when waters became too warm on the beach, spawning continues in deeper coastal waters.
 - 2. <u>Beach spawning</u>. Spawning occurs on sand, gravel, or pebble beaches (Andriyashev 1954, Jangaard 1964, Hart 1983, Barton et al. 1977, Pahlke 1981a). Spawning occurs at high tide (Hart 1973) and generally during periods of onshore winds for Atlantic capelin (Frank and Leggett 1981a). However, capelin have been reported to spawn in offshore winds in the Kodiak area (Warner 1981). Spawning usually occurs at night or during dull, cloudy weather (Jangaard 1974); however, Ellis (1962) reports that capelin spawn during daylight in the Canadian arctic when there are 24 hours of light.
 - B. Reproductive Seasonality Capelin spawn in May and June in the Kodiak area (Warner 1981) and in late spring in Bristol Bay (Rogers et al. 1980). In the Bering Sea, they spawn in summer, slightly later near Pt. Barrow, and in the Beaufort Sea in August and September (Rogers et al. 1980, Craig and Haldorson 1980).
 - C. Reproductive Behavior At the spawning grounds, capelin segregate into schools by sex. Males school near the beaches, while the females remain in slightly deeper water. As the females ripen, individuals proceed to the beaches to spawn, followed by small groups of males. Generally, two males squeeze the female between them on the beach, extruding milt over eggs deposited in a slight hollow. The eggs are covered with sand or gravel by tidal action (ADF&G 1969). Spawning occurred for over four weeks in Norton Sound (Pahlke 1981b).
 - D. Age at Sexual Maturity During the first year, males and females are the same size, but during the second year, males grow at a faster rate. A few capelin mature and spawn at age 2, but most maturation occurs at age 3 (Jangaard 1974). Spawning capelin in Norton Sound and Togiak consist mainly of ages 2 and 3 fish (Pahlke 1981b); on Kodiak most were age 2 (ADF&G 1969).

E. Frequency of Breeding

During and following the spawning season, large numbers of dead capelin can be observed floating on the surface or stranded on the beach. The mortality rate of spawning capelin is high, and most investigators believe that postspawning survival is negligible (Jangaard 1974).

- F. Fecundity Fecundity in capelin varies widely with geographic location. Nikolsky (1963) reports that fecundity in Pacific capelin ranges from 15,300 to 39,300 eggs. Capelin in southern British Columbia, however, produce 4,600 to 6,700 eggs (Hart 1973), and in the Sea of Japan fecundity ranges from 15,000 to 57,000 eggs (Andriyashev 1954). The eggs are approximately 1 mm in diameter and stick to the substrate (Andriyashev 1954, Hart 1973).
- G. Incubation Period/Emergence

Frank and Leggett (1981b) found that the incubation period in capelin was influenced by the average temperature, which varied between years and between positions on the beach. Incubation temperatures were determined by water temperature, air temperature, and hours of sunlight. Hatching occurs in 55 days at 0°C, 30 days at 5°C, and 15 days at 1C°C (Jeffers 1931). Emergence of larvae from the beach is a clearly defined, abrupt transition to a Atlantic capelin larvae accumulate on the pelagic existence. beach as they hatch and are released synchronously by onshore winds (Frank and Leggett 1981a). Because no food is available to the larvae while in the sediments, rapid physical deterioration occurs if larvae are unable to leave the beach before yolk sac reserves are depleted (ibid.). Environmental conditions during the early larval period can influence growth efficiency, size at first feeding, and the prey-capture ability of larvae, independently of the yolk reserves at hatching or the food available (Frank and Leggett 1982b).

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

Capelin in Newfoundland overwinter in large, inactive schools in cold water near the bottom at depths from 140 to 200 m (Winters 1970). In the spring, these fish move into warming surface waters and disperse into smaller feeding schools. About a month before spawning, capelin migrate to shallow water and segregate into schools by sex, with the males closest to shore (Jangaard 1974). During the summer and early fall, juvenile and adult Atlantic capelin were widely distributed in small schools (Bailey et al. 1977). In November, the capelin concentrated into dense schools and moved to deeper water (ibid.).

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

Physical and biological factors such as the availability of food, water temperatures, and winds can contribute to the survival of emergent and larval capelin. Onshore winds replace cold, food-poor, predator-laden upwelling waters, which occupy the nearshore areas during offshore winds, with warmer, food-rich, predator-deficient surface waters (Frank and Leggett 1983).

Haddock and winter flounder consume large quantities of Atlantic capelin eggs during the spawning period (Jangaard 1974, Frank and Leggett 1984). Egg mortality from predation may be significantly greater at deep-water demersal spawning sites and may have a significant impact on recruitment of demersal spawners (Frank and Leggett 1984).

Many fish are predators of adult and juvenile capelin, including cod and salmon in the Atlantic (Jangaard 1974) and arctic char, saffron cod, and starry flounder in the Canadian arctic (Ellis 1962). Marine mammals also consume capelin as a primary part of their diet. In the Gulf of Alaska, harbor seals and Steller sea lions are predators, especially in nearshore waters in the spring and summer (Pitcher and Calkins 1978, Pitcher 1981). Other capelin predators include ribbon seals in the Pribilof Islands area (Lowry et al. 1978), spotted seals in the southeastern Bering Sea in the spring (ibid.), and belukha whales in the coastal northern Bering and Chukchi seas in summer (Seaman et al. 1982). Competition between capelin and other zooplankton-feeding species may occur. In the Newfoundland area, the diets of capelin, arctic cod, and squid overlap. In years when capelin have reduced their zooplankton consumption, the abundance of arctic cod and squid has increased (Vesin et al. 1981).

B. Human-related

Capelin have adhesive, demersal eggs, and any contamination of the beach or offshore substrate where capelin spawn could result in heavy mortality. Juvenile and adult capelin are pelagic, relying on planktonic food sources, and thus are vulnerable to contamination of surface waters. A summary of possible impacts from human-related activities includes the following:

- ² Changes in biological oxygen demand or nutrient loading
- ° Changes in the chemical composition of water
- [°] Changes in dissolved oxygen, temperature, pH, or salinity
- Changes in sedimentation rates, turbidity, or suspended solids
- ° Changes in substrate composition and location
- Increased susceptibility to harvest or predation
- ° Shock waves, blasting

(For additional impacts information, see the Impacts of Land and Water Use volume of this series.)

VIII. LEGAL STATUS

The ADF&G has managerial authority over capelin, extending to 3 mi offshore. Because harvesting of capelin is minimal, no management plan has been formulated. A policy statement, however, has been established that defines the relationship between herring and capelin fisheries that could occur simutaneously.

IX. LIMITATIONS OF INFORMATION

Generally, most work on capelin has been done on Atlantic rather than Pacific populations, and very little work has been done on capelin in Alaskan waters. No information is available on the pH, dissolved, oxygen, or turbidity tolerances of capelin. It is not known if offshore spawning populations of capelin exist. Seasonal movements of Pacific capelin have not been studied.

REFERENCES

- ADF&G. 1969. Inventory and cataloging of the sport fish and sport fish waters in southwest Alaska. Fed. Aid in Fish Rest. Ann. rept. Vol. 10. Proj. F-9-1, Job 6-A.
- Andriyashev, A. 1954. Fishes of the northern seas of the USSR. (Transl. Israel Prog. Sci. Transl., Jerusalem, 1964). 617 pp.
- Bailey, R., K. Able, and W. Leggett. 1977. Seasonal and vertical distribution and growth of juvenile and adult capelin (<u>Mallotus villosus</u>) in the St. Lawrence estuary and western Gulf of St. Lawrence. J. Fish. Res. Bd. Can. 34:2,030-2,040.
- Bakke, S., and H. Bjorke. 1973. Diving observations on Barents Sea capelin at the spawning grounds off northern Norway. Fisk Dir. Skr. Ser. Havunders., 16:140-147. Cited in Pahlke 1981a.
- Barton, L., I. Warner, and P. Shafford. 1977. Herring spawning surveys in the southern Bering Sea. Environmental assessment of the Alaskan outer continental shelf. Ann. rept. Vol. 7. OCSEAP, NOAA, BLM. 798 pp.
- Bjorke, H. 1976. Some preliminary results on food and feeding of young capelin larvae. Int. Cons. Explor. Sea C.M. 1976/H:37. Pelagic Fish (Northern) Committee. 12 pp. Cited in Frank and Leggett 1982a.
- Craig, P., and L. Haldorson. 1980. Beaufort Sea barrier island-lagoon ecological process studies: final rept., Simpson Lagoon. Part 4: Fish. Pages 384-678 in Environmental assessment of the Alaskan continental shelf. 1981. Final rept. Vol. 7. OCSEAP, NOAA, BLM. 678 pp.
- Ellis, D. 1962. Observations on the distribution and ecology of some arctic fish. Arctic 15:179-189.
- Frank, K., and W. Leggett. 1981a. Wind regulation of emergence times and early larval survival in capelin (<u>Mallotus villosus</u>). Can. J. Fish. Aq. Sci. 38(2):215-223.
- . 1981b. Prediction of egg development and mortality rates in capelin (<u>Mallotus villosus</u>) from meterological, hydrographic, and biological factors. Can. J. Fish. Aq. Sci. 38:1,327-1,338.

. 1982a. Coastal water mass replacement: its effect on zooplankton dynamics and the predator-prey complex associated with larval capelin (<u>Mallotus villosus</u>). Can. J. Fish. Aq. Sci. 39(7):991-1,003.

. 1982b. Environmental regulation of growth rate, efficiency, and swimming performance in larval capelin (<u>Mallotus villosus</u>) and its application to the match/mismatch hypothesis. Can J. Fish. Aq. Sci. 39(5):691-699.

- _____. 1983. Survival value of an opportunistic life-stage transition in capelin (<u>Mallotus villosus</u>) Can. J. Fish. Aq. Sci. 40(9):1,442-1,448.
- . 1984. Selective exploitation of capelin (<u>Mallotus villosus</u>) eggs by winter flounder (<u>Pseudopleuronectes</u> <u>americanus</u>): capelin egg mortality rates, contribution of egg energy to the annual growth of flounder. Can. J. Fish. Aq. Sci. 41(9):1,294-1,302.
- Hart, J. 1973. Pacific fishes of Canada. Fish. Res. Bd. Can. Bull. 180. 740 pp.
- Jacquaz, B., K. Able, and W. Leggett. 1977. Seasonal distribution, abundance and growth of larval capelin (<u>Mallotus villosus</u>) in the St. Lawrence estuary and northwestern Gulf of St. Lawrence. J. Fish. Res. Bd. Can. 34:2,015-2,029.
- Jangaard, P. 1974. The capelin (<u>Mallotus villosus</u>): biology, distribution, exploitation, utilization, and composition. Fish. Res. Bd. Can. Bull. 186. 70 pp.
- Jeffers, G. 1931. The life history of the capelin, <u>Mallotus</u> villosus (O.F. Muller). Ph. D. Thesis, Univ. Toronto, Toronto, Ont. 86 pp. Cited in Jangaard 1974.
- Lowry, L., K. Frost, and J. Burns. 1978. Trophic relationships among ice inhabiting phocid seals. Environmental assessment of the Alaskan continental shelf. Ann. rept. Vol. 1. OCSEAP, NOAA, BLM. 775 pp.
- Nikolsky, G. 1963. The ecology of fishes. New York: Academic Press. 352 pp.
- Pahlke, K. 1981a. Capelin, <u>mallotus</u> <u>villosus</u> (Muller), life history and utilization. Briefing rept. to the ADF&G Bering Sea herring staff. 16 pp.

______. 1981b. Progress report: capelin studies. Memo dated July 24, 1981, to John Clark, ADF&G, Juneau.

- Pearcy, W., C. Hopkins, S. Gronvik, and R. Evans. 1979. Feeding habits of cod, capelin, and herring in Balsfjorden, northern Norway, July-August 1978: the importance of euphausiids. Sarsia 64(4):269-277.
- Pitcher, K. 1981. Prey of the steller sea lion, <u>Eumetopias</u> jubatus, in the Gulf of Alaska. Fish. Bull. 79(3):467-472.
- Pitcher, K., and D. Calkins. 1978. Biology of the harbor seal, <u>Phoca</u> <u>vitulina</u> <u>richardi</u>, in the Gulf of Alaska. Environmental assessment of the Alaskan continental shelf. Ann. rept. Vol 1. OCSEAP, NOAA, BLM. 775 pp.
- Pitt, T. 1958. Age and growth of the capelin, <u>Mallotus villosus</u> (Muller), from Newfoundland Grand Banks areas. J. Fish. Res. Bd. Can. 15(3):295-311. Cited in Pahlke 1981a.
- Rogers, B., M. Wangerin, K. Garrison, and D. Rogers. 1980. Epipelagic meroplankton, juvenile fish, and forage fish: distribution and relative abundance in coastal waters near Yakutat. Environmental assessment of the Alaskan continental shelf. Final rept. Vol. 17. OCSEAP, NOAA, BLM. 658 pp.
- Russell-Hunter, W. 1970. Aquatic productivity: an introduction to some basic aspects of biological oceanography and limnology. New York: MacMillan Pub. Co. 306 pp.
- Saetre, R., and J. Gjosaetre. 1975. Ecological investigations on the spawning grounds of the Barents Sea capelin. Fisk Dir. Skr. Ser. Havunders. 16:203-227. Cited in Pahlke 1981a.
- Seaman, G., L. Lowry, and K. Frost. 1982. Foods of beluga whales, Delphinapterus leucas, in western Alaska. Cetology 44:1-19.
- Templeman, W. 1948. The life history of the capelin <u>Mallotus</u> villosus in Newfoundland waters. Newfoundland Govt. Lab. Bull. No. 17. St. Johns, Newfoundland. 151 pp. Cited in Pahlke 1981a.
- Vesin, J., W. Leggett, and K. Able. 1981. Feeding ecology of capelin (<u>Mallotus villosus</u>) in the estuary and western Gulf of St. Lawrence and its multispecies interactions. Can. J. Fish. Aq. Sci. 38(3):257-267.
- Warner, I. 1981. Capelin, a part of Alaska's future. Alaska Seas and Coasts 9(12):4-7.
- Whitmore, C. 1985. Personal communication. Herring Research Biologist, ADF&G, Div. Commer. Fish., Anchorage.
- Winters, G. 1969. Capelin (<u>Mallotus villosus</u>). Pages 94-101 <u>in</u> F.E. Firth, ed. Encyclopedia of marine resources. New York: Van Nostrand Reinhold Co. Cited in Jangaard 1974.

_____. 1970. Biological changes in coastal capelin from the overwintering to the spawning condition. J. Fish. Res. Bd. Can. 27(12):2,215-2,225.

Pacific Herring Life History and Habitat Requirements Southwest, Southcentral, Arctic, and Western Alaska



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

- I. NAME
 - A. Common Name: Pacific herring
 - B. Scientific Name: <u>Clupea harengus pallasi</u>

II. RANGE

A. Worldwide

In North America, herring are found from San Diego Bay, California, to Cape Bathurst in the Beaufort Sea (Hart 1973). In Asia, they range from Taksi Bay to the Yellow Sea (Andriyashev 1954).

B. Statewide In Alaska, herring are in a continuous distribution from Dixon Entrance in Southeastern Alaska to Point Barrow (ADF&G 1978).

C. Regional Distribution Maps

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

- D. Regional Distribution Summary
 - 1. <u>Southwest</u>. Major concentrations exist in the Kodiak area, along the Alaska Peninsula and Aleutian Islands, and in Bristol Bay. (For more detailed narrative information, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)
 - 2. <u>Southcentral</u>. Major concentrations exist in Prince William Sound and lower Cook Inlet. (For more detailed information, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)
- III. PHYSICAL HABITAT REQUIREMENTS
 - A. Water Quality

In the Bering Sea, temperature may have the greatest influence on the seasonal distribution of herring (Wespestad and Barton 1981). Dense schools of overwintering adult herring have been found at temperatures of from 2 to 3.5° C in the Bering Sea (Dudnik and Usoltsev 1964). Herring moving from the overwintering grounds in the Bering Sea to spawning grounds have passed through water at subzero temperatures (Wespestad and Barton 1981). Immature herring may occupy less saline waters than adults (Taylor 1964). Juveniles, however, are found in a wide range of salinities in British Columbia, with most concentrations located at 25 parts pers thousand (o/oo) (Hourston 1959). Herring eggs and fry were found in Imuruk Basin near Port Clarence, Alaska, in water of 4 o/oo salinity (Barton 1978). Immature fish in the Bering Sea exhibit greater tolerance or preference for colder, less saline areas on their overwintering grounds on the continental shelf than do adult fish (Westpestad and Barton 1981). The timing of spawning in the western Bering Sea is related to winter and spring water temperatures, with early maturation occurring in warm years and delayed development in colder years (Prokhorov 1968). In Bristol Bay and Port Heiden, herring appeared on the spawning grounds when temperatures reached 6° C. A temperature of 10°C has been documented in Bristol Bay during the spawning season (Warner and Shafford 1977). Water temperatures on Bering Sea spawning grounds between Norton Sound and Bristol Bay have ranged between 5.6° and 11.7°C (Barton 1979). In the Kotzebue Sound-Chukchi Sea area, adult herring were caught in areas where water temperatures ranged from 2 to 14°C. Juvenile herring were caught in Krusenstern Lagoon in mid August of 1980 in water temperatures up to 18.3°C (Whitmore and Bergstrom 1983). 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 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 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 winddriven 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, rock, and sand. 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

retain their ice cover into July, herring spawning could be delayed until August in some years (Whitmore and Bergstrom 1983).

C. Reproductive Behavior

1981).

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).

Because areas in the Chukchi Sea, where spawning occurs,

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 make contact with the substrate (ibid.). The extrusion of eqgs 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 eqgs on the substrate (Hourston and Haegele 1980). Eggs are fertilized by milt broadcast or dissipated in the water by males (ibid.).

D. Age at Sexual Maturity

Sexual maturity begins at age 2. Most herring do not spawn until ages 3 and 4. 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 4 to 6 (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 4 to 8 in the Bering Sea produce 26.6 to 77.8 thousand eggs (ibid.). Warner and Shafford (1977) found that the fecundity of

herring from Bristol Bay ranged from 13.1 to 71.9 thousand eggs for herring ranging in size from 171 to 320 mm.

- 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. 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 Bristol Bay and possibly that spawn in 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 Concentrations in water from 2 to 4°C on the Barton 1981). overwintering grounds begin in October (Bering Sea), continuing Mature fish (adults) arrive at wintering areas into winter. 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). Desiccation of eggs by high tidal fluctuation and low salinity caused by freshwater runoff of melting snow and ice also contribute to mortality. Sea birds have been documented as major predators of herring eggs in the intertidal area. Predation by flatfish upon eggs has also been documented (Wespestad and Barton 1981). In Norton Sound, Bering cisco, saffron cod, sculpins, and snails (Littorina planaxis) were found to consume herring eggs (Whitmore 1985, Stekol 1983). Egg survival decreases as the layers of egg deposition increase and oxygen cannot reach the bottom layers. The number of healthy larvae that will hatch from a deposition nine layers thick will very likely be less than for eggs in the same area four layers thick (Hourston and Haegele 1980). Environmental stress during the egg stage also results in malformed larvae and eventual death (ibid.).
 - 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.).

- Adult. The natural mortality of adult herring is about 30% 4. (ibid.). The probability of mortality increases with age, particularly for males. Mortality rates increase at age 5 as a consequence of senility, disease, and spawning mortality (Wespestad and Barton 1981). 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). Predation upon herring by northern pike captured in Hotham Inlet in Kotzebue Sound has been documented. Herring have been found to be a major food item for sheefish in northern Kotzebue Sound during November (Whitmore and Bergstrom 1983). Natural mortality of herring through all life stages in the Bering Sea has been estimated to be 47% (Wespestad and Barton 1981).
- 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
- ^o Reduction in food supply
- ^o Reduction in protective cover (e.g., seaweed beds)
- Obstruction of migration routes
- Shock waves in the aquatic environment
- ° Human harvest

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

- VIII. LEGAL STATUS
 - A. Managerial Authority

Herring are managed within the 3-mi limit by the State of Alaska, Department of Fish and Game, and in the Fisheries Conservation Zone (3 to 200-mi limit) by the U.S. Department of Commerce, National Marine Fisheries Service, as directed by the joint policy of the State of Alaska 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. REFERENCES

- ADF&G. 1978. Alaska's fisheries atlas. Vol. 2 [R.F. Mclean and K.J. Delaney, comps.]. 43 pp. + maps.
- Alderdice, D.F., and F.P. Velsen. 1971. Some effects of salinity and temperature on early development of Pacific herring (<u>Clupea pallasi</u>). J. Fish. Res. Bd. Can. 18:1,545-1,562. Cited in Wespestad and Barton 1981.
- Andriyashev, A.P. 1954. Fish of northern Soviet seas. Izdatelstvo. Akad. Nauk. USSR, Moscow. (Transl. Israel Prog. Sci Transl., Jerusalem, 1964).
- Bakkala, R.G., and G.B. Smith. 1978. Demersal fish resources of the eastern Bering Sea: spring 1976. USDC: NWAFC. Seattle, WA.
- Barton, L.H. 1978. Finfish resource surveys in Norton Sound and Kotzebue Sound. OCSEAP, final report (March 1976-September 1978). ADF&G, Div. Commer. Fish., Anchorage.
- ______. 1979. Assessment of spawning herring and capelin stocks at selected coastal areas in the eastern Bering Sea. Ann. rept. to NPFMC. ADF&G, Div. Commer. Fish., Anchorage.
- Dudnik, Y.J., and E.A. Usoltsev. 1964. The herring of the eastern part of the Bering Sea. Pages 225-229 <u>in</u> P.A. Moisev, ed. Soviet fisheries investigations in the northeast Pacific. Part 2. (Transl. Israel Prog. Sci. Transl., Jerusalem, 1968). Cited in Wespestad and Barton 1979, 1981.
- Gilmer, T. 1978. Cape Romanzof herring project, May 22-June 20, 1978. ADF&G, Div. Commer. Fish., Anchorage.
- Hart, J.L. 1973. Pacific fishes of Canada. Fish. Res. Bd. Can. Bull. 180.
- Henderson, G.T., C.E. Lucas, and J.H. Fraser. 1936. Ecological relations between the herring and plankton investigated with plankton indicator. J. Mar. Biol. Assoc. U.K. 21(1):277-291. Cited in Wespestad and Barton 1981.
- Hourston, H.S. 1959. Effects of some aspects of environment on the distribution of juvenile herring in Barkley Sound. J. Fish. Res. Bd. Can. 16:28.
- Hourston, H.S., and C.W. Haegele. 1980. Herring on Canada's Pacific coast. Can. Spec. Publ. Fish. Aquatic Sci. 48:23.
- Kachina, T.F., and R.Y. Akinova. 1972. The biology of the Korfo-Koraginski herring in the first year of life. Izv. Tikhookean. Nauchnoissled, Inst. Rybn. Khoz. Okeanogra. Cited in Wespestad and Barton 1979.

- Kaganovskii, A.G. 1955. Basic traits of behavior of pelagic fishes and methods of scouting and forecasting them in far eastern waters. Akad. Nauk. SSSR., Tr. Soveshch. Ikhtiol. Kom. 5 (Trudy soveshchaniya po voprosam povedeniya i razvedki ryb 1953): 26-33. In Russian. (Transl. Natl. Mar. Fish Sev. Biol. Lab., Honolulu, HI). Cited in Wespestad and Barton 1979.
- Malloy, L. 1983-1984. Personal communication. Westward Regional Biologist, ADF&G, Div. Commer. Fish., Kodiak.
- Morris, B.F. 1981. An assessment of the living marine resources of the Central Bering Sea and potential resource use conflicts between commercial fisheries and petroleum development in the Navarin Basin, Proposed Sale No. 83. USDC: NMFS, EAD. Anchorage. 232 pp.
- Nagasaki, F. 1958. The fecundity of Pacific herring (<u>Clupea pallasi</u>) in British Columbia coastal waters. J. Fish. Res. Bd. Can. 15:313-30. Cited in Wespestad and Barton 1981.
- Outram, D.N., and R.O. Humphreys. 1974. The Pacific herring in British Columbia waters. Fish. Mar. Serv. Can. Pac. Biol. Sta. Cir. 100. Nanaimo, B.C.
- Prokhorov, V.G. 1968. Winter period of life of herring in the Bering Sea. Proc. Pac. Sci. Res. Fish. and Ocean. 64:329-338. (In Russian, transl. 1970, Fish. Res. Bd. Can. Transl. Ser. 1433).
- Rounsefell, G.A. 1930. Contribution to the biology of the Pacific herring, <u>Clupea Paliaii</u> and the condition of the fishery in Alaska. Bull. U.S. Bureau Fish. 45:227-320.
- Rosenthal, R.S. 1978. An investigation of the herring on seaweed fishery in Prince William Sound, Alaska: estimates of standing crop, growth rate of kelps, and patterns of recolonization in harvested areas. Alaska Coastal Research Job No. Ocean-04-78. 45 pp.
- Rumyantsev, A.I., and M.A. Darda. 1970. Summer herring in the eastern Bering Sea. Pages 409-441 in P.A. Moiseev, ed. Soviet fisheries investigations in the northeastern Pacific, Part 5. (Transl. Israel Prog. Sci. Transl., Jerusalem, 1972).
- Scattergood, L.W., C.J. Sindermann, and R.E. Skud. 1959. Spawning of North American herring. Trans. Am. Fish. Soc. 88(3):164-8. Cited in Wepestad and Barton 1981.
- Shaboneev, I.E. 1965. Biology and fishing of herring in the eastern part of the Bering Sea. Pages 130-154 in P.A. Moiseev, ed. Soviet fisheries investigations in the northeastern Pacific, Part 4. (Transl. Israel Prog. Sci. Transl., Jerusalem, 1968).

- Stekoll, M.S. 1983. Observations on the biology of the intertidal alga, Fiscus sp., in Norton Sound, Univ. Alaska, Juneau. 5 pp.
- Svetovidov, A.N. 1952. Clupeidae, fauna of the USSR, Fishes II, 1. Acad. Sci. USSR, Moscow. Cited in Wespestad and Barton 1981.
- Taylor, F.H.C. 1964. Life history and present status of British Columbia herring stocks. Fish. Res. Bd. Can. Bull. 143.
- Warner, I.M., and P. Shafford. 1977. Forage fish spawning surveys southern Bering Sea. Alaska Marine Environmental Assessment Project, proj. completion rept. 111 p.
- Wespestad, V.G., and L.H. Barton. 1979. Distribution and migration status of Pacific herring. NOAA, NMFS; ADF&G. 212 pp.
- ______. 1981. Distribution, migration and status of Pacific herring. Pages 509-525 in D.W. Hood and J.A. Calder, eds. The eastern Bering Sea shelf: oceanography and resources. Vol. 1. USDC: NOAA, OMPA.
- Whitmore, D.C. 1985. Pacific herring (<u>Clupea harengus pallasi</u>) spawn and spawn substrate observations, Norton Sound, Alaska, 1984. ADF&G, Div. Commer. Fish., Anchorage. 11 pp. Draft.
- Whitmore, D.C., and D.J. Bergstrom. 1983. Assessment of herring (<u>Clupea</u> <u>harengus pallasi</u>) stocks in southeastern Chukchi Sea, 1980-1981. Informational Leaflet No. 210. ADF&G, Div. Commer. Fish, Juneau. 27 pp.



Map 1. Range of saffron cod (Morrow 1980, Wolotira 1985)

- I. NAME
 - A. Common Names: Saffron cod, navaga, far eastern navaga
 - B. Scientific Names: <u>Eleginus gracilis</u> (Tilesius), <u>Eleginus navaga</u> (Pallas)
 - C. Species Group Representation Cods (family Gadidae) are primarily northern hemisphere marine fishes. The genus <u>Eleginus</u> is comprised of two species, <u>E. gracilis</u> and <u>E. navaga</u>. Both species are very similar externally and are differentiated by several meristic characteristics, which are given by Svetovidov (1948). The two species are apparently geographically segregated throughout their ranges. <u>E. navaga</u> is found in European, Siberian, and North American arctic waters and is replaced by <u>E. gracilis</u> in North Pacific waters, including the Bering, Okhotsk, Japan, Yellow, and

Chukchi seas (Walters 1955, Wolotira 1985). Meristic differences between the two species are possibly factors of this geographic segregation and associated environmental variability, as well as genetic segregation (Wolotira 1985). For the purposes of this narrative, the two species will not be differentiated, and both will be referred to as saffron cod.

II. RANGE

Β.

A. k'orldwide

The saffron cod is found in the nearshore coastal zones of the eastern North Pacific from Sitka, Alaska, through the Bering, Chukchi, and Beaufort seas. They range eastward in the Beaufort Sea to Cambridge Bay (approximately 68°N x 105°W and west to the Sea of Okhotsk and Sea of Japan (Dunn and Vinter 1984, Andriyashev 1954, Morrow 1980). The saffron cod is rare along the southern coast of Korea but is found in the Yellow Sea (Andriyashev 1954). Statewide

The distribution of saffron cod off Alaska is in the nearshore coastal zone, south to Baronof Island and north along the Bering, Chukchi, and Beaufort sea coasts (Andriyashev 1954, Morrow 1980, Craig and Haldorson 1981). The northern Bering Sea is the center of its distribution (see map 1) (Wolotira et al. 1979).

C. Regional Distribution Maps

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

- D. Regional Distribution Summary
 - 1. Arctic and Western. Saffron cod occur throughout the Western and Arctic regions of Alaska; however, they are most abundant in Norton and Kotzebue sounds and the adjacent northeastern Bering Sea and southeastern Chukchi Sea (Andriyashev 1954, Frost and Lowry 1981, Morrow 1980). Wolotira et al. (1979) found saffron cod to be much less abundant in the central and southeastern Chukchi Sea and Kotzebue Sound than in the northern Bering Sea and Norton Sound. Greatest densities north of Bering Strait were found in relatively shallow waters near the mouth of Kotzebue Sound, offshore from the northern Seward Peninsula, and in waters less than 25 m deep between Cape Lisburne and Point Hope (Wolotira et al. 1979). Craig and Haldorson (1981) report that the Beaufort Sea is the northern limit of distribution for saffron cod. They are widespread along the Beaufort coastline but are not generally Bendock (1979) also reported a low relative abundant. abundance of saffron cod in Prudhoe Bay from 1 July through 1 September 1976.

(For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Arctic Region and volume 2 of the Alaska Habitat Management Guide for the Western Region.)

III. PHYSICAL HABITAT REQUIREMENTS

- A. Aquatic
 - 1. Water quality:
 - a. <u>Dissolved oxygen (D.O.) and pH</u>. No information is available on the pH and D.O. requirements of saffron cod.
 - b. Turbidity. No information is available specifically documenting the levels of turbidity tolerated by saffron Muench et al. (1981) reported that waters of cod. Norton Sound (the major concentration area of saffron cod) were distinctly stratified in terms of temperature and turbidity during the open-water period. Water turbidity was very generally estimated by lateral visibility and tended to be much greater below the 20 ft depth. Visibility in the upper 20 ft of water was 15 to 20 ft; visibility below the 20 ft depth was usually only 2 to 4 ft because of a heavy silt load in the deeper waters (ibid.).
 - Craig (1984) characterizes the nearshore Salinity. с. environment of the Alaskan Beaufort Sea as a band of relatively warm (5-10°C), turbid (10-25%), brackish, and shallow water. This band varies in width and depth with freshwater input to coastal waters, nearshore currents, prevailing winds, and topographic features. Barton (1979) found a similar pattern of surface salinities in Norton Sound. The lowest salinities occurred in June and progressively increased into the fall (range = 2.7 to 20.1 ppt; mean = 15.3 ppt). This is probably a function of melting pack ice and freshwater runoff throughout the season from the river systems in Norton Sound, as well as the Yukon River discharge (Barton 1979, Nebert 1974). In the Beaufort Sea, saffron cod were observed to increase in nearshore waters as the open-water season progressed and salinities increased (i.e., after spring floods and ice-melt) (Craig 1984). In winter (February), saffron cod were caught near the Colville River delta, where salinities were measured at 18 to 32 ppt (Craig and Haldorson 1981). It was thought that they moved closer inshore to spawn at this time. Mukhacheva (1959) reported that normal embryonic development of the demersal eggs of saffron cod occurs in salinities of 28 to 30 ppt. Morrow (1980) mentioned that saffron cod often enter rivers and may go considerable distances upstream, though they usually stay within the region of tidal influence. Thus it is apparent that

saffron cod are able to tolerate (at least for short time periods) a wide range of frequently fluctuating salinities.

- 2. Water depth:
 - Adult. Saffron cod are thought to reside in the coastal а. zone, coming close to shore in the fall and winter to spawn and moving into deeper water (30 to 50 m) in summer to feed (Andrivashev 1954, Lowry et al. 1983, Morrow 1980, Svetovidov 1948). Lowry et al. (1983) report that saffron cod are present and abundant in the nearshore shallow waters of the Chukchi Sea in June and July, as is indicated by their importance in the diets seals and belukha whales at Shishmaref and of Eschscholtz Bay at that time. Trawl surveys conducted from August to September 1977 in offshore areas (40 to 400 m) of the northeastern Chukchi and Beaufort seas failed to detect any significant concentrations of saffron cod. They postulate that saffron cod remain in the nearshore environment (0 to 25 m) throughout the (1979) year. Wolotira et al. encountered large concentrations of saffron cod from September through October 1976 in depths of 0 to 25 m in Norton Sound, the northeast Bering Sea, and the southern Chukchi Sea. During this 1976 survey and a subsequent 1979 trawl survey (July - August), nearly all saffron cod were found at depths of less than 50 m.
 - b. <u>Juvenile</u>. Juvenile saffron cod were restricted to shallow waters in Norton Sound and the southeastern Chukchi Sea. They were frequently encountered at depths of 0 to 25 m, and their density generally decreased with increased depth (Pereyra et al. 1977).
- 3. Water temperature:
 - a. <u>Summer/fall</u>. Surface water temperatures in Norton Sound were recorded by Zimmerman et al. (1977) and ranged from 13 to 18°C during the summer period. They observed a temperature stratification in the sound at about the 20-ft depth (11-13°C). At depths greater than 40 ft, temperatures were 4 to 6°C. Fleming and Heggarty (1966) recorded temperatures up to 15°C at all depths in the nearshore zone of Norton Sound. This area remains relatively warm in summer because of the general shallowness and the current system. Bottom temperatures are typically 15°C near the shore and drop to 0 to 4°C offshore in the outer Norton and Kotzebue sounds and Bering and Chukchi seas.
 - b. <u>Winter</u>. Water temperatures near the sea bottom approach freezing throughout the major distribution range of saffron cod. Vast ice flows often cause ice-scouring of the littoral zone sea beds from the beach to depths of at least 6 m (Sparks and Pereyra 1966).

Spawning takes place between December and early March (February in Norton Sound) at temperatures of -1.0 to -1.8°C (Lowry et al. 1983; Morrow 1980; Pokrovskava 1960). Normal embryonic development occurs at temperatures of -3.8 to 8.0°C. Egg development is suspended below -3.8°C; however, eggs will resume growth even after freezing in ice once temperatures are greater -3.8°C. Larvae cannot survive in than water temperatures greater than 8°C (Mukhacheva 1959).

B. Substrate and Cover Requirements

Saffron cod are a semidemersal species and reportedly spawn over clean sandy or pebbly bottoms (Morrow 1980, Andriyashev 1954). Larvae are pelagic and stay near the surface after hatching. They often associate with the jellyfish <u>Cyanea</u> ferruginea, seeking protection inside the mantle and tentacles from predators (Andriyashev 1954). Upon transformation, juveniles descend to the bottom and assume demersal habits similar to those of adults (Lowry et al. 1983).

- IV. NUTRITIONAL REQUIREMENTS
 - A. Food Species Used

Barton (1979) characterized the saffron cod as a generalist in terms of feeding habits. It consumes all food groups encountered; larval boreal smelt (<u>Osmerus mordax</u>) and opossom shrimp (<u>Neomysis</u> <u>spp.</u>) were the most important prey species in Norton Sound (Barton 1979, Neimark et al. 1979). Saffron cod diets include isopods, amphipods, pelecypods, mysids, nematodes, plant material, polycheate worms, shrimps, small fishes, and decapods (Andriyashev 1954, Craig 1984, Craig and Haldorson 1981, Lowry et al. 1983, Morrow 1980, Neimark et al. 1979, Percy 1975).

- B. Types of Feeding Areas Used Larval saffron cod are pelagic and feed on plankton near the water surface throughout the spring and summer (April-August) (Andriyashev 1954, Lowry et al. 1983). Juvenile and adult saffron cod are semidemersal and feed on the numerous epibenthic organisms described above. Adults are thought to migrate into deeper waters (30-50 m) during late spring and summer to feed (Morrow 1980).
 C. Factors Limiting Availability of Food
- C. Factors Limiting Availability of Food The availability of food probably has some influence on saffron cod populations and their distribution and abundance; however, no studies have been conducted to show such limitations.
- V. REPRODUCTIVE CHARACTERISTICS
 - A. Reproductive Habitat
 - Saffron cod move from water 30 to 60 m deep to shallower ice-covered inshore waters to spawn (Morrow 1980). Spawning aggregations form in autumn-early winter near river mouths, bays, and inlets in such places as Shishmaref, Kotzebue Sound, and the

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- V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

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B. Reproductive Seasonality

Saffron cod probably spawn between December and early March throughout their range. Timing and duration of the spawning period is related to the region and the severity of winter weather (Pokrovskaya 1960). The only documented spawning to date is during February in Norton Sound (Lowry et al. 1983). Samples collected from subsistence catches jigged through the ice just offshore from Kotzebue, southeast Chukchi Sea, on 15-30 November 1978 were all large saffron cod approaching maturity (Craig and Haldorson 1981).

- C. Reproductive Behavior The spawning behavior of saffron cod has not been documented.
- D. Age at Sexual Maturity

Sexual maturity of the saffron cod is reached at 2 to 3 years and individuals probably live 8 to 9 years in Pacific waters and 12 years in the arctic (Lester et al. 1956, Pokrovskaya 1957). No biological studies with this information are available for saffron cod in the Bering Sea. Craig and Haldorson (1981) caught primarily small, young (ages 1 and 2) saffron cod in August in Simpson Lagoon, Beaufort Sea. The maturity of their specimens was difficult to determine because of the age and limited size range of the fish.

- E. Frequency of Breeding Sexual maturity for saffron cod is reached at two or three years, after which the fish apparently spawn annually (Svetovidov 1948, Andriyashev 1954).
- F. Fecundity

Fecundity of saffron cod is between 25,000 and 210,000 eggs per female (Svetovidov 1948). Egg diameter was measured in large mature fish caught in Kotzebue Sound in November; egg diameters of females averaged 0.9 mm (n = 11, S.D. = 0.16, range = 0.6 - 1.1 mm) (Craig and Haldorson 1981). They also measured egg diameters of fish caught in late August in Simpson Lagoon, Beaufort Sea. Egg diameters of these fish were as large as 0.4-0.6 mm, but the maturity of the eggs was unknown (ibid.). Results from a number of Soviet studies were summarized by Wolotira (1985). Egg size and fecundity tended to vary considerably in different geographic regions. Egg diameter tends to increase, and the number of eggs tends to decrease from east to west in European arctic waters and from north to south in western Pacific waters (Wolotira 1985).

G. Incubation Period/Emergence

The incubation period for saffron cod eggs is variable. Under normal environmental conditions in Pacific waters, Mukhacheva (1957) determined the development period to be about 2.5 months. In arctic waters, a four-month development period was indicated (Khaldinova 1936). Larvae typically hatch in the spring from April to June and are planktonic for the first few months (Andriyashev 1954, Morrow 1980). Growth is probably very slow until August, when larvae transform into fry and descend to the bottom to assume a demersal life (Svetovidov 1948).

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

Saffron cod are known to make onshore-offshore migrations, which are generally associated with spawning onshore in winter and feeding offshore in summer and fall. Bottom trawl surveys have been conducted in various widely scattered portions of the range of saffron cod and tend to show much variation by area, year of sampling, and season of this movement (Barton 1979, Bendock 1979, Blackburn et al. 1981, Craig 1984, Craig and Haldorson 1981, Lowry et al. 1983, and Wolotira et al. 1979). Except for a few studies, information on saffron cod most often has been collected only incidentally to research on other species.

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

Saffron cod are an important food resource for marine birds and mammals where they are locally abundant. They were the primary food of ringed seals in late spring-early summer at Shishmaref in June and July; spotted seals collected near Wainwright in summer had fed primarily on saffron cod; and belukha whales in Kotzebue Sound fed primarily on saffron cod in June (Lowry et al. 1983).

It appears that in the colder, arctic waters of the Chukchi and Beaufort seas, saffron cod are less abundant and are replaced by arctic cod in the diets of marine mammals. This relationship occurs on a seasonal basis in the Bering Sea as well and may be related to seasonal depth distributions and abundances of each species. In either case, the eggs, larvae, juvenile, and adult forms of both species are critical factors in the trophic relationships in northern seas.

Wolotira et al. (1977) reported differences in abundance and in age and growth between saffron cod populations in the Chukchi Sea and in the northern Bering Sea. Between ages zero and four years, Chukchi Sea individuals tend to be smaller in comparison to fish of the same ages in Norton Sound. Beyond about four years of age, however, this growth difference decreases, and Chukchi Sea fish average larger than equal-aged individuals of Norton Sound. Wolotira (1985) suggests that two geographically isolated populations exist on either side of the Bering Strait. Temperature and food availability may also be factors influencing these differences in populations. The western Alaskan saffron cod resource has not been previously commercially exploited or otherwise impacted by humans. Wolotira (1985) estimated natural mortality from declining relative abundance of cohorts over time and from single-season agefrequency analysis. The estimate indicated that betwen 60 and 80% of the Norton Sound population dies annually and that less than 1% of the stock survives beyond age 5 (ibid.). Environmental factors (i.e., temperature, severity of winter, limited food sources) may cause this high level of natural mortality, but this has not been determined.

Disease does not appear to be a factor in limiting or influencing the population of saffron cod. McCain et al. (1981) conducted a study on the frequency of pathological diseases in marine fish populations in the Bering Sea, Gulf of Alaska, Norton Sound, and Chukchi Sea. They found no tumors in over 10,000 saffron cod they collected and examined from Norton Sound and the Chukchi Sea, whereas Pacific cod (Gadus macrocephalus) collected in the adjacent northwest and southern Bering Sea were affected by skin ulcers and pseudobranchial tumors. They were unsure whether saffron cod were not susceptible to the tumors or simply were not (ibid.). exposed to the tumor-inducing factor Trematode metacercarial cysts were observed in the skin of saffron cod in the Norton Sound/Chukchi Sea area. Of 10,826 saffron cod examined from Norton Sound, 0.8% were affected. No adverse effects on the fish were apparent (ibid.).

B. Human-related

The main concern regarding human-related impacts on saffron cod populations is in relation to oil development in Norton and Kotzebue sounds and the Bering, Chukchi, and Beaufort seas. A primary problem in the event of an oil spill (in winter) is that sinking oil in a saffron cod spawning area could kill or cause abnormal development of eggs and larvae (Lowry et al. 1983). Adult mortality is known to occur within 24 hours when individuals are exposed to the soluble fractions of crude oil at less than 2 ppm at 3°C (DeVries 1976). The benthic food organisms utilized by saffron cod also are known to be very sensitive to dispersed crude oil (ibid.).

In summer, saffron cod larvae are present in the surface waters, where exposure to toxic pollutants is most likely. After metamorphosis, the juveniles descend to the bottom but tend to stay nearshore (0-25 m), where effects of development are most likely to be present (Lowry et al. 1983).

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

- Alternation of preferred water temperatures, pH, dissolved oxygen, and chemical composition
- Introduction of water-soluble substances
- Increase in suspended organic or mineral material
- Increase in sedimentation rates and turbidity
- Reduction in food supply

Increased susceptibility to harvest or predation
 Seismic shock waves, blasting

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

VIII. LEGAL USE

The Alaska Department of Fish and Game has managerial authority over saffron cod extending through the 3-mi territorial sea. However, since harvesting of saffron cod is limited to minimal subsistence use, no management plan has been formulated.

IX. LIMITATIONS OF INFORMATION

Very little information is available for saffron cod populations throughout the species' range in Alaska. Most data, other than a few demersal studies conducted in the northern Bering Sea and southeastern Chukchi Sea, have been collected incidentially, while research has focused on other species. Information is needed on basic life history functions, limitations due to food availability, seasonal distribution, abundance, and movements, spawning densities, and known spawning areas, depth preferences, egg and larval requirements, and the influence of physical factors and competition on population size.

REFERENCES

- Andriyashev, A.P. 1954. Fishes of the northern seas of the USSR. (Transl. Israel Prog. Sci. Transl., Jerusalem, 1964). 617 pp.
- Barton, L.H. 1979. Finfish resource surveys in Norton Sound and Kotzebue Sound. Pages 75-313 in Environmental assessment of the Alaskan continental shelf. Final reports of principal investigators. Vol. 4: Biological studies. BLM, NOAA, OCSEAP. 238 pp.
- Bendock. T.N. 1979. Beaufort Sea estuarine fishery study. Pages 670-729 in Environmental assessment of the Alaskan continental shelf. Final reports of principal investigators. Vol. 4: Biological studies. BLM, NOAA, OCSEAP. 59 pp.
- Blackburn, J.E., K. Anderson, C.I. Hamilton, and S.J. Starr. 1981. Pelagic and demersal fish assessment in the Lower Cook Inlet estuary system. Pages 259-602 in Environmental assessment of the Alaskan continental shelf. Final reports of principal investigators. Vol. 12: Biological studies. BLM, NOAA, OCSEAP. 43 pp.
- Craig, P.C. 1984. Fish use of coastal waters of the Alaskan Beaufort Sea: a review. Trans. Am. Fish. Soc. 113(3):265-282.
- Craig, P.C., and L. Haldorson. 1981. Beaufort Sea barrier island-lagoon ecological process studies: final report, Simpson Lagoon. Part 4: Fish. Pages 384-678 in Environmental assessment of the Alaskan

continental shelf. Final reports of principal investigators. Vol. 7. BLM, NOAA, OCSEAP. 294 pp.

- DeVries, A.L. 1976. The physiological effects of acute and chronic exposure to hydrocarbons and of petroleum on the nearshore fishes of the Bering Sea. Pages 1-14 in Environmental assessment of the Alaskan continental shelf. Annual reports of principal investigators. Vol. 8. BLM, NOAA, OCSEAP. 14 pp.
- Dunn, J.R., and D.M. Vinter. 1984. Development of larvae of the saffron cod <u>Eleginus gracilis</u> with comments on the identification of Gadid larvae in Pacific waters contiguous to Canada and Alaska, USA. Can. J. Fish and Aquat. Sci. 41(2):304-318.
- Flemming, R.H., and D. Heggarty. 1966. Oceanography of the Southeastern Chukchi Sea. Pages 697-754 in N.J. Wilimovsky and J.N. Wolf, eds. Environment of the Cape Thompson region, Alaska. USAEC, Washington, DC.
- Frost, K.J., and L.F. Lowry. 1981. Trophic importance of some marine gadids in northern Alaska, USA and their body-otolith size relationships. USDC, NMFS, Fish. Bull. 79(1):187-192.
- Khaldinova, N.A. 1936. Materialy po razmnozheniv i rasviti Belomorskoi navagi (<u>Eleginus navaga</u> (Pallus) (Notes on the reproduction and development of White Sea <u>navaga</u>). Zool. Zh. 15(2). In Russian. Cited in Wolotira 1985.
- Lestev, A.V., G.I. Greshenko, and B.M. Kozlov. 1956. Promysel navagi V Vodakh Sakhalina (<u>Navaga</u> fisheries in Sakhalin waters). Sov. Sakhalin, 48 pp. In Russian. Cited in Wolotira 1985.
- Lowry, L.F., K.J. Frost, and J.J. Burns. 1983. Trophic relationships among ice-inhabiting phocid seals and functionally related marine mammals in the Chukchi Sea. Pages 179-229 in Environmental assessment of the Alaskan continental shelf. Final reports of principal investigators. Vol. 19. BLM, NCAA, OCSEAP. 50 pp.
- McCain, B.B., H.O. Hodgins, A.K. Sparks, W.D. Gronlund, and M.S. Myers. 1981. Determine the frequency and pathology of marine fish diseases in the Bering Sea, Gulf of Alaska, Norton Sound, and Chukchi Sea. Pages 1-64 in Environmental assessment of the Alaskan continental shelf. Final reports of principal investigators. Vol. 13: Biological studies. BLM, NOAA, OCSEAP. 64 pp.
- Morrow, J.E. 1980. The freshwater fishes of Alaska. Anchorage: Alaska Northwest Publishing Co. 248 pp.
- Muench, R.D., R.B. Tripp, and J.D. Cline. 1981. Circulation and hydrography of Norton Sound. Pages 77-93 in D.W. Hood and J.A. Calder,

eds. The eastern Bering Sea shelf: oceanography and resources Vol. 1. USDC: NOAA, OMPA.

- Mukhacheva, V.A. 1959. Notes on the development of the far eastern navaga (<u>Eleginus gracilis</u> Tilesius). AIBS (Transl. from Akad. Nauk. USSR. Institut Okeanologii; Trudy, 20).
- Nebert, D. 1974. The physical oceanography of Norton Sound. Pages 19-30 in Environmental study of the marine environment near Nome, Alaska. Inst. Mar. Sci. Rept. R74-3, Sea Grant Rept. 73-14. Univ. Alaska, Fairbanks. 11 pp.
- Neimark, L.M., R.T. Cooney, and C.R. Geist. 1979. Feeding behavior of Bering Sea coastal fish species. Pages 675-679 in B.R. Melteff, ed. Alaskan fisheries: 200 years and 200 miles of change. Proceedings of the twenty-ninth Alaska science conference. 4 pp.
- NWAFC (Northwest and Alaska Fisheries Center). 1985. Distribution information from bottom trawls, data through 1984. Resource Assessment and Conservation Engineering Division. USDC: NOAA, NMFS. Seattle. 1 p. computer map.
- Percy, R. 1975. Fishes of the outer MacKenzie delta. Beaufort Sea Tech. Rept. 8. Beaufort Sea Project, Dept. of Environment, Victoria, B.C. 114 pp.
- Pereyra, W.T., R.J. Wolotira, T.M. Sample, and M. Morin. 1977. Baseline studies of fish and shellfish resources of Norton Sound and the southeastern Chukchi Sea. Pages 288-316 in Environmental assessment of the Alaskan continental shelf. Annual reports of principal investigators. Vol. 8: Receptors - fish, littoral, benthos. BLM, NOAA, OCSEAP. 28 pp.
- Pokrovskaya, T.N. 1957. Vozrast i rost navagi karskogo morya (Age and growth of Kara Sea navaga). In Russian. Transl. Inst. Okeanol. Akad. Nauk USSR 26:245-253. Cited in Wolotira 1985.
- . 1960. Geograficheskaya izmenchivost' biologii navagi (roda <u>Eleginus</u>) (Geographical variability in the biology of the navaga [genus <u>Eleginus</u>]). In Russian. Transl. Inst. Okeanol. Akad. Nauk USSR 31:19-110. Cited in Wolotira 1985.
- Sparks, A.K., and W.T. Pereyra. 1966. Benthic invertebrates of the Southeastern Chukchi Sea. Pages 817-838 in N.J. Wilimovsky and J.N. Wolf, eds. Environment of the Cape Thompson region, Alaska. USAEC, Washington, DC. 21 pp.
- Svetovidov, A.N. 1948. Fishes. Gadiformes. Fauna of the USSR. Vol. 9, No. 4. Idat. Akad. Nauk. (Transl. Israel Prog. Sci. Transl., Jerusalem, 1962). 304 pp. Cited in Wolotira 1985.
- Turner, L.M. 1886. Contributions to the natural history of Alaska. Arctic Ser. Publ. Signal Serv., U.S. Army, No. II. U.S. Gov't. Printing Office, Washington, DC. 226 pp.
- Walters, V. 1955. Fishes of western arctic America and eastern arctic Siberia, taxonomy and zoogeography. Bull. Am. Mus. Nat. Hist. 106(5):225-368.
- Wolotira, R.J. 1985. Saffron cod (<u>Eleginus gracilis</u>) in western Alaska: the resource and its potential. NOAA Tech. Memo, NMFS F/NWC-79. USDC: NOAA, NMFS. 119 pp.
- Wolotira, R.J., T.M. Sample, and M. Morin, Jr. 1979. Baseline studies of fish and shellfish resources of Norton Sound and the southeastern Chukchi Sea. Pages 258-572 in Environmental assessment of the Alaskan continental shelf. Final reports of principal investigators. Vol. 6: Biological studies. BLM, NOAA, OCSEAP. 314 pp.
- Zimmerman, S.T., J.H. Gnagy, N.I. Calvin, J.S. MacKinnon, L. Barr, J. Fujioka, and T.R. Merrell. 1977. Baseline/reconnaissance characterization, littoral biota, Gulf of Alaska and Bering Sea. Pages 1-228 <u>in Environmental assessment of the Alaskan continental shelf</u>. Annual reports of principal investigators. Vol. 8: Receptors - fish, littoral, benthos. BLM, NOAA, OCSEAP. 228 pp.



Map 1. Range of starry flounder (Morrow 1980, NWAFC 1985).

- I. NAME
 - A. Common Name: Starry flounder
 - B. Scientific Name: Platichthys stellatus
 - C. Species Group Representation The starry flounder is a member of the flatfish family, Pleuronectidae. This family is marine, but a few species, including the starry flounder, enter fresh water.

II. RANGE

A. Worldwide

The starry flounder has a distribution ranging along the coast of North American from southern California north to the Arctic Ocean, then east along the arctic coast of Canada to Bathurst Inlet. To the west, starry flounders are found along the Chukchi and Bering coasts of Siberia and southward to Japan and Korea (Hart 1973, Morrow 1980).

B. Statewide

The starry flounder ranges along the entire coastline of Alaska, excluding the Aleutian Islands. From northern California to the Bering Sea it is perhaps the most abundant of the flatfish in nearshore areas (Morrow 1980).

C. Regional Distribution Maps

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

- D. Regional Distribution Summary
 - 1. Arctic. Starry flounder is distributed along the coast of the Arctic Region in nearshore areas and brackish water. These areas are also inhabited by the arctic flounder, <u>Liopsetta glacialis</u> (ibid.). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Arctic Region.)

III. PHYSICAL HABITAT REQUIREMENTS

- A. Aquatic
 - 1. <u>Water quality</u>. No information is available on the pH, dissolved oxygen, or turbidity tolerances of starry flounder. Starry flounder tolerates a wide range of salinities. It is common in brackish water and may ascend rivers even into fresh water (Morrow 1980). Juvenile flatfish in California were found in salinities of 6 to 10 parts per thousand (Hart 1973). Larval starry flounder in the Canadian Northwest Territories were found in colder, more saline waters below the surface waters (Ratynski 1983). Alverson and Wilimovsky (1966) found that salinity was a limiting factor in the distribution of starry flounder in the southeastern Chukchi Sea. Starry flounders are more common in low-salinity water and are replaced by other forms in high-salinity water.
 - 2. <u>Water depth</u>. Starry flounders are normally found in shallow water, but catches have been reported from water deeper than 275 m (Hart 1973). Depth distribution for starry flounder may be seasonal. Morrow (1980) reports that they summer in shallow nearshore water and winter in water up to 300 m.
 - 3. <u>Temperature</u>. Starry flounders are reported to spawn when water temperatures are near 11°C. Temperatures for hatching have not been reported in the field; however, in the lab, eggs hatched in 68 hours at 12.5°C and in 110 hours at 10.5°C (Morrow 1980). Adult starry flounders in Washington stopped

feeding in winter when the bottom temperatures were lowest (8-9°C) (Miller 1967).

- 4. <u>Substrate</u>. Starry flounder prefers a soft sand or mud substrate. When disturbed, it may use dorsal, anal, and caudal fins to cover itself with sand or mud (Morrow 1980). Starry flounder is taken commercially on gravel, clear shifting sand, hard stable sand, and mud, appearing to avoid only rock (Orcutt 1950). Starry flounder can alter its colors and color patterns to match the substrate (ibid.).
- IV. NUTRITONAL REQUIREMENTS
 - A. Food Species Used

The pelagic larvae of starry flounder feed on plankton (ibid.) After metamorphosis, starry flounders become bottom dwellers. Juvenile starry flounders in Washington consumed polychaete worms, mysids, amphipods, and clams (Thornburgh 1978), whereas adults fed mainly on nemertean and polychaete worms, small clams and crabs, and brittle stars (Miller 1967). Adults from the outer MacKenzie delta in Canada consumed isopods and plant material (Percy 1975). Various investigators have reported that starry flounders ate razor and surf clams in Kodiak, clams and sand shrimp in Cook Inlet, and herring eggs-on-kelp, clam siphons, brittle stars, and crabs in the northeast Gulf of Alaska (Blackburn et al. 1980). The primary foods in the northeast Bering Sea and Southeast Chukchi Sea were brittle stars and clams (Jewett and Feder 1980). Starry flounders near Kotzebue were found with herring eggs in their stomachs (Alt 1979).

- B. Types of Feeding Areas Used Starry flounders feed on organisms that live on or burrow into silt substrates. Miller (1967) often found mud and, occasionally, bits of bark and pebbles in the stomachs.
- C. Factors Limiting Availability of Food

Light and temperature may limit the production of plankton, which is the food of pelagic larvae of starry flounder. Adults are benthic feeders and forage on many species. Any disruption of the bottom sediment, however, could destroy the food source of adults. Feeding Behavior

- D. Feeding Behavior The food habits of the starry flounder vary with increases in the size of the fish (Orcutt 1950). Observations on food in the stomachs indicated that starry flounders cracked the shells of large clams, swallowed smaller clams, brittle stars, and pea crabs whole, and swallowed whole or severed at any level nemerteans, priapulids, and polychaetes worms (Miller 1967). Starry flounders in Washington apparently began feeding about sunrise and fed through the day until sunset (ibid.).
- V. REPRODUCTIVE CHARACTERISTICS
 - A. Reproductive Habitat
 - There is evidence that spawning starry flounders use shallow water near river mouths and sloughs. In California, starry flounders in

spawning condition were commonly caught in depths of 30 m or less (Orcutt 1950).

B. Reproductive Seasonality

In California, ripe, spawning, and spent fish occurred in November, became more numerous in the middle part of January, and gradually disappeared in February (ibid.). Spawning occurs from February to April in Puget Sound and British Columbia and later farther north, with the height of the spawning season corresponding with water temperatures near 11°C (Hart 1973, Morrow 1980).

- C. Reproductive Behavior No information is available on the reproductive behavior of the starry flounder.
- D. Age at Sexual Maturity

Sexual maturity for starry flounder in California and Washington is reached at age 2 for males and age 3 for females (Orcutt 1950, Campana 1984). Females grow faster and reach a larger size than males (Campana 1984). The growth of Washington starry flounders slows after sexual maturation, especially in males (ibid.).

- E. Frequency of Breeding Spawning in California occurs no more often than once a year (Orcutt 1950). The arctic flounder (<u>Liopsetta glacialis</u>), which ranges from Bristol Bay northward, apparently spawns only every second year (Morrow 1950).
- F. Fecundity The fecundity of a female 565 mm standard length was about 11,000,000 eggs (Orcutt 1950). The eggs have diameters ranging from .89 to 1.01 mm, are slightly lighter than seawater, and are nonadhesive (Hart 1973).
- G. Incubation Period/Emergency Orcutt (1950) found the times from fertilization to hatching were 110 hours at 10.5°C and 68 hours at 12.5°C. Metamorphosis from the planktonic to benthic life stage occurs when the fish is about 7 mm long at an age ranging from 27 to 104 days (Policansky 1982, Policansky and Sieswerda 1979). Policansky (1982) noted that although size and age both influence the onset of metamorphosis, the influence of size is stronger. The time to metamorphosis is shorter than that for most flatfish, which would limit the dispersal of starry flounder (Policansky and Sieswerda 1979).
- VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS Starry flounders make inshore-offshore migrations with the seasons. During summer, the fish are inshore, in shallow water and estuaries. In the winter, they move into deeper water (Morrow 1980). Tagging has shown that starry flounders seldom move more than 8 km (Manzer 1952). Juveniles and adults, however, have been recorded moving up rivers as far as 200 km (Manzer 1952, Morrow 1980).

VII. FACTORS AFFECTING POPULATIONS

A. Natural

Starry flounders are pelagic in their larval stage, and growth and survival are strongly influenced by physical and biological factors, such as water temperature and planktonic food sources. Cold years or years with low food supply could lead to high mortality and low dispersal, which would reduce local recruitment of stocks.

In a study conducted in the southeastern Chukchi Sea, Alverson and Wilimovsky (1966) found an extremely low density of starry flounders, with smaller sizes than reported in more southern waters. They suggested that the physical climate of the Arctic Ocean area may limit the population size of flatfish and depress normal growth patterns.

B. Human-related

Starry flounder eggs are buoyant, and the larvae are planktonic. These characteristics make them vulnerable to any toxicants that may be released into the water. Juveniles and adults are benthic and rely on benthic food sources, so that any contamination or disruption of the sediment could reduce the population. A summary of possible impacts from human-related activities includes the following:

- ° Changes in biological oxygen demand or nutrient loading
- ° Changes in the chemical composition of water
- [°] Changes in dissolved oxygen, temperature, pH, or salinity
- ° Entrapment
- ° Changes in sedimentation rates, turbidity, or suspended solids
- [°] Changes in substrate composition and location
- Shock waves, blasting

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

VIII. LEGAL STATUS

The Alaska Department of Fish and Game has managerial authority over starry flounder extending to 3 mi offshore. Because harvesting of starry flounder is minimal, however, no management plan has been formulated.

IX. LIMITATIONS OF INFORMATION

Little information has been collected on populations of starry flounder in Alaska; most studies have been conducted on populations in California, Washington, and British Columbia. Little information exists on tolerances of starry flounder to water-quality parameters such dissolved oxygen, or turbidity. as pH, Information on reproductive characteristics, such as seasonality, age at maturity, frequency of breeding, fecundity, and incubation period is not available for starry flounder in Alaska. Factors affecting Alaskan populations of starry flounder, such as predation and competition, have not been studied.

REFERENCES

- Alverson, D., and N. Wilimovsky. 1966. Fishery investigations of the southeastern Chukchi Sea. Pages 843-860 in N. Wilimovsky, ed. Environment of the Cape Thompson region, Alaska. U.S. Atomic Energy Commission, Div. Tech. Info. Ext., Oak Ridge, TN. 1,250 pp.
- Alt, K. 1979. Inventory and cataloging of sport fish and sport fish waters of western Alaska. ADF&G, Fed. Aid in Fish Rest. Ann. rept. Vol. 20. Proj. F-9-11, Job G-I-P.
- Blackburn, J., K. Anderson, C. Hamilton, and S. Starr. 1980. Pelagic and demersal fish assessment in the Lower Cook Inlet estuary system. Pages 107-450 in Environmental assessment of the Alaskan continental shelf. Final rept. Vol. 17. USDI: NOAA. 658 pp.
- Campana, S. 1984. Comparison of age determination methods for the starry flounder. Trans. Am. Fish. Soc. 113:365-369.
- Hart, J. 1973. Pacific fishes of Canada. Fish. Res. Bd. Can. Bull. 180. Ottawa. 740 pp.
- Jewett, S., and H. Feder. 1980. Autumn food of adult starry flounders, <u>Platichthys stellatus</u>, from the northeastern Bering Sea and southeastern Chukchi Sea. J. Conseil 39(1):7-14.
- Manzer, J. 1952. Notes on dispersion and growth of some British Columbia bottom fishes. J. Fish. Res. Bd. Can. 8(5):374-377.
- Miller, B. 1967. Stomach contents of adult starry flounder and sand sole in East Sound, Orcas Island, WA. J. Fish. Res. Bd. Can. 24(12):2,515-2,526.
- Morrow, J. 1980. The freshwater fishes of Alaska. Anchorage: Alaska Northwest Publishing Co. 248 pp.
- NWAFC (Northwest and Alaska Fisheries Center). 1985. Distribution information from bottom trawls, data through 1984. Resource Assessment and Conservation Engineering Division. USDC: NOAA, NMFS. Seattle. 1 p. computer map.
- Orcutt, H. 1950. The life history of the starry flounder, <u>Platicthys</u> stellatus (Pallas). Calif. Div. Fish. Game Fish. Bull. 78. 64 pp.
- Percy, R. 1975. Fishes of the outer MacKenzie delta. Beaufort Sea Tech. Rept. No. 8. Beaufort Sea Project, Dept. of the Environment, Victoria, B.C.
- Policansky, D. 1982. Influence of age, size and temperature on metamorphosis in the starry flounder, <u>Platichthys stellatus</u>. Can. J. Fish. Aquatic Sci. 39(3):514-517.

- Policansky, D., and P. Sieswerda. 1979. Early life history of the starry flounder, <u>Platichthys stellatus</u>, reared through metamorphosis in the laboratory. Trans. Am. Fish. Soc. 108:326-327.
- Ratynski, R. 1983. Mid summer icthyoplankton populations of Tuktoyaktuk Harbor, Northwest Territories, Canada. Can. Tech. Rept. Fish. Aquat. Sci. 1218. IV-21.
- Thornburgh, K. 1978. Patterns of resource utilization in flatfish communities. M.S. Thesis, Univ. Washington. 123 pp.



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

- I. NAME
 - A. Common Names: King crab, golden king crab, brown king crab, blue king crab, red king crab
 - B. Scientific Names: <u>Paralithodes camtschatica</u> (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 (<u>Paralithodes camtschatica</u>) is the most abundant species. Blue king crab (<u>Paralithodes platypus</u>) is not as abundant but morphologically is similar to red king crab. Golden king crab inhabits deeper water (greater than 100 fathoms) than the other two species, and its relative abundance is unknown. Because of the emphasis upon red king crab and the resulting availability of information on its abundance, the following summary emphasizes the life history of the red king crab.

III. RANGE

A. Worldwide

Red king crab is not only the most abundant of the three commercial species; its distribution is the most widespread. In Asian waters, red king crab is found from the Sea of Japan northward into the Sea of Okhotsk and along the shores of the Kamchatka Peninsula. The northern limit on the Asian coast is Cape 01yutorsky. On the west coast of North America, distribution extends northward from Vancouver Island, British Columbia, to Point Barrow (MacGinitie 1955). Red king crab is not found in the North Atlantic or in the southern hemisphere. The distribution of blue king crab extends along the North Pacific rim from the Sea of Japan to Southeast Alaska, including the Bering and Chuckchi seas. Golden king crab inhabits deeper areas along the continental slopes of the North Pacific Ocean from the Sea of Japan to Vancouver Island, including the Bering Sea (NPFMC 1980; Otto, pers. comm.).

B. Statewide

Red king crab generally occurs along the coast of southeast Alaska to the Bering Strait. Blue king crab has a similar latitudinal range but is distributed in widely separated discrete populations (Somerton 1985).

C. Regional Distribution Maps

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

- D. Regional Distribution Summary
 - 1. <u>Southwest</u>. Major concentrations of red king crab are located near Kodiak Island, the south Alaska Peninsula, the Aleutian Islands, and in the southeastern Bering Sea. Golden king crab is found in the same area described above and is abundant in the Aleutian Islands area (ibid.). Isolated populations of blue king crab occur in the Kodiak and Bering Sea area. (For more detailed rarrative information, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)
 - 2. <u>Southcentral</u>. Major concentrations of red king crab are located in lower Cook Inlet and Prince William Sound. Golden king crab is found in the same area. Isolated populations of blue king crab occur in the Prince William Sound area. (For

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

- 3. <u>Arctic and Western</u>. King crabs are found throughout the Western Region and in the Arctic Region as far north as Point Barrow. The distribution of red king crab covers most of the eastern Bering Sea and is generally associated with the continental land mass. A concentration of red king crab is found in Norton Sound (Otto 1981). Blue king crab tends to be associated with the offshore areas near St. Lawrence and St. Matthew islands (ibid.). Golden king crab is found in the eastern Bering Sea along the continental shelf break in deeper waters and is most abundant in the Aleutian Islands (ibid.).
- 4. <u>Southeast</u>. Golden king crab occupies fjords and trenches of Southeast Alaska.

IV. PHYSICAL HABITAT REQUIREMENTS

A. Water Quality

King crabs are unable to withstand wide variations in salinity and are adapted to cold water (Eldridge 1972). Distribution of the red king crab in the southeastern Bering Sea is dependent upon bottom temperatures. Water temperatures where this species occurs range from -1 to 10° C (Bartlett 1976). Summering adult male and female red king crabs inhabit a temperature range of from 0 to 5.5°C. Maximum abundance of female red king crab occurs at a temperature range of from 3 to 5°C, and maximum abundance of males at 1.5°C (Stinson 1975). Water temperatures influence the frequency of molting. Larvae of red king crab can molt successfully in water temperatures between 2 and $12^{\circ}C$, but a decrease in temperature from 10 to 5°C delays the development time (Kurata 1959, 1960a, 1960b, 1961). Laboratory studies geared toward the culture of red king crab indicate that the optimum temperature for development from fertilization to egg stage was 3 to 8°C and about 3°C from the zoeae stage to hatching (Nakanishi 1985). The optimum temperature for culture at the zoeae, glaucothoe, and young crab stages was also 8°C. The tolerance range of temperature and salinity, however, was decreased at the glaucothoe and young crab stages (ibid.).

B. Water Quantity

Red and blue king crab larvae are pelagic. Female and small male red king crabs are most abundant at intermediate depths (Eldridge 1972). Juveniles are most abundant in inshore waters and relatively shallow waters of less than 75 fathoms, and they have been found to depths of 58 fathoms (NPFMC 1980). After the fifth molt, juvenile crabs inhabit rock crevices, kelp patches, or other protective niches (Jewett and Powell 1981). Young red king crabs less than one year of age and 3 to 12 mm in carapace length exist mainly as solitary individuals among rock crevices, kelp patches, and other protected areas, where they settle as larvae (Powell and Nickerson 1965a). Red king crabs 9 to 19 mm in carapace length are common on barnacle-encrusted dock pilings in the Kodiak area. Adult red king crabs appear to prefer a mud or sandy substrate (Eldridge 1972) and have been found at depths of 200 fathoms (NPFMC 1980). Golden king crabs in Prince William Sound have been found in the deep-water trench running from Hinchinbrook Entrance in the westward arc to Knight Island Passage (ADF&G 1978). Catches of golden king crab in British Columbia fjords found the greatest preponderance of juvenile king crabs at depths of 50 to 800 m, adult male from 101 to 150 m, and adult females from 151 to 250 m (Sloan 1985). Adult male and female blue king crabs were primarily found on a sand/mud substrate in the Bering Sea at depths greater than 60 m (Palacias et al. 1985). Juvenile blue king crabs caught in trawl surveys in the Bering Sea were found predominantly in areas with rocky shellhash substrates (ibid.). It is believed that shellhash serves as a refuge material that survival of juvenile blue king crab is dependent upon. This substrate provides refuge from predators. The survival of the blue king crab is therefore limited to the presence of molluscs found within the species assemblage that occurs in, and are responsible for developing rocky-shellhash substrates (Palacias et al. 1985, Armstrong et al. 1985).

- V. NUTRITIONAL REQUIREMENTS
 - A. Preferred Foods
 - 1. Larvae. Larvae feed primarily on diatoms.
 - 2. <u>Juveniles</u>. The preferred diet of postlarval red king crab on the west Kamchatka shelf were hydroids (<u>Lafoeina maxima</u>) (Tsalkina 1969). In lower Cook Inlet, postlarval red king crab ingested detrital materials, diatoms, Bryozoa, harpacticoid copepods, ostracods, and sediment (Feder and Jewett 1981).
 - 3. Adults. The diet differs according to the geographic region. Red king crab feeds on dominant benthic forms (Kun and Mikulich 1954, Kulichkova 1955). In the southeastern Bering Sea, a number of food-habit studies have been performed. Food items have been cockles (Clinocardium ciliatum), a snail (Solariella sp.), a clam (Nuculana fossa), brittle stars (Amphiuridae), a polychaete worm (Cistenides sp.), and snow crab (Chionoecetes sp.) (Feder and Jewett 1980). Tarverdieva (1976) found the main foods to be polychaete worms, gastropods of sanddollars (Echinarachnius parma), 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 radiata, Clinocarduim californiense. mollusks (Nuculana Chlamys sp.); snails (Solariella sp. and Buccinidae); crusta-Hyas coarctatus alutacesus, ceans (crab: Erimacrus isenbeckii, and Pagarus sp.); and sand fleas (Amphipoda).

McLaughlin and Hebard (1961) determined major food items to be molluscs (bivalves), echinoderms, and decapod crustaceans. The diets of the two sexes were not found to be significantly different. King crabs in the Bering Sea must often compete for food with other bottom-feeding organisms (snow crabs, sea stars, Pacific cod, yellowfin sole, Alaska plaice rock sole. and flathead sole) (Feder and Jewett 1981, Takeuchi 1959). Pearson et al. (1984) determined that polychaetes were the most important items. followed by sand dollars (Echinorachnius parma) and clams (Tellina sp.) in terms of caloric contribution to the diet of red king crab in the southeastern Bering Sea. His studies accounted for the rapid digestion rates of soft-bodied invertebrates that are rarely seen in conventional stomach analyses.

The diet of red king crab in the Gulf of Alaska (Kodiak and Afognak islands) is diverse. Prey in Izhut Bay at Afognak Island were fishes, probably capelin (Mallotus villosus), which was an unusual occurrence. In Kiliuda Bay at Kodiak Island, prey consisted of clams, and on the outer Kodiak shelf, crabs, clams, crustaceans, and fishes were important; crabs from shallow bays at Kodiak Island preved 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 (<u>Spisula polynyma</u>), whereas crabs from Kamishak ate mostly barnacles. Diets of postlarval king crabs in Cook Inlet contained detrital material, diatoms, bryozoa, harpacticoid copepods, ostracods, and sediment (Feder et al. 1980).

B. Feeding Behavior

The king crab is omnivorous during the juvenile and adult phases of its life (Eldridge 1972). Laboratory studies performed by Rice et al. (1985)found that food consumption by juvenile red king crab increased linearly with an increase in temperature.

VI. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

The preferred habitat for reproduction of red king crab is shallow water of less than 50 fathoms and offshore ocean banks (ibid.). Molting and mating have been observed in 10 to 90 ft of water in areas where kelp is common (Jewett and Powell 1981).

In the Kodiak area, breeding red king crabs were concentrated at depths of three to eight fathoms within the lower zone of kelp and boulders. In this area, breeding crabs appeared to prefer kelp areas where <u>Alaria</u>, <u>Costaria</u>, and <u>Laminaria</u> were common. Rocks and kelp probably provided protection to the soft female during edysis (molt) and the subsequent mating (Powell and Nickerson 1965b).

B. Reproductive Seasonality

Red king crab females molt and mate from February through May. Males of the same species molt earlier than females, and young adults of both sexes molt earlier than old adults. Mature males tend to molt biennially or even triennially. Males molt prior to arriving on the mating grounds and therefore arrive in hard-shell condition (Eldridge 1972). Around Kodiak Island, female red king crabs begin to move toward the mating grounds in November. Young females and older males reach the spawning grounds first (Powell, pers. comm.). Powell and Nickerson (1965b) found that red king crabs in the Kodiak area molted and mated from mid February through the third week of April. The female migration to the spawning grounds begins about the same time as that for males. In Cook Inlet, the timing of the mating period for red king crabs differs slightly between bays. In Kachemak Bay, red king crabs begin spawning in February, with a peak in April. Kamishak Bay red king crabs may spawn slightly later (ADF&G 1978). Examination of female blue king crabs from the Bering Sea indicates that large females are unable to produce a fully developed ovary in one year, and therefore reproduce biennially, whereas females smaller than 110 mm tend to reproduce annually (Jensen et al. 1985). Differences in reproductive biology are evident in groups of Bering Sea golden king crabs from closely adjacent areas (Otto et

al. 1985). In the Bering Sea, available information indicates that spawning of golden king crab occurs over a protracted period extending from at least February to April (Otto et al. 1985). Female golden king crabs caught in British Columbia fjords are continuous aseasonal spawners with similar proportions of egg-bearing individuals found at all times of the year (Sloan 1985c). In the same area, red king crabs exhibited strong seasonal reproductive patterns (Sloan 1985a).

C. Reproductive Behavior

After the larvae hatch, females molt and then mate (McMullen 1969). Upon arrival at the spawning grounds, females may emit a pheromone that attracts males (NPFMC 1980). Males select females according to size and behavior. Female crabs can mate only in the soft-shell condition (Jewett and Powell 1981), and those not mating after molting will not extrude eggs (ADF&G 1978). For mating to be successful among females of each congregation, an adequate number of capable males must be present in the vicinity during the brief receptive period following female ecdysis (molt). Mating will be unsuccessful for females waiting for a partner longer than five days after molting (Powell et al. 1974).

Male king crabs will grasp females at the base of both claws while facing them, "embracing" for up to 16 days. After the female molts, the male crab releases her old shell and reclasps the female (Jewett and Powell 1981). Small males probably produce fewer spermatophores than large males, possibly resulting in a diminished ability to fertilize the greater egg masses of large females. Copulation and deposition of sperm on the female's gonopores can occur only after the female molts and before ovulation (Powell and Nickerson 1965b).

D. Age and Size at Sexual Maturity

There is a wide enough variation in size at maturity to suggest that age and growth rate in red king crabs are also important factors in reaching sexual maturity (Hilsinger 1983). Age is difficult to assess in king crabs because all hard parts of the crab that could be used for aging are lost during the molt. In the Kodiak area, the carapace length of mature female red king crabs ranges from about 93 mm to 120 mm. About 50% of the females are mature at about 100 mm (Powell et al. 1972). In the southeastern Bering Sea, sexual maturity for female red king crabs has been attained between a minimum carapace length of 86 to 102 mm (Wallace et al. 1949). Females appear to breed shortly after attaining sexual maturity (Haynes and Lehman 1969). In female crabs, molting is correlated with reproduction (Powell and Nickerson 1965b).

Male red king crabs as small as 86 mm carapace length have been found capable of mating. They attain sexual maturity at a smaller size and younger age than do females. It is uncertain, however, whether the small mature males are functioning adequately as brood stock. In captivity, Gulf of Alaska male red king crab were found to reach 50% maturity at 86 mm (Powell et al. 1972).

Male red king crabs grow larger than female red king crabs. Male red king crabs may grow as large as 24 lb in 15 years, whereas a female red king crab of the same age would be only 10 lb (NPFMC 1980). In the Bering Sea, size at maturity increases with decreasing latitude for both golden and red king crabs (Jewett et al. 1985, Powell et al. 1983). Golden king crabs inhabiting fjords in northern Bristish Columbia were found to mature at about 114 mm carapace length for males and 105.5 mm carapace length for females (Jewett et al. 1975).

E. Fecundity

The number of eggs produced by the female increases with carapace size. In Kodiak waters, small female red king crabs may carry 50,000 to 100,000 eggs, with large females carrying 400,000 eggs (Eldridge 1972). In Cook Inlet, fecundity has been reported to range from 25,000 to 390,000 eggs (Haynes 1968). The low numbers of eggs carried by some females could be attributed to partial fertilization of large females by smaller males (ibid.). It could also be related to the food supply and age of the individual female because males very rarely mate with females larger than themselves (Hilsinger, pers. comm.; Powell et al. 1972). Female

golden king crabs from northern British Columbia have been found to carry up to 27,000 eggs (Jewett et al. 1985). The egg size of Lithodes spp. is about double the size found in Paralithodes spp. (Haynes 1968, Sasakawa 1965). Size at maturity for golden king crabs from different areas in the Bering Sea is somewhat different Male crabs from the eastern Aleutians area mature at by area. about 130 mm carapace length, and females from the same area reach maturity at about 111 mm carapace length. Male and female golden king crabs from the Pribilof Islands District mature at about 107 and 120 mm carapace length, respectively. Male and female golden king crab from the St. Matthew area mature at the respective size of 92 and 97.7 mm (Jewett et al. 1985. Based on observation of presence of eggs on the pleopods, 50% of the female blue king crabs sampled from St. Matthew Island and the Pribilof Islands reached sexual maturity at about 81 mm and 96 mm, respectively (Somerton and MacIntosh 1983). The size at which sexual maturity was attained for 50% of the female blue king crabs examined from Olga Bay of Kodiak Island and from Prince William Sound reached 94 and 87 mm, respectively (ibid.). Size at maturity of male blue king crabs differed considerably between sampling locations. The size at maturity, based upon the relationship of chela growth to carapace size, of 50% of the male blue king crabs from St. Matthew Island and the Pribilof Islands in the Bering Sea were 77 and 108 mm, respectively. Fifty percent of the Olga Bay and Prince William Sound male blue king crabs were believed to mature at 87 and 93 mm, respectively (ibid.).

F. Frequency of Breeding

Molting occurs before mating each year. Female red king crabs after five years probably molt annually (Powell and Nickerson 1965b). Female red king crabs apparently mate with only one male (Eldridge 1972). The mating ability of males varies with their size and is affected by the time of year they molt (ibid.). Males of varying sizes and shell ages have been shown to mate successfully (producing fertilized clutches of greater than 75%) with four to nine females (Powell et al. 1974). Captive males are polygamous and have been documented to mate with 14 females during one season (Jewett and Powell 1981).

Female molting is closely associated with reproduction, with one molt occurring annually prior to extrusion of the eggs (Gray and Powell 1966). After attaining sexual maturity, possibly in the fourth and fifth year, adult red king crabs molt annually for several years, and then some individuals begin to skip molt at approximately seven years of age (Powell and Nickerson 1965b). Male red king crabs that molt during the mating season may not mate after molting because molting may have interfered with mating. Molting areas for male red king crabs may be distant from the mating grounds. Males who skip molt two consecutive years may die after the next breeding period (Haynes and Lehman 1969).

Males generally molt annually, but males older than eight years may shed their exoskeletons once every two or three years (Manen and Curl 1981). These skip-molt males may play an important role in the reproductive success of stocks, compared to newly molted males whose mating ability is hampered by the process of molting (ibid.).

G. Incubation/Emergence

Female red king crabs carry their eggs externally for about 11 Eggs develop into prezoeae within five months of months. fertilization and remain in this state while carried by the Just before mating, prezoeae hatch and molt into zoeae female. larvae, which assume a pelagic existence (Eldridge 1972). Egg development may be slowed by colder temperatures. Eggs hatch during a three-month period from March through June. Peak hatch periods and larval abundance in the eastern Bering Sea occur from early May through mid July. Larvae are concentrated along the north Aleutian shelf from Unimak Island into Bristol Bay (Manen and Curl 1981). The time interval between molts progressively increases from a minimum of three weeks for early postlarval juveniles to a maximum of three years for adult males (NPFMC 1980).

During the first year, juvenile red king crabs undergo 11 molts and in the following year 8 molts (Manen and Curl 1981). Eggs of blue king crab from the Bering Sea show a rate of development similar to that of red king crab, indicating an ovigerous period of 11-12 months (Jensen et al. 1985).

VII. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

A. Larvae

Released red king crab larvae are pelagic, with some swimming ability. Studies indicate that ocean currents distribute larvae into nursery areas that are shallow and close to shore. In Cook Inlet, red king crab larvae are present in the plankton from mid February to late June. Larvae remain planktonic about 30 to 40 days. After the fifth molt, larvae become benthic. In Cook Inlet, the demersal-benthic settling generally occurs from mid April to late August but is heaviest during July through August (ADF&G 1978). The red king crab juvenile form occurs after the sixth molt. Movements and development of golden king crab at this stage are mostly unknown. However, Sloan (1985a) indicates that isolated fjords in British Columbia serve as retention areas for larvae of golden king crab hatched in the same area.

B. Juveniles

First-year red king crab juveniles assume a solitary benthic existence in relatively shallow water and in the Gulf of Alaska are abundant in waters close to shore (Eldridge 1972). Large concentrations of juveniles have been found at depths of 29 fathoms (Powell and Reynolds 1969). During their second year, red king crab juveniles aggregate into large groups called "pods." Pods are maintained until the crabs

large groups called "pods." Pods are maintained until the crabs reach sexual maturity. Upon reaching sexual maturity, crabs segregate by sex and size. Pods are believed to provide protection against predators. Pods are found year-round and are comprised of both males and females of similar size. Pods appear to disband when crabs feed or change location. The development and movements of golden and blue king crabs at this stage are unknown. Subadult and adult aggregations of red king crab are more scattered and circular compared to pod formation (Powell and Nickerson 1965a).

From the first through the fifth instar stage of development (6-8 mm carapace length), juvenile blue king crabs are pure white in coloration. Juvenile blue king crabs from this size up to 25 mm carapace length may remain white or may turn brown, orange, purple, or may attain a molted coloration. It is believed that the diversity in coloration or light and dark shading may prevent predation upon year classes that randomly settle on heterogeneous substrates (Armstrong et al. 1985).

C.

Adult.

Adults inhabit deeper water than juveniles (Eldridge 1972). Males segregate from females except during the mating season (ibid.). Adult red king crabs also segregate by size within sex-segregated King crabs follow distinct annual migragroups (NPFMC 1980). tional patterns associated with the mating season, moving to shallow water of less than 50 fathoms along the shoreline and onto offshore ocean banks in the Gulf of Alaska. Young adults precede old adults, and males migrate before females (Powell and Nickerson 1965b). A molting and mating/spawning migration occurs in the spring, and a feeding migration offshore occurs in the fall (Marukawa 1933). The migration of red king crabs to shallow water in the Kodiak area begins in January and continues through April (NPFMC 1980). Migration timing in the eastern Bering Sea is believed to be similar but later than that of the Kodiak stock (ADNR/USFWS 1983). In Cook Inlet, red king crabs undergo seasonal migrations consisting of an inshore movement in spring and summer and an offshore movement to deeper waters in fall/winter. Ιn Kachemak Bay, the inshore spawning migration begins in late December and extends through May. Peak movement is in early March. Offshore movement in the area, which is termed the feeding migration, begins in September and extends through November. This movement is a slow foraging process rather than a direct journey into deeper water (ADF&G 1978).

Golden king crabs caught in northern British Columbia Fiords were found at significantly greater depths than were red king crab. Water depths inhabited by golden king crab are related to both parasitized and unparasitized king crabs (Sloan 1985a). Sloan also proposes that juvenile female golden king crabs found in fjords recruit in relatively shallow water at depths less than 100 m. Females of the same area and species mate and extrude eggs usually at less than 150 m depths and incubate eggs from between 150 to 250 m depths. Spawned-out females dominate the unparasitized female population at depths greater than 200 m. These crab may inhabit these depths for a year and may then

migrate to depths ranging from 50 to 150 m, where lesser migratory adult males most frequently occur. The behavior of parasitized golden king crabs of both sexes in fjord areas was similar to spawned-out or "matted setae" females and are the largest component of the crab population at a depth range of 200 to 400 m (ibid.).

VIII. FACTORS INFLUENCING POPULATIONS

- A. Natural
 - 1. <u>Predation</u>. 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 (<u>Erimacrus isenbeckii</u>) have been observed to prey upon juvenile king crabs when the pod was disbanded after being disturbed by divers. Sculpins (<u>Hemilepidotus</u> <u>hemilepidotus</u>) 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. <u>Disease and parasites</u>. Adult crabs are affected by diseases or parasites. Instances of the following afflictions occur:

- Rust disease: infestation of exoskeleton by chitindestroying bacteria; affects P. <u>camtschatica</u> and P. platypus in the North Pacific (Sindermann 1970)
- [°] Rhizocephalan: Briarosaccus callosus infects <u>P. platypus</u>, <u>P. camtschatica</u>, and <u>L. aequispina</u> (This parasitic barnacle will inhibit molting, cause "parasitic castration," and retard gonad development [NMFS 1983, Sloan 1985a].)
- Nemertean worm (<u>Carcinomertes</u> sp.) infestations have been found in red king crab egg clutches and have been known to prev on the eggs (Wickam et al. 1985). <u>Carcinomertes</u> has been documented in Kachemak Bay (Cook Inlet) king crabs. Infestation has coincided with reduced egg clutches and high egg mortality (Merritt, pers. comm.; NMFS 1983).
- [°] Acanthocephalan, a parasitic pseudocoelomate found in connective tissue of the midgut of the king crab, causes damage to the intestinal wall. This organism has been documented in king crabs from Cook Inlet and Bristol Bay (NMFS 1983).

B. Human-related

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

- Alteration of preferred water temperatures, pH, dissolved oxygen, and chemical composition
- ^o Alteration of preferred substrate
- ° Alteration of intertidal areas
- ^o Increase in suspended organic or mineral material
- ^o Reduction in food supply
- ^o Reduction in protective cover (e.g., seaweed beds)
- ° Obstruction of migration routes
- Shock waves in aquatic environment
- * Human harvest (including handling of nonlegal crabs)
- ' Transportation of diseased crab leading to possible epizootic diseases and outbreaks

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

IX. LEGAL STATUS

A. Managerial Authority

King crab fisheries throughout Alaska are managed by the State of Alaska under regulations defined by the Alaska Board of Fisheries. King crab fisheries in the Bering Sea-Aleutian area are managed under a policy defined by the Alaska Board of Fisheries and the North Pacific Management Council (McCrary 1984).

REFERENCES

- ADF&G. 1978. Alaska's fisheries atlas. Vol. 2 (R.F. McLean and K.J. Delaney, eds.). 43 pp. + maps.
- ADNR/USFWS. 1983. Bristol Bay Cooperative Management Plan. Anchorage. 495 pp.
- Armstrong, D.A., J.L. Armstrong, R. Palacias, G. Williams, and G. Jensen. 1985. Early life history of juvenile blue king crab, <u>Paralithodes</u> <u>playtypus</u>, around the Pribilof Islands. In Lowell Wakefield fisheries symposium series, international king crab symposium abstracts. Univ. Alaska Sea Grant, Fairbanks. 47 pp.
- Bartlett, L.D. 1976. King crab (family Lithodidae). Pages 531-545 <u>in</u> Pereyra et al. 1976.
- Cunningham, D. 1969. A study of the food and feeding relationships of the Alaska king crab, <u>Paralithodes</u> <u>camtshatica</u>. M.S. Thesis, San Diego State College. Cited in Feder and Jewett 1981.
- Eldridge, P. 1972. The king crab fisheries in the Gulf of Alaska. Pages 211-266 in D.H. Rosenburg, ed. A review of the oceanography and renewable resources of the northern Gulf of Alaska. Institute of Marine Science. Rept. R72-23. Univ. Alaska, Fairbanks.

- Feder, H.M., A.J. Paul, M.K. Hoberg, S.L. Jewett, G.M. Matheke, K. McCumby, J. McDonald, R. Rice, and P. Shoemaker. 1980. Distribution, abundance, community structure, and trophic relationships of the nearshore benthos of Cook Inlet. NOAA/OCSEAP, final rept. Cited in Feder and Jewett 1981.
- Feder, H.M., and S.C. Jewett. 1980. A survey of epifaunal invertebrates of the southeastern Bering Sea with notes of the feeding biology of selected species. Institute of Marine Science. Rept. R78-5. Univ. Alaska, Fairbanks.
- . 1981. Feeding interactions in the eastern Bering Sea with emphasis on the benthos. Pages 129-1261 in D.W. Hood and J.A. Calder, eds. The eastern Bering Sea shelf: oceanography and resources. Vol. 2. USDC: NOAA, OMPA.
- Gray, G.W., and G.C. Powell. 1966. Sex ratios and distribution of spawning king crab in Alitak Bay, Kodiak Island, Alaska. Crustaceana 10:303-309.
- Haynes, E.B. 1968. Relation of fecundity and egg length to carapace length in king crab, <u>Paralithodes camtschatica</u>. Proc. Natl. Shellfish Assoc. 58:60-62.
- Haynes, E., and C. Lehman. 1969. Minutes of the second Alaskan shellfish conference. ADF&G, Informational Leaflet No. 135. Juneau. 102 pp.
- Hilsinger, J.R. 1983. King and Tanner crab summary. ADF&G, Div. Commer. Fish., memo for presentation at king and Tanner crab workshop. Sandpoint.
 - _____. 1983. Personal communication. Mgt. Coordinator, Central Region, ADF&G, Div. Commer. Fish., Anchorage.
- Jensen, G.C., D.A. Armstrong, and G. Williams. 1985. Reproductive biology of blue king crab, <u>Paralithodes platypus</u>, in the Pribilof Islands. In Lowell Wakefield fisheries symposium series, international king crab symposium abstracts. Univ. Alaska Sea Grant, Fairbanks.
- Jewett, S.C., and G.C. Powell. 1981. Nearshore movement of king crab. Alaska Seas and Coasts 9(3):6-8.
- Jewett, S.C., N.A. Sloan, and D.A. Somerton. 1985. Size at sexual maturity and fecundity of the fjord-dwelling golden king crab <u>Lithodes</u> <u>aequispina</u> Benedict from northern British Columbia. J. Crustacean Biol. 5(3):377-385.
- Kulichkova, V.A. 1955. Feeding of Kamschatka crab during the spring summer period on the shores of Kamschatka and Saghalin. Izv. TINRO. Vol. 43. Cited in Feder and Jewett 1981.

- Kun, M.S., and L.V. Mikulich. 1954. Diet composition of far eastern crab of commercial quality during the summer. Izv. TINRO. Vol. 41. Cited in Feder and Jewett 1981.
- Kurata, H. 1959. Studies on the larvae and post-larvae of <u>Paralithodes</u> <u>camtschatica</u>: I, rearing of the larvae with special reference to food of the zoeae. Bull. Hokkaido Reg. Fish. Res. Lab. 20:76-83. Cited in Feder and Jewett 1981.
 - . 1960a. Studies on the larvae and post-larvae of <u>Paralithodes</u> <u>camtschatica</u>: II, feeding habits of zoea. Bull. Hokkaido Reg. Fish. Res. Lab. 21:1-8. Cited in Pereyra et al. 1975.
- . 1960b. Studies on the larvae and post-larvae of <u>Paralithodes</u> <u>camtschatica</u>: III, the influence of temperature and salinity on the survival and growth of larvae. Bull. Hokkaido Reg. Fish. Res. Lab. 21:9-14. Cited in Feder and Jewett 1981.
- ______. 1961. Studies on the larvae and post-larvae of <u>Paralithodes</u> <u>camtschatica</u>: growth of the post-larvae. Hokkaido Fish. Exp. Sta. Month. Rept. 18(1):1-9. Cited in Pereyra et al. 1976.
- MacGinitie, G.E. 1955. Distribution and ecology of the marine invertebrates of Point Barrow, Alaska. Smithsonian Coll. 128:1-201.
- McCrary, J.A. 1984. Personal communication. Asst. Regional Supervisor, ADF&G, Div. Commer. Fish., Kodiak.
- McLaughlin, P.A., and F.H. Hebard. 1961. Stomach contents of Bering Sea king crabs. USFWS Spec. Sci. Rept. 291. Cited in Pereyra et. al. 1975.
- McMullen, J.C. 1969. Effects of delayed mating on the reproduction of king crab Paralithodes camtschatica. J. Fish. Res. Bd. Can. 26(10).
- Manen, C.A., and H.E. Curl. 1981. Draft summary report of the shellfish workshop. St. George Basin lease area synthesis meeting. Anchorage, AK. April 28-30, 1981. 31 pp.
- Marukawa, H. 1933. Biology and fishery research on Japanese king crab <u>Paralithodes camtschatica</u> (Tilesius). J. Imp. Exp. Sta., Tokyo 4(37). Cited in Pereyra et al. 1976.
- Merritt, M.F. 1985. Personal communication. Lower Cook Inlet Shellfish Research Biologist, ADF&G, Div. Commer. Fish., Homer.
- NMFS. 1983. Unpublished data. Results of king crab study.

- NPFMC. 1980. Alaska king crab draft fishery management plan. Anchorage, AK. 115 pp.
- Otto, R.S. 1981. Eastern Bering Sea crab fisheries. Pages 1,037-1,066 in D.W. Hood and J.A. Calder, eds. The eastern Bering Sea shelf: oceanography and resources. Vol. 2. USDC: OMPA, NOAA. Seattle, WA.

. 1983-84. Personal communication. Laboratory Director, NOAA, NMFS, NWAFC, Kodiak, AK.

- Otto, R.S., P. Cummiskey, and K.H. Cronk. 1985. Observations on the reproductive biology of golden king crabs, <u>Lithodes aequispina</u>, in the Bering Sea and Aleutian Islands. In Lowell Wakefield fisheries symposium series, international king crab symposium abstracts. Univ. Alaska Sea Grant, Fairbanks. 47 pp.
- Nakanishi, Takashi. 1985. The effects of environment on the survival rate, growth, and respiration of eggs and larvae of king crab, <u>Paralithodes</u> <u>camtshatica</u> in Lowell Wakefield fisheries symposium series, international king crab symposium abstracts. Univ. Alaska Sea Grant, Fairbanks. 47 pp.
- Palacias, R., D.A. Armstrong, G. Williams, and J.L. Armstrong. 1985. Community analyses applied to characterization of blue king crab habitat around the Pribilof Islands. In Lowell Wakefield fisheries symposium series, international king crab symposium abstracts. Univ. Alaska Sea Grant, Fairbanks. 47 pp.
- Pearson, W., and D. Woodruff, and B. Higgins. 1984. Feeding ecology of juvenile king and Tanner crab in the southeastern Bering Sea. Final rept., April 1984 to NOAA/OCSEAP Contract 2311105131.
- Pereyra, W.T., J.E. Reeves, and R.G. Bakkala. 1976. Demersal fish and shellfish resource of the eastern Bering Sea in the baseline year 1975. USDC: NOAA, NMFS, Northwest Fisheries Center processed rept. 619 pp.
- Powell, G.C. 1979. Stars for kings. Sea Frontiers 25. Cited in Feder and Jewett 1981.

_____. 1983. Personal communication. King Crab Research Biologist, ADF&G, Div. Commer. Fish., Kodiak.

Powell, G.C., and R.B. Nickerson. 1965a. Aggregation among juvenile king crabs (<u>Paralithodes</u> <u>camtschatica</u> Tilesius), Kodiak, AK. Animal Behaviour 13:374-380.

_____. 1965b. Reproduction of king crabs (<u>Paralithodes</u> <u>camtschatica</u> [Tilesius]). J. Fish. Res. Bd. Can. 22(1):101-111.

- Powell, G.C., and R.E. Reynolds. 1965. Movements of tagged king crab, <u>Paralithodes camtshatica</u> (Tilesius), in the Kodiak Island-Lower Cook Inlet region of Alaska, 1954–1963. ADF&G, Div. Commer. Fish., Informational Leaflet No. 55, Juneau.
- Powell, G.C., B. Shafford, and M. Jones. 1972. Reproductive biology of young adult king crabs (<u>Paralithodes camtschatica</u> [Tilesius]) at Kodiak, Alaska. Pages 77-87 in Proceedings of the National Shellfisheries Association. Vol. 63.
- Powell, G.C., K.E. James, and C.L. Hurd. 1974. Ability of male king crab Paralithodes camtshatica to mate repeatedly. Fish. Bull. 72(1).
- Powell, G.C., R. Peterson, and L. Schultz. 1983. The red king crab, <u>Paralithodes camtshatica</u> (Tilesus), in Norton Sound, Alaska: History of biological research and resource utilization through 1982. ADF&G,
- Rice, S.D., C.C. Broderson, and P.J. Arasmith. 1985. Feeding rates, molting success, and survival of juvenile red king crabs at different temperatures. In Lowell Wakefield fisheries symposium series, international king crab symposium abstracts. Univ. Alaska Sea Grant, Fairbanks. 47 pp.
- Sasakawa, Y. 1975. Studies of blue king crab resources in the Western Bering Sea - III. Ovarian weight, carried egg number and diameters. Bulletin of the Japanese Society of Scientific Fisheries 41-941-944. Cited in Jewett et al. 1985.
- Sindermann, C.J. 1970. Principal diseases of marine fish and shellfish. New York: Academic Press.
- Sloan, N.A. 1985. Life history characteristics of fjord dwelling golden king crabs (<u>Lithodes aequispina</u>). Mar. Ecol. Prog. Ser. Vol. 22:219-228.
- Somerton, D.A. 1985. Allopatric distribution of blue and red king crabs: some possible explanation. In Lowell Wakefield fisheries symposium series, international king crab symposium abstracts. Univ. Alaska Sea Grant, Fairbanks. 47 pp.
- Stinson, J.E. 1975. The effects of ocean currents, bottom temperatures, and other biological considerations in regard to the location and abundance of mature southeastern Bering Sea king crab, <u>Paralithodes</u> <u>camtschatica</u>. Univ. Washington, Fish. Res. Inst. Call. Fish Courses Project. 11 pp. Cited in Pereyra et al. 1975.
- Takeuchi, I. 1959. Food of king crab (<u>Paralithodes camtschatica</u>) off the west coast of Kamchatka in 1958. Bull. Hokkaido Reg. Fish. Res. Lab. 20:67-75. Cited in Feder and Jewett 1981.

- Tarverdieva, M.R. 1976. Feeding of the Kamchatka king crab <u>Paralithodes</u> <u>camtshatica</u> and Tanner crabs, <u>Chionoecetes opilio</u> in the <u>southeastern</u> part of the Bering Sea. Biology Morya 2:41-8 (transl. from Russian). Cited in Feder and Jewett 1981.
- Tsalkina, A.V. 1969. Characteristics of epifauna of the west Kamchatka shelf (from problems of commercial hydrobiology). Fish. Res. Bd. Can., transl. Ser. No. 1568. Cited in Feder and Jewett 1981.
- Wallace, M.M., C.J. Pertiut, and A.H. Hvatum. 1949. Contributions to the biology of the king crab <u>Paralithodes camtschatica</u> (Tilesius). USFWS, Fish. Leaflet 340. 50 pp.
- Wickam, P.E., S.F. Blair, and A. Kris. 1985. Predation by nemerteans on eggs of Alaskan king crabs. In Lowell Wakefield fisheries symposium series, international king crab symposium abstracts. Univ. Alaska Sea Grant, Fairbanks. 47 pp.

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Map 1. Range of Tanner crab (ADF&G 1978; Kessler, pers. comm.; Otto, pers. comm)

- I. NAME
 - A. Common Names: Tanner crab, snow crab, queen crab, spider crab
 - B. Scientific Names: <u>Chionoecetes bairdi</u>, <u>C. opilio</u>, <u>C. angulatus</u>, <u>C. tanneri</u>

II. EXTENT TO WHICH SPECIES REPRESENTS GROUP

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

III. RANGE

A. Worldwide

Tanner crabs have a circumarctic distribution, extending into the temperate waters on the east and west coasts of North America. <u>C. bairdi</u> occurs primarily in the eastern Pacific Ocean from Oregon (Hosie 1974) northward to the Aleutian Islands and the eastern Bering Sea. <u>C. bairdi</u> also exists in the western Pacific Ocean near Kamchatka. <u>C. opilio</u> occurs from the eastern Bering Sea northward to the Beaufort Sea and in the western Atlantic Ocean south to Casco Bay, Maine (Garth 1958). <u>C. angulatus</u> and <u>C. tanneri</u> occur in deeper water in the North Pacific from the California Coast north to the Bering Sea (NPFMC 1981; Colgate, pers. comm).

B. Statewide

<u>C. bairdi</u> occurs from Southeast Alaska north to the southeastern Bering Sea along the continental shelf edge to the U.S.-USSR convention line. <u>C. opilio</u> occurs in the Bering Sea (ADF&G 1978). Regional Distribution Maps

- C. Regional Distribution Maps To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for each region. Most of the maps in this series are at 1:250,000 scale, but some are at 1:1,000,000 scale. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of selected fish and wildlife species has been prepared and may be found in the Atlas that accompanies each regional guide.
- D. Regional Distribution Summary
 - 1. <u>Southwest</u>. Concentrations of <u>C</u>. <u>bairdi</u> occur in the Kodiak Island, Bristol Bay, and South Peninsula/Aleutian Islands areas. <u>C</u>. <u>opilio</u> occurs in the eastern Bering Sea, with greatest concentrations north of 58° north latitude. (For more detailed narrative information, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)
 - 2. Southcentral. Concentrations of <u>C</u>. bairdi occur in the Prince William Sound and lower Cook Inlet areas. Small-sized Tanner crabs (<u>C</u>. bairdi) have also been found in upper Cook Inlet, primarily in the Central District (Kyle, pers. comm.). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)
 - 3. <u>Arctic and Western</u>. Concentrations of <u>C</u>. <u>bairdi</u> have been located in a broad band extending from inner Bristol Bay westward along the outer continental shelf edge to 187° west longitude (Otto et al. 1984). <u>C</u>. <u>opilio</u> occurs from the Bering Strait south to Unimak Island, with the exception of the northern or eastern shores of Bristol Bay, immediately south of Unimak Island (Otto 1981, Otto et al. 1984b).

IV. PHYSICAL HABITAT REQUIREMENTS

A. Water Quality

Adult distribution is restricted by low salinity and high temperature. Laboratory experiments show that mortality of <u>C</u>. <u>opilio</u> occurs if the crabs are exposed to salinities of less than 22.5 parts per thousand (o/oo). <u>C</u>. <u>opilio</u> reaches 50% mortality after 18.8 days when the temperature has been held at 16°C (McLeese 1968). <u>C</u>. <u>bairdi</u> is found in warmer slope and outer continental shelf waters of the southern Bering Sea where average temperatures are 4.5°C. <u>C</u>. <u>opilio</u> is located in colder waters where the mean temperature is 2.4°C (NPFMC 1981).

B. Water Quantity

Tanner crabs of all sizes are abundant in water as shallow as 10 m (Donaldson, pers. comm.). Juveniles occur at varying depths (NPFMC 1981); they have been found to settle out along the sea bottom at depths between 298 and 349 m (Ito 1968). <u>C. bairdi</u> 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 (<u>C. bairdi</u> 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 <u>C. bairdi</u> smaller than 40 mm have been located in Lisianski Strait as deep as 230 m (Carlson and Straty 1981).

Adult <u>C. bairdi</u> occur between shore water and 473 m, with major concentrations at less than 300 m. <u>C. opilio</u> has been found between 13 m and 454 m, with major concentrations usually at less than 155 m (NPFMC 1981, Somerton 1981, Colgate 1983).

C. Substrate

The preferred substrate of <u>C</u>. <u>bairdi</u> has been described as green and black mud, fine gray and black sand, and shell (Garth 1958). Postlarval and juvenile <u>C</u>. <u>bairdi</u> 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 <u>C</u>. <u>bairdi</u> was found among dense centers of spongelike material (Jewett 1982).

- V. NUTRITIONAL REQUIREMENTS
 - A. Preferred Foods
 - 1. Larvae. Larvae feed on plankton in the water column.
 - 2. <u>Juveniles</u>. The diet of juveniles is uncertain. They are believed to feed on detritus, crustaceans, and molluscs accumulated on the sea floor (NPFMC 1981).
 - 3. <u>Adult.</u> Identifiable stomach contents for <u>C</u>. <u>opilio</u> and <u>C</u>. <u>bairdi</u> in the Bering Sea were primarily polychaetes, crustaceans, and molluscs (Tarverdieva 1976). <u>C</u>. <u>opilio</u> consumes polychaetes and brittle stars (Feder and Jewett 1981). In Norton Sound, stomach contents of <u>C</u>. <u>opilio</u> included clams (<u>Nucula tenuis</u>) (Feder and Jewett 1978). Important food items for <u>C</u>. bairdi in the Kodiak area were arthopods (mainly

juvenile <u>C</u>. <u>bairdi</u>), fishes, and molluscs (Jewett and Feder 1982). Clams (<u>Macoma</u> spp.), hermit crabs (<u>Paqurus</u> spp.), and barnacles (<u>Balanus</u> spp.) were documented in stomachs of <u>C</u>. <u>bairdi</u> in lower Cook Inlet. In Prince William Sound, the diet of <u>C</u>. <u>bairdi</u> contained polychaetes, clams, <u>C</u>. <u>bairdi</u>, crustaceans, and detritus (Feder and Jewett 1981).

- B. Feeding locations Larvae feed in the water column; juvenile and adult crabs are benthic.
- C. Factors Limiting Availability of Food

Adverse climatic conditions may affect the availability of plankton during the larval release period, and primary prey species may have suffered a population decline, either or both of which circumstances would limit the availability of food (Donaldson, pers. comm.)

- D. Feeding Behavior Larvae are planktivores; adults are benthic omnivores.
- VI. REPRODUCTIVE CHARACTERISTICS
 - A. Reproductive Habitat

Directed studies regarding preferred mating habitat have yet to be performed.

B. Reproductive Seasonality

Mating occurs during two periods that overlap, in winter and early spring: 1) females molting to maturity (primiparous) are mated by males right after ecdysis during the winter, and 2) multiparous females (carrying fully developed eggs) undergo egg hatch and either mate or use stored sperm to fertilize the new egg clutch in the spring (Colgate, pers. comm.; Paul et al. 1983). In laboratory studies, females not bred on the day of their maturity molt extruded either nonfertilized eggs or no eggs at all (Paul et al. 1983). The breeding season for C. <u>bairdi</u> near Kodiak Island is from January to May (Donaldson 1975).

C. Breeding Behavior

Males and females integrate on the mating grounds. It is suspected that the male is attracted to the female by her release of a chemical or chemicals (Adams 1979). Males mate with primiparous females just after the females undergo terminal molt to maturity. This puberty molt occurs only once in the female's life (Ito 1963, Watson 1972). Spermatozoa are then transferred to and stored in the female's seminal receptacles. Eggs released during future ovulations may be fertilized by spermatozoa stored since the first mating. If the female is unattended by a male during her molt to maturity, ovulation may occur; however, the eggs will remain infertile (Adams 1979). In captivity, old-shell female C. bairdi can mate as multiparous females or produce normal-size egg clutches of viable eggs utilizing sperm stored for two years (Paul et al. 1983). These characteristics are not known for C. opilio. Male Tanner crabs are capable of mating at the size at which they reach maturity (Donaldson 1975). A male may fertilize up to six females in one season (Watson 1972).

- D. Age and Size at Sexual Maturity
 - Female <u>C</u>. <u>bairdi</u> in the Gulf of Alaska reach sexual maturity at about five years and males at six years (Donaldson, pers. comm.). Female <u>C</u>. <u>bairdi</u> undergo their final molt as they reach maturity (Donaldson et al. 1981). Studies in the Gulf of Alaska have shown that 50% of the female <u>C</u>. <u>bairdi</u> have reached maturity at 83 and 97 mm at the molt to maturity. Among male <u>C</u>. <u>bairdi</u>, 90 mm appears to be the size at which the molt to maturity occurs. Such an animal would grow to 112 mm. In the Sea of Japan, maturity of male <u>C</u>. <u>opilio</u> 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 (<u>C</u>. <u>bairdi</u>) to reach maturity (Donaldson et al. 1981).
- E. Fecundity

The fecundity of Tanner crabs increases from their first to their second reproductive year, then decreases slightly in succeeding years. Fecundity may be less the first year because of the energy requirements of the first molt (Somerton 1981). The number of eggs carried by the female is a linear function of carapace width (Hilsinger 1975). In the Bering Sea, the fecundity range for C. bairdi is from 89,000 to 424,000 eggs (NPFMC 1981) and in the Gulf of Alaska, 85,000 to 231,000 eggs (Hilsinger 1975). The fecundity of C. opilio in the Gulf of St. Lawrence has been found to range from 20,000 to 40,000 eggs (Watson 1969). The average percentages, by location, of adult females not carrying egg clutches between 1977 and 1981 were as follows: Kodiak, 5.8%; the eastern Aleutians, 2.3%; Sand Point, 3.6%; and Cook Inlet, 3.5%.

F. Frequency of Mating

Complete hardening of the shell (exoskeleton) may occur 16 to 71 days after the molt (Adams 1982). Old-shell mature females have been found capable of mating after the terminal molt (Donaldson Primiparous, or first-mating, female C. bairdi mate and 1977). deposit egg clutches from mid winter to early spring. Multiparous females hatch clutches and deposit new eggs in the spring. Primiparous females must breed within one week after the final molt in order to produce viable egg clutches (Paul 1982b). Male C. bairdi can mate twice on the same day or several times within a week in captivity. At each occurrence, males typically deposit enough sperm to fertilize several egg clutches (Paul et al. 1983). In the Kodiak area, scuba divers observed males of 70 to 160 mm (average 112 mm) carapace width grasping pubescent females. Males were always larger than the females they grasped. In the laboratory, clutches of viable eqqs were produced by primiparous females whose mates were 65 to 140 mm in carapace width. Even though the sizes of the males these females mated with were variable over 90% had sufficient numbers of stored sperm to fertilize subsequent egg clutches (ibid.).

G. Incubation Period/Emergence and Larval Development Eggs are fertilized as they are released and are retained in the brood chamber, where they remain 11 months to a year (Bartlett 1976, Somerton 1981). The spring egg hatch is synchronized to the availability of prey food (Ito 1967, Watson 1970). Egg hatching (larval release) appears to coincide with plankton blooms (NPFMC 1981). Peak hatching in the Bering Sea occurs in mid May (Drury 1980). In the southeastern Bering Sea, larvae of C. opilio appeared in plankton two weeks prior to the hatchout of \overline{C} . bairdi. Larval development of Tanner crab is dependent upon the temperature regime and the condition of the plankton on which they feed (Incze et al. 1982). Planktonic larvae molt and progress through several distinct stages prior to settling to the bottom as Growth rates from the larval to the juvenile stages juveniles. are dependent upon temperature (NPFMC 1981). In Wakasa Bay (Sea of Japan), the developmental period between the larval and juvenile stages for <u>C</u>. <u>opi</u>lio may last about 63 days at water temperatures of 11 to 13°C (Kon 1970). The duration of the development to each zoeal stage is a minimum of 30 days (Incze et al. 1982). The duration of the megalops stage may be longer than 30 days for larvae of both C. opilio and C. bairdi (ibid.). The size of juvenile crabs between molts increases from about 25 to 36% for each of the first six molts preceeding the molt to maturity (Donaldson et al. 1981).

VII. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

A. Larvae

Tanner crab larvae are planktonic. Plankton studies indicate that larvae undergo diurnal vertical migrations in response to the movement of the plankton bloom (ibid.). Distribution of Chionoecetes (spp.) in the Sea of Japan is associated with upwelling (Abe 1977). In the Sea of Japan, where spawning occurs from January to April, prezoae (Chionoecetes spp.) move from depths of 225 to 275 m almost directly toward the sea surface after phototaxis (Kon 1967). From March to May in the Sea of Japan, crabs at the second zoea stage inhabit depths of 25 to 100 m, and in May they drop to about 150 to 200 m as a result of increasing sea-surface temperatures (Kon 1982). In the Sea of Japan, the metamorphosis from the second zoea stage to megalops occurs in early April at 150 to 200 m, where the temperature ranges from 6 to 12°C. After metamorphosis, 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, although the species form aggregations of like individuals at the same stage of development upon metamorphosis. Distribution of megalops is patchlike on the substrate, where like groups seek a particular habitat, and are not arranged as bands along depth contours (NPFMC 1981). The direction and magnitude of currents in the Bering Sea do not
transport <u>C. opilio</u> and <u>C. bairdi</u> 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 <u>C. opilio</u>, some areas where juveniles are found to occur harbor few adults. Both juvenile and adult <u>C. bairdi</u> occur concurrently throughout their range in the eastern Bering Sea. In Bristol Bay, mature <u>C. opilio</u> and <u>C. bairdi</u> are sedentary and remain in identifiable cohorts near the area where they mature.

C. Adults

Tagging studies show that adult <u>C</u>. <u>bairdi</u> perform only limited movements, which average 15 mi around Kodiak (Donaldson, pers. comm.), that are neither directional nor clearly seasonal. Mature males perform their seasonal breeding migration apparently at random, possibly guided by pheromones released by the female. In the Bering Sea, <u>C</u>. <u>bairdi</u> segregate by size group. At about five years of age for females and six years of age for males, the two sexes separate into sex-specific schools (ADNR/USFWS 1983). Female <u>C</u>. <u>tanneri</u> 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 <u>C</u>. <u>opilio</u> 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
 - Predation. Most information regarding predation is on larval crabs. Few reports are available on the predation of juveniles and adults. The best data are available for <u>C. opilio, C. bairdi, and C. opilio elongatus</u>. A total of 37 predators have been documented as preying upon the genus <u>Chionoecetes</u> from different areas. Predators include at least 7 species of invertebrates, 26 species of fish, and 4 species of marine mammals (Jewett 1982).
 - a. <u>Eggs</u>. Predation on eggs by the nemertean worm (<u>Carcinonemertes</u> spp.) has been documented (Hilsinger 1975).
 - b. Larvae and juvenile. Chionoecetes (spp.) is the most frequently reported predator upon Chionoecetes. Large crabs (greater than 40 mm CW) near Kodiak Island were more cannibalistic than small crabs (less than or equal to 40 mm). Red king crabs (Paralithodes 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), wottled and eel pouts (Lycodes palearis). C. bairdi from 1.8 to 70 mm CW have been documented as the most frequently occurring prey for Pacific cod taken near Kodiak Island during the months of June and July. An estimate of 1.5 x 10¹ crabs are eaten annually by the Kodiak cod population of $6.9 \times 10^{\prime}$ fish (Jewett 1982). Tanner crabs have comprised a large percentage of diets for four species of sculpins (cottidae). In the Gulf of Alaska and Kodiak Island area, yellow Irish lords (Hemilepidotus jordani) and the great sculpin (Myoxocephalus polyacanthocephalus) preyed significantly upon Tanner crabs. The great sculpin seems to prefer mature female Tanner crabs (Hilsinger. pers. comm.). Flatfishes (Pleuronectidae), particularly the rock sole (Lepidopsettia biliniata), were found to feed on Tanner crabs. In the northerly areas of the Bering Sea, Tanner crabs are especially important as prey of bearded seals (Jewett 1982).

- c. <u>Adult</u>. Predators upon adults include Pacific cod and octopuses (Ellson et al. 1950). Adults appear to have few predators, although those in molt would be vulnerable to large fish, octopuses, and sea stars (Hilsinger, pers. comm.).
- 2. Diseases:
 - a. <u>Black Mat Syndrome</u>. BMS, or <u>Trichomaris invadens</u>, is a marine fungus that has been found to infect Tanner crab, primarily in the Gulf of Alaska. Black tarlike modules encrust the shell and may break off into the meat during processing. The fungus appears to be debilitating, possibly inhibiting molting, and is believed to be fatal to the animal (Hicks 1982, Sparks and Hibbits 1978).
 - b. <u>Rust disease</u>. Chitin-digesting bacteria induce lesions on the crab shell that soften, pit, and blacken the shell. Examination of chitin-disgesting bacterium on Oregon crabs indicates that 47% were <u>photobacterium</u> <u>sp</u>. (Grischkowsky and Follett 1982).
 - c. Other bacterial agents. Studies performed by the ADF&G indicate that <u>Pseudomonas sp.</u>, <u>Moraxella sp.</u>, and <u>Flavobacterium sp.</u> proved lethal to Tanner crab under laboratory condition (Grischkowsky and Follett 1982).
- 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
- ^o Reduction in food supply
- ^o Reduction in protective cover (e.g., seaweed beds)
- ° Obstruction of migration routes
- Shock waves in aquatic environment
- ^o Human harvest (including handling of nonlegal crabs)

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

- IX. LEGAL STATUS
 - A. Managerial Authority

The Tanner crab resource is managed under a joint State-Federal Fisheries 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 William Sound, Yakutat, Southeast Alaska) and manages jointly with the National Marine Fisheries Service (NMFS) where significant fisheries exist beyond 3 mi. In Kodiak, south Peninsula, Aleutians, and Bering Sea areas, both state and federal emergency orders are jointly issued to close or open fisheries. The NMGS manages the foreign fishery, and both state and federal managment regimes are guided by policies in the Fishery Management Plan developed by the North Pacific Management Council in coordination with the Alaska Board of Fisheries (McCrary 1984).

X. LIMITATIONS OF INFORMATION

Little information is available on the early life history of the Tanner crab, its migrational patterns, and the causes of its mortality. Reliable techniques for calculating the age of Tanner crabs need to be developed.

REFERENCES

Adams, A.E. 1979. The life history of the snow crab, <u>Chionoecetes</u> opilio: a literature review. Univ. Alaska, Sea Grant Rept. 78-13.

______. 1982. The mating behavior of <u>Chionoecetes</u> <u>bairdi</u>. In Proceedings of the international symposium on the genus <u>Chionoecetes</u>. Univ. Alaska, Sea Grant Rept. 82-10.

ADF&G. 1978. Alaska's fisheries atlas. Vol. 2 [R.F. Mclean and K.J. Delaney, comps.]. 43 pp. + maps.

- ADNR/USFWS. 1983. Bristol Bay Cooperative Management Plan. Anchorage. 495 pp.
- Bartlett, L.D. 1976. Tanner crab (family Majidae). Pages 545-556 <u>in</u> W.T. Pereyra, J.E. Reeves, and R.G. Bakkala, eds. Demersal fish and

shellfish resources of the eastern Bering Sea in the baseline year of 1975. USDC. Processed rept.

- Carlson, H.R., and R.R. Straty. 1981. Habitat and nursery grounds of the Pacific rockfish, <u>Sebastes</u> spp. in rocky coastal areas of Southeastern Alaska. Mar. Fish. Rev. 43(7).
- Colgate, W.A. 1983. Technical report to industry on the Westward Region Tanner crab, <u>Chionoecetes</u> <u>bairdi</u>, population index surveys. ADF&G, Div. Commer. Fish., Kodiak. 70 pp.
- _____. 1984. Personal communication. Tanner Crab Research Biologist, ADF&G, Div. Commer. Fish., Kodiak.
- Donaldson, W.E. 1975. Kodiak Tanner crab research. Unpubl. tech. rept. ADF&G, Kodiak.
- _____. 1977. Kodiak Tanner crab research. ADF&G completion rept. Proj. 5-34-R. Commercial Fisheries Research and Development Act. 60 pp.
- _____. 1984. Personal communication. Habitat Biologist, ADF&G, Div. Habitat, Anchorage.
- Donaldson, W.E., R.T. Cooney, and J.R. Helsinger. 1981. Growth, age and size at maturity of Tanner crab, <u>Chionoecetes bairdi</u> (M.J. Rathburn) in the northern Gulf of Alaska (Decopoda, Brachywa). Crustaceana 40(3):286-302.
- Drury, W.H. 1980. Ecological studies in the Bering Strait region. FW. 237, final rept. to OCSEAP. 308 pp.
- Ellson, R.G., D.E. Powell, and H.H. Hildegrand. 1950. Exploratory fishing expedition to the northern Bering Sea in June and July, 1949. USFWS, Fish Leaflet 369. 56 pp.
- Feder, H.M., and S.C. Jewett. 1978. Survey of the epifaunal invertebrates of Norton Sound, southeastern Chukchi Sea, and Kotzebue Sound. Rept. 78-1, Institute of Marine Science, Univ. Alaska, Fairbanks.
- . 1981. Feeding interactions in the eastern Bering Sea with emphasis on the benthos. Pages 1229-1261 in D.W. Hood, and J.A. Calder, eds. The eastern Bering Sea shelf: oceanography and resources. Vol. 2. USDC: OMPA, NOAA.
- Garth, J.S. 1958. Brachyura of the Pacific Coast of America. Allen Hancock Pacific Expeditions. Vol. 21. Univ. Southern California Press. 854 pp. Cited in NPFMC 1981.

- Grischkowsky, R.S., and J.E. Follett. 1982. Tanner crab disease in Alaska. Proceedings of the international symposium on the genius <u>Chionoecetes</u>. Univ. Alaska, Sea Grant Rept. 82-10.
- Hicks, D.M. 1982. Abundance and distribution of Black Mat Syndrome on stocks of Tanner crabs, <u>Chionoecetes bairdi</u> in the northwestern Gulf of Alaska. Proceedings of the international symposium on the genus Chionoecetes. Univ. Alaska, Sea Grant Rept. 82-10.
- Hilsinger, J.R. 1975. Some aspects of the reproductive biology of female snow crab (<u>Chionoecetes bairdi</u>). Institute of Marine Science, Univ. Alaska, Fairbanks. Cited in Pereyra et al. 1976.
- _____. 1984. Personal communication. Mgt. Coordinator, Central Region, ADF&G, Div. Commer. Fish., Anchorage.
- Hosie, M.J. 1974. Southern range extension of the <u>Bairdi</u> crab, <u>Chionoecetes bairdi</u> Rathburn. Calif. Fish and Game 60(1):44-47. Cited in Somerton 1981.
- Incze, L.S., D.A. Armstrong, and D.L. Wencker. 1982. Rates of development and growth of larvae of <u>Chionoecetes</u> <u>bairdi</u> and <u>C. Opilio</u> in the southeastern Bering Sea. Proceedings of the international symposium on the genus Chionoecetes. Univ. Alaska, Sea Grant Rept. 82-10.
- Ito, K. 1963. A few studies on the ripeness of eggs, zuwigani (<u>Chionoecetes opilio</u>). Bull. Jap. Sea. Reg. Fish. Res. Lab. 2:65-76. (Transl. Fish. Res. Bd. Can., Transl. Ser. 111.7). Processed rept. USDC.

. 1967. Ecological studies on the edible crab, <u>Chionoecetes opilio</u> (O. Fabricus) in the Japan Sea. I: When do female crabs first spawn and how do they advance into the following reproductive stage. Bull. Jap. Sea Reg. Fish. Res. Lab. 17:67-84. (Transl. Fish. Res. Bd. Can., Transl. Ser. No. 1103.)

- . 1968. Ecological studies on the edible crab, <u>Chionoecetes opilio</u> (0. Fabricus) in the Japan Sea. II: Description of young crabs, with note on their distribution. Bull. Jap. Sea. Reg. Fish. Res. Lab. 19:43-50. (Transl. Fish. Res. Bd. Can., Transl. Ser. No. 1184.)
- . 1970. Ecological studies on the edible crab <u>Chionoecetes</u> <u>opilio</u> (0. Fabricus) in the Japan Sea. III: Age and growth as estimated on one basis of the seasonal changes in the carapace width frequencies and carapace hardness. Bull. Jap. Sea. Reg. Fish. Res. Lab. 22:81-116. (Transl. Fish. Res. Bd. Can., Transl. Ser. No. 1512.)
- Jewett, S.C. 1982. Predation on crabs of the genus <u>Chinoecetes</u>: literature review. Proceedings of the international symposium on the genus <u>Chionoecetes</u>. Univ. Alaska, Sea Grant Rept. 82-10.

- Jewett, S.C., and H.M. Feder. 1982. Food of the Tanner crab <u>Chionoecetes</u> <u>bairdi</u> near Kodiak Island, Alaska. Proceedings of the international symposium on the genus <u>Chionoecetes</u>. Univ. Alaska, Sea Grant Rept. 82-10.
- Kessler, R. 1984. Personal communication. Shellfish Biologsit, NOAA, NMFS, NWAFC, Kodiak, AK.
- Kinder, T.H., and J.D. Schumacher. 1982. Circulation over the continental shelf of the southeastern Bering Sea. Pages 53-75 <u>in</u> D.W. Hood and J.A. Calder, eds. The eastern Bering Sea shelf: oceanography and resources. Vol. 1. USDC: OMPA, NOAA.
- Kon, T. 1967. Fisheries biology of the Tanner crab. I: On the prezoeal larvae. Bull. Jap. Soc. Sci. Fish. 33(8):726-730. (In Japanese, with English Summary.)
- ______. 1969. Fisheries biology of the Tanner crab. III: The density distribution and carapace width composition in relation to the depth. Bull. Jap. Soc. Sci. Fish. 35(7). (Transl. Fish. Res. Bd. Can., Transl. Ser. No. 1363.)
 - ______. 1970. Fisheries biology of the Tanner crab. IV: The duration of the planktonic stages estimated by rearing experiment of larvae. Bull. Jap. Soc. Sci. Fish. 361(3):219-224. (Transl. Fish. Res. Bd. Can., Tranl. Ser. No. 1603.)
- . 1982. On the planktonic larvae life of the zuwai crab, <u>Chionoecetes opilio</u>, occurring along the coast of the central Japan Sea. Proceedings of the international symposium on the genus Chionoecetes. Univ. Alaska, Sea Grant Rept. 82-10.
- McCrary, J.A. 1984. Personal communication. Asst. Regional Supervisor, ADF&G, Div. Commer. Fish., Kodiak.
- McLeese, D.W. 1968. Temperature resistance of the spider crab, Chionoecetes opilio. J. Fish. Sci. Bd. Can. 25(8):1733-1736.
- NPFMC. 1981. Fishery Management Plan for the commercial Tanner crab fishery off the coast of Alaska. Anchorage. 197 pp.
- Otto, K.S. 1981. Eastern Bering Sea crab fisheries. Pages 1,039-1,066 in D.W. Hood and J.A. Calder, eds. The eastern Bering Sea shelf: oceanography and resources. Vol. 2. USDC: NOAA, OMPA. Seattle, WA.
- _____. 1984. Personal communication. Laboratory Director, NOAA, NMFS, ______NWAFC, Kodiak, AK.
- Otto, K.S., B.G. Stevens, R.A. McIntosh, K.L. Stahl-Johnson, and S.J. Wilson. 1984b. United States crab research in the eastern Bering Sea

during 1984. [Document submitted to the annual meeting of the International North Pacific Fisheries Commission, Vancouver, British Columbia, October 1984.] NWAFC, NMFS, NOAA, Seattle, WA. 36 pp.

Paul, J.M. 1982a. Distribution of Juvenile <u>Chionoecetes</u> <u>bairdi</u> in Cook Inlet. Proceedings of the international symposium on the genus Chionoecetes. Univ. Alaska, Sea Grant Rept. 82-10.

÷.

- ______. 1982b. Mating frequency and sperm storage factors affecting egg production in multiparous <u>Chionoecetes bairdi</u>. In Proceedings of the international symposium on the genus <u>Chionoecetes</u>. Univ. Alaska, Sea Grant Rept. 82-10.
- Paul, A.J., A.E. Adams, J.M. Paul, H.M. Feder, and W.E. Donaldson. 1983. Some aspects of reproductive biology of the crab <u>Chionoecetes</u> <u>bairdi</u>. Univ. Alaska, Sea Grant Rept. 83-1.
- Sinoda, M. 1968. Studies on the fishery of zuwai crab in the Japan Sea. Ph.D. Thesis submitted to Dept. Fish., Kyoto Univ., Japan.
- Somerton, D.A. 1981. Life history and population dynamics of two species of Tanner crab, <u>Chionoecetes</u> <u>bairdi</u> and <u>C. opilio</u>, in the eastern Bering Sea with implications for the management of the commercial harvest. Ph.D. Dissert., Univ. Wash., Seattle. 211 pp.
- . 1982. Effects of sea ice on the distribution and population fluctuations of <u>C</u>. <u>opilio</u> in the eastern Bering Sea. Proceedings of the international symposium on the genus <u>Chionoecetes</u>. Univ. Alaska, Sea Grant Rept. 82-10.
- Sparks, A.K., and J. Hibbits. 1978. Black Mat Syndrome, an invasive mycotic disease of the Tanner crab, <u>Chionoecetes</u> <u>bairdi</u>. Invert. Path. 34:184-191 (1979). Cited in Hicks 1982.
- Tarverdieva, M.J. 1976. Feeding of one Kamchatka king crab <u>Paralithodes</u> <u>camtschatica</u>, and Tanner crabs, <u>Chionoecetes bairdi</u> and <u>Chionoecetes</u> <u>opilio</u> in the southeastern part of the Bering Sea. Sov. J. of Mar. Biol. 2:34-39. Cited in Feder and Jewett 1981.
- Watson, J. 1969. Biological investigations on the spider crab, <u>Chionoecetes opilio</u>. Proceedings Atlantic crab fisheries development. Can. Fish. Rept. 13:24-27.

_____. 1970. Maturity, mating and egg laying in the spider crab, Chionoecetes opilio. J. Fish. Res. Bd. Can. 27:1607-1616.

_____. 1972. Mating behavior in the spider crab <u>Chionoecetes</u> opilio. J. Fish. Res. Bd. Can. 29(4):447-449.