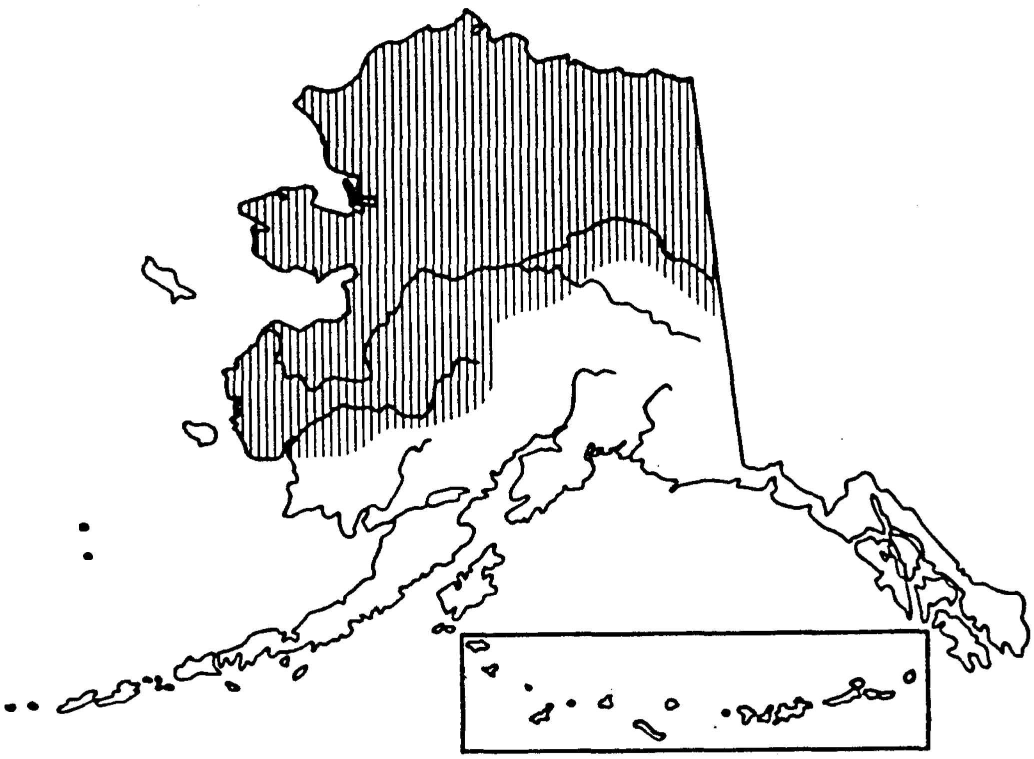
Alaska Habitat Management Guide species life histories for three whitefish species were combined into this single file. Links to individual section on each species are below.

Broad Whitefish Life History and Habitat Requirements
Arctic, Western, and Interior Regions



Map 1. Range of broad whitefish (Morrow 1980)

I. NAME

A. Common Names: Broad whitefish, round-nose whitefish, sheep-nose whitefish, small-headed whitefish, Kennicott's whitefish

B. Scientific Name: Coregonus nasus Pallus, 1776
Due to taxonomic confusion in identifying broad whitefish, the following scientific names have been used since 1883 to describe Coregonus nasus: Coregonus kennicottii, Coregonus nelsoni, Coregonus nasus kennicotti, Coregonus clupeaformis, Prosopium cylindraceum, and Prosopium kennicotti.

C. Native Names: See appendix A.

II. RANGE

A. Worldwide
Broad whitefish are distributed in the fresh and brackish waters of the arctic and subarctic drainages of northwestern North

America and northern Eurasia, south to about 60° north latitude (Baxter 1973, Scott and Crossman 1973). The western limit of the range is the Pechora River, USSR (52° E), just west of the Ural Mountains, from which they occur east to the Bering Sea, south to the Bay of Korf, and in the Penzhia River on the northeastern corner of the Sea of 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 Island, Yukon Territory (ibid.). A nonanadromous population exists in Teslin Lake at the headwaters of the Yukon River (ibid.).

B. Statewide

Broad whitefish are found throughout Alaska from the Kuskokwim River north to the arctic coast (Alt 1971, Morrow 1980). They are present throughout the Yukon River drainage from the mouth to the headwaters in British Columbia, including the Innoko, Koyukuk, and Porcupine river tributaries in Alaska (Alt 1971). In the Tanana River drainage (part of the Yukon River system), they are widespread in the Minto flats area and the lower Tolovana, Chatanika, and Tatalina rivers (Alt, pers. comm.). They are also found in most of the rivers draining into the Bering, Chukchi, and Beaufort seas (Alt 1971, Morrow 1980).

C. Regional Distribution Maps

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

D. Regional Distribution Summary

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

2. Western-Interior. Broad whitefish are found in most major drainages where there is 1) summer access to tundra lakes and ponds, 2) suitable sand or fine gravel in moving water for spawning, and 3) adequate oxygenated water for winter survival (Baxter 1973). They are widely distributed in the Yukon River drainage from the mouth to the headwaters (Scott and Crossman 1973). Alt (1983) reported that broad whitefish were very abundant in the Innoko River system. They were taken in early September 1982 in all surveyed areas of the Iditarod River. They were also taken 7 mi up the Yentna River, near the mouth of the Dishna River, and 8 mi up the North Fork of the Innoko River (Alt 1983). Broad whitefish are found in the Porcupine and Koyukuk rivers and are widespread in the Minto flats region of the Tanana River drainage but apparently are rare farther upstream (Alt, pers. comm.). A single broad whitefish was captured in the Tanana River 14 km upstream from its confluence with the Chena River in September 1971 (Alt 1972). This represents the farthest upstream penetration of this species documented in the Tanana drainage (ibid.). They are also common in the entire Kuskokwim River system (Alt 1971, Baxter 1973). Alt (1972) reported that broad whitefish exist in Highpower Creek, 1,350 km up the Kuskokwim River. (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Western and Interior regions.)

III. PHYSICAL HABITAT REQUIREMENTS

A. Water Quality

1. The pH factor. In the Yukon-Kuskokwim delta, broad whitefish have been observed in tundra ponds containing a pH in the range of 5.5 to 6.0 (Hale 1981). They have been observed in the central arctic coastal plain lakes, where pH values ranged from 7.5 to 9.0 (Bendock and Burr 1985). Broad whitefish also were observed at stream survey sites in the Topagoruk and Ikpikpuk river drainages within the central arctic coastal plain, where pH values ranged from 8.0 to 9.0 (ibid.). However, the exact range they can tolerate or prefer is unknown (ibid.).

2. Dissolved oxygen (D.O.). Little information is available on the dissolved oxygen requirements of broad whitefish. Baxter (1973) reports that broad whitefish in the Kuskokwim River drainage appear to need at least 2 mg/l at a water temperature of 0°C to survive. Bendock (1980) found broad whitefish overwintering in deeper pools and depressions of the Colville

River, where D.O. levels ranged from 1.4 to 4.6 mg/l. Fish found at the lower D.O. level appeared healthy. Bendock (1977) also found late winter under-ice D.O. readings in the Sagavanirktok River that varied between 7 mg/l and saturation (in excess of 15 mg/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 period. Because of wind-generated turbulence of bottom sediments, nearshore turbidity readings fluctuated widely (1-146 NTU recorded 80 m from shore) from day to day. Divers observed that a vertical stratification of water currents occurred in the center of the lagoon even though the water depth was only 2 m. Currents were slower at the bottom, and thus the flocculent detrital layer often remained in place despite relatively high velocities of overlying water. Kogl (1971) reported turbidity readings taken during July 1970 in the Colville River drainage that ranged from 0 to 20 ppm. The highest reading occurred at the outlet of Nanuk Lake on the Nechelik Channel of the Colville River delta.

   Most experimental work has shown that many species of fish can survive high concentrations of suspended matter for short periods. Prolonged exposure to some types of materials in most species, however, results in a thickening of the cells of the respiratory epithelium and the eventual fusion of adjacent gill lamellae, which definitely interferes with respiration. Fish do not have gill cleaners for removing foreign matter and rely on the flow of water through the gill chambers (Bell 1973).

   Excess turbidity in the form of settleable solids can kill buried eggs and alevins by denying water interchange and can smother food organisms. Primary food production is lowered above levels of 25 NTU (ibid.). Alaska turbidity standards for anadromous waters are set at no more than 25 NTU over background levels (ADEC 1979).

4. Salinity. Broad whitefish have been caught in waters with salinities as high as 30 ppt during summer conditions and 0 ppt during winter conditions in the Beaufort Sea (Craig and Haldorson 1980). Bendock (1977) captured broad whitefish in open-water leads of Prudhoe Bay with a salinity of less than 2.5 ppt during the early spring when fresh river water mixes with the more saline water of the ocean.

   In the arctic, broad whitefish are confined to fresh or slightly brackish water near coastal areas (Berg 1948, Muth 1969). Alt (1976) reports that broad whitefish are seldom taken in water with salinities greater than 20 ppt. Thus the Bering, Chukchi, and Beaufort seas should act as isolating barriers between fish of the Kuskokwim, Yukon, and Sagavanirktok river systems (Alt 1976).

B. Water Quantity

Broad whitefish in Alaska generally occur in streams where the gradient is less than 0.75 m/km (Kogl 1971). Current velocities for several bodies of water on the North Slope, where broad whitefish occur, range from 0 to approximately 180 cm/sec (ibid.). Hale (1981), based on information from Jones (n.d.), states that upstream migration might be inhibited by stream reaches longer than 100 m with velocities in the range of 40 cm/sec.

C. Water Temperature

Broad whitefish were captured in the Arctic Region and northwest Canada in water temperatures ranging from 0 to 16°C (Muth 1969, Bendock 1977). They overwinter at 0°C, with no apparent ill effects (Baxter 1973). They may also tolerate summer temperatures in shallow ponds of the Kuskokwim River delta up to about 20°C (Hale 1981).

There is little information on preferred temperatures, but fish from the MacKenzie River (0 to 15.5°C annual range) have a greater growth rate than fish from the Coppermine River (0 to 10°C annual range) (Muth 1969). The environmental factors (water temperature, longer ice-free period, and food availability) are suggested as the primary causes of growth differences between Coppermine and MacKenzie river fish (ibid.). Alt (1976) suggests that the slower growth rate of broad whitefish from the Sagavanirktok River and Imuruk Basin as compared to populations from the Yukon-Kuskokwim drainage may be the result of the shorter ice-free period in the Arctic Region. Food availability and genetic differences could be secondary factors (Alt 1976).

D. Substrate

Little information was found relating to the substrate required by broad whitefish. The lacustrine stock of broad whitefish in Lake Minchumina, northwest of Denali National Monument, evidently spawns on gravel and cobble along the lakeshore (Hale 1981). Baxter (1973) notes that they were found spawning in areas with sand and fine gravel in the Yukon-Kuskokwim delta. Broad whitefish were taken by Bendock and Burr (1985) in rivers draining the central arctic coastal plain, which were characterized by an unvegetated substrate of silt and mixed sand. He also captured broad whitefish in thaw lakes, with typically unvegetated or sparsely vegetated silt bottoms and in deflation lakes characterized by vegetated sandy bottoms (ibid.).

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

Broad whitefish are opportunistic feeders able to use a wide range of food items. Percy (1975) captured broad whitefish fry along the arctic coast, in streams, and in delta lakes, and the stomach contents were analyzed. He noted a distinct difference in the diets of these three groups. Coastal fry were principally feeding on chironomids (midges) and copepods. Stream specimens had fed on plecopterans (stoneflies), crustaceans, and 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% gastropods, and 5% trichopterans (caddisflies) (ibid.). Stomach contents of broad whitefish sampled in Prudhoe Bay during late July revealed that 58% (n = 12) were empty; the remainder included 80% amphipoda, 20% pelecypoda, and 40% dipteran larvae and adults (Furniss 1973).

From stream surveys, Hablett (1979) found that 76% (n = 83) of the broad whitefish sampled in the Colville River had empty stomachs. Food items found in the remaining fish included snails, aerial insects, chironomid larvae, and zooplankton. Fifteen percent (n = 35) of the Innoko River broad whitefish stomachs sampled during the spring upstream migration contained food (Alt 1983). Food items of fish captured on summer feeding grounds were clams, caddisflies, snails, diptera larvae, and beetles (ibid.).

Bendock (1982) reports that 46% (n = 66) of the broad whitefish stomachs examined from coastal plain lakes contained food. Prey items in descending frequency of occurrence included clams, snails, chironomid larvae, and zooplankton (Bendock 1982).

B. Types of Feeding Areas Used

As is suggested by their short gill rakers and blunt snouts, broad whitefish are apparently bottom feeders (McPhail and Lindsey 1970).

Upon entering the Beaufort Sea when the larger rivers break up in early June, anadromous broad whitefish forage along the mainland coastline, inhabiting shallow bays and lagoons (Bendock 1977). In the Sagavanirktok and Colville river deltas, young-of-the-year and age 1 broad whitefish seldom travel beyond the waters adjacent to the rivers (ibid.). Overflow channels and oxbows connected to the Colville River are used extensively by young-of-the-year and immature broad whitefish (Hablett 1979).

In the Kuskokwim drainage, the nonanadromous broad whitefish usually feed in lakes that connect with river channels. The adult and young broad whitefish leave the tundra lakes, ponds, and sloughs in the fall to overwinter in the deeper river channels (Baxter 1973).

Alt (1983) reports that nonanadromous broad whitefish migrate upstream in early summer and move into the lake and slough environment to feed along the lower 140 mi of the Innoko River and lower Iditarod River. In 1982, they were captured in shallow lakes that in 1981 had been dry because of low water levels (ibid.).

C. Factors Limiting Availability of Food

Little documentation was found that discussed factors limiting the availability of food. In the Beaufort Sea, the primary food source of anadromous fish are marine-derived organisms (mysids, amphipods, etc.). This is because of the low input of terrestrially derived carbons to the brackish water nearshore zone. The availability of suitable feeding habitat in the nearshore zone is limited by the thermoregulatory and osmoregulatory abilities of the anadromous broad whitefish. Therefore, the suitable feeding habitat for anadromous broad whitefish in the Beaufort Sea would be defined by high temperatures (less than 15°C), low salinity (15 ppt), and the availability of prey organisms recruited from the marine waters offshore (Johnson 1984).

D. Feeding Behavior

Broad whitefish do not feed in the Kuskokwim River from the time they leave their summer feeding areas in the fall until the next spring, when they return to the tundra lakes (Baxter 1973). For spawners, this is a period of eight to nine months without feeding. Baxter (1973) found no food in hundreds of broad whitefish that he examined during fall and winter months. Bendock (1977) reports that all of the spawning broad whitefish captured in the Sagavanirktok River during the last week of September had empty stomachs. Innoko River broad whitefish (in the Western Region) do not feed during the spring upstream migration (Alt 1983).

During the summer open-water season, the anadromous fish emerge from the overwintering areas and disperse along the coast of the Beaufort Sea. Their summer dispersal is predominantly for feeding purposes; in excess of 80% of the annual food budget is obtained during the summer open-water season (Johnson 1984).

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Little documentation was found on reproductive habitat characteristics. In the Yukon-Kuskokwim river drainages, with the possible exception of Lake Minchumina, all broad whitefish spawning areas reported by Baxter (1973) have been in moving water. Baxter (1973) states that adult broad whitefish require flowing water for their eggs to develop to the final stages before spawning.

Both anadromous and nonanadromous populations of broad whitefish travel up the main stem of larger rivers to spawn, sometimes traveling several hundred miles (Baxter 1973, Bendock 1977). Bendock 1977 also reports that anadromous adult broad whitefish reenter the Sagavanirktok River in late August and spawn in deep pools throughout the lower reaches of the delta. (Additional information on spawning substrate is discussed in the Physical Habitat Requirements section.)

B. Reproductive Seasonality

In the fall, broad whitefish leave their summer feeding areas and move toward the spawning grounds. Broad whitefish apparently move upstream in small groups, and the run is spread over several months. The peak catch at Umiat on the Colville River occurred at the end of July (Kogl 1971). An annual upstream spawning migration, peaking during September and October in the inner delta, has been documented in the MacKenzie River (DeGraaf and Machniak 1977, Percy 1975). Adults apparently move downstream after spawning and overwinter in deeper parts of the rivers or in estuaries (Morrow 1980, Baxter 1973). Tag-return data indicate that the downstream run of spent fish in the MacKenzie River occurs during the first two weeks of November (Percy 1975).

All broad whitefish (n = 12) captured near the mouth of the Pilgram River, Imuruk Basin, on 19 September were in spawning condition (Alt 1980). Bendock (1977) captured ripe broad whitefish in the Sagavanirktok River during the last week in September. Baxter (1973) reported the following seasonal distribution for broad whitefish in the Kuskokwim River drainage:

1. June and July. The entire population spends summers feeding as a mixed-age-and-sex group on the tundra in the lakes and ponds and, to a lesser extent, in the tundra sloughs.
2. August. Sexually mature females that will spawn in the fall start their out-migration from summer feeding areas and slowly ascend the Kuskokwim River, 5 to 10 mi per day. The earlier ripening fish spawn farthest upriver.
3. September. Sexual development of males occurs more rapidly, and the males join the females in the upstream migration.
4. Late September through October. The nonspawning adults leave the tundra feeding areas and apparently mill in the Kuskokwim River generally below the spawning population.
5. October to December. The immature fish leave the tundra and mill with the nonspawning adults. The youngest fish leave last.
6. October to early December. The only area surveyed in the main Kuskokwim River during the spawning season was at river mile 89. Spawning starts about the time the Kuskokwim River freezes over in this area.
7. Mid December to May. After spawning, the entire broad whitefish population moves downstream and appears to be mixed for the rest of the winter in deeper pools of the lower Kuskokwim River.
8. Late May or early June. As soon as the melting snow and ice flushes the Kialik River and it becomes oxygenated, broad whitefish populations enter the river and proceed upstream to their summer feeding areas. This migration occurs before the ice is out of the tundra lakes, ponds, and sloughs and will proceed above the anchor ice in the sloughs. The older fish appear in the upper reaches of the rivers first, with no apparent differences between spent and developing fish.

   In the Nizhnyaya and Tungusky rivers in the USSR, broad whitefish spawn from the end of October to the beginning of November at water temperatures close to 0°C (Berg 1948).

D. Age at Sexual Maturity

Limited data on the sexual maturity of Sagavanirktok River fish indicate that males mature at ages 7 to 9 and females at ages 8 to 10 (Alt 1976). Age at maturity for both sexes from the Colville

River samples was seven to eight years (Alt and Kogl 1973). Fifty percent (n = ?) of the age 9 broad whitefish sampled from the Colville River and the eastern margin of Foggy Bay in the Beaufort Sea during 1975 and 1976 were mature (Bendock 1977). Twenty-three (n = ?) of those fish between ages 11 and 13 had redeveloping gonads and would not spawn in the year of capture (ibid.). Broad whitefish captured from arctic coastal plain lakes ranged from 5 to 20 years. The age of sexual maturity was 10 years for both sexes (Bendock 1982).

In Imuruk Basin samples, males mature between ages 6 and 8, whereas females mature between ages 7 and 8 (n = 53) (Alt 1976). Gonad examinations of specimens from the Innoko River suggest that all age 6 and older fish, except for a 376-mm female, were mature (Alt 1983).

Data indicate a somewhat earlier age at maturity for Porcupine River broad whitefish. Males reach sexual maturity at age 5 and females at age 5 or 6 (n = 32) (Alt 1976). Minto flats samples (n = 79) ranged from ages 5 to 11, and all were mature except one age-5 400-mm male (ibid.).

Holitna River specimens ranged from ages 4 to 8 (n = 73). Examinations of the gonads of these fish indicate that males mature at ages 5 and 6 and females at ages 6 and 7 (ibid.).

The maximum age reported by Craig and Haldorson (1980) for broad whitefish from Simpson Lagoon in the Beaufort Sea was 22 years. Longevity is generally greater for broad whitefish of the arctic coastal plain lakes than for either their anadromous counterparts (from Prudhoe Bay) or Interior Alaska broad whitefish (Bendock 1982).

E. Frequency of Breeding

In the Kuskokwim and Yukon river systems, larger broad whitefish do not spawn every year after they become adults (Baxter 1973). During the winter, part of the population consists of large adult fish that have immature gonads. These fish are quite fat in physical condition, especially in the nuchal hump. The other part of the adult population consists of those that have spawned recently. These fish have lost almost all their abdominal fat, and the nuchal hump is lower than that of the nonspawning adults (ibid.).

Females in the Minto flats area are apparently nonconsecutive spawners because many large fish were found during the summer that contained tiny undeveloped eggs and residual eggs from the previous year's spawning (Alt 1972). Other investigators have noted the nonconsecutive spawning of northern fishes. Baxter (1973) presumes that it is possibly caused by the paucity of the food supply and the lack of trace elements and vitamins in the food.

Based on field examinations of fish in the Innoko River, consecutive spawning is probably the rule for broad whitefish in that system (Alt 1983).

F. Fecundity

An exceptionally large broad whitefish for the Kuskokwim River, fork length (FL) = 590 mm, had an estimated egg number of 127,700; a large fish, FL = 522 mm, had an estimated 71,480 eggs; and an average fish, FL = 476 mm, had an estimated 46,220 eggs (Baxter 1973). Age was not given for these fish. Berg (1948) reported the fecundity of broad whitefish up to age 8 in the Kara River, USSR. The fecundity of the fish varied from 14,000 to 29,000 eggs. The fecundity of a sample (n = 11) from the MacKenzie River ranged from 26,922 to 65,798 eggs/female, with a mean of 39,721 eggs/female (DeGraaf and Machniak 1977).

G. Incubation Period/Emergence

The timing and requirement for egg and fry development is largely unknown, but young-of-the-year fish have been documented in coastal waters in the summer (Bendock 1977, Craig and Haldorson 1980), indicating early movement away from spawning areas (USFWS 1982). Morrow (1980) states that the young hatch in the spring and move downstream.

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

Most of the natural mortality apparently occurs during the winter months that follow spawning (Baxter 1973). The exact cause of mortality was not given but may be any of several factors, including low D.O. or freezing (ibid.). Predation is also a major cause of mortality (Berg 1948). In the Kolyma River, Russia, the eggs of broad whitefish were found in the intestines of grayling, round whitefish, Siberian whitefish, dace, longnose sucker, and sturgeon (ibid.).

1. Overwintering. During the winter, the critical habitats are freshwater pools located under the ice that are fed by springs or the interstitial flow of the major rivers (Johnson 1984). As the river ice increases in thickness, it freezes into the substrate in shallow areas and riffles (Bendock 1977). By mid winter, this process has effectively created a series of discontinuous pools of water under the ice. This constitutes the only overwinter habitat for fish occupying the lower reaches of these rivers (ibid.).

   Overwinter locations have been reported in pools from the lower Sagavanirktok River and from the Colville River in the vicinity of Umiat (Bendock 1977, 1980). Overwintering broad whitefish were also netted in several lakes in the inner MacKenzie delta (Percy 1975).

B. Human-related

Significant loss or reduction of overwintering habitats could result in populationwide reductions in numbers. Access to the overwintering pools is also essential if the populations are to be maintained (Johnson 1984). The overwintering and fall spawning areas within river deltas are extremely sensitive to disruption because concentrated numbers of fish are restricted to small pockets of under-ice water in these areas (Bendock 1977). Large-scale gravel mining in river deltas can disrupt their hydrologic regime, thus affecting the availability of fall spawning and overwintering habitat (ibid.).

The start of intensive fishing may lead to sharp successional changes. From studies in Russia, Reshetnikov (1979) states that fishing usually reduces the abundance of large and old fishes and that at least 10 years are needed to allow the population to return to its original state. He also notes that overfishing leads to a change in the composition of the ichthyofauna and that valuable commercial fishes with a long life cycle (inconnu, whitefishes, trout) are replaced by species with a short life cycle. Such changes in the compositions of the ichthyofauna, attributed to fishing and the eutrophication processes, were recorded in Lake Imandra, Syamozero, and the Pskov-Chudskoye body of water in Siberia, USSR (Reshetnikov 1979).

1. Drilling fluids. An intensive investigation was conducted in the vicinity of Prudhoe Bay, Alaska, in early and mid 1979 to examine the environmental implications of offshore drilling fluid disposal in the arctic. Components of this investigation included measurement of environmental parameters, test discharges of freshwater drilling effluents (above and below ice), benthic studies, acute toxicity testing, and long-term biological effects studies. Ninety-six-hour LC50s values (concentrations at which 50% of the test organisms died over a 96-hour period) for broad whitefish varied from 6.4% for XC-Polymer drilling fluids (from mid-well depth) to greater than 20.0% for CMC/Gel drilling fluids (from upper portions of the well)(Tornberg et al. 1980).
2. Barriers. To date, the primary coastal developmental activity in the Alaskan Beaufort Sea is the 13,000-ft-long West Dock Causeway extending into the brackish nearshore zone of Prudhoe Bay (Johnson 1984). Baker (1985) states that the Prudhoe Bay Waterflood Studies have obtained sufficient data to clearly establish the negative effect of the West Dock Causeway on four species of anadromous fishes. The study of the effects of the West Dock Causeway on anadromous fish has been ongoing for over four years (Johnson 1984). Baker (1985) reports that it has been established that the causeway has degraded habitat and blocked the movement of anadromous fishes by creating thermal and salinity gradient barriers. A sharp decrease in temperature accompanied by an increase in salinity blocks the movement of fishes. It is the presence of these gradients, not the physical presence of the causeway, that results in the barrier to fish movement (Johnson 1984). These gradients may present a barrier that could delay the arrival of the anadromous fish to their overwintering habitat, resulting in high overwintering mortality (ibid.).

A summary of potential impacts from human-related activities in the Beaufort Sea estuary includes the following (Bendock 1977):

- A large-scale reduction in invertebrate fauna may have a profound effect on the fishery.
- Overwintering and fall spawning areas within river deltas are extremely sensitive to disruption because of the concentrated number of fish restricted to small pockets of under-ice water.
- Large-scale gravel mining in river deltas can disrupt their hydrologic regime, thus affecting the availability of fall spawning and overwintering habitat.

The following are other possible impacts:

- Changes in biological oxygen demand, nutrient loading
- Changes in chemical composition of water
- Changes in dissolved oxygen, temperature, pH, salinity
- Changes in flow or water level, entrapment
- Changes in sedimentation rates, turbidity, suspended solids
- Changes in substrate composition and location
- Competition with introduced species
- Increased susceptibility to harvest or predation
- Inducement of impingement or entrainment
- Physical barriers to movement
- Shock waves and blasting in aquatic environments

(For additional impacts information, see the Impacts of Land and Water Use volume of this series.)

VIII. LEGAL STATUS

The Alaska Board of Fisheries develops regulations governing the harvest of broad whitefish throughout its freshwater and coastal marine range. Because only localized harvesting by commercial, subsistence, and sport fishermen occurs, no statewide management plan has been formulated.

IX. LIMITATIONS OF INFORMATION

There are major gaps in our current knowledge critical to the future management of broad whitefish and their habitat requirements. More extensive information is needed on velocity, depth, temperature, and salinity requirements. Little information was found on the effects of environmental changes. A better understanding of early life history, population dynamics, population genetics, species identification, and spawning populations is necessary.

Russian scientists have conducted research on broad whitefish, including studies on hatchery production, that have been published in Russian language journals for which translations are not readily available.

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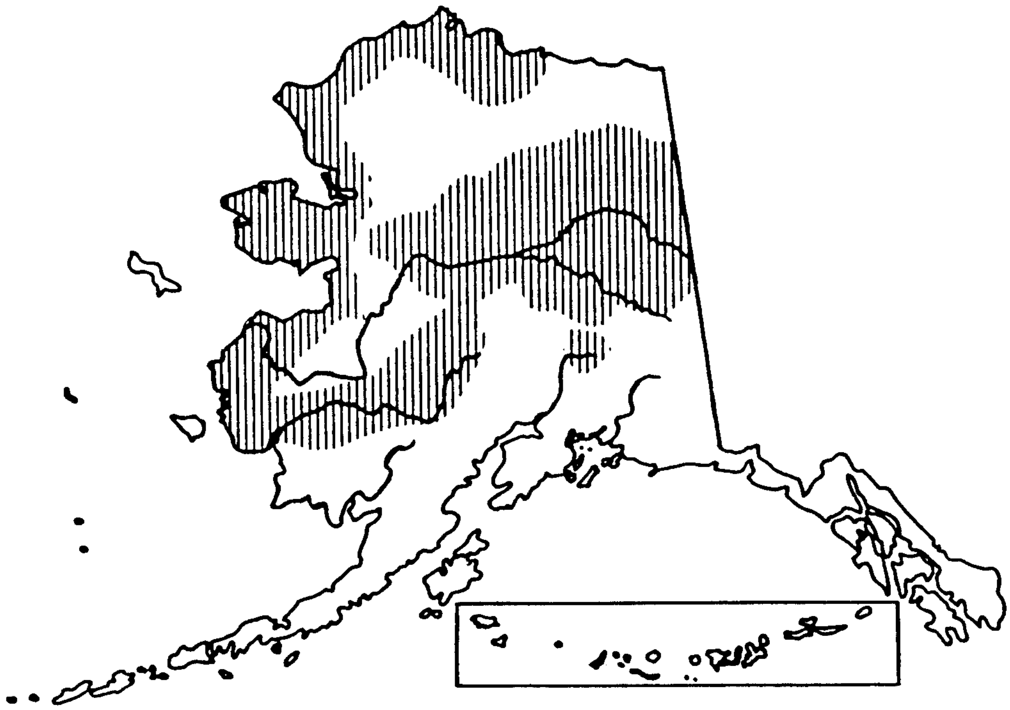
Humpback Whitefish Life History and Habitat Requirements
Western and Interior Regions



Map 1. Range of humpback whitefish, Coregonus clupeaformis complex (Morrow 1980)

I. NAME
   A. Common Name: Humpback whitefish
   B. Scientific Name: Coregonus pidschian (Gmelin)
   C. Native Names: See appendix A.
   D. Species Group Representation

   The humpback whitefish belongs to a group of three closely related species known as the Coregonus clupeaformis complex. McPhail and Lindsey (1970) and Morrow (1980) separate the complex into three species based on gill raker count, which is determined genetically. However, even gill raker numbers can change with environmental modification and selective pressures over a few generations (McPhail and Linsey 1970).

The species in Alaska known as humpback whitefish, *Coregonus pidschian*, has average gill raker counts of 21 to 23, with a range from 17 to 25. The species called Alaska whitefish, *C. nelsoni*, averages 24 or 25 gill rakers, with a range of 22 to 27. Lake whitefish, *C. clupeaformis*, has average gill raker counts of 26, with a range of 24 to 33 (Morrow 1980).
Alt (1979a) noted few differences in life history parameters when populations of whitefish were separated by gill raker counts. The populations generally occupy a similar habitat and have similar growth, age at maturity, and spawning periods, with lake dwellers spawning later in the season than stream dwellers. Because little distinction exists between the forms in the *Coregonus clupeaformis* complex, Alt (ibid.) considers the humpback whitefish in Alaska a single species for management purposes, unless two forms occur sympatrically.

II. RANGE

A. Worldwide

The *Coregonus clupeaformis* complex is widely distributed in North American fresh waters from Atlantic coastal watersheds westward across Canada and the northern United States to British Columbia, the Yukon Territory, and Alaska (Scott and Crossman 1973). The humpback whitefish, *C. pidschian*, is distributed from Bristol Bay to arctic Alaska and eastward along the arctic coast to the lower Mackenzie River (McPhail and Lindsey 1970). The humpback whitefish is replaced by *C. lavaretus* in Russia and Europe (Alt 1979a).

B. Statewide

The humpback whitefish is found in most of the Alaskan rivers that empty into the Bering, Chukchi, and Beaufort seas (Morrow 1980). Humpback whitefish are found in waters south of the Alaska Range, such as the Susitna, Copper, and Alsek rivers, and Eyak Lake near Cordova (Alt 1979a). They are also present in waters of the Bristol Bay drainage (map 1).

C. Regional Distribution Maps

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

D. Regional Distribution Summary

1. Western and Interior regions. Humpback whitefish reach their greatest abundance statewide in the Yukon and Kuskokwim drainages. They are found in all major tributaries of the

Tanana drainage. Humpback whitefish are year-round residents of large deep lakes, such as Lake Minchumina, and are summer residents of smaller lakes (ibid.). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Western and Interior regions.)

III. PHYSICAL HABITAT REQUIREMENTS

A. Water Quality

Little information is available on the pH, turbidity, or dissolved oxygen tolerances of humpback whitefish. Humpback whitefish have been found overwintering in the Sagavanirktok River on the arctic coast, with dissolved oxygen near 7 ppm (Bendock 1977). In the spawning grounds of other whitefish species in Europe, the oxygen concentration of bottom water must be at least 8 mg/l so that viable larvae can develop in the eggs (Fluchter 1980).

Humpback whitefish can tolerate brackish water, and some populations may winter in the sea near river mouths (Morrow 1980, McPhail and Lindsey 1970). Studies in Kotzebue Sound, Hotham Inlet, and the Kobuk River delta found humpback whitefish in both fresh and brackish waters (Alt 1979b). Small rearing whitefish from one to three years old were captured only in brackish water. Immature and nonspawning fish were common in brackish water, and prespawning fish were captured mainly in fresh water (ibid.).

B. Water Velocity and Depth

Humpback whitefish in Great Slave Lake have been taken at depths from 10 to 100 m (Rawson 1951) and were most abundant near the bottom at all depths sampled in Squanga Lake, Yukon Territory (Lindsey 1963). Overwintering fish in the Sagavanirktok River were taken under the ice in water .5 m deep (Bendock 1977).

Spawning usually occurs in shallow water. Alt (1979a, 1983) reported whitefish spawning in a shallow riffle of the Yukon River, in water from 0.5 to 2.5 m deep in the Chatanika River, and in water from 1.5 to 3.0 m deep in the Innoko River. Current speed was 2 to 4 mph (approximately 50-100 m/sec) in spawning areas of the Innoko River (Alt 1983).

C. Water Temperature

Little information is available on the temperature tolerances of humpback whitefish. Humpback whitefish spawn in water temperatures ranging from 0 to 3°C in the Innoko, Kobuk, and Chatanika rivers (Alt 1979a, 1983).

For *Coregonus lavaretus pidschian*, a closely related form in Siberia, the main factor determining the growth rate of fingerlings is temperature (Protopopov 1982). The higher the temperatures rise during spring and summer, the larger the size of the young. Their length and weight during the first year are closely correlated with water temperature. In European whitefish species, the larvae were shown to be relatively insensitive to temperature (Fluchter 1980). However, temperatures ranging from 2 to 26°C were needed in order for production of the necessary zooplankton species to provide sufficient food for the whitefish larvae (ibid.).

D. Substrate and Cover Requirements

Substrate requirements of humpback whitefish have not been noted, except for spawning. Whitefish spawn over a gravel bottom in the Chatanika River (Alt 1979a) and over small- and medium-size gravel in the Innoko River (Alt 1983). Humpback whitefish were captured in the lower Yukon River over a gravel bottom (Alt 1980).

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

Young humpback whitefish feed mainly on zooplankton, but adults feed primarily on benthic organisms such as mollusks, crustaceans, and chironomid larvae (Nikolskii 1961). In Alaska, snails and clams usually predominate in the diet of adult humpback whitefish. In the Innoko River, a tributary of the lower Yukon River, caddis flies and snails were found most often in whitefish stomachs, but beetles, clams, diptera larvae, and cladocerans were also eaten (Alt 1983). In the Andreafsky River, another tributary of the lower Yukon River, snails were eaten by whitefish (Alt 1981), and in tributaries of the lower Kuskokwim River, whitefish fed on snails, clams, and diptera larvae (Alt 1977).

In brackish water of Kotzebue Sound and Hotham Inlet, whitefish also fed primarily on snails, clams, and insects, but herring eggs on kelp and ninespine sticklebacks were seasonally important foods (Alt 1979b). In lakes on the south slope of the Brooks Range, snails and clams were eaten by whitefish (Roguski and Spetz 1968). In lakes of the Sheenjek River drainage, a tributary of the Porcupine River, whitefish fed on snails, clams, amphipods, corixids, chironomid larvae, and cladocerans (Craig and Wells 1975).

The feeding habits of humpack whitefish in a lake in northern Sweden were found to vary seasonally, annually, and with the size of the fish (Nilsson 1958). Whitefish switch prey types in response to seasonal and annual fluctuations in the abundance and availability of prey species.

B. Types of Feeding Areas Used

Coregonus lavaretus pidschian, the Siberian humpback whitefish, feeds primarily in shallow areas where benthic organisms are abundant (Kirillov 1982). Alaskan humpback whitefish may feed mainly during the summer in rivers such as the Andreafsky and Innoko (Alt 1981, 1983). Stomachs of whitefish migrating up the Innoko River in May were empty, as were the stomachs of whitefish near spawning grounds in September and October. Thus, the feeding period for these fish lasts about three months during the summer and may occur during the winter (Alt 1983).

C. Factors Limiting Availability of Food

Larval whitefish have specific food requirements, and growth is delayed if the required food species are not present. Adult whitefish can select from a wider range of food species and can switch prey types seasonally and annually.

D. Feeding Behavior

Whitefish feed mainly on benthic organisms, but the species eaten varies in different rivers (Nikolskii 1961). Craig and Wells (1975) also note that whitefish feed on a variety of both benthic and planktonic species, indicating that the fish can adjust to changing availability of prey items. Whitefish feed primarily on a variety of benthic forms, and bottom feeding is evident from detritus found in stomachs of whitefish from the lower Kuskokwim River (Alt 1977). Siberian whitefish, *Coregonus lavaretus pidschian*, switch from benthic feeding in summer to preying on fish during winter (Kirillov 1982).

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Spawning of the Siberian humpback whitefish, *Coregonus lavaretus pidschian*, takes place on gravel at a water temperature below 4°C (Nikolskii 1961). Great Slave Lake humpback whitefish spawn over rocky reefs in lakes or the shallows of rivers (McPhail and Lindsey 1970).

Alt (1979a) reports that Alaskan humpback whitefish spawn in shallow riffles of the main Yukon River and in swift, shallow water over a gravel bottom in the Chatanika River. Water temperatures in these spawning areas ranged from 0 to 3°C. In the main Innoko River, Alt (1983) found spent and ripe humpback whitefish in areas with a gravel bottom, current speed of 3 to 4 mph, and a water temperature near 0°C with shore ice forming. Baxter (pers. comm.) captured ripe humpback whitefish in the main Kuskokwim River over sand substrate when the river was iced over, the water temperature was 0°C, and there was a slight downstream current.

B. Reproductive Seasonality

Spawning of whitefish in the *Coregonus clupeaformis* complex occurs from late summer to November or December (McPhail and Lindsey 1970). In Alaska, humpback whitefish usually spawn in October (Morrow 1980). The spawning period extends from late September through early October in the Chatanika (Alt 1979a) and Innoko rivers (Alt 1983) and from September through October in the Colville River (Bendock 1979). Ripe humpback whitefish have been found in the main Kuskokwim River near Bethel in early November (Baxter, pers. comm.).

C. Reproductive Behavior

Spawning behavior of humpback whitefish has not been described; however, Morrow (1980) notes that it may be similar to that of Alaska whitefish, *Coregonus nelsoni*. Alaska whitefish spawn actively both at night and in the daytime (ibid.). The females begin to swim vertically and are joined by one or two males. Eggs and milt are extruded as the fish approach the surface of the water (ibid.).

D. Age at Sexual Maturity

Humpback whitefish in Alaska generally reach sexual maturity by ages 4 to 7 (Alt 1979a, 1977; Kramer 1975). In some areas, however, whitefish grow more slowly. Humpback whitefish mature at age 8 in the Colville River (Alt and Kogl 1973) and in the Kotzebue Sound and Hotham Inlet area (Alt 1979b). In lakes of the Sheenjek River drainage, a tributary of the Porcupine River, whitefish mature at ages 9 to 15 (Craig and Wells 1975). Alt (1979a) notes that whitefish populations in Interior Alaska streams appear to be faster-growing than fish of coastal and arctic streams, probably because of the longer growing season of interior waters. However, genetic factors or low food availability could also reduce the growth rate.

E. Frequency of Breeding

Alt (1977, 1983) found that consecutive spawning is most common for humpback whitefish in the lower Kuskokwim system and the Innoko River, a tributary of the lower Yukon River. In Lake Minchumina, Kramer (1975) found it difficult to determine the age of maturity of humpback whitefish because of the presence of nonconsecutive spawners. McPhail and Lindsey (1970) suspect that in some northern lakes whitefish of the _Coregonus clupeaformis_ complex spawn every other year.

F. Fecundity

Fecundity of humpback whitefish in Alaska has not been studied. Fecundity of the Siberian whitefish, _Coregunus lavaretus pidschian_, varies from one population to another and ranges from 8,000 to 50,000 eggs per female (Nikolskii 1961). The eggs measure about .12 cm in diameter (ibid.).

G. Incubation Period/Emergence

Little is known about the early stages of humpback whitefish in Alaska. Morrow (1980) assumes that the young hatch in late winter and spring, move downstream, and return as mature adults. Alt (1979b) found that the estuarine area of Kotzebue Sound was an important feeding and rearing area for humpback whitefish.

Laboratory experiments with eggs of European whitefish species showed that water as cold as 1°C delayed hatching by eight weeks (Fluchter 1980). This delay in hatching allowed the release of whitefish larvae when the zooplankton density was higher, coordinating the larval release with their food supply.

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

Humpback whitefish migrate upstream to feeding areas in the early summer and move further upstream to spawning grounds in the fall (Alt 1979a). Some humpback whitefish are anadromous, but it is not known how far the wintering fish move from river mouths. They have been taken in the Beaufort Sea several miles offshore of the Colville and Sagavanirktok rivers, as well as in Kotzebue Sound, off the coast of Nome, and around the mouths of the Yukon and Kuskokwim rivers (Morrow 1980, Bendock 1977, Alt 1979b).

In the Kuskokwim River system, the fish move from the main river into tributaries, such as the Aniak River, in late May for summer feeding (Alt 1977). Catches in August indicate movements either back into the Kuskokwim River or further up the tributaries into feeding or spawning areas. Tagging studies by Baxter (n.d.) indicate that humpback whitefish may travel over 600 km up the Kuskokwim River to spawning grounds.

In the Innoko River, a tributary of the lower Yukon River, whitefish move from the Yukon into the lower Innoko during late May and early June (Alt 1983). Humpback whitefish were observed feeding in the slow-moving water of the main Innoko River in mid June (ibid.). After summer feeding, whitefish continue up the Innoko to spawning grounds and are abundant in the upper river and tributaries in September. Movement downstream to overwintering areas occurs in October and November (ibid.).

Migration patterns of humpback whitefish in the lower and middle Yukon River are not fully known, but both river resident and anadromous populations probably exist (Alt 1980). The anadromous populations overwinter in the lower Yukon River. After breakup there is an upstream migration in the main Yukon and tributary rivers. By late June, most whitefish have moved upstream in the tributaries to summer feeding areas in lakes and sloughs (ibid.).

Humpback whitefish overwinter in Hotham Inlet and the lower Kobuk River and feed upstream in lakes and sloughs. The prespawning fish continue moving slowly upstream in the Kobuk River during the summer. Whitefish spawn in the upper Kobuk river in October and then migrate rapidly back to the lower Kobuk River (Alt 1979a).

In the Colville River, whitefish migrate uptream past Umiat in late July and early August, possibly spawning in the upper Colville River in the fall (Alt and Kogl 1973). Adult humpback whitefish were sampled along beaches between the Sagavanirktok and Colville rivers from July through August (Bendock 1977), possibly before migrating upstream in these rivers.

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

Egg, larval, and juvenile stages of humpback whitefish are dependent on physical factors such as water temperature and dissolved oxygen for growth and development. Laboratory feeding experiments of European whitefish species have shown that there are two main reasons for the high natural mortality rate of whitefish larvae: high sensitivity to even a short-term lack of food and specific food requirements (Fluchter 1980). Whitefish larvae can feed only on juvenile stages of certain zooplanktonic crustaceans (ibid.).

Predation in all the life history stages of humpback whitefish probably influences population numbers. A prespawning female humpback whitefish was found in a pike stomach in the Pilgrim River on the Seward Peninsula (Alt 1980). Unidentifiable whitefish have been found in pike stomachs from the Minto flats area (northwest of Fairbanks) and the Andreafsky and Innoko rivers (lower Yukon drainage) (Alt 1968, 1981, 1983; Cheney 1971, 1972). Whitefish have also been found in burbot stomachs from the Glennallen area (Williams 1970).

Competition for food with other fish species, especially other whitefish, may also regulate populations of humpback whitefish. In a lake in northern Sweden, the growth rate and prey species consumed by humpback whitefish changed in areas where populations of other whitefish species occurred (Nilsson 1958).

B. Human-related

Water quality is important to the egg and larval stages of humpback whitefish. Whitefish are dependent on physical factors such as dissolved oxygen and temperature for growth and development (Fluchter 1980, Protopopov 1982). Any disturbances that degrade whitefish spawning, rearing, or feeding habitats or that degrade water quality may adversely their affect population levels. A summary of possible impacts from human-related activities includes the following:

- Change in water temperature
- Addition of physical barriers to migration
- Change in levels of dissolved oxygen
- Removal or addition of substrate materials in spawning or feeding areas
- Change in levels of biocides or toxic chemicals

(The Impacts of Land and Water Use volume of this series contains additional information regarding impacts.)

VIII. LEGAL STATUS

The Alaska Board of Fisheries develops regulations governing the harvest of humpback whitefish throughout its freshwater and coastal marine range. Because only localized harvesting by commercial, subsistence, and sport fishermen occurs, no statewide management plan has been formulated.

IX. LIMITATIONS OF INFORMATION

Little information is available on pH, turbidity, or dissolved oxygen tolerances of the different life history stages of humpback whitefish. Their spawning behavior and the physical features they require in their spawning grounds have not been studied. The fecundity of humpback whitefish in Alaska is unknown. Little is known also about the incubation period and emergence of Alaskan humpback whitefish. The seaward extent of whitefish migrations is unknown, and the extent of upstream migrations in Alaska has not been extensively studied. The degree to which factors such as competition and predation regulate whitefish populations is also unknown.

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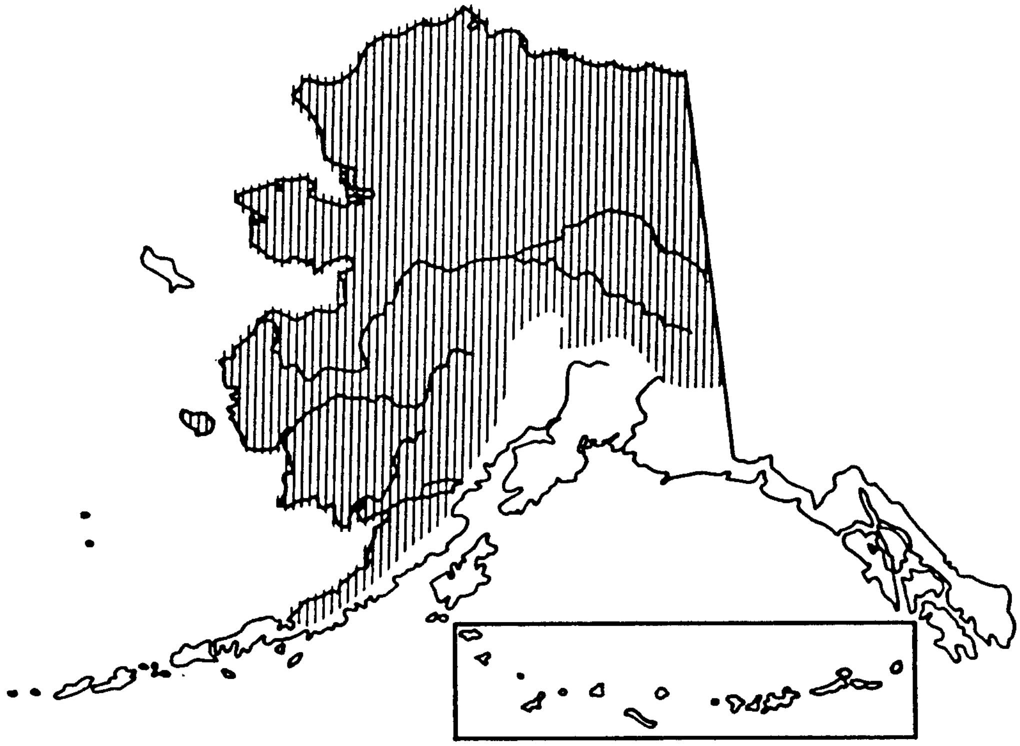
Least Cisco Life History and Habitat Requirements
Arctic, Western, and Interior Regions



Map 1. Range of least cisco

I. NAME
   A. Common Names: Least cisco, lake herring
   B. Scientific Name: Coregonus sardinella Valenciennes
   C. Native Names: See appendix A.
   D. The least cisco is a member of the family Salmonidae, subfamily Coregoninae, the whitefishes. Whitefishes are common throughout the north, inhabiting both lakes and rivers, and some species exhibit anadromous characteristics. There are many species of whitefish and cisco recognized, but because of extensive 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 are rarely found in the region between Prudhoe Bay and Herschel Island, and these two major populations are geographically isolated (Bendock 1979).

C. Regional Distribution Maps

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

D. Regional Distribution Summary

In the Arctic, Western, and Interior regions, least cisco are present in most streams and lakes north of the Alaska Range and in the nearshore zone of the marine coastal environment. Least cisco are present and abundant throughout the Colville, Kuskokwim, and Yukon river drainages (Morrow 1980). They ascend the Yukon River upstream at least as far as Circle (McPhail and Lindsey 1970). In the arctic, least cisco apparently do not penetrate very far inland (ibid.). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for either the Arctic or the Western and Interior regions.)

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

1. Water quality:

   a. Dissolved oxygen (DO) and pH. No information exists on the DO and pH requirements of least cisco. Craig and Haldorson (1981) reported an average DO level of 9.8 ml/l during the open-water period in 1977 in Simpson Lagoon, Beaufort Sea (range = 7.0 to 12.0 ml/l, n = 40). Least cisco were widely distributed and abundant in this area.

   b. Turbidity. Little information is available on the turbidity requirements of least cisco. Craig and Haldorson (1981) defined a narrow band of water immediately adjacent to the shoreline in the Beaufort Sea where wind-generated turbidity fluctuated widely from day to day (1-146 NTU, recorded 80 m from shore). This band of coastal water was inhabitated throughout the summer by anadromous fishes, of which least cisco was one of the most abundant species.

   c. Salinity. Anadromous least cisco inhabit brackish waters throughout the summer, at which time they make extensive migrations along the coast (at least 100 mi distance). Craig and Haldorson (1981) measured salinities in Simpson Lagoon, Beaufort Sea, during the open-water period, in which anadromous least cisco are present. Salinities ranged from nearly fresh to saline. In late June and early July, melting ice and river-flooding caused low salinities (1-10 ppt) in the lagoon. Between mid July and September, brackish conditions existed (18-25 ppt). In fall, least cisco migrate back into freshwater rivers and lakes to spawn and over-winter. Presumably, their coastal environment becomes uninhabitable in winter because of thick nearshore ice and hypersaline conditions, which are common in winter. Alt (1971) reported a high abundance of least cisco in the Imuruk Basin-Grantly Harbor-Port Clarence (Norton Sound) area. Salinity values there ranged from 23 ppt in Grantly Harbor and 29 ppt in Port Clarence to 3.8 ppt in the upper Imuruk Basin (ibid.).

2. Water velocity and depth. Least cisco inhabit a wide variety of habitats: shallow, slow-moving lakes and sloughs; large, deep, fast-moving rivers; and shallow tributary streams. Migratory forms of least cisco spend the winter in freshwater rivers and river deltas and the summer and early fall in coastal regions immediately adjacent to the shoreline. On the Beaufort Sea coast, Craig (1984) found least cisco abundant in the nearshore brackish-water zone. The depth of this zone fluctuated widely with freshwater input, nearshore currents, prevailing winds, and topographic features (ibid.).

In the Chatanika River, near Fairbanks, least cisco spawning sites have been defined. Water depths range between 1.3 and 2.6 m at these sites, and the average velocity is about .5 m/s (Kepler 1973). Water depth and stream velocity appeared to be important for spawning, because males and females move toward the surface, perpendicular to the current, while the eggs are released and fertilized (ibid.). In connection with building roads and culverts along the gas pipeline route, Jones et al. (1974) studied the critical velocities of 17 species of fish in the Mackenzie River. They determined that flow rates in culverts (100 m long) should be kept below .3 to .4 m/s to allow successful passage of the majority of mature individuals of migratory species.

3. Water temperature. Least cisco are apparently tolerant of a wide range of temperatures. Alt (1971) reported July temperatures of 12 to 13°C in shallow, slow-moving waters of the Imuruk Basin area. Kepler (1973) reported surface temperatures of 0 to 3°C during the spawning period (late September) in the Chatanika River. Craig and Haldorson (1981) reported temperatures of 0 to 6°C during the spring and fall and 7 to 10°C during the summer in Simpson Lagoon on the arctic coast. Craig and Griffiths (1981) attributed the nearshore distribution of anadromous fishes to an association with the band of relatively warm and brackish water that flows along the Beaufort Sea coast. Walters (1955) suggested that the habits of feeding during summer in the sea and moving up rivers and into lakes for the winter might be an arctic adaptation to escape the low winter temperatures (below 0°C) in sea water yet also take advantage of higher food abundance in coastal waters during the short arctic summer.
4. Substrate. Little is known about substrate requirements for least cisco. Adults are known to spawn over sand and gravel bottoms in shallow areas of lakes and streams. The eggs are simply scattered over the bottom (McPhail and Lindsey 1970). Alt (pers. comm.) found them spawning over a gravel bottom in the upper Innoko River in 4 to 8 ft of water.

IV. NUTRITIONAL REQUIREMENTS

A. Foods Species Used

Least cisco are generalists in their food habits. They consume a wide variety of the secondary producers (invertebrates) in both marine and freshwater environments. Composition of food items is largely dependent upon the specific location at which least cisco species are sampled. Primary food items recorded are various species of copepods, cladocerans, 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, ice-cover, and reduced light availability. However, least cisco captured in winter have been known to be feeding (Mann 1975).

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Least cisco spawn in freshwater rivers, river deltas, tributary streams, and lakes. Adults spawn over sand and gravel bottoms in shallow areas (McPhail and Lindsey 1970).

B. Reproductive Seasonality

Least cisco spawn in the fall, as is characteristic of many coregonids. Some variation in spawning time occurs between geographically isolated populations, but spawning typically takes place in late September and October (Scott and Crossman 1973, McPhail and Lindsey 1970, Morrow 1980, Kepler 1973, Mann and McCart 1980). In the Chatanika River near Fairbanks, the peak spawning period was the last week of September (Kepler 1973).

C. Reproductive Behavior

During the upstream spawning migration, least cisco generally move at night and rest in quiet pools during daylight hours. Kepler (1973) caught only small groups of least cisco in gill nets during overnight sampling, indicating that they migrate in small groups. Observations of least cisco in the Chatanika River revealed that least cisco spawn at night, with most spawning activity occurring from 10 P.M. to midnight (Kepler 1973). Alt (1983), however, observed least cisco actively spawning at 1 P.M. in the Innoko River, a tributary of the Yukon River.

During spawning, a female swims almost vertically toward the surface, with her ventral side upstream. As many as five males may join her (but usually only one or two) and swim vertically and close to her (Morrow 1980). As they approach the surface, eggs and milt are released. The fish break the surface, fall over backward, and swim to the bottom of the pool. It is not known whether a female deposits all her eggs in one night or whether more nights are required (ibid.).

D. Age at Sexual Maturity

Age at sexual maturity apparently varies among different geographically isolated populations of least cisco, as well as among different life history types of least cisco that occur sympatically. In the Minto flats area, Interior Alaska, Kepler (1973) determined that some least cisco males mature at two years and that most mature by three years of age; some females mature at three years, but most mature at four years. On the Colville River, in the Arctic Region, Alt and Kogl (1973) found that individual least cisco mature at four years, whereas the majority were mature at five years. In the Yukon Territory, North Slope, and eastern MacKenzie River delta drainages, Mann (1974) found differences in age at sexual maturity between sympatric "dwarf" and "normal" populations of least cisco. Dwarf individuals matured at three to four years, and 100% of the normal individuals were mature at seven years (freshwater population) and eight years (anadromous population).

E. Frequency of Breeding

Information regarding frequency of breeding in least cisco populations is inconsistent. Isolated geographic populations vary in behavior and life functions because of the different environmental conditions present. Kepler (1973) examined least cisco ovaries from specimens captured during July and August in the Minto flats area. The presence of retained eggs plus those that could develop fully by mid September indicated that all individuals sampled were consecutive spawners. In Trout Lake, Yukon Territory, Mann and McCart (1981) determined that least cisco spawn consecutively after reaching maturity. In contrast, several other authors have reported alternate-year spawning of least cisco in localized populations: Mann (1974) for least cisco captured in the Mackenzie River delta, Furniss (1975) for least cisco captured in Prudhoe Bay, and Alt and Kogl (1973) for least cisco captured in the Colville River delta. Mann (1974), however, points out that a great deal of subjectivity may be inherent in the methods used to determine mature spawners (i.e., eggs have the potential to ripen for the upcoming spawning season) and mature nonspawners (eggs are in resting stage).

F. Fecundity

Kepler (1973) found that fecundity in least cisco was more closely correlated with age than with length. In samples (from the Chatanika River) of individual least cisco ranging from 2+ to 7+ years, fecundity ranged from 27,825 to 93,500 eggs. Mann (1974) found that fecundity varied greatly between local populations of least cisco in the Yukon Territory's north slope and the eastern Mackenzie River delta drainages. In sympatric "normal" and "dwarf" populations, fecundity of normal least cisco exceeded that of dwarf least cisco by nearly 30 times (Mann and McCart 1981). Fecundity of normal, nonmigratory populations in Trout Lake, Yukon Territory, ranged from 7,886 to 19,261 eggs (mean = 12,059, s.d. = 3,330, n = 13). The dwarf populations from the same lake had a lower fecundity, ranging from 223 to 1,080 eggs (mean = 412, s.d. = 105, n = 33) (Mann 1974). Egg diameter at time of spawning for normal individuals was consistently 1.5 mm. Egg diameter for dwarf individuals at time of spawning exceeded that for normal individuals by an average of 0.3 mm diameter (Mann and McCart 1981).

G. Incubation Period/Emergence

Eggs are demersal and lodge in crevices between gravel where they incubate and overwinter (late September to late May or early June) (McPhail and Lindsey 1970). In Siberia, larvae of the migratory forms move downstream toward the sea soon after hatching (Scott and Crossman 1973). Alt (1983) also reported that young-of-the-year least cisco undertake a slow downstream migration to rearing areas in slower, deeper waters of the lower Yukon River.

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

Least cisco are characterized by several life history types. Mann (1974) defined three types: anadromous, freshwater migratory, and freshwater nonmigratory. Anadromous forms of least cisco generally spend the summer months feeding in the nearshore coastal marine zone and migrate into the lower reaches of coastal rivers and river deltas in the fall. In the Beaufort Sea, this movement is associated with the ice-free period; in Prudhoe Bay, e.g., ice-out generally occurs in the first two weeks of June, and least cisco first appear during the first week of July (1975 and 1976) (Bendock 1979). Moulton et al. (1985) reported high catches of large (greater than 250 mm) least cisco in Gwydyr Bay in early July in 1984; a major movement occurred about 20 July through Gwydyr Bay and Prudhoe Bay. Craig and Haldorson (1981) reported least cisco movements through Simpson Lagoon in the last week of June. Tagging studies indicate that the Colville River is the primary freshwater source of these fish. Tagged individuals showed an eastward movement through Simpson Lagoon, followed by a build-up in Prudhoe Bay from breakup through mid August, and then a westward movement until freeze-up (Bendock 1979, Craig and Haldorson 1981, Moulton et al. 1985). Mann (1975) reported similar findings in the Mackenzie River delta population of least cisco. In September, the nearshore brackish water zone freezes over, and least cisco move into the freshwater deltas to spawn and overwinter. The presence of shore-fast ice and hypersaline conditions prevent least cisco from utilizing the marine environment until breakup occurs again in the spring (Bendock 1979, Craig and Haldorson 1981). Utilization of the more productive marine environment for feeding generally fosters greater growth rates and greater maximum age in these migratory least cisco than in the nonmigratory forms (Scott and Crossman 1973).

Mann (1974) defined a second migratory form of least cisco that remains in fresh water rather than migrating to sea. He concluded from seasonal sampling results that least cisco migrated into Peter Lake, Yukon Territory, in September to spawn. This population had direct access to the Mackenzie River delta and the Beaufort Sea, but growth rates (similar to other lake resident populations) indicated they resided in fresh water throughout the year (Mann 1974).

Alt (1983) reports that in the Innoko River, a tributary of the lower Yukon River, least cisco begin an upstream migration in late spring, or soon after ice-out. They move into lakes and sloughs to feed along the migration route. This feeding migration is composed mainly of mature fish, although immature individuals of ages 1 and 2 are present (ibid.). In late summer (August), the mature fish continue the upstream movement towards spawning areas. After spawning occurs, they apparently move downstream again to the Yukon River. It is not known whether this population is anadromous or not (Alt 1983). Similar movements were recorded in the Chatanika River near Fairbanks (Kepler 1973).

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

It is apparent that natural environmental factors influence nearly all local populations of least cisco. Lindsey (1981) documented the fact that a significant amount of plasticity occurs in morphological characteristics of whitefish genera because of coinhabitation of certain species. In least cisco, this may be related to the sympatric "dwarf" and "normal" populations documented by Mann and McCart (1980). Lindsey and Kratt (1982) reported a jumbo spotted form of least cisco in lakes of the southern Yukon Territory. They identified a variety of natural factors that could cause such distinct differentiation from other least cisco: glacial isolation, high levels of dissolved solids in the lakes, high lacustrine productivity and summer temperatures, lack of significant competition, and the migratory nature of the population.

Predation presumably has some influence on least cisco populations. Craig and Haldorson (1981) suggest that anadromous fish species use the nearshore coastal marine zone because there is a low predator density in that environment. Freshwater predators of least cisco include pike, burbot, lake trout, and sheefish. Eggs and young least cisco are very important in the diets of these predators (Alt 1977).

B. Human-related

Anadromous least cisco would potentially be vulnerable to disturbances from construction and/or oil development in the nearshore marine zone during the summer feeding migrations. The presence of a solid-fill causeway in the nearshore coastal zone of the Beaufort Sea (Prudhoe Bay) has been shown to cause temperature and salinity gradients that affect least cisco movements (Moulton et al. 1985). In freshwater streams, construction of roads, culverts, dams, etc., would create unnatural barriers (either physical or due to water velocity) and possibly cause a loss of spawning habitat.

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

- Alteration of preferred water temperatures, pH, dissolved oxygen, and chemical composition
- Introduction of water-soluble substrates
- Increase in suspended organic or mineral material
- Increase in sedimentation
- Reduction in food supply
- Human harvest
- Seismic shock waves

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

VIII. LEGAL STATUS

The Board of Fisheries develops regulations governing the harvest of least cisco throughout its freshwater and coastal marine range. Because only localized harvesting by commercial, subsistence, and sport fishermen occurs, no statewide management plan has been formulated.

IX. LIMITATIONS OF INFORMATION

Least cisco inhabit much of Interior Alaska in the Yukon and Kuskokwim river drainages and coastal Alaska from Bristol Bay through the Bering, Chukchi, and Beaufort seas. Because of the variations in local populations, apparently caused by geographic isolation and numerous natural environmental factors, it is difficult to generalize about the life history characteristics of the species. Information on least cisco is available primarily in areas where studies actually targetted on other species. Thus, there is a general data gap for least cisco distribution and abundance in many portions of its range, particularly uninhabited areas and/or areas not yet proposed for development.

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