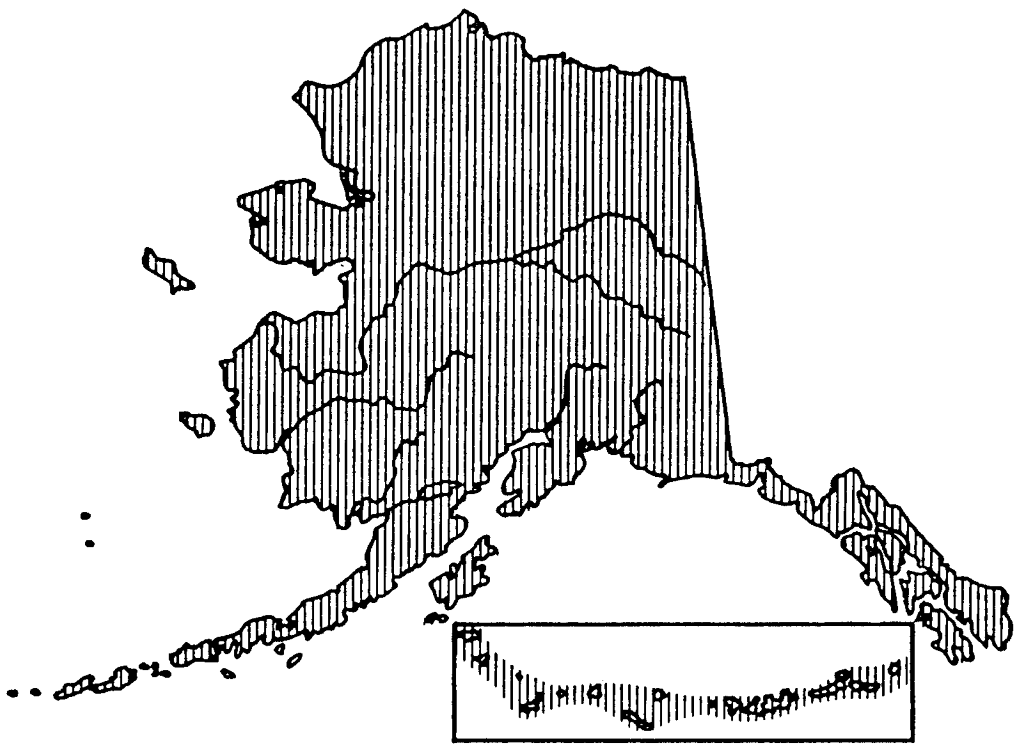
Arctic Char Life History and Habitat Requirements
Southwest, Southcentral, Arctic, Western, and Interior Regions



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

I. NAME

A. Common Names: Dolly Varden, arctic char

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

Dolly Varden and arctic char are two closely related salmonids of the subfamily Salmoninae. Members of the genus Salvelinus are morphologically and ecologically very plastic species. Although this has allowed char to adapt to changing environmental conditions it has been a nightmare for taxonomists, who must attempt to compartmentalize a continuum of life history types and morphological forms into recognizable groups.

Morrow (1980a) stated that both Salvelinus malma and S. alpinus are valid species in Alaska, with S. malma composed of a northern form and a southern form. McPhail (1961) divided the North

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

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

C. Native Names: See appendix A.

II. RANGE

A. Statewide

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

B. Regional Distribution Maps

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

C. Regional Distribution Summary

1. Southwest. Char are widely distributed throughout most systems in the Southwest Region. Important drainages of Bristol Bay include the Togiak River, the Wood River Lakes system, the Tikchik-Nushagak system, the Iliamna-Kvichak system, the Naknek River and Lake, and the Becharof and Ugashik rivers. Some important lake-river systems in the Kodiak region include Uganik, Little River, Karluk, Ayakulik

(Red River), Akalura, Saltery, Buskin, and Barabara lakes. Char are also abundant in the Aleutian Islands (ADF&G 1976, 1977a, and 1977b). (For more detailed narrative information on char distribution in the Southwest Region, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)

2. Southcentral. Char are widely distributed throughout the Southcentral area. They are found in the Klutina and Tonsina river drainages and small tributary streams of the Copper River (Williams, pers. comm.). In the Prince William Sound area, nearly all freshwater systems, with the possible exception of short glacial streams on the southeast side of the Kenai Peninsula, contain char. Char are found in lakes and streams on the Kenai Peninsula, most notably the Kenai River, Kasilof River, Deep Creek, Stariski Creek, Anchor River, and lakes in the Swanson River drainages. Char are also found in many streams draining into the west side of Cook Inlet and in the Susitna River drainage (ADF&G 1978). (For more detailed narrative information on char distribution in the Southcentral Region, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)
3. Arctic. Char are found in every major watershed in the Northwest Alaska area, including the Selawik, Kobuk, Noatak, Wulik, and Kivalina rivers (ADF&G 1978, 1984). On the North Slope from Cape Lisburne to Demarcation Point, char are found in most rivers and many lakes. Char have not been reported from rivers or lakes on the arctic coastal plain west of Teshekpuk Lake (Hablett 1979, Bendock and Burr 1984); much of this area, however, has not been extensively surveyed. (For more detailed narrative information on char distribution in the Arctic Region, see volume 2 of the Alaska Habitat Management Guide for the Arctic Region.)
4. Western and Interior. Anadromous char are found south of the Kuskokwim River in Kuskokwim Bay drainages such as the Goodnews, Arolik, and Kanektok rivers (ADF&G 1978, Alt 1977). Dwarf stream resident char and lake resident char are also found in Kuskokwim Bay drainages (Alt 1977). Stream resident char are found in tributaries of the Yukon and Kuskokwim rivers, but they rarely enter the main stem of these rivers (Alt 1980, 1977). Anadromous char are not found in the Yukon or Kuskokwim rivers (ibid.).

   Lower Kuskokwim tributaries supporting fairly large populations of resident stream char include the Aniak, Kisaralik, Kwithluk, and Tuluksak rivers (ADF&G 1978, Alt 1977). In the Yukon River drainage, char are present as resident species in streams flowing into the Yukon River, from the Andreafsky River upstream to the Melozitna River. The Melozitna River is the furthest upstream where large-size resident char have been found, but dwarf-size resident char are present in small tributary streams further up the Yukon and in the Upper Tanana drainage (Alt 1981, 1980). (For more detailed narrative information on char distribution in the Western and Interior regions, see Volume 2 of the Alaska Habitat Management Guide for the Western and Interior regions.)

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

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

1. Water quality:

a. Temperature. Recorded water temperatures during the spawning period range from 0.5 to nearly 13°C (Morrow 1980b, Moore 1975). In Southeast Alaska, spawning occurs when water temperatures are 5.5 to 6.5°C (Morrow 1980b). Water temperatures on char spawning redds in the Wulik and Kivalina river drainages in Northwest Alaska in August ranged from 6.5 to 11°C (Alt 1978). Egg hatching and alevin development are quite slow but do appear to be dependent upon temperature, with warmer-than-normal temperatures accelerating hatching and resulting in earlier-than-normal fry emergence. Blackett (1968) determined that Southeast Alaska anadromous char eggs held in a hatchery began hatching after 129 days in water with a temperature range of 8.3 to 0.6°C. No upper or lower temperature tolerance limits of char eggs or alevins were found in the literature; however, eggs are frequently exposed to temperatures from 0.0 to 2.2°C during incubation, and Scott and Crossman (1973) report significant egg mortality at temperatures above 7.8°C. Juvenile char have been observed burrowing into the substrate when water temperatures decreased to 2°C (Elliott and Reed 1974). Emigration of char from overwintering areas to summer feeding areas usually occurs after ice breakup in lakes at about 4°C (Armstrong 1965, ADF&G 1977b). Fish reduce feeding and seek overwintering areas when temperatures decrease to or below 5°C (Krueger 1981, ADF&G 1977b). Vertical distribution in lakes appears to be temperature-dependent, with char preferring mid water and bottom depths with temperatures lower than 12.8°C (ADF&G 1976).

b. Dissolved oxygen (D.O). No information was found in the literature on the influence of dissolved oxygen levels on the survival and development of char; however, inferences can be made from work on other salmonid species. Sufficient transport of D.O. to, and metabolic wastes from, developing eggs and alevins by intragravel flow is crucial for survival of eggs and alevins (Vaux

1962, Wickett 1958). Relatively low intragravel D.O. levels during the egg development stage may increase egg mortality, influence the rate of egg development, or reduce the fitness of alevins (Alderdice et al. 1958, Silver et al. 1963).

c. Turbidity. Little work has focused on the influence of turbidity on the survival and development of char; however, inferences can be made from work on other salmonid species. Deposition of fine sediments in spawning areas could reduce the water interchange in the redd and retard or prevent the emergence of fry (Koski 1966). Accumulation of organic debris can reduce dissolved oxygen below safe levels through oxidation (Reiser and Bjornn 1979).

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

2. Water quantity. Sufficient water velocity and depth are required to allow adequate water flow during egg and alevin development. Low flows and cold winter temperatures could cause redds to desiccate or freeze (Krueger 1981). Excessive velocities or flooding can cause egg dislodgement and/or displacement of juvenile (presmolt) char from rearing areas as well as hinder upstream fish migration (ibid.). Juvenile char in the Terror River on Kodiak Island are associated with relatively slow current velocities in pools, quiet side channels, and sloughs and tributaries (Wilson et al. 1981). Habitat preference studies for juvenile char in streams along the route of the Trans Alaska Pipeline System (TAPS) indicated that juvenile char prefer pools with low current velocities, generally below 0.3 m/sec, located adjacent to swift-flowing water (DenBeste and McCart 1984). Anadromous char juveniles and fry in the Sagavanirktok River and neighboring drainages are most abundant in the vicinity of spring water sources (McCart et al. 1972). Proximity to perennial sources of water is probably important in assuring their overwinter survival without having to undertake extensive migrations (ibid.). Char have been observed spawning in water depths of 0.15 to 4.5 m (Krueger 1981, ADF&G 1977b, Alt 1978) and in slow-to-moderate current velocities ranging from 0.3 to 1.2 m/sec (1.0 to 3.8 ft/sec) (Blackett 1968, Scott and Crossman 1973, Alt 1978).

3. Substrate. Preferred spawning substrate is small-to-coarse (walnut-size) gravel (Scott and Crossman 1973, McPhail and Lindsey 1970). Blackett (1968) found char in Southeast Alaska spawning primarily in small gravels, 6 to 50 mm in diameter. Wilson et al. (1981) found char on Kodiak Island spawning on gravels ranging from 2 to 32 mm in diameter. In the Wulik and Kivalina river drainages in Northwest Alaska, char spawn over substrate that is predominantly medium and coarse gravel, with some fine gravel, sand, and boulders (Alt 1978). Char in the Anaktuvuk River also spawn over mixed substrate, ranging from sand to gravel up to three inches (8 cm) in diameter (Bendock 1981). A gravel layer over fertilized eggs in the redd protects eggs from sunlight and predation and reduces disturbance by ice and floods (Krueger 1981). In streams along the route of the TAPS, juvenile char prefer shallow pools with medium-to-coarse rock substrates (DenBeste and McCart 1984). Juvenile char burrow into substrate interstices and logging debris and slash to avoid cooling water temperatures (Elliott and Reed 1974).

B. Cover Requirements

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

IV. NUTRITIONAL REQUIREMENTS

A. Preferred Foods

Fry begin active feeding as soon as they emerge. Juveniles feed on various winged insects, larvae of mayflies (Ephemeroptera) and midges (Chironomidae), and various small crustaceans (Karzanovskii 1962, Krueger 1981). In the Bristol Bay drainages, fish (sticklebacks, sculpins, blackfish, and salmon fry), fish eggs, and invertebrates (snails, leeches, clams, insects, and insect larvae) are major food sources (Alt 1977, Moriarity 1977, Greenback 1967). Rearing char from the Noatak and Wulik rivers consume fly (Diptera), mayfly, and stonefly (Plecoptera) larvae (DeCicco 1983). Russell (1980) found that char in the Lake Clark area of Bristol Bay consumed gastropods, pelycopods, caddis fly (Trichoptera) larvae and adults, ants and small wasps (Hymenoptera), midge pupae and adults, adult aquatic beetles

(Coleoptera), and small crustaceans (amphipods, copepods, and cladocerans). In the Wood River Lakes system, char feed on sockeye salmon smolt during the smolt's summer migration to Nushagak Bay (Rogers 1972, Buklis 1979). Ruggerone and Rogers (1984) found that the number of smolt consumed in a 24-hour period increased when large smolt migrations occurred. When smolt migrations in excess of 80,000 smolts/24 hours took place, char consumption of smolts increased to 5.6 smolts/char per 24 hours.

Palmisano (1971) studied the food habits of char in lakes on Amchitka Island. He found that in lakes with access to the sea, crustaceans and aquatic insects were the major foods. Char in landlocked lakes on Amchitka fed primarily on aquatic insects, fish, and fish eggs (ibid.). Stream resident (nonanadromous) char in the Sagavanirktok and Canning river drainages on the North Slope feed mainly on dipteran larvae (mostly chironomids), stonefly, nymphs, and caddis fly larvae (Craig 1977a, McCart et al. 1972). The diet of large fry in the Canning drainage is generally similar to that of older residents, although the fry feed on fewer kinds and smaller individuals (Craig 1977a). Craig (1977b) found that spring resident char in Sadlerochit Spring in the Arctic National Wildlife Range fed primarily on larvae of stream-dwelling benthic invertebrates, which have high densities in the spring.

In marine waters, smelt, herring, juvenile salmon, 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. Off Amchitka Island, char fed on a variety of items, mainly amphipods, mysids, and small fish (Neuhold et al. 1974). Once North Slope char enter coastal waters they feed on insects (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 gravel-bottomed lakes (Krueger 1981, ADF&G 1977a).

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

B. Reproductive Seasonality

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

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

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

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

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

C. Reproductive Behavior

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

D. Age at Sexual Maturity

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

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

E. Fecundity

The fecundity of char varies by stock, location, and size of female. Eggs of anadromous stocks are much larger than those of nonanadromous fish and increase in size with fish age and length (Blackett 1968, Morrow 1980b). Fecundity of anadromous char is also higher than for nonanadromous stocks (McCart et al. 1972). In Alaska, the number of eggs generally ranges from 600 to 8,000 per female (ADF&G 1978, Morrow 1980b, McPhail and Lindsey 1970), though Russell (pers. comm.) has observed dwarf, prespawning females with as few as 20 mature eggs in the Tazimina Lakes in Southwest Alaska, and fecundity of female lake resident char from the Canning River drainage ranged from 54 to 1,600 eggs (Craig 1977a).

F. Frequency of Breeding

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

G. Incubation Period/Emergence

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

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

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

A. Anadromous

1. Out-migration. Juvenile anadromous char rear in streams and lakes. After a variable number of years (usually at age four or five) most char juveniles undergo a physiological change and, in the spring, migrate seaward as smolts (ADF&G 1977a, 1977b). Most immature and mature char emigrate from overwintering areas to marine summer feeding areas following ice breakup from April to June. In the Sagavanirktok and neighboring North Slope drainages, it is likely that seaward migration occurs during the spring flood in late May and June (McCart et al. 1972). In the Canning River, char begin to leave overwintering areas in May, with a large scale emigration observed in late June and early July (Craig 1977a). In the Anaktuvuk River, char out-migrate in mid June (Bendock 1982). Departure from overwintering habitats may more closely coincide with breakup along the Beaufort Sea coast than with breakup near the overwintering site (ibid.) The char smolt migration in the Anchor River on the Kenai Peninsula takes place in late May and early June (Hammarstrom and Wallis 1983). Nonlake systems may support an additional autumn smolt out-migration (Armstrong 1965 and 1970, Armstrong and Kissner 1969, Dinneford and Elliott 1975, Elliott and Dinneford 1976). In the Noatak, Wulik, and Kivalina rivers, some fish that will spawn in the current year do not migrate seaward in the spring but rather go directly from overwintering to spawning grounds. Some of these summer spawners that spawn in early to mid August probably do migrate to sea for a month or two after spawning (DeCicco 1982, Alt 1978). Alt (1978) estimated that in the Wulik and Kivalina rivers probably in excess of 50% of the prespawning fish do not go out to the ocean at breakup.
2. Marine environment. Individuals remain at sea feeding in the estuary and along the coast for a period of a few weeks to seven months (Morrow 1980b). While in the marine environment, char stay in coastal areas. In some cases char in the Beaufort Sea may travel great distances along the coast (up to 300 km)(Craig and McCart 1976).
3. Spawning and overwintering. Char generally begin reentering fresh water in July and may continue through December, with spawners entering first, followed by immature fish and nonspawners (ADF&G 1977a). Mature anadromous char in the Sagavanirktok River have been taken in the vicinity of spawning tributaries as early as June 26. Mature migrants enter downstream spawning tributaries earlier than those further upstream (McCart et al. 1972). Immature migrants may make this return journey several times before they mature for the first time (ibid.). Although it appears that char return to their natal stream to spawn, nonspawners from Beaufort Sea drainages and from the Wulik and Kivalina river drainages may

overwinter elsewhere in the same drainage or in nonnatal drainages (Craig 1977a, Craig and McCart 1976, DeCicco 1984). Radio-tagging studies of char in the Anaktuvuk River indicate that during the ice-covered months (October to May) char are confined residents of limited overwintering habitat, and movement at this time is minimal (Bendock 1982). In the Chignik River system on the Alaska Peninsula, char, which migrate to sea from April through June, return to Chignik Lake and Black Lake from late July through September to spawn and overwinter (Roos 1959). Emigration of spawned-out char to overwintering areas usually occurs within two weeks after completion of spawning, typically during late October and November. Immature char move to overwintering areas earlier, primarily in July, August, and September (Blackett and Armstrong 1965, Krueger 1981). Adult char usually remain in fresh water through the winter months to avoid the cooler water temperatures of the marine environment (ADF&G 1977a). Overwintering sites include deep lakes, deep river pools, and groundwater spring areas.

B. Nonanadromous

1. Lake residents. Lake resident char move into streams for short periods of time. Studies in the Wood River Lakes system show that discrete subpopulations of resident lake char concentrate at inlets and outlets of the lakes during early summer to feed on out-migrating sockeye salmon smolt (McBride 1979). During late summer, char move to deeper lake waters, probably in response to a declining availability of sockeye salmon smolt and to escape warming surface waters (Nelson 1966). Mature spawners usually move back to the lake margins to spawn in the fall. Resident lake char in the Sagavanirktok drainage do not undertake any long migrations, though they do sometimes enter streams (McCart et al. 1972).

2. Stream residents. Little is known about the life history of resident stream char. In the Sagavanirktok River and neighboring drainages, they are common in mountain and spring streams. Overwintering of stream residents occurs in deep pools of streams and rivers (Morrow 1980b). In Minook Creek, a small tributary of the Yukon River near Rampart, the stream resident char leave smaller tributaries, such as Little Minook Creek and Ruby Creek, in late fall and early winter, apparently spending the winter in the lower reaches of Minook Creek itself (Armstrong and Morrow 1980). During the summer, stream residents in the Kuskokwim and Yukon river drainages congregate in areas where salmon spawn to feed on the salmon eggs (Alt 1980, 1977; ADF&G 1978). In the Sagavanirktok, Canning, Firth, and Babbage rivers, apparently all stream resident char are males;

however, stream resident females have occasionally been found in Fish Creek, Yukon Territory (Craig and McCart 1976). A consequence of this pattern is that female char are significantly more abundant in nearshore areas than are males (ibid.).

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

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

B. Human-related

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

- ° Alteration of preferred water temperatures, pH, dissolved oxygen, and chemical composition

- Alteration of preferred water velocity and depth
- Alteration of preferred stream morphology
- Increase in suspended organic or mineral material
- Increase in sedimentation and reduction in permeability of substrate
- Reduction in food supply
- Reduction in protective cover (e.g., overhanging stream banks or vegetation)
- Shock waves in aquatic environment
- Human harvest

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

VIII. LEGAL STATUS

A. Managerial Authority

The Alaska Board of Fisheries develops regulations governing the sport harvest of fish in Alaska. Research and monitoring of char populations is conducted mainly by the Alaska Department of Fish and Game, Division of Sport Fish.

IX. LIMITATIONS OF INFORMATION

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

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