# A Review of the Systematics and Ecology of Arctic Char, *Salvelinus alpinus*, in the Western Arctic

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P.J. McCart

Western Region
Department of Fisheries and Oceans
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July 1980

# A REVIEW OF THE SYSTEMATICS AND ECOLOGY OF ARCTIC CHAR, *Salvelinus alpinus*, IN THE WESTERN ARCTIC

by

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biological consultants

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This is the 128th Technical Report

from the Western Region, Winnipeg

# PREFACE

This report is presented in fulfillment of the Department of Supply and Services Contract KF709-8-2844 let to Aquatic Environments Limited for a study concerning the detailed review of the systematics and ecology of the western Arctic form of Arctic char. The work was done on behalf of the Fish and Marine Mammal Management Division, Fisheries Resources Section, Research and Resource Services Directorate, Fisheries and Oceans, Western Region. The report is published upon recommendation by Dr. G. H. Lawler, Director-General, and by Mr. R. W. Moshenko, Scientific Authority for this study.

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## ABSTRACT

McCart, P.J. 1980. A review of the systematics and ecology of Arctic char, *Salvelinus alpinus*, in the western Arctic. Can. Tech. Rep. Fish. Aquat. Sci. 935: vii + 89 p.

This study is a review of information describing the systematics and ecology of Arctic char, *Salvelinus alpinus*, in the western Arctic. The study area extends from Prudhoe Bay, Alaska, to the Mackenzie Delta, Northwest Territories, and includes numerous Beaufort Sea drainages as well as two rivers (Big Fish and the Rat) which are tributaries to the Mackenzie River.

Fish habitat within the study area, including streams, lakes, and nearshore marine habitats are described in detail.

A review of information describing the systematics of Arctic char within the study area indicates that there are two forms of Arctic char within the study area: a western Arctic form which occurs as anadromous and isolated stream resident populations and is known from only one lake, and an eastern Arctic form which occurs only in lakes. The angayukaksurak (*S. anaktuvukensis*) which has been described as occurring in the study area appears to be only a variant of the western Arctic form.

Four distinct life history types are described:

1. Lake Resident--populations of char inhabiting lakes. While a few individuals may enter tributary streams on feeding excursions during the summer, these populations are almost entirely confined to lakes.

2. Isolated Stream Resident--populations occupying spring-fed stream channels and isolated from contact with populations further downstream by impassable falls or other blockages to upstream movement.

3. Anadromous--populations with a migrant component which enters the sea to feed during the summer. In the study area, anadromous char spawn and overwinter only in stream in the vicinity of perennial groundwater sources.

4. Residual--these are fish, almost exclusively male, which are associated with anadromous populations but which mature without having undertaken a seaward migration.

Each of these life history types is described first, in terms of its distribution and general life history pattern, and second, in terms of quantitative life history parameters. The latter include age and growth, first year growth, age at first seaward migration, weight-length relationships, sex ratios, parasites, and food habits. Reproduction is also described for each of the major life history types including spawning locations, spawning habitat, spawning coloration and secondary sexual characters, spawning season, age at maturity, fecundity, ovary weights, egg size, testis weights, frequency of spawning, and spawning behavior.

The advantages of anadromy are briefly discussed. These are generally related to the larger size of anadromous fish and include: greater fecundity (number of eggs produced); larger egg size, resulting in larger fry with presumably better survival; greater choice in spawning sites, because large fish are able to utilize a wider range of bottom materials and tolerate a greater range of water velocities; better preparation of the spawning nest with increased gravel permeabilities and, presumably, greater egg-to-fry survival; and greater success in securing mates. The first four points apply exclusively to females, while the last is common to both sexes. Apparently, the major advantage of anadromy accrues to populations through the increased reproductive capacity of females. This may, in large part, explain the consistent tendency throughout the study area for a proportion of the male Arctic char to remain, mature, and die entirely in fresh water, while almost all females undertake a seaward migration.

The impact of development on Arctic char populations in the study area is discussed in general terms and some recommendations are made concerning the management of fisheries.


Key words: age; anadromy; distribution; fishery management; growth; habitat; life history; migrations; reproduction; *Salvelinus anaktuvukensis*.


## RESUME

McCart, P.J. 1980. A review of the systematics and ecology of Arctic char, *Salvelinus alpinus*, in the western Arctic. Can. Tech. Rep. Fish. Aquat. Sci. 935: vii + 89 p.

L'auteur fait le survol des connaissances taxonomiques et écologiques sur l'omble chevalier, *Salvelinus alpinus*, de l'ouest de l'Arctique, c'est-à-dire, de la Prudhoe Bay en Alaska, jusqu'au delta du Mackenzie, en passant par les nombreux tributaires de la Beaufort Sea et deux affluents du Mackenzie, les rivières Big Fish et Rat.

Les habitats, fluviatiles, lacustres et côtiers, sont décrits en détail.

Du point de vue de la systématique, deux formes d'omble chevalier se trouvent dans la région étudiée: la forme occidentale, anadrome ou constituant des isolats fluviatiles et qu'on ne retrouve que dans un seul lac; la forme orientale, strictement lacustre. L'"angayukaksurak" (*S. anaktuvukensis*) ne serait qu'une variante de la forme occidentale.

Quatre cycles évolutifs sont décrits:

1. celui des populations lacustres, c'est-à-dire, confinées aux lacs si on excepte qu'elles peuvent s'aventurer l'été dans leurs tributaires à la recherche de nourriture.

2. celui des isolats fluviatiles, coupés des populations d'aval par des chutes infranchissables à ces dernières ou par d'autres obstacles et dont l'habitat est alimenté par de l'eau de source.

3. celui des populations anadromes, dont une fraction descent vers la mer en été à la recherche de nourriture. Dans la région étudiée, les anadromes fraient et hivernent uniquement dans les cours

d'eau situés à proximité de sources pérennes.

4. celui des marginaux, mâles pour la plupart, des populations anadromes qui parviennent à maturité sans avoir émigré en mer.

Cette description commence d'abord par celle de la répartition de chaque type de population et des aspects généraux de chaque cycle évolutif puis se poursuit par celle des paramètres quantitatifs (longévité, croissance, notamment durant la première année, âge lors de la première descente vers la mer, rapports masse/longueur, rapports de masculinité, parasites, habitudes trophiques). L'auteur décrit ensuite la reproduction y compris les frayères et leurs emplacements, la livrée des géniteurs, leurs caractères sexuels secondaires, la fraie, l'âge à la maturité, la fécondité, le poids des ovaires, celui des testicules, la grosseur des oeufs, la fréquence de la reproduction, son éthologie.

L'auteur traite brièvement des avantages de l'état anadrome, lesquels découlent du plus grand développement qu'ils favorisent et se traduisent par: une fécondité supérieure (ponte supérieure); des oeufs plus gros, donc des alevins plus gros et plus viables; de meilleures possibilités de sélection des frayères, parce que des sujets plus gros peuvent utiliser une gamme plus large de substrats et tolérer des courants plus variés; une meilleure préparation des nids donc une meilleure perméabilité du gravier et présumément, une survie accrue des oeufs jusqu'au stade alevin, et une probabilité favorisée de fécondation. Les quatre premiers points concernent uniquement les femelles, le dernier les deux sexes. Il semble que le principal avantage de l'état anadrome soit conféré aux populations par l'aptitude accrue des femelles à se reproduire. Ceci peut en grande partie expliquer pourquoi, dans la région étudiée, une certaine proportion des mâles a tendance à rester en eau douce, à y atteindre la maturité et à y mourir, tandis que presque toutes les femelles entreprennent une migration vers la mer.

Les répercussions générales de la valorisation des populations d'omble chevalier, dans la région étudiée sont abordées et sont suivies de certaines recommandations concernant l'aménagement de la pêche.

Mots-clés: âge; état anadrome; répartition; gestion des pêches; croissance; habitat; cycle évolutif; migrations; reproduction; *Salvelinus oreektuvukenis*.

## INTRODUCTION

Since the late 1960's, with the discovery of the Prudhoe Bay and Mackenzie Delta oil and gas deposits, a great deal of environmental research has been conducted in the western Arctic, from the Mackenzie Valley west into Alaska. This research has included extensive studies of freshwater and anadromous fishes.

In the western Arctic, some of the most widespread and valuable fishes are the Arctic char. They occur variously as lake-resident, stream-resident, and anadromous populations. Despite the fact that they have a widespread distribution, there are few papers in the formal literature describing the ecology of Arctic char in the western Arctic. None provides detailed information describing anadromous populations, the most important group within the general area. Such information is available, however, in reports and data files, the result of studies by industry and various government agencies in Alaska and Canada. This document synthesizes the available data describing Arctic char in Beaufort Sea drainages in Alaska and Canada including the Mackenzie River and its tributaries.

The major purpose of the document is to provide a detailed basis for future studies of Arctic char in the western Arctic, for the assessment of the potential impact of development, and for the management of the species. The need for such a broad information base is becoming apparent with the increasing rate of development in the North both onshore and, more recently, offshore in the Beaufort Sea and with the increasing exploitation of the species as access to the area improves.

## DESCRIPTION OF THE STUDY AREA

The study area (Fig. 1) extends from Prudhoe Bay, Alaska, in the west to the Mackenzie River Delta and the Peel River in the east. Most of the drainages, for which data describing Arctic char populations are available, enter the Beaufort Sea directly. These include drainages from the Sagavanirktok River in the west to the Blow River in the east. In addition to the foregoing, data are available for several populations in drainages tributary to the Mackenzie River. These include the Big Fish River (Fish River on some maps) Drainage which enters the Mackenzie Delta south of Coalmine Lake, and the Rat River which enters Husky Channel near its confluence with the Peel River. All of these drainages lie between 67°N and 71°N Latitude, well within the Arctic Circle (66°33'N).

### ENVIRONMENTAL FACTORS

#### *Climate*

##### *Air temperature*

The climate within the study area is rigorous and the mean annual air temperature is below freezing, generally between -10 and -9°C (Burns 1973; Johnson and Hartman 1969). The warmest month is usually July, the coldest January or February. Typically, the highest summer and lowest winter temperatures are recorded inland, within the mountain ranges where the climate is more continental and therefore more extreme than it is along the Arctic coast. The length of winter (mean number of days when daily temperature is <0°C) averages about 225 days for locations within the study area with an average of 10 to 30 frost-free days (Burns 1973). Figure 2 presents data describing seasonal distribution in air temperature at Komakuk Beach, Yukon Territory. This station (69°35'N, 140°11'W, elevation 9.1 m) is located near the coast, approximately mid-way in the study area, about 30 km west of the mouth of the Firth River, a major producer of Arctic char. At this station, during the period 1958-1970 the mean annual air temperature was -11°C and the mean daily maximum was -7.3°C. There was an average of 64 frost-free days annually, with frost occurring every month of the year.

##### *Precipitation*

Mean annual precipitation is low, ranging from about 127 mm along the coast to about 381 mm at higher elevations within the mountains (Burns 1974; Johnson and Hartman 1969). Most of the precipitation occurs as rain during the summer period. At Komakuk Beach (Fig. 2), both mean and maximum monthly precipitation occurred during July and August. At this station, the mean annual precipitation during the period 1958-1970 was 125 mm including 73 mm of rain and 516 mm of snow.

In more southerly latitudes, a region with such limited precipitation would be a desert. However, the shallow permafrost table underlying this area is impermeable to water and prevents the downward percolation of precipitation as subterranean drainage. Thus, most runoff water remains at or near the surface and streams continue to run throughout the summer. At the same time, the generally low air temperatures and high humidity reduce surface evaporation. The results are most apparent along the Arctic Coastal Plain, particularly at the western end of the study area in the Teshekpak Section, where the low relief slows drainage and water accumulates in thousands of shallow lakes, ponds, and marshes.

There is one other effect, important to fishes, of the confinement of much of the water near the ground surface and in shallow waterbodies. During the summer period of 24 h insolation, water temperatures may rise very rapidly so that shallow bodies of water and the streams draining them frequently have temperatures in excess of 18°C. Some species of fish, including grayling and, to a lesser extent, juvenile Arctic char, take advantage of these high temperatures by moving into such waters during the summer.

#### *Light conditions*

Areas within the Arctic actually enjoy more hours of daylight per year than do areas at lower latitudes. For example, at latitude 69°N, the approximate center of our area of study, there are about 5500 h of daylight per year while at 45°N, the approximate latitude of Montreal, there are only 4860 h. In the Arctic, however, there is a much greater concentration of the total annual daylight budget in the summer months. At 69°N, 77% of the total budget is received during the spring-summer period from March 21 to September 21 compared with approximately 60% at 45°N (Johnson and Hartman 1969). This comes about because of the greater seasonal change in day length in the Arctic

(Fig. 3). In the study area, there is a period of approximately five weeks beginning in early December, during which the sun does not rise above the horizon. Thereafter, day length increases rapidly until late May when a long, eight week period of continuous daylight begins. From late July, day length decreases rapidly until the beginning of the next sunless period.

One feature of the light regime which should be emphasized is that, even during the summer period of continuous daylight, light levels are far from constant throughout each 24 h period. There is, in fact, a regular daily cycle in light intensity with levels highest about noon when the sun is high in the southern sky and lowest about midnight when the sun is low in the north. During the course of a study of invertebrate drift at Echooka Spring in Alaska, for example, light levels at the water surface ranged from a high of 5900 ft candles at 1100 h, July 21, to a low of 20 ft candles at 0100 h, July 22, 1971, when the sun was shadowed by nearby hills (McCart et al. 1972). Thus, the recorded maximum light intensity was approximately 295 times the minimum, despite the fact that the measurements were made during the period of continuous daylight at the latitude of the spring. Such variation in light intensity may be important in regulating the daily activity patterns of aquatic animals, for example, the movements of fish and the pattern of downstream drift of some stream invertebrates.

*Permafrost*

The study area lies within the Continuous Permafrost Zone and, nearly everywhere, is underlain by ground which has been maintained in a frozen condition for thousands of years. Such permanently frozen ground is called permafrost, defined as ground whose temperature has remained continuously below freezing (0°C) for a period of two or more years. It is thought that the existing permafrost first formed in the Arctic during the period of extreme cold weather at the beginning of the most recent (Pleistocene) ice age (Brown 1970).

The permafrost is overlain by the active layer which thaws during the summer and refreezes each winter. The active layer, 46 to 91 cm thick in the study area, is usually vegetated and insulates the underlying permafrost from summer heating. The upper limit of the permafrost is called the permafrost table. Permafrost on the North Slope is often more than 300 m thick. At its lower limit, the downward penetration of the frozen ground is balanced by the upward flow of heat from the interior of the earth.

Permafrost may be dry, containing no water at all, or wet, containing ice in proportions up to 100% (pure ice in the form of ice lenses or ice wedges). Ice acts as a cement producing a rock-like, stable substrate impermeable to water. However, the relationship of active layer and permafrost is not static and the presence of underlying permafrost is often indicated by distinctive features which develop at the ground surface. Permafrost-related surface features important to aquatic organisms include melt (or thermokarst) lakes and beaded streams. The former develop when the land surface subsides due to the melting of ground ice. The resulting hollow fills with water forming a lake or pond. These are most common on the poorly drained Arctic Coastal Plain but examples occur throughout the study area. Beaded streams are formed when large chunks of ground ice are melted out at intervals along the course of a stream leaving pools (the beads) connected by narrower stream channels (Brown 1970). Many of the streams in the Arctic foothills are of this type.

Degradation of permafrost accompanied by the melting of ground ice does occur under natural conditions (e.g., the formation of melt lakes). However, the rate of degradation can be very much accelerated where human activity results in a disturbance of the ground surface which affects the insulating properties of the active layer. In high-ice content, fine-grained soils such as silts, there may be settling, caving, and subsidence of the ground surface as water is lost through drainage and evaporation. Liquified, fine-grained soils can flow down slopes as mud, producing thaw gullies. Erosion of this kind can affect the aquatic environment where the eroded material enters lakes or streams. Within the study area, one of the more spectacular examples of such degradation occurs adjacent to the Kavik River, Alaska, and has resulted in some movement of materials into the stream.

## STREAMS

Craig and McCart (1975) describe three broadly-defined stream types within the study area: mountain, spring, and tundra streams. Arctic char may occur in all three types but are most common in the first two. The following description has been taken from their presentation with some minor modifications.

*Mountain streams*

The Mountain Streams originate in the Brooks Range and the British, Barn, and Richardson mountains. In Alaska the upper courses of these streams were glaciated during the Pleistocene giving some valleys a rounded appearance. Where the valleys are broad and flat, the streams tend to break up into a number of interconnecting channels forming a braided pattern. Most of these channels are dry except during periods of high water.

Flows in these streams derive from two main sources: springs and surface runoff. The springs are perennial and provide the only source of winter flow. Some springs enter the beds of the Mountain Streams directly, others originate some distance away and flow through separate channels (see Spring Streams) before joining the Mountain Streams. One obvious indicator of the presence of spring water sources are the large areas of icings or *aufeis* which build up during the winter in braided areas downstream of springs. Keller et al. (1961) reports one of the larger *aufeis* fields as 19 km long with ice up to 6 m thick. Some *aufeis* may persist throughout the summer.

Surface runoff, the second major source of flow in the Mountain Streams, derives chiefly from the melting of ice and snow and reaches a peak during the spring thaw which begins in late May or early June. During the spring flood, some scouring of streambeds and undercutting of banks occurs.

The spring flood normally subsides by early July but marked variations in discharge occur in response to heavy rainfall in the mountain valleys. The silt load varies with flow and is highest

during the spring flood. Turbidity and suspended sediment levels decrease as surface runoff declines in late summer and the bottom can be seen at depths of 2 m.

The Mountain Streams flow for about five months of the year. About mid-October, surface runoff ceases and the only flow is provided by groundwater sources in localized areas.

Summer water temperatures in the Mountain Streams seldom exceed 10°C (Fig. 4). The highest temperatures recorded were 13°C in the Sagavanirktok River (June 24, 1969) and 15°C in the Canning River (August 6, 1973). Large masses of melting *aufeis* can influence stream temperatures resulting in considerable longitudinal differences. For example, the water temperature above a large area of *aufeis* on Section Creek was 10°C compared with 4.5°C immediately below (June 21, 1970).

Water samples taken from Mountain Streams reflect the nature of the limestone bedrock in which the streams originate. The water is moderately hard with a predominance of calcium ions. A comparison of conductivity, pH, and calcium concentrations in the three stream types is shown in Table 1.

*Spring streams*

As already indicated, the Spring Streams are spring-fed tributaries of the Mountain Streams. Perennial springs have been located in many Mountain Streams (Fig. 5) and undoubtedly more are present. Most originate in or along the northern edge of the Arctic Mountain Province and are associated with the Lisburne Limestone Group, but others, located in the Arctic Coastal Plain Province, may discharge through Tertiary sediments (Mutch and McCart 1974).

Most of the perennial springs originate from subpermafrost water (Mutch and McCart 1974). An unfrozen conduit (a talik) is required for surface discharge of water from beneath permafrost. Once established, the perennial flow of water at a temperature above freezing keeps the conduit open. Subpermafrost water is discharged at the surface through fractures and faults in bedrock, cavernous zones in limestone, or large openings in volcanic rocks and permeable unconsolidated deposits.

Subpermafrost water is generally fresh, indicating that it is recharged from the surface and that it circulates. However, brackish and saline waters beneath the permafrost have been found in the coastal regions of western Alaska, the Arctic Coastal Plain, the Foothills of the Brooks Range.

Usually little is known regarding the relation of springs to permafrost and consequently it is not always possible to determine categorically if the water in particular springs is supra-, intra-, or sub-permafrost, or a mixture of these types.

The Spring Stream habitat is one of relative stability and this appears to have a profound biological influence. Kalff and Hobbie (1973) have described these areas as "green oases in the polar environment". Streambanks are often overgrown with vegetation and the streambed is covered in most places with a heavy growth of moss or algae.

These are all small streams, generally less than 1.5 km in length and only a few metres wide. Some Spring Streams are isolated from any influence by other streams. For example, Shublik Springs is separated from the Canning River by a 9 m waterfall and so it is not affected by floods in the Canning River or by channels meandering in the Canning floodplain. Other springs originate in or close to the floodplain of the Mountain Streams and have shorter isolated sections. As the channels of the Mountain Stream meander and intercept the Spring Streams, the lengths of the latter change. In many, the lower portions are subject to brief periods of overflow from adjacent Mountain Streams. Groundwater sources which discharge directly into active channels of Mountain Streams have no isolated sections and therefore are not included in the Spring Stream category.

Except when there is overflow from nearby Mountain Streams, turbidity and suspended sediment levels in Spring Streams remain low (Fig. 6) and total discharge is relatively stable (Fig. 7).

In general, the water temperatures of most springs in the study area range from 0 to 4°C in the early or late winter, to 4 to 11°C in the summer. The exceptions are the two thermal springs, Sadlerochit Spring (13°C on April 14, 1972) and Cache Creek Spring (16°C on November 11, 1972).

Groundwater samples were collected from 19 locations. Most of these springs represent freshwater sources (dissolved solids content <300 mg/L) and are of the Ca (Mg)-$HCO_3(SO_4)$ or karst-type (Table 2).

The thermal springs on Cache Creek, N.W.T., diverge most noticeably from the karst-type groundwater (Table 2). Three additional springs also differ in dissolved solids content. The springs at Firth River-2, Sadlerochit Springs, and Spring River have intermediate values between the karst-type water and the mineral waters found at Cache Creek. These three springs originate near the ocean and it is possible that the differences in levels of dissolved solids may be due to passage through evaporites in the Tertiary sediments of the Coastal Plain (Mutch and McCart 1974).

During the summer sampling periods, dissolved oxygen concentration in Spring Streams were generally high and saturation percentages were similar to those in other stream types: Mountain Streams (76 to 100%), Spring Streams (74 to 100%), and Tundra Streams (78 to 100%). However, a considerable variation existed in the dissolved oxygen concentrations measured at the orifices of the groundwater sources. The lowest values were found at the Cache Creek orifice on May 10, 1973, where the dissolved oxygen concentration was only 0.2 ppm (2% saturation at 16°C).

*Tundra streams*

These streams drain the tundra-covered slopes of the Arctic Foothills and Coastal Plain provinces. They tend to be small meandering streams, 30-65 km in length, which flow into Mountain Streams or directly into the Beaufort Sea. For the most part, the streams are confined to a single channel though there are braided areas in the largest of them. With few exceptions, neither *aufeis* nor springs are found on these streams, and flows cease completely during the winter. Many Tundra Streams

are of the type known as "beaded" streams (Brown 1970).

Discharge rates in Tundra Streams are intermediate between those of Mountain Streams and Spring Streams, overlapping both. A spring flood occurs in late May or early June. In Weir Creek, a tributary to the Kavik River, flow began May 30, 1973 (Fig. 7), one week after the Kavik River itself began flowing. Weir Creek is approximately 39 km in length and has a 155 $km^2$ drainage basin. Floodwaters overflowed high banks and across stream meanders. As the bottom ice melted, water levels receded and thereafter, fluctuations in discharge reflected the wet summer of 1973. Flow ceased in Weir Creek about October 15. The open water period extended approximately 4.5 months in 1973, one month longer than in the previous year (May 27 to September 13, 1972).

The Tundra Streams often overflow their banks during the spring freshet but flooding is less severe than that in the Mountain Streams. This is reflected in the lower levels of turbidity and suspended silt loads (Fig. 6). There are a number of factors which contribute to this stability: (a) most drainage originates as runoff which passes through the surrounding tundra with its high water absorbing capacity, before entering the streams, and (b) there are lakes, ponds, and marshy areas associated with streams which take up water during periods of heavy runoff and release it slowly.

The slow passage of water through shallow ponded areas and superficial ground layers results in rapid warming by the sun, and water temperatures in the Tundra Streams are generally higher than those in either of the other types (Fig. 4). A maximum of 20°C was recorded in Happy Valley Creek (July 9, 1971). In this stream there was considerable diel variation (6°C) in water temperatures even during the summer period of continuous daylight. Summer temperatures in other Tundra Streams usually exceeded 10°C, and temperatures exceeding 15.6° were recorded in six additional streams.

Tundra Streams originate outside the limestone areas and the quality of these waters is influenced during its passage through the tundra. These waters have lower concentrations of calcium and lower pH and conductivity than found in the Mountain or Spring Streams (Table 1). The water is often stained a yellow to brown colour.

*Benthic invertebrates*

A wide range in the numbers of benthic invertebrates was found in the 55 locations sampled. Values ranged from only 22 organisms/$m^2$ in the upper Canning River to over 84,000/$m^2$ in Echooka Spring. Overlap occurs, but the three stream types are characterized by different invertebrate densities. Spring Streams have significantly greater densities of benthic invertebrates than Tundra Streams and Tundra Streams have significantly more than Mountain Streams (Fig. 8). This pattern emerges despite such complicating factors as seasonal and geographic variation.

A further distinction between the three stream types is the kind of benthic invertebrates that are present and the frequency in which they occur. While the specimens were not identified to the species level, a comparison of major taxonomic groups indicates that the greatest diversity occurs in the Spring Streams. These streams contained 22 of the 23 identified taxonomic groups compared to 18 each for the two other stream types (Table 3). Furthermore, these groups occurred more frequently in Spring Stream samples. For example, 14 of these groups were found in at least 10% of all Spring Stream samples collected compared to 12 for Tundra Streams and 7 for Mountain Streams. The benthic fauna in Mountain Streams was also unique in its lack of certain taxonomic groups. Trichopterans were absent at almost all sites and amphipods and triclads were generally found in rivers only in the eastern portion of the study area.

LAKES

In the following, lakes situated along the Arctic Coastal Plain are considered separately from those situated in the Foothills and Mountain provinces.

Lakes along the Arctic Coastal Plain are generally shallow, often containing little, if any, free water during the period of maximal ice development in late winter. These lakes, shallow and exposed to wind forces, are typically monomictic (i.e., a single, continuous period of mixing during the ice-free season), and isothermal during the summer with low rates of primary production. Firth Lake (Fig. 9 and Table 4) is an example.

As part of a water availability study, Jones (1976) examined 49 of the larger lakes distributed along approximately 514 km of the Coastal Plain from Prudhoe Bay, Alaska, to the vicinity of Deep Creek, Yukon Territory. Of the 49 lakes, 21 were devoid of fish, while 18 harboured populations of fish including ninespine stickleback, *Pungitius pungitius* (11 lakes), grayling, *Thymallus arcticus* (5), lake whitefish, *Coregonus clupeaformis* (3), broad whitefish, *Coregonus nasus* (3), least cisco, *Coregonus sardinella* (1), and pond smelt, *Hypomesus olidus* (2). All of the lakes were shallow (the greatest mean depth was only 4.0 m) but those known to have fish populations were generally deeper and slightly larger than those without fish (Table 5). There were no data regarding fish populations for 10 of the lakes. None of the lakes harboured a resident population of Arctic char and, in fact, none is known to be present in any lake along the coastal plain within the study area. While juvenile Arctic char do occasionally enter such lakes during the summer, especially lakes with relatively short connections to Mountain Streams, such use appears to be incidental and minor.

All of the lake-resident Arctic char populations known from the study area inhabit relatively deep lakes within the Foothill and Mountain provinces. The locations of these lakes are indicated in Fig. 1.

Within the study area, only three lakes situated in the Foothill and Mountain provinces have been subjected to detailed limnological investigation. These are Peters and Schrader lakes in Alaska (Hobbie 1961, 1962, and 1964) and an unnamed lake (code name Lake 105) in the Yukon Territory (McCart et al. 1974). Only the first two support populations of Arctic char. These lakes are deeper than those on the coastal plain. They are protected from wind by the surrounding terrain, and in some summers may be thermally stratified, as Lake 105 was in 1973 (Fig. 9). Hobbie (1962) found that in

1958, Schrader Lake became thermally stratified early in spring and remained so throughout the summer. At the end of August, the temperature was 10°C at the surface and 4°C at the bottom. In 1959, however, stratification did not occur and the lake was isothermal at less than 4°C throughout the summer. The marked annual difference in the thermal behaviour of Schrader Lake was probably related to annual differences in weather: the summer of 1958 was warm and calm while in 1959 the weather was cold and stormy. Neighbouring Lake Peters, smaller and shallower than Schrader Lake, did not stratify in either year.

Hobbie (1973) notes that thermal stratification is only likely to occur in lakes in sheltered localities along the southern margin of the tundra and that when Arctic lakes are ice free, they are almost always close to complete saturation of oxygen. The oxygen deficit in Lake 105 (Fig. 9) may be, in part, a carry-over from the preceeding winter. This could result if marked temperature stratification were to occur immediately after ice-melt, during a period of warm, calm weather, before complete mixing of the water column has taken place.

As is typical of Arctic lakes, nutrient concentrations and phytoplankton primary productivity are both very low in lakes within the study area (Table 4).

There are a number of factors limiting primary productivity in the north including light and, most importantly, nutrient levels. Hobbie (1973) points out that nutrient concentrations are always low in Arctic waters undisturbed by man. Kalff (1969) suggests that these low nutrient concentrations appear to be the most important reason for low primary production. A variety of factors contribute to this including the nature of the bedrock (particularly on the Shield), poor soil development, the thin active layer available for leaching, the limited runoff which restricts the transport of nutrients, the slow microbial breakdown of organic materials and recycling of their nutrients, and even the general absence of thunderstorms which assist in the nitrification process.

The length of the period of ice cover varies from year to year and even from lake to lake and is affected by such factors as altitude, thermal regime, snow cover, and wind. In general, however, ice formation in lakes in the study area begins in late September or early October. Low winter temperatures combined with short periods of daylight result in a prolonged period of radiation loss from lake surfaces and ice formation to depths of two metres or more. On most lakes, the ice cover breaks up in late June or early July when daylight approaches 24 h and air temperatures are highest. The ice-free season in lakes in the study area, the period to which fish production is almost entirely confined, is, therefore, only three to three and one half months in length.

At Peters Lake, Hobbie (1962) examined the rates of ice formation during parts of three winters (Fig. 10). He found that 90% of the ice thickness was produced in the first four months of winter, and reached a maximum thickness of up to 2 m by May. He also found a relationship between the amount of snow accumulation on the ice and the rate of ice production. In 1961, for instance, when there was a heavy snowfall, the ice was thinner than in 1959, a year of light snowfall. Thus, the greater the snow accumulation and the earlier in the season the accumulation begins, the thinner the ice will be.

## THE MARINE ENVIRONMENT

As will be demonstrated later in this review, Arctic char, during the marine phase of their life history, are confined to a very narrow corridor immediately alongshore. This description of the marine environment will, therefore, deal only with nearshore habitats.

The most detailed study, within the study area, of nearshore marine habitats in relation to fish is one conducted at Simpson Lagoon between the mouths of the Sagavanirktok and Colville rivers. This lagoon is typical of many such scattered along the Beaufort Sea coast which are important to Arctic char. In their report of this study, Craig and Haldorson (1980) describe physical and chemical conditions within the lagoon:

*The annual cycle*

The ice-free period in Simpson Lagoon is short, lasting about 3 months. Initial stages of spring breakup consist of flooding from the Kuparuk and Ugnuravik rivers in early June, and the formation of open water leads along mainland and island shorelines in mid-June. By late June and early July, the shorelead is 10 - 100 m wide with cold (0 - 4.5°C), clear and almost fresh waters (2.1 - 6.0 ppt). Most nearshore ice soon melts or is moved away by winds and currents, and the lagoon is 90% ice-free by mid-July.

Ocean ice may hold fast against the outside of the barrier islands until mid- or late July, at which time the ice is moved about 10 km offshore by winds. Thereafter, ice floes occasionally are blown back to the islands by wind, but the lagoon itself remains ice-free for the duration of the summer.

Freeze-up begins in the lagoon in late September, when slush ice forms in shallow, calm waters. Lagoon waters were open on 1 October 1978, although ice cover probably developed over the entire lagoon during the next two weeks.

During winter months, surface ice steadily increases in thickness. In November, the ice is 50 cm thick and maximum thicknesses of about 2 m are reached in late winter (April). At this time, approximately 90% of the lagoon volume is frozen solid and the only unfrozen water is located in the lagoon center where under-ice depths are 0.3 - 1.0 m.

*Temperature and salinity*

Dramatic seasonal changes in the physical environment present stringent conditions for life in Simpson Lagoon. Water temperatures range from summer highs to 10-13°C to winter lows of -2°C. Summer salinities run the gamut from fresh to saline water, and in winter the water may become hypersaline (up to 68 ppt, Crane and Cooney 1974). A generalized seasonal pattern for these physical characteristics is as follows:

Spring (late June - early July): waters cold (0-5°C) and nearly fresh (1-10 ppt) because of melting ice and river flooding.

Summer (mid-July - mid-August): waters relatively warm (7-10°C) and brackish (18-25 ppt).

Fall (late August - September): rapid cooling (0-6°C), waters brackish (18-25 ppt).

Winter (mid-October - early June): water cold (0 to -2°C) and initially brackish (25-30 ppt), becoming saline or hypersaline (35-60 ppt) by winter's end.

Because coastal circulation patterns tend to hold discharge from North Slope rivers near the coastline, waters become progressively more saline with increasing distance from shore. Lagoon waters are generally warmer and less saline than waters outside the barrier islands; furthermore, temperatures decrease and salinity increases with distance from the mainland shore... An exception to this pattern was observed on one occasion in 1977 when an apparent upwelling brought cold marine water against the outside of the barrier islands.

Little vertical stratification of temperature or salinity occurs in the lagoon. Bottom conditions were generally within 1°C and 3 ppt salinity of surface conditions. In the deep channel (3-4 m) between Spy and Leavitt islands, however, a tongue of cold hypersaline water was recorded (C. Mungall, pers. comm.). Similar hypersaline pockets of water were recorded in deep (4 m) pools in Kaktovik Lagoon in summer (Griffiths et al. 1977).

*Turbidity*

Lagoon waters are turbid to varying degrees for almost the entire open-water period. Because of variations in wind-generated turbulence, nearshore turbidity readings fluctuated widely (1-146 NTU recorded 80 m from shore) from day to day. Wave-washed waters around the lagoon edges are generally more turbid than waters elsewhere; there is often a band of murky water along the shoreline... Maximum turbidities occured during and after period of high winds; the correlation between turbidity (measured 80 m from the shoreline) and wind speed was highly significant (correlation coefficient $r=0.629$, $P<0.001$, $n=56$). After winds slacken, turbidity readings fall rapidly as the sediments quickly settle out.

Simpson Lagoon, despite its shallow nature, is not a homogeneous mixture of wind-churned water. SCUBA divers observed that a vertical stratification of water currents occurred in the lagoon center even though the water depth was only 2 m. Currents were slower at the bottom and thus the flocculant detrital layer often remained in place despite relatively high velocities of overlying water.

*Dissolved oxygen*

Dissolved oxygen concentrations remained high at all stations during the open-water period. The average summer value was 9.8 mL/L range (7.0-12.0 mL/L).

Other studies of nearshore habitats along the Beaufort Sea coast, frequented by Arctic char, have been conducted at Kaktovik Lagoon near Barter Island, Alaska (Griffiths et al. 1977), and at Nunaluk Lagoon near the mouth of the Firth River, Yukon Territory (Griffiths et al. 1975). Conditions in the vicinity of Kaktovik Lagoon were generally similar to those described for Simpson Lagoon above. Nunaluk Lagoon was, however, typically much less saline, averaging about 4‰ during the ice-free season, due to the influence of the Firth and Malcolm rivers. Maximum open-water salinities at Nunaluk Lagoon (29.8‰) were, however, higher than the maxima recorded at Kaktovik Lagoon (20.8‰). The Nunaluk maximum was the result of an influx of marine water just prior to freeze-up.

Tides along the Beaufort Sea coast are small, irregular, and unpredictable (Johnson and Hartman 1969; Lewellen 1970) and wind-generated changes in water levels are of more importance than those caused by tidal fluctuations. In the vicinity of Kaktovik Lagoon (Griffiths et al. 1977), daily fluctuations in water levels typically averaged 10-15 cm (Fig. 11), although the difference between the highest level (August 27) and the lowest level (August 24) was 75 cm (Fig. 11). The highest water levels corresponded to periods of strong westerly winds, and the lowest levels to periods of easterly winds.

## SYSTEMATICS OF THE *SALVELINUS ALPINUS* COMPLEX IN THE STUDY AREA

"Systematics is the scientific study of the kinds and diversity of organisms and of any and all relationships between them" (Simpson 1961). As Mayr (1969) has pointed out, the relationships referred to are not simply phylogenetic ones but may include all the biological relationships among organisms: evolutionary, ecological, and behavioural. Systematics is not confined to studies of the relationships of species but encompasses populations on the one hand and higher taxa on the other.

Studies of the systematics of Arctic char have certainly not progressed to the point where scientists can claim to have examined all the biological relationships of the fish which are commonly designated as Arctic char. In fact, there is not yet any agreement on the taxonomy or classification of Arctic char. Is there a single species of Arctic char or are there several species which have been included within this designation and which must be distinguished? Current opinion generally supports the latter view, that there is a group of closely related, sibling species in Europe, Asia, and North America which are included within what is referred to as the "*Salvelinus alpinus* complex."

The most complete study of the *Salvelinus alpinus* complex as it exists in western North America is that of McPhail (1961). McPhail recognized two distinct species in western North America, the Arctic char *(S. alpinus)* and the Dolly Varden *(S. malma)*, both including several forms. However, Behnke (1972), in a review of the literature, commented that, "I suspect that further studies of *S. malma* and *S. alpinus* in North America

may demonstrate that there is more variability and not such a neat pattern of differentiation as implied by McPhail (1961)".

Since Behnke's comment, Morrow (1973) and Frohne (1973) have described a new species of char, *Salvelinus anaktuvukensis*, from springs in headwater localities in the Brooks Range in Alaska. The indicated distribution of the presumptive species includes a portion of the area in which the studies described in this review were carried out. Even more recently, Cavender (1978) has suggested that the bull trout, *Salvelinus confluentus*, should be distinguished from the Dolly Varden, *Salvelinus malma*, with which it has been confused in the past.

What follows is a brief review of the available information regarding the systematics of the *Salvelinus alpinus* complex in western North America and an analysis of the forms occurring within the study area described in this report.

## MERISTIC STUDIES

Meristic characters are those which can be counted, e.g., the numbers of scales, vertebrae, finrays, etc. The numbers of many meristic characters are not fixed but vary from individual to individual within populations. Populations can be distinguished if counts for some meristic character are significantly higher or lower in one than in the other. In studies of systematic relationships within the *S. alpinus* group, three meristic series have traditionally been enumerated: pyloric caeca, gillrakers, and vertebrae (Behnke 1972). Other meristic series can also be useful. McPhail (1961) found that the numbers of lateral line pores could be used to distinguish some forms of the *Salvelinus alpinus* complex in North America. Morrow (1973) used the foregoing (vertebrae excepted) as well as a variety of finray counts and counts of branchiostegal rays and tongue teeth to describe *S. anaktuvukensis*. Most recently, Cavender (1978) found that counts of mandibular pores were useful in separating *S. malma* from *S. confluentus*.

The information which forms the basis of the following review is based on previously unreported data obtained from samples collected by Aquatic Environments Limited during the course of its work within the study area, from Prudhoe Bay, Alaska, and the Mackenzie River along with data from McPhail (1961), McCart and Craig (1971), McCart and Craig (1973), Benhke (1972), Morrow (1973), Frohne (1973), McCart and Bain (1974), and Cavender (1978).

McPhail (1961) used meristic characters and, to some extent, geographical location, to distinguish two major groups each including two forms within the *S. alpinus* complex in North America. These were:

1. The Dolly Varden *(S. malma)* group including a northern and southern form, and

2. The Arctic char *(S. alpinus)* group including an eastern and western Arctic-Bering Sea form.

Reanalysis of McPhail's data suggests that his distinctions may have been too complex and that his northern Dolly Varden and western Arctic-Bering Sea Arctic char are, in fact, the same form. Morrow (1973) has recognized this and has called all these fish by the name northern Dolly Varden. We are thus left with three forms: the southern Dolly Varden, eastern Arctic char, and the northern Dolly Varden-western Arctic-Bering Sea Arctic char. In this report, the latter have been designated western Arctic char in contradistinction to the eastern Arctic char.

Morrow (1973) named a new species of char *S. anaktuvukensis* from the Brooks Range in Alaska which he described as being most closely related to the Dolly Varden *(S. malma)*. He states that the new species differs from the western Arctic char (which, as indicated, he calls the northern Dolly Varden) that occur in the same general area, in having greater average numbers of dorsal, anal, pectoral, and pelvic finrays, lateral line pores, and number of parr marks. Morrow's conclusion was supported by a more detailed statistical analysis of the same data carried out by Frohne (1973).

Cavender (1978) further complicated the relationship of *Salvelinus* in western North America by suggesting a specific distinction between the bull trout *(S. confluentus)* and the Dolly Varden *(S. malma)*. He based his separation of the two species primarily on characters of the head and cranial skeleton. Among meristic series, he found that the traditional characters--vertebrae, gillrakers, and pyloric caeca--were very similar for the two species but that the numbers of mandibular pores and branchiostegal rays, though there was some overlap in ranges, were quite different in the two species.

As a result of the various studies, we are left with five forms within the *Salvelinus alpinus* complex in western North America:

1. The Dolly Varden *(S. malma)*
2. The bull trout *(S. confluentus)*
3. The angayukaksurak *(S. anaktuvukensis)*
4. The eastern Arctic char *(S. alpinus)*
5. The western Arctic char *(S. alpinus)*

For the purposes of this study, the main concern is with the forms of Arctic char occurring within the study area. McCart and Craig (1971) described two forms, the eastern and western forms of Arctic char in the Sagavanirktok Drainage within the study area. Morrow (1973) includes a large part of the study area in the supposed range of the angayukaksurak, "... from Howard Pass in the west to the Romanzoff Mountains in the east..." including, to the west, the Hulahula and Atchalik rivers. I have been unable to locate the latter and it may be either a misspelling or variant spelling of the Aichilik River which does lie within the study area, to the west of the Hulahula.

As a first step in assessing the systematic status of char populations within the study area, data describing four meristic variables have been analysed for 93 samples of char from western North America including 26 from within the study area. The method used was agglomerative hierarchical clustering, an objective statistic which classifies "n" individuals into "g" groups based on the values of "p" variables measured on each (Everitt 1974). It differs from discriminant analysis in that the groups are not determined *a priori* (Anderberg 1973). Cluster analysis has been used in studies similar to the present one to search for natural groupings and to construct taxonomies (Everitt 1974; Anderberg 1973).

In this instance, the data were means for populations for four meristic variables:

1. Upper limb gillrakers, first arch left side
2. Lower limb gillrakers, first arch left side
3. Pyloric caeca
4. Lateral line pores

Each of these characters has proved useful in the past in separating taxonomic groups among the *Salvelinus alpinus* complex and data are therefore available for a wide range of populations. The sources include McPhail (1961), Morrow (1973), and Aquatic Environments Limited File Data.

The analysis, presented as a dendrogram (Fig. 12) indicates that there are three well defined groups among the samples which correspond to previously described forms. These are:

1. The eastern Arctic char *(S. alpinus)*
2. The western Arctic char *(S. alpinus)*
3. A combined group including the Dolly Varden *(S. malma)* and bull trout *(S. confluentus)*.

As previously indicated, the Dolly Varden and bull trout are best separated by characters (especially branchiostegal rays, mandibular pores, and gillraker morphology) not included in this analysis. A smaller sample of 75 samples, analysed for these four meristic characters as well as vertebral counts gave almost identical groupings.

Of the 26 samples from the study area, one (Sadlerochi Spring) was classified with *S. malma/ S. confluentus*, 20 were classified with the western Arctic char, and five were classified with the eastern Arctic char. On the basis of the four characters, the angayukaksurak was classified along with the group including anadromous and freshwater resident western Arctic char. However, some of the characters, particularly finray counts, which Morrow (1973) indicates are particularly useful in distinguishing *S. anaktuvukensis,* were not included in the analysis. To further clarify the status of this species, a second cluster analysis was performed for 42 samples for which data describing population means were available for eight variables, the four included in the first analysis as well as pectoral, pelvic, anal, and dorsal finrays. Again, *S. anaktuvukensis* was classified with the group including western Arctic char (Fig. 13). Note also that the Sadlerochit Spring population, classified with *S. malma/S. confluentus* in the four variable run, is now classified with the western Arctic char.

While the cluster analysis with eight variables suggests that *S. anaktuvukensis* is not very different meristically from many populations of western Arctic char, it is possible that some of the differences between *S. anaktuvukensis* and western Arctic char were obscured by the fact that the analysis was based on population means rather than on data for individual fish. To test this possibility, cluster analysis was performed on data for individual fish in the samples of *S. anaktuvukensis* and other samples in the same subcluster--Lowe River, Fish Creek, Canning River, Canning River, Canning Tributary, Kavik River, Joe Creek, Echooka River, and Brooks Lake. As might be expected (Fig. 14), individuals of *S. anaktuvukensis* tend to group together but are certainly not distinctly grouped with respect to other individuals. Some of the individuals included in the same major cluster as the majority of *S. anaktuvukensis* are from samples of anadromous populations of western Arctic char including those in the Echooka River, Kavik River, Canning River, and Fish Creek. This would seem to obviate any suggestion that all the samples analysed are angayukaksurak and that, therefore, no differences would be expected.

As previously indicated, Morrow (1973) states that *S. anaktuvukensis* can be distinguished from the western Arctic form of Arctic char (which he calls the northern form of *S. malma)* by greater average numbers of dorsal, anal, pectoral, and pelvic finrays, lateral line pores, and number of parr marks (though Morrow presents no average for the latter character, only a range). Table 6 presents a comparison of meristic data for the *S. anaktuvukensis* with similar data for populations of stream resident Arctic char from the study area, both isolated and anadromous. Two sets of data are included for *S. anaktuvukensis*. One is from Morrow's synopsis of the species characteristics, presented in the text of the paper and presumably based on his total sample of 43 fish. The other set is from data for 21 individual fish presented in tabular form in the paper. These comparisons indicate that, except for dorsal and pelvic finrays, the means for *S. anaktuvukensis* fall within the range of means for other populations. Though the means for dorsal and pelvic finrays are somewhat higher than for other populations, the range of individual counts is generally within the range for other populations. The exception is the count of 17 dorsal rays which Morrow records for *S. anaktuvukensis* not duplicated elsewhere. Such differences are to be expected in isolated populations inhabiting unusual habitats such as perennial springs and seem little grounds for specific distinction. If minor differences in the mean values of meristic characters can be used to define species, then the population inhabiting Sadlerochit Spring, a warm mineral spring within the study area, would appear to have an even greater claim to species designation. This population has unusually low mean counts for gillrakers, pyloric caeca, lateral line pores, pectoral, pelvic, dorsal, and anal finrays. In fact, there is no reason to suppose that this is anything but a somewhat aberrant, isolated population of western Arctic char whose meristic characteristics have been influenced by the unusual environment in which it lives. McCart and Bain (1974) and Bain (1974) have demonstrated that stream resident populations of western Arctic char isolated above impassable falls, may differ meristically from the anadromous populations downstream from which they presumably originated. In the first instance, McCart and Bain found that char inhabiting a warm, saline spring in upper Cache Creek, N.W.T., had significantly more total gillrakers and parr marks but significantly fewer pyloric caeca and vertebrae than anadromous char immediately downstream of the barrier falls. In the second, Bain found that isolated char in the Upper Babbage River had significantly fewer total gillrakers and vertebrae than the anadromous population inhabiting Fish Hole Creek, a downstream tributary of the Babbage River. An examination of the data in Table 6 indicates that, in general, isolated populations tend to have fewer elements in meristic series than their anadromous counterparts. The exceptions are dorsal rays, where the mean of means for the samples are the same (14.5 rays) and pelvic rays where the mean of means for the isolated populations (9.1) slightly exceeds that for the anadromous ones (9.0).

Another feature of the meristic characteristics of isolated stream resident populations is that there is much greater variability in mean values among populations than there is among anadromous populations. Several factors may be involved:

1. Isolated populations inhabit unusual habitats supplied by perennial sources of groundwater, some of them mineral and thermal (e.g., Sadlerochit Springs and Upper Cache Creek).

2. They are, by definition, cut off from any genetic interchange with other populations while even a low rate of straying will provide some genetic interchange between anadromous populations.

3. The total breeding populations of isolated populations may be very small increasing the likelihood of random fixation of the genetic component of meristic variation. In Upper Cache Creek, for example, the total population is confined to about 400 m of stream during the breeding season and probably numbers less than 100 mature fish.

Overall, there seems no reason to assume that those populations which Morrow (1973) designates as *S. anaktuvukensis* are any more than isolated populations of the western Arctic form of Arctic char. As demonstrated, there is no clear evidence of specific identity from the meristic data which he presents. Some of the other differences which he indicates--late spawning season, dark colouration, dwarfism, confinement to headwater streams--will be shown in later sections of this report to be characteristic of isolated, stream resident populations of western Arctic char wherever they occur in the study area.

In conclusion, the meristic data indicate that there are only two forms of the *Salvelinus alpinus* complex in the study area, the western Arctic form of the Arctic char which includes all the stream resident populations, isolated and anadromous, as well as one lake resident population (Canning Lake 28) and the eastern Arctic form of the Arctic char which occurs only in association with lakes. These two forms can be distinguished on the basis of only two easily enumerated meristic characters, total gillraker counts and pyloric caeca counts (Fig. 15). The eastern Arctic form is distinguished by high pyloric caeca (mean=39.3, range=21-59, N=224) and total first arch gillraker (mean=27.4, range=19.33, N=218) counts while the western Arctic form is distinguished by low counts for pyloric caeca (mean=29.0, range=16-45, N=1098) and total gillrakers (mean=21.3, range=16-28, N=1045).

The eastern and western forms of Arctic char within the study area can also be distinguished physiologically. As part of Aquatic Environments Limited's studies, samples of liver, muscle, eyes, and eye lens nuclei were examined electrophoretically. Each tissue was typed for esterases, glucose-phosphate isomerase, lactate dehydrogenase, and general proteins. The only consistent results were obtained for liver esterases.

In preparation, livers were thawed then homogenized in an equal volume of 25% unbuffered sucrose solution containing 0.1% Bromophenol Blue. Homogenates were frozen and thawed three times, centrifuged at 1000 G for ten minutes, then stored at -20°C until use.

Electrophoresis was carried out in an ORTEC Electrophoresis System with pulsed power supply. This system uses vertical slab acrylamide gel with 12 sample wells per slab. The buffer used was Tris-$SO_4$, pH 9. The percent concentration of acrylamide used in typing liver esterases was 8 or 9%. The substrate used was a-Naphthyl-acetate, butyrate. Runs were completed when the tracking dye reached 0.5 to 1 cm from the bottom of the gel slab. In each run, unknown samples were compared with a previously typed control.

Figure 16 illustrates typical pattern for liver esterases. Four regions were discernible of which Region 1 proved most useful. In this region, samples from individual fish displayed either a fast or slow pattern. The distribution of these patterns among populations in the study area is given in Table 7. All of the eastern Arctic char from the study area and from Redfish Lake, just south of the Brooks Range in Alaska, exhibit a fast pattern while 98.6% of the western Arctic char exhibit a slow one.

## MAJOR LIFE HISTORY TYPES: DISTRIBUTION AND HABITS

Four major life history types can be defined for Arctic char inhabiting the study area. Briefly, these are:

1. Lake Resident--populations of char inhabiting lakes. While a few individuals may enter tributary streams on feeding excursions during the summer, these populations are almost entirely confined to lakes.

2. Isolated Stream Resident--populations occupying spring-fed stream channels and isolated from contact with populations further downstream by impassable falls or other blockages to upstream movement.

3. Anadromous--populations with a migrant component which enters the sea to feed during the summer. In the study area, anadromous char spawn and overwinter only in streams in the vicinity of perennial groundwater sources.

4. Residual--these are fish, almost exclusively male, which are associated with anadromous populations but which mature without having undertaken a seaward migration.

In what follows, each of these life history types is described in terms of its distribution and general life history pattern. More quantitative information is provided in later sections of the report.

### LAKE RESIDENT

Lake resident populations have been found in 12 lakes within the study area. These are Chandler Lake in the Colville Drainage; Campsite Lake, Galbraith Lake, the Atigun Lakes, and Porcupine Lake in the Sagavanirktok Drainage; three unnamed lakes in the Canning River Drainage (code-named CT28, Canning Fork Lake, and Big Lake); Peters and Schrader lakes in the Sadlerochit Drainage; and two unnamed lakes (code-named 103 and 204) in the Firth Drainage. The locations of these lakes are indicated in Fig. 1.

Most lake resident populations in the study area are of the eastern Arctic form of Arctic char. The only exception is the population inhabiting Lake CT28 in the Canning Drainage which is of the western Arctic form. Growth of lake resident populations is slow to moderate and the fish are generally long-lived. Population density may be very low where char occur together with other salmonid species (e.g., Galbraith Lake, Campsite Lake, and Schrader Lake where they occur together with lake trout, *Salvelinus namaycush)*, or very dense where they occur alone (e.g., Big Lake and Lakes 103 and 104).

None of the lake resident populations in the study area is anadromous and major events in their life history are almost entirely confined to the lakes. There is no evidence, for example, of lake resident fish spawning in streams. Juveniles and occasionally adults may, however, make short excursions into tributary streams to feed during the summer. Such behaviour has been observed at Campsite Lake, Big Lake, and Schrader Lake. Fish may also congregate off the mouths of tributaries feeding on materials entering the lake with the streamflow.

Overall, the life history of lake resident fish in the study area is a simple one and follows a pattern similar to that of lake resident char elsewhere.

## ISOLATED STREAM RESIDENT POPULATIONS

Isolated stream resident populations of fish occur widely in the study area (Fig. 1). These include Shublik Spring and an unnamed spring (CT-41C) in the Canning Drainage (McCart and Craig 1973); Sadlerochit Spring in the Sadlerochit Drainage (Craig 1977b); the upper Babbage River (Bain 1974), and Cache Creek Spring in the Big Fish Drainage (McCart and Bain 1974). One other population, which occurs downstream of an impassable falls dividing the upper and lower Babbage River appears to be confined to the plunge pool at their base and has many of the characteristics of an isolated population (Bain 1974).

All of the isolated stream resident populations in the study area are of the western Arctic form. They are all entirely confined to streams fed by major sources of groundwater. Cache Creek Spring is thermal (15-16°C at orifice) and mineral (2640 mg/L TDS). Sadlerochit Spring is also thermal (11-14°C at orifice) but only moderately mineral. Groundwater at the other locations is typical of karst springs, cooler (5-9°C at their orifices) and less mineral (192-245 mg/L).

Grayling occur together with Arctic char in Sadlerochit Springs and the lower Babbage River but Arctic char are the only species at the other locations.

Isolated populations are characterized by slow growth, retention of parr marks throughout life, and dark spawning colouration. Nothing is known of their movements within streams but there must be some behavioural mechanism which inhibits any lengthy downstream movement (Northcote 1969). Jones (1976) surveyed approximately 6 km of Sadlerochit Spring and found that Arctic char were concentrated in the first 1.5 km downstream of the spring orifices. Fish moving downstream would be lost to the population, particularly where fish are isolated by impassable falls as they are at Shublik, the Upper Babbage, and Cache Creek. Bain (1974) suggests that this may be the origin of the small population inhabiting the plunge pool at the base of the Babbage Falls.

The population inhabiting Cache Creek, described by McCart and Bain (1974), is particularly interesting. The spring waters originate from several orifices in the bed of a stream and during the summer, most of the discharge originates as surface runoff. As a result, the normal seasonal pattern is reversed and the fish inhabit warm (14-16°C) water during the winter and cooler water in spring and summer. Winter oxygen concentrations are low (0.5-4 ppm) but concentrations of other gases appear to be high as many fish suffer from gas-bubble disease. The spawning period for this population appears to be very late, December or even later, probably a response to very high incubation temperatures. There were significant differences in a number of meristic characters between Arctic char living above and immediately below the waterfall suggesting that there was little downstream loss even though the upstream population occupied only about 400 m of stream during the winter.

## ANADROMOUS POPULATIONS

The anadromous life history pattern is the most common one within the study area and considerable effort has been expended in detailing its various aspects. The following is a summary of this information.

### *Juveniles in freshwater*

Fry typically emerge from the spawning gravels in May or June and begin feeding along the margins of streams. The extent to which fry move before establishing themselves is not known. Craig (1977a) found, however, that at Spring CS-10 on the Canning River, few fry passed through a weir operated between May 23 and October 7, 1973, from spring break-up to the initial stages of freeze-up. Though fry were abundant, only 41 were captured leaving and 6 entering the stream. Most spent their first growing season in the spring in the vicinity of the area where they were spawned.

Older juveniles appear to be much more active. Craig (1978) recorded the movements of 4057 freshwater resident char (approximately 84% juveniles and 16% mature residual males) in and out of Spring CS-10 (Fig. 17). Most of these were in the 60 to 200 mm length range with a preponderance of age 1 fish. In general, their movements were downstream into the Canning River during the spring and summer, and upstream into CS-10 in the fall. The downstream movements presumably occurred as fish moved to summer feeding areas in the Canning River and the upstream movements as they moved to overwintering areas within the spring stream. The mature male residual component of the resident populatino had the additional stimulus that in the fall migrant anadromous char spawned in the spring stream at CS-10. Residual males may have been moving upstream as much to participate in spawning as to overwinter.

Note that, in anadromous populations, juveniles that will eventually smolt* and move

*The term smolt can be variously defined. As used here, it refers to first-time seaward migrants only.

seaward cannot be distinguished from those that will mature entirely in fresh water without having undertaken a seaward migration.

Juvenile char and residual males are most common in Mountain and Spring Streams but they do sometimes enter at least the lower reaches of Foothill Streams. Craig and Poulin (1975) captured 216 Arctic char at a weir on Weir Creek, a small Foothill Stream Tributary to the Kavik River. Most (94%) of these were juveniles between the ages of 1 and 3, the remainder were mature residual males. These char first entered the stream in the spring, moved in and out throughout the summer, and left before the stream froze up in the fall. No Arctic char were taken after mid September though the weir continued to operate until September 26.

*Timing of seaward movements*

Seaward migrants are difficult to capture in streams in the study area because their movements generally coincide with the spring freshet when high water and ice make sampling difficult. The only good data are those of Yoshihara (1973) who monitored the downstream migration of juvenile anadromous fish from Foggy Island on the Beaufort Sea immediately adjacent to the Sagavanirktok River Delta. Gillnets were first set on June 9, 1972, in about 60 cm of water which flowed over solid ground ice, to determine whether char were moving over ground ice. No char were captured. Ground ice lifted on June 10 exposing 100 m of open water approximately 15-60 cm deep between the shore and the pack ice. Nets were fished between the ice floes, and on June 12, two juvenile out-migrants were captured. Smolts were captured continually from June 12 through the first week of July. Ninety percent were captured between June 22 and July 5, 1972.

Bendock (1977) reports that the first fish captured during a study at Prudhoe Bay was an Arctic char taken June 22. Arctic char were taken in the first nets set by Griffiths et al. (1975) at Nunaluk Lagoon, also on June 22.

*Distribution and movements at sea*

Having entered the sea, Arctic char distribute themselves in nearshore habitats along the entire Beaufort Sea coast adjacent to the study area (Craig and McCart 1976). There is probably considerable mixing of stocks from different drainages during this phase of their life history. The results of four tagging studies (Furniss 1975; Craig and McCart 1976; Craig 1977a; and Jessop et al. 1974) within the study area, which provide an indication of coastal distribution, are presented in Fig. 18. Obviously, migrant char move considerable distances along the coast during their summer migration. One char tagged in the Sagavanirktok Drainage was recaptured approximately 300 km to the west at Elson Lagoon (Furniss 1975). Another, tagged in the Firth River and recaptured in the Canning River, had moved approximately 150 km along the coast.

While at sea, Arctic char and other anadromous species remain very close to shore. Griffiths et al. (1975) and Furniss (1975) both report sighting Arctic char migrating along the coast in very shallow water. Studies at Simpson Lagoon between the mouths of the Sagavanirktok and Colville rivers, included an assessment of the distribution of anadromous species (Craig and Haldorson 1980). They found (Fig. 19) that Arctic char, in common with other anadromous species:

1. Were more abundant in lagoon habitats than in more marine ones;

2. Were more abundant nearshore than offshore in both lagoon and marine habitats;

3. Used the mainland shoreline more extensively than island shorelines but catches along the inside and outside of islands were similar.

These observations, which indicate that Arctic char typically move and feed very close to shore are supported by numerous other observations in the study area including studies at Prudhoe Bay (Furniss 1975; Bendock 1977), Kaktovik Lagoon (Griffiths et al. 1977), and Nunaluk Lagoon (Griffiths et al. 1975).

On the basis of their Simpson Lagoon data, Craig and Haldorson prepared a hypothetical density distribution for nearshore fishes (species combined) inhabiting Simpson Lagoon (Fig. 20) which reflects, in large part, the distribution of Arctic char. They defined four zones of fish density:

Zone 1. Highest densities of fish, occurring in a narrow band about 100 m wide along mainland shorelines, particularly around points of land but not in shallow embayments. Anadromous fishes (Arctic and least cisco, char, whitefish) and some marine species (fourhorn sculpin, Arctic cod) abundant in this zone.

Zone 2. A band of medium density of fish around mainland and barrier island (lagoon-side) shorelines, extending perhaps 500 m offshore or to the 1.5 m depth contour. Fish species along mainland are as in Zone 1, but relatively few anadromous fish other than Arctic cisco and char occur in Zone 2 along the barrier islands.

Zone 3. Generally lower densities of fish in the lagoon center and along a narrow band about 100 m wide on the ocean side of the barrier islands. Principal species caught on outer shoreline of barrier islands are Arctic char and fourhorn sculpin.

Zone 4. Lowest densities of fish (especially low densities of anadromous species) in the cold marine waters seaward of the barrier islands. Marine fishes (e.g., sculpin, cod, snailfish) inhabit these waters. Additional species are encountered further offshore.

While Arctic char are typically concentrated very close to shore, they can, under some circumstances, be found some distance away. Craig and Haldorson (1980) found that during stormy conditions, anadromous fish including Arctic char, moved seaward away from their usual zone of concentration (Fig. 21). In a shallow bay between Milne and Kavearak points, anadromous fish were taken up to 1750 m offshore. Bendock (1977) reports that Arctic char have been taken at Cross Island about 18 km off the mouth of the Sagavanirktok River.

Craig and Haldorson (1980) suggest that Arctic char and other species may be concentrated

along shorelines because they prefer the slightly warmer and less saline waters generally found along shorelines. There is some suggestion from other work (Bendock 1977) that salinity does affect distribution. Bendock suggested that the low relative abundance of anadromous fish, including char, in Prudhoe Bay in 1977 compared with 1976 might be the result of the higher salinity in the bay during 1977. In the latter year, when salinities were high, anadromous fishes appeared to move into or through the bay in response to short term decreases in salinity. For example,

> ...during the period of July 31 to August 8, each decrease in salinity was matched by a corresponding increase in the numbers of char captured and vice versa. When salinities remained at a high level for a day, numbers of fish caught remained low...
>
> This contrasts with results obtained in 1976, when, during period of moderate or low salinity, no correlation could be made between fish abundance and increases or decreases in salinity. It is probable that the fish were remaining in areas of fresher water, such as river deltas, during the periods of high salinity in 1977.

Furniss (1975) made some interesting observations regarding direction of movement of Arctic char in Prudhoe Bay. In late July, 1974, 61% of captured fish (N=18) were travelling east to west and 39% west to east. In mid-August, these directions were reversed with 32% travelling west and 68% east (N=76). Movements to the west would take them away from the Sagavanirktok River and to the east toward it. The eastward tendency in August might represent a movement toward the stream mouths and spawning and overwintering areas.

*Seaward movements of potential spawners*

Both juvenile fish and mature non-spawners travel seaward during the summer. There is, however, some question about whether mature fish which will spawn in the fall journey seaward during the preceeding summer. Craig (1977a) presents definite evidence, from testis weight and egg size data, that in the Canning River at least, some males and females do so. Both males and females whose gonad condition indicated that they would spawn in the year of capture were taken in coastal waters.

Using similar egg size and testis weight data, Griffiths et al. (1977) found that among mature Arctic char taken at Kaktovik Lagoon, 51% of females (N=37) and 28% of males (N=18) would have spawned in the fall of the year of capture. In contrast, Griffiths et al. (1975), concluded that few potential spawners left the Firth River and entered Nunaluk Lagoon in the summer preceeding spawning. Glova and McCart (1974) found that the arrival of spawning fish in the upper Firth River preceeded that of non-spawners by approximately one month and suggested that either spawning fish spend only a short period at sea in the summer before spawning or that they do not, in fact, migrate all the way to sea.

Craig (1977a) noted that in samples taken in the Canning River and along the adjacent coastline, immature fish were proportionately more abundant in coastal than in river samples (51% v. 24%). In his river samples, 64% of males and 80% of females were mature. He ascribes this difference to the tendency for immature fish aged 6, 7, and 8 to enter the ocean during the summer while mature fish of the same age groups, which will spawn in the fall, tend to remain behind in fresh water.

Furniss and Alt (1976) made the following observations of Arctic char in the Sagavanirktok Drainage:

> In June, 1974, a large number of adult size char were noted by aerial observation at the mouth of the Echooka River. It was hypothesized that these fish may have been a group of nonspawning (in 1973) adults that overwintered in the Sagavanirktok River drainage and would not migrate to the ocean in the spring of 1974 but rather remain in the river and spawn in the Echooka River or some nearby stream in the fall. By mid-July, 1974, many of the group had moved out and only 78 char could be captured for tagging. These fish were all potential spawners. In late July the fish had dispersed from the mouth of the Echooka River. A group of approximately 200 char were found near the Echooka spawning grounds and possibly were the same fish. Smaller numbers were located in the Ivishak River.

The outline above suggests that while mature fish can and do enter the sea in the summer prior to spawning, there may be considerable variation among populations in the degree to which this occurs.

*Upstream movements*

Griffiths et al. (1975, 1977) include figures demonstrating that mature fish, both spawners and non-spawners, tend to leave the sea and move back into streams before the smaller juvenile fish (Fig. 22). From mid-June to late September, the mean fork lengths of samples fell from approximately 500 mm to values between about 250 and 350 mm. At the same time the percentage of immature fish in samples increased and in September, only immature fish were taken. The last fish to leave the sea were, therefore, the youngest and smallest of the seaward migrants. Bendock (1977) notes a similar pattern at Prudhoe Bay where, among anadromous species including Arctic char, the percentages of fish greater than 200 mm fork length were 24% in June, 41% in July, 74% in August, and only 0.1% in September. He notes that immature Arctic char remained in the bay until freeze-up.

Glova and McCart (1974) observed a distinct segregation in the timing and longitudinal distribution of spawning and non-spawning fish during the fall upstream migration in the Firth River. As previously indicated, the arrival of spawning fish on the upper Firth preceded that of non-spawners by approximately one month and it appears either that spawning fish spend a very short period at sea or that they do not, in fact, migrate all the way to sea. Mature migrant char (green) of both sexes, which would spawn in the coming fall, were captured in the upper Firth July 24, 1972. On the same date, a mature fish (fork length 530 mm) was captured in Joe Creek at the same location at which it was tagged June 9, 1972. A female char in faint spawning colouration, with eggs 3.5 mm diameter, was also taken in the same area, July 25, 1972.

Longitudinal aerial and ground surveys along the Firth River (July 29 - October 9, 1972) indicated the early upstream migrants were predominantly mature fish (Fig. 23). These were distributed from the confluence with Joe Creek to the upper end of *aufeis* A. They were widely scattered in small groups rarely exceeding 20 fish or often as single individuals. Even at the end of August, less than 5% of the eventual total migrant population (peak estimate 32,000; September 21, 1972) could be located, almost all of these in the upper Firth close to the Alaskan border. Seine samples of the larger groups in this area revealed that all these early migrants were mature anadromous spawners. From the end of August to September 21, there was a great increase in the numbers of migrant fish (mostly immatures) within the upper Firth, concentrated in large schools (3000-5000 fish). Intensive seine sampling of these schools, from the confluence of Muskeg Creek to the Alaskan border, indicated that, at least to mid September, there was little mixing of immature and mature migrants (Table 8). Few immature migrants (range 0-20.3%) were collected on known spawning grounds in the upper Firth. In addition, the percentage of matures (spawners and non-spawners) in large schools of overwintering fish ranged from 0.0 to 6.4%. Schools of immature migrants were most common in large backwaters or in nearshore areas adjacent to spawning sites in the main channel.

At Spring CS-10 on the Canning River (Craig 1978), the first anadromous spawners entered the spring stream on August 24 and continued to enter the spring in small numbers throughout September. The entry of immature anadromous char was somewhat later, beginning about September 1.

The situation in the Sagavanirktok Drainage is unusual in that there appears to be an almost total segregation of spawning fish and those which are only overwintering (McCart et al. 1972; Yoshihara 1973; Furniss 1975). Major spawning areas are located on several upriver tributaries including the Echooka River, the upper Ivishak River, Flood Creek, Saviukviayak River, Lupine River, Ribdon River, and Accomplishment Creek but overwintering of juveniles and non-spawning mature fish is almost entirely confined to the lower Ivishak River downstream of its confluence with the Saviukviayak. Yoshihara (1973) took various samples from spawning grounds and found high proportions of spawning compared with non-spawning fish: 96.3% in Accomplishment Creek and the Lupine River (N=108), and 97.4% in the upper Ivishak (N=270). In the lower Ivishak the reverse was true. Of 64 char examined only 12.6% were potential spawners. During an aerial survey of the entire Ivishak River (September 21, 1971), 12,808 char were enumerated of which only 11.6% were thought to be potential spawners. Most of these were found in the upper end of the river above its confluence with the Saviukviayak. No redds were seen downstream of this tributary but approximately 360 were seen in the next 5 km upstream within the influence of major springs.

Furniss (1975) comments that this aggregation of approximately 12,000 mature, non-spawning char occurs every year in the Ivishak River and suggests that it might represent the entire population of such fish for the Sagavanirktok Drainage since no other such aggregations are known.

As elsewhere, the upstream movement of spawning fish preceeds that of migrant juveniles and non-spawning mature fish. In the Ivishak River, the peak movement of mature fish migrating to spawning areas occurred August 21, 1972, while that of juveniles and non-spawners occurred between September 1 and 6. No major upstream movements of migrant fish occurred after September 7.

In 1971, the movements of spawning Arctic char into the Lupine River, approximately 45 km upstream of the mouth of the Ivishak, peaked between September 2 and 4 and no fish were taken after September 8.

*Location of spawning grounds and overwintering areas*

The locations of known spawning grounds of anadromous Arctic char are indicated in Fig. 24. Without exception these are associated with major sources of groundwater (Fig. 5) and many of them are open and free of ice, except along their margins, throughout the winter.

Overwintering areas (Fig. 25) generally correspond with spawning grounds though there are some exceptions. The major exception, already discussed in a previous section, is in the Sagavanirktok Drainage where juveniles and non-spawners typically overwinter in the lower Ivishak River but spawn in upstream tributaries (Yoshihara 1973). Segregation was still apparent in the Firth River in late September with spawning fish concentrated in the upper reaches of the study area and non-spawners generally distributed further downstream (Fig. 23). Where their distributions overlapped during the spawning season, non-spawners tended to occupy large backwaters or the margins of spawning areas (Glova and McCart 1974).

After having spawned, mature fish tend to remain in the vicinity but may move downstream out of open water to overwinter under cover of ice (Craig 1977a).

*Homing*

Craig and McCart (1976) examined the available tagging data and concluded that while spawners appear to home to their natal streams to spawn, some non-spawning char may wander into non-natal drainages to overwinter. They list six fish tagged in one river and recaptured well upstream in another.

| Tagging Location | Recapture Location |
|---|---|
| 1. Sagavanirktok River | Colville River |
| 2. Sagavanirktok River | Canning River |
| 3. Canning River | Sagavanirktok River |
| 4. Firth River | Canning River |
| 5. Firth River | Kongakut River |
| 6. Rat River | Big Fish River |

Interdrainage exchange is thought to be the exception rather than the rule, although this may reflect some sampling bias since the majority of recapture efforts were conducted in the same streams where the fish were originally tagged.

Furniss (1975) examined most of the same data and reached similar conclusions.

Certainly, the data are very few and this is a subject area where further study would be useful. For anadromous fish, spawning areas are already well known and fish are easily captured so that tagging and recapture effort can be concentrated rather narrowly.

RESIDUAL CHAR

Residual char are the component of anadromous populations which does not go to sea but matures entirely in fresh water. In the study area, these occur widely and are almost exclusively males. Hence, the disproportionate representation of females among those fish that do go to sea. Male residualism is not unusual among salmonids (see McCart 1970, for a review) but is more developed and more pervasive among Arctic char populations in the study area than anywhere else it has been described.

Residual fish disperse throughout streams and tributaries during the summer feeding period returning to spawning areas in the fall (Craig 1977a). While there is, at present, no direct evidence, they presumably act as accessory males in spawning acts involving larger anadromous fish. The behaviour of accessory males is described in detail for *Oncorhynchus nerka* by McCart (1970). Bain (1974) reports seeing such behaviour among Arctic char in the Firth River. This is an interesting aspect of the reproduction of Arctic char in the study area which deserves further study.

## MAJOR LIFE HISTORY TYPES: LIFE HISTORIES

AGE AND GROWTH

Detailed data describing the age and growth of various populations of Arctic char in the study area are presented in Tables 9 through 12. These data are summarized, by life history type, in Table 13 and Fig. 26. All lengths are fork lengths and all ages were determined from otoliths.

The growth rates of lake resident Arctic char are extremely variable (Table 9 ) with a greater range between populations in the mean lengths of age classes than any other life history type (Fig. 26). The slowest growing population is that in Big Lake. These fish attain mean lengths of only 132 mm by age 5 and 171 by age 10. The largest fish taken was 189 mm (age 8) and the oldest, age 16 (160 mm). The char in Porcupine Lake also appear to have relatively slow growth. The largest fish in a small sample of only 12 fish was 262 mm at age 16. Both Big Lake in the headwaters of the Canning River and Porcupine Lake in the headwaters of the Ivishak River (Sagavanirktok Drainage) are small lakes situated in mountain valleys at altitudes of about 900 m.

Among the fastest growing populations are those in Campsite Lake (mean lengths of 348 and 423 mm at ages 5 and 10, respectively) and Chandler Lake (mean length of 424 mm at age 10). Campsite Lake also produced the longest (562 mm at age 13) and oldest fish (a 482 mm fish, age 27).

The growth of fish in CT-28, the only lake resident population of the western Arctic form so far identified, is intermediate (193 mm mean length at age 5 and 391 mm at age 10).

Isolated stream resident fish are among the slowest growing and, with residual males, the shortest lived of the four life history types (Table 10). Of the populations for which data are available, the lowest growth rate appears to be that of char occupying an unnamed spring (CT-41C) in the Canning River Drainage. These attain a mean length of only 149 mm by age 5. The oldest fish in a sample of 141 char was age 7. The growth of these fish is lower than that of any of the samples of juveniles and residual males associated with anadromous stocks (Table 11) but is higher than that for lake resident fish in Big Lake (Table 9).

The fastest growing of the isolated stream resident populations are those in the upper Babbage River (mean length of 173 mm at age 5) and Cache Creek (mean length of 171 mm at age 5). The former occupies typical karst springs (Bain 1974) and the latter a saline warm spring (McCart and Bain 1974). The largest (355 mm) and oldest (age 11) individual also came from the upper Babbage River.

Isolated stream resident populations appear to be relatively short-lived and only one individual more than 10 years old was taken (Table 10).

Among juveniles and residual males associated with anadromous populations, the slowest growing (Table 11) appear to be those in tributaries to the Canning River (mean 170 mm at age 5) and in Section Creek (mean 175 to 188 mm at age 5). The fastest growth, by a considerable margin, is in the Kavik River (mean 293 mm at age 5). The largest individual (418 mm) was taken from the Firth River. Fish in the oldest age class, age 11, were taken in several locations including the Kavik River, Spring CS-10 in the Canning Drainage, and in the Firth River.

The growth rates of the migrant segment of anadromous populations is much more uniform than that of lake resident populations which cover much the same age range. At age 10, for example, the mean length of the fastest growing lake resident population is approximately 2.5 times that of the slowest while at the same age, the mean length of the fastest growing migrant anadromous population is only 1.4 times the slowest (Table 13).

It is difficult to distinguish the growth rates of individual populations of migrant fish. Some samples are for coastal areas where fish from a variety of populations mix, others are from spawning grounds and include only mature fish (e.g., the Lupine River, Ribdon River, Accomplishment Creek, and Section Creek samples). Spawning fish may not be representative of the growth of an individual population because, for example, fish which spawn at early ages may grow faster than the average for their age class. The remaining samples include spawning fish as well as migrant juveniles and mature non-spawners in varying proportions.

Another source of variation in growth among migrant anadromous fish is the range in their life histories, particularly age at first seaward migration but also including such factors as age at maturation and frequency of spawning. Yoshihara (1973) provides some data which indicate how age at first seaward migration can affect growth. He compared the lengths of three groups of char taken at Foggy Island near the mouth of the Sagavanirktok River during their seaward migration (Table 14). First time migrants were considerably smaller than same age fish entering the sea for the second and third time. At age 5, for example, first time migrants were only 70% the length of second time migrants and 58% that of third time migrants. Seaward migration at an early age obviously confers some benefits in terms of growth.

Some data are available comparing the growth of the sexes. At Campsite Lake, the available data were insufficient to demonstrate any significant difference in the growth of the sexes and data were therefore combined (McCart et al. 1972). Bain (1974) compared the length-age relationships of the sexes in an isolated population in the upper Babbage River and found no significant differences ($P>0.05$) in their mean lengths in age groups 1 through 7. Beyond that age, sample sizes were too small for statistical comparison. He also found no significant differences in the mean lengths of fish in various age groups in the population of stream resident fish in the lower Babbage River.

Craig (1977a) found no significant differences in the mean lengths of juvenile females and juvenile and mature residual males from the Canning River in the age groups in which they overlapped (Fig. 27). He did, however, find significant differences in the mean lengths of migrant fish age 8 or older (Fig. 27). In these age classes, males were significantly larger ($P<0.01$). Yoshihara (1973) performed no statistical tests but he did find that among the oldest age classes, age 9 or older, the mean lengths of anadromous males in the Sagavanirktok Drainage generally exceeded those of females. Bain (1974) compared the mean lengths within age classes of migrant char in Fish Hole Creek and found that only in age group 10 was the mean length of males significantly greater ($P<0.01$) than for females. He notes, however, that the difference may have been an artifact of small sample size ($N=6$).

Griffiths et al. (1975) found that, during the marine phase in Nunaluk Lagoon, the mean lengths of males exceeded those of females in age groups 7 through 12. These differences were significant ($P<0.05$) at ages 7 and 8, the only two where numbers were sufficient to permit statistical analysis. The evidence is certainly not conclusive but, overall, it would appear that the freshwater growth of stream resident char is very similar for the sexes but that among migrant fish, the mean lengths of males tend to exceed those of females among the older age classes (age 7+). Certainly, the largest migrant char taken in the study area are all males.

## FIRST YEAR GROWTH

Data describing the first year growth of the fry of anadromous populations are available for the Sagavanirktok River (Yoshihara 1973), Accomplishment Creek (McCart et al. 1972), the middle and upper Canning River and Spring CS-10 tributary to the Canning River (Craig 1977a), the upper and lower Firth River and Joe Creek (Glova and McCart 1974), and Fish Hole Creek (Bain 1974). In Fig. 28, an envelope of growth is presented for these populations along with lines describing the fastest (Sagavanirktok River) and slowest growing (Fish Hole Creek) of these populations.

Young-of-the-year are often difficult to sample in lakes. At Campsite Lake, however, fry are common in shallow water near the lake outlet. Their growth rate (McCart et al. 1972) is very close to that described for the fastest growing anadromous fish.

Data describing first year growth of isolated stream resident populations are available for the upper Babbage River (Bain 1974) and Cache Creek Spring (McCart and Bain 1974). Growth in the upper Babbage overlaps the low end of the range for anadromous fish and is similar to that of anadromous fry in Fish Hole Creek, also in the Babbage Drainage. Young-of-the-year in Cache Creek Spring were measured on only one date, May 10. The fish inhabit a warm spring in which spawning and incubation temperatures range from 11 to 16°C. The large size of these fry so early in the year suggest that they hatch, emerge, and begin feeding well before fry in more typical environments.

Data describing the lengths of newly emerged or immediately pre-emergent fry are presented in Table 15. Among fry of anadromous populations, length at emergence ranges from 19 mm to about 27 mm. While the fry included in the Joe Creek sample are described as yolk-sac, it is likely that those at the upper end of the length range, to 32 mm, had been feeding for some time. Yoshihara's data are for pre-emergent fry only, removed from spawning redds, and illustrate the late development of alevins. He suggests that those taken April 21, which still had 75% of their yolk sac remaining, had hatched approximately one week before collection. On May 15, alevins still possessed approximately 50% of the volume of their yolk sac but by May 28, yolk sacs had been absorbed.

There is only one sample from an isolated stream resident population, the upper Babbage River. These fry were significantly smaller ($t=6.2$, $P<0.01$) than those taken the same day in Fish Hole Creek (Bain 1974).

Periods of emergence are not well defined but it is likely that most fry emerge during May and June. Craig (1977a) found emergent fry as early as April 11 in springs in the Canning River Drainage but states that peak emergence occurred during the last few days of May and early June. Glova and McCart (1974) found newly emerged fry as early as May 11 in Joe Creek, a tributary of the Firth River. Yoshihara (1973) states that, in the Sagavanirktok Drainage, fry began emerging from the gravel in mid June at a length of approximately 25 mm. By July 2, almost all had emerged and only pre-emergent individuals were captured during the sampling of spawning substrates where they were formerly abundant.

After emergence, anadromous fry grow rapidly from mid June to mid August. Growth slows in late August and ceases by the end of September. At the end of the growth period, young-of-the-year averaged 35 to 52 mm in the slowest growing populatino (Fish Hole Creek) and 61 to 83 mm in the fastest (Sagavanirktok).

There may be differences between years in the growth of fry from the same locality. Bain (1974) found significant differences in the lengths of anadromous fry collected on approximately the same dates in 1972 and 1973 in Fish Hole Creek (Table 16). He also found differences between years in the growth of fry of the isolated population in the upper Babbage River but not that in the lower Babbage River.

## AGE AT FIRST SEAWARD MIGRATION

Age at first seaward migration can be determined in several ways·

1. By examining the age structure of juvenile fish during their first seaward migration;

2. By examining the age structure of fish actually taken at sea;

3. By examining the pattern of development of otoliths to determine the age at which increases in the width of annuli occur that might be indicative of increased marine growth, and

4. By determining the age at which there are changes in the sex ratios of the juvenile and residual male component of anadromous populations.

Yoshihara (1973) provides the only data describing the age structure of juvenile fish captured during their first seaward migration (Table 14). He obtained a total of 151 such fish from the Sagavanirktok River of which 1 (0.7%) was age 2, 61 (40.3%) were age 3, 83 (55.0%) were age 4, and 6 (4.0%) were age 5.

An examination of the growth data for fish taken in marine locations (Table 12) indicates that there was one locality at which the youngest fish were age 1, one where the youngest fish were age 2, four age 3, and three age 4. These data suggest that while fish may smolt as early as age 1, they more commonly move seaward for the first time at ages 3 or 4.

There have been several attempts to determine the age at first seaward migration from otoliths patterns. Data from McCart et al. (1972) and Bain (1974)(Table 17) indicate that a small percentage of fish move seaward as early as age 1, and a few as late as age 5, but most go to sea as smolts at ages 2 and 3. Yoshihara (1973) measured the length of otoliths of 3571 char from the Sagavanirktok Drainage (Fig. 29). He found that the greatest yearly growth increment for otoliths was for age 3 char which, he states, corresponds directly with the age of initial migration to the marine environment in that drainage as determined from an examination of the age distribution among first time migrants captured moving downstream.

Data describing the sex ratios, by age, of a combined sample of juvenile and residual fish from anadromous populations are presented in Table 18. These show that the percentage of males begins to rise at age 3, though not significantly (Chi square=2.2, $P>0.05$), and that by age four the fish are predominantly male (Chi square=39.9, $P<0.05$). These data suggest some seaward movement by a predominantly female smolt run at age 3 increasing at age 4.

Overall, the data suggest that in some populations, individuals may move seaward for the first time as early as age 1 and 2 but that most are age 3 or 4.

## WEIGHT-LENGTH RELATIONSHIPS

Weight-length relationships for various populations within the study area are presented in Table 19. The approximate ranges covered by the relationships for freshwater resident populations (including lake resident, isolated stream resident, and juveniles and residual fish associated with anadromous populations) and for migrant anadromous fish are indicated in Fig. 30. There is considerable overlap in the relationships of the various freshwater life history types and these have not been distinguished. As a group, however, they occupy a range which is distinct from that of migrant anadromous char. The latter generally weigh more than same-length freshwater-resident fish, presumably the result of better feeding conditions in the marine environment.

## SEX RATIOS

Table 20 provides data on the sex ratios of samples of Arctic char from the study area, arranged by life history types. The data indicate the following:

1. Although samples from some localities indicate some imbalance in the presentation of the sexes, lake resident populations overall had an approximate equal ratio of males (47.7%) to females (Chi square=1.4, $P>0.05$).

2. While there were no significant differences in samples from any individual localities, there were, overall, significantly more females (54.8%) than males in samples from isolated stream resident populations.

3. Presmolt, stream resident juveniles of anadromous populations had, overall, a slight preponderance of males (54.1%) over females (Chi square=7.1, $P<0.05$).

4. Mature, residual stream resident fish associated with anadromous populations were almost exclusively male (98.5%).

5. Migrant anadromous fish whether taken in the sea or in fresh water were predominantly (67.8%) female (Chi square=999.9, $P<0.05$). The predominance of females was greater (74.1%) among fish taken on spawning grounds than among those taken elsewhere (62.4% to 67.4%). A comparison of these data for spawning fish (N=3000, 25.9% male) and a combined sample of migrant fish taken elsewhere (N=4891, 35.8% male) indicates that this difference is significant ($X^2=62.8$, $P<0.05$). Most of the spawning fish came from one drainage, the Sagavanirktok, however, and it is difficult to determine the biological significance of this observation.

Age specific sex ratios have been determined for a combined sample of juvenile and residual anadromous char from nine localities (Table 18). The data show that the percentage of males begins to rise at age 3 (to 55.6%), increases dramatically at age 4 (to 77.7%), and is close to 100% by age 6. The differences are significant ($P<0.05$) from age 4 on.

## PARASITES

There have been two studies of parasites of Arctic char in the study area. Mudry and McCart (1974) named a new species of nematode parasite, *Bulbodacnitis alpinus*, from Arctic char within the study area. It is present in both anadromous and isolated stream resident populations, all representative of the western Arctic form, but is absent from lake resident populations including unnamed lake CT-28, the only one inhabited by fish of the western Arctic form. The authors conclude that presence of the parasite in streams and its absence

from lakes is probably dependent on differences in lake and stream habitats rather than physiological differences between the eastern and western forms.

Mudry and McCart (1976) examined the metazoan parasites of Arctic char from 11 localities within the study area (Table 21). Fourteen species of metazoan parasites were recovered from a total of 128 *Salvelinus alpinus* from the north slope of Canada and Alaska collected between March 31, 1971, and November 5, 1972. The parasites consisted of one monogean, four digeneans, four cestodes, two nematodes, one acanthocephalan, and two copepods. Of the parasites recovered, one was described as a new species *(Bulbodacnitis alpinus* Mudry and McCart 1974) and three others were new North American host records *(Tetrarhynchus alaskensis, Cystidicola stigmatura,* and *Cyanthocephalus truncatus)*. All of the localities sampled during the study were range extensions of the parasites found.

## FOOD HABITS

Arctic char are opportunistic in their food habits and eat a wide variety of organisms. In what follows, food habits are discussed separately for each life history type. Table 22 is a list of references used as sources of food habits information.

Most of the data describing the food habits of Arctic char in the study area are in the form of frequency of occurrence expressed as a percentage. Such data indicate the percentage of the stomachs in the total sample in which a particular organism occurred. They are not an entirely satisfactory description of food habits because they take no account of the relative biomass of food organisms. Small organisms can occur widely and have, therefore, a high frequency of occurrence while constituting only a small proportion of the total volume of food and the total caloric intake of a population. Larger organisms, on the other hand, may have a relatively low frequency of occurrence but may be much more important to a population than smaller organisms which occur more frequently.

Data for some stomach samples, principally marine ones, have been analysed according to a method similar to the Points Method described by Hynes (1950). A number is assigned in accordance with the degree of fullness of a stomach. In this case, empty stomachs were assigned 0 points; those with a trace of food, 2 points; 1/4 full, 5 points; 1/2 full, 10 points; 3/4 full, 15 points; full, 20 points; distended stomachs, 25 points. Each food organism present is assigned its relative proportion by volume of the total. For example, a fish with a full stomach would be assigned 20 points. Assuming that copepods accounted for half of the stomach contents and equal volumes of cladocerans and rotifers accounted for the remainder, the points would be divided as follows: Copepoda, 10; Cladocera, 5; Rotifera, 5. The points method, although subjective, avoids the problems inherent in other commonly used techniques such as the volumetric, gravimetric, and numbers method (Hynes 1950).

### *Lake resident*

Stomach content data are available for Arctic char from 10 lakes within the study area (Table 23). A total of 643 stomachs was examined of which 12% were empty, ranging from 0% to 86% for individual localities. The organisms with the highest mean percentage occurrence include the Trichoptera (mean 26%), chironomid larvae (22%), and Gastropoda (19%). These are either relatively large organisms, or ones (the chironomids) which, though small, are generally very abundant in Arctic lakes and streams. It would appear that the lake resident char are maximizing their caloric intake in relation to effort by concentrating on organisms which are either individually large or are abundant and obtained without excessive effort.

Other than lakes 103 and 104, where ninespine sticklebacks were a common food item, fish were absent from the stomach samples. No other fish species occur in two of the lakes (Big Lake and Lake CT-28) but they do occur in each of the other lakes sampled.

Some interesting comparisons can be made between the stomach contents of fishes in lakes 103 and 104 in the Yukon Territory. These small lakes are separated by less than 50 m of stream and were sampled simultaneously. Trichoptera were the most frequently occurring food items in each of the lakes and Gastropoda and fish were also important. Major differences between them are that:

1. Cladocera were important in Lake 103 but were nearly absent from stomachs in Lake 104.

2. Gastropoda *(Pisidium)* were important in the stomachs of fish from Lake 104 but were not found in those of fish from Lake 103.

The data for Lake 104 indicate that Cladocera were most important to, in fact the only food of, small fish but that their importance declined as the fish grew. None of the larger fish (309 mm or greater) had eaten these organisms.

Unidentified organic and/or plant materials occurred in the stomachs of fish from six lakes. While this may have been ingested inadvertently while feeding on other organisms, there is the possibility that in some locations, lake resident Arctic char may derive a portion of their energy income from non-selective deposit feeding or by digesting the organisms adhering to moss or other plant materials. Skreslet (1973) has suggested such a possibility for Arctic char inhabiting Lake Nordlaguna, Jan Mayen Island.

The reported occurrence of Culicidae in the stomachs of char from Chandler Lake, where such larvae occurred in 90% and pupae in 55% of stomachs, is unusual. This group, the mosquitoes, normally occupies small ponds during development and rarely occurs in lakes, particularly where there are populations of predatory fish. The group formerly included the phantom midges *(Chaoborus)* and it may be these that are referred to. The accompanying text (Furniss 1974) does, however, refer to the organisms as "mosquitoes".

The occurrence of Simuliidae, a stream-dwelling group, in the stomachs of some fish suggest that, prior to capture, these fish had been feeding either in the lower reaches of tributary streams, or just off their mouths. Both habits have been observed in predominantly lake-resident Arctic char.

*Stream resident*

Stream resident fish include pre-smolts, juveniles, residual males, and juvenile and mature fish inhabiting isolated springs. Data are available for 14 locations within the study area (Table 24). In total 1816 stomachs were examined of which 18% were empty, ranging from 0% to 52% at individual localities. The most commonly occurring foods among such fish are chironomid larvae (mean frequency of occurrence, 52%), Trichoptera larvae (20%), and Plecoptera larvae (19%). These are all relatively large and/or common food items.

Figure 31 compares the relative occurrence of various food items in the stomachs of pre-smolt juvenile Arctic char with that of mature fish (mostly residual males) for those locations (Fish Hole Creek, lower Babbage River, and Canning River near CS-10) for which separate samples of the two types are available. Stomach contents are, in turn, compared with data describing the frequency of occurrence of benthic organisms in Surber samples from 25 mountain streams within the study area (Craig and McCart 1975). Such streams are the typical habitat of pre-smolt juveile and residual male Arctic char associated with anadromous populations. Relative frequency of occurrence, in which the most frequently occurring item in the stomachs of the two types of fish and in the benthos samples are given a value of 100 and the occurrence of other groups are scaled proportionately, was used in order to simplify comparisons and to emphasize any differences, particularly those which might indicate selectivity in choice of food.

Some general conclusions are possible:

1. Some groups which appear in benthic samples (the Ephemeroptera, Coleoptera, Amphipoda, Hydracarina, Nematoda, Oligochaeta, Tricladida) appear rarely or not at all in the stomachs of Arctic char.

2. One group, the Trichoptera, is far more frequently encountered in the stomachs of fish, particularly residual males, than in samples of the benthos.

3. In comparison with pre-smolt juveniles, residual males, which are larger, appear to make greater use of larger food organisms including the Trichoptera, terrestrial insects, fish, and fish eggs. The latter, only seasonally available, were predominantly those of Arctic char.

4. Both types of fish utilize the chironomidae but they occur relatively more frequently in the stomachs of juveniles than in those of residual males.

5. Overall, aquatic organisms occurred much more frequently in the stomachs of both types of fish than did those of terrestrial origin.

Figure 32 compares the relative occurrence of food items in the stomach contents of fish from four isolated populations (upper Babbage Springs, Sadlerochit Springs, Shublik Springs, and Unnamed Spring) with the relative occurrence of the same items in the benthos of 13 springs within the study area (data from Craig and McCart 1975). Again, Ephemeroptera were relatively less frequent in stomach contents than in benthic samples as were Simuliidae, Tipulidae, Diptera other than Chironomidae, Amphipoda and other Crustacea, Gastropoda, Hydracarina, Nematoda, Oligochaeta, and Tricladida. Neither fish nor fish eggs were taken in either benthic samples or fish stomachs. The most frequently occurring food items were Trichoptera, which occurred at a slightly higher relative frequency (73%) than in benthos samples (68%), and Chironomidae which had a relative frequency of 100% in both stomach and benthos samples. Those terrestrial insects which occur in streams only accidentally and which are not adequately sampled by the Surber sampler, had a relative frequency of 33% in stomachs but overall, this group was not nearly as important as aquatic invertebrates.

*Migrant Arctic char*

*Freshwater*

Data describing stomach contents are available for andromous Arctic char taken in fresh water either as spawning or overwintering fish (Table 25). The samples include some fish specifically identified as anadromous and some for which the life history stage is unspecified in the original reference but which, from their lengths, almost certainly include a major proportion of anadromous fish. Overall, data for 2260 fish are available of which 79% had empty stomachs, ranging from 27 to 100% for individual localities. It appears that having once migrated to sea, anadromous fish do most of their feeding in the marine environment and most do not eat after returning to fresh water in the late summer.

Among those stomachs that held food at the time of capture, the most frequently occuring items were chironomid larvae (mean percent frequency of 27%), unidentified insects (mean 21%), plant material (mean 18%), and fish remains (mean 16%).

*Marine*

Data describing the stomach contents of 1715 Arctic char captured in coastal waters are available in two forms, as percent frequency of occurrence and as percent volume (Points Method)(Table 26). Both methods indicate that three groups (the Amphipoda, Mysidacea, and fish) were the most important foods of Arctic char in the marine environment. The correspondence between the results of the two methods is quite close suggesting that the most frequently occuring items tend to be those which are most important to fish in terms of volume.

Data describing the percentage of empty stomachs are available for 1518 of the total sample of 1715 Arctic char. Overall, 46% were empty but this high percentage is largely due to a single sample from the Sagavanirktok Delta in which 70% of 521 stomachs were empty. The high frequency of Mysidacea (54%) in the stomachs of this sample indicates that they had recently been feeding in the marine environment but their presence in the Delta suggests that they had entered the upstream migratory phase of their life history, a period when, as indicated in the preceeding section, most fish cease feeding. If this sample is eliminated, empty stomachs comprise only 33% of a total sample of 997 fish.

Nunaluk Lagoon shows a considerable freshwater influence in the presence of Plecoptera, Trichoptera, as well as Chironomidae and other Diptera in the stomachs of Arctic char. There is similar evidence of freshwater influence in samples taken in the

vicinity of the Sagavanirktok River and, in one instance, at Prudhoe Bay. It is not clear whether this is because these organisms are washed down into the lagoons where they are eaten or because char take short excursions into fresh water where they feed on these organisms then return to the lagoons before the food organisms are digested.

Figure 33 compares the percent volumes of four major groups of food items in the stomachs of Arctic char from Nunaluk Lagoon. The data demonstrate:

1. A decline in the importance of the Insecta (primarily chironomids) with increasing size;

2. An initial increase in the importance of the Crustacea (primarily Amphipoda and Mysidacea) from only 4% in small fish less than 300 mm, to 40-46% in intermediate size fish 301 to 500 mm, declining again to 9% in fish larger than 500 mm, and

3. A gradual increase in the importance of fish from 11% in smallest size group to 80% in the largest.

Prey size appears to be important with small fish selecting small organisms (chironomid larvae), intermediate fish selecting organisms of medium size (amphipods and mysids), and large fish selecting the largest prey (other fish).

At Nunaluk Lagoon, Arctic char did occasionally eat their own kind (Table 26) but the species most commonly taken was the fourhorn sculpin, a bottom dwelling species.

At Nunaluk Lagoon and Kaktovik Lagoon, samples of the benthos were taken during the same period that Arctic char were being studied. The Faber Net samples fish larvae and the larger zooplankton near the water surface; the corer, Ekman Grab, and Ponar Grab all sample the benthos; the dredge samples organisms just at the surface of the substrate. The best correspondence with stomach contents is with the dredge samples which included appreciable proportions of both amphipods and mysids, both important char foods, though not fish. Annelids, which live within soft substrates, were an important component of various samples of the benthos but were absent from stomachs. The Faber Net took copepods, a minor component of stomach contents, almost exclusively. It would appear that Arctic char were feeding on organisms found on or close to the surface of the substrate rather than on infaunal organisms such as annelids or on organisms found either in midwater or at the water's surface.

*Summary of food habits*

1. Arctic char eat a wide variety of organisms that are available to them. In streams the most common food items are insects, particularly larvae of the Chironomidae, but also immature stages of Plecoptera, Trichoptera, and other Diptera, as well as adult terrestrial insects that have landed on the surface of the water. The food habits of lake-resident fish vary greatly from lake to lake. Organisms most commonly eaten are Trichoptera and Chironomidae larvae, and Gastropods. In some lakes amphipods and fish are also important. In coastal waters, char feed almost exclusively on crustaceans (mostly amphipods and mysids) and fish (particularly fourhorn sculpins), although insects (especially chironomid larvae) are eaten in areas where there is a strong freshwater influence (Nunaluk Lagoon, for example).

2. Selection of food items appears to be related to availability, size, and ease of capture of the particular food item. This could explain why certain organisms (in particular, the infaunal ones such as the annelids) that are abundant in the benthos of lakes, streams, and coastal waters are rarely eaten or not at all, and others, the Trichoptera for example, that form a small part of the benthos, are among the most frequently occurring food items in the stomachs of Arctic char. Organisms, such as the larvae of the Chironomidae, that are both abundant and readily accessible are eaten most frequently.

3. Although detritus and plant material were found in the stomachs of several fish, bottom deposits probably do not form a major part of the diet (with the possible exception of very unproductive waters) and are probably ingested accidentally while feeding on other bottom dwelling organisms (particularly small ones such as the Chironomidae).

4. Although certain organisms (such as the Chironomidae) are eaten by all size classes, in general, small fish eat small organisms (cladocerans and other small crustaceans), while large fish eat large organisms (Trichoptera, terrestrial insects, and other fish).

5. Arctic char are more dependent on aquatic than terrestrial organisms, although when available the latter are also eaten.

6. Migrant Arctic char do not feed extensively in fresh water; those that are feeding tend to eat more fish and fewer insects than stream resident char.

## REPRODUCTION

### SPAWNING LOCATIONS AND DESCRIPTION OF SPAWNING HABITAT

The locations within the study area at which Arctic char are known to spawn are indicated in Fig. 24. The most precise information is available for anadromous Arctic char, which are easily seen during aerial surveys, and for stream-resident populations occupying short, isolated stretches of Spring Streams. Nothing is known of the locations of spawning of lake resident populations except that they appear to spawn within the lakes within which they reside, rather than in tributary streams.

Anadromous char within the study area apparently never spawn in lakes. All of the known spawning areas are in streams, typically Mountain Streams, close to major sources of groundwater and upstream of any *aufeis* which may form. Most of the spawning areas are located sufficiently close to groundwater sources that they remain ice-free throughout the winter.

The groundwater sources may be Spring Streams tributary to the Mountain Streams or sources which enter the beds of the Mountain Streams directly. Whatever the source of the groundwater, anadromous char usually spawn in the mainstems rather than moving up into the smaller Spring Streams tributary to them. Where they do enter and spawn in Spring

Streams, for example Spring CS-10, tributary to the Marsh Fork of the Canning River (Craig 1977a), they tend to concentrate in the lower reaches and few move up close to the spring orifices. The apparent reluctance to enter small streams may have survival value in that large anadromous fish may be very vulnerable to predation in such streams. In the fall, grizzly bears are common in the valleys of the major Beaufort Sea drainages. Even wolves have been observed capturing spawning anadromous fish in small streams--at Wood Creek, a small tributary of Fish Hole Creek in the Babbage River Drainage (H. Bain, pers. comm.).

There have been no detailed studies of the physical characteristics of spawning areas or redds of anadromous Arctic char in the study area. The following observations are scattered through the available reports.

Substrates utilized by spawning anadromous Arctic char range from small gravel with some pea size chips and silt in a redd in a small (2.1 $m^3sec^{-1}$) spring-fed tributary of the Lupine River, Alaska (Yoshihara 1973), to gravel and small boulders between 2 and 10 cm in diameter on the Firth River, Y.T. (Author's own observations). Relatively clean substrates of the latter variety appear to be the most common.

The redd observed by Yoshihara (1973) was located in 0.2 m of water with a surface velocity of 0.6 $m/sec^{-1}$. The redd, which apparently included several individual nests, was 3.5 m long and 1.2 m wide at its center.

McCart (1972-Unpublished Report) reports that in Accomplishment Creek, a tributary of the Sagavanirktok River, Alaska, the identifiable spawning areas were associated with large pools. Fish were observed both in the pools and spread out over gravel areas toward the tails of the pools. Spawning appeared to be concentrated in the tails with the deeper parts of the pools serving as holding areas for fish not yet ripe. Jessop et al. (1974) state that char spawn in pools in Fish Creek, Y.T., but utilize riffles with gravel substrates in Cache Creek, N.W.T.

Several authors (McCart et al. 1972; Bain 1974; Craig 1977c) note heavy growths of filamentous algae over substrates in spawning areas. These are most conspicuous during the winter when flows are stable but, in areas subject to surface runoff and freshets, they disappear during the open water period.

## SPAWNING COLOURATION AND SECONDARY SEXUAL CHARACTERISTICS

Spawning colouration varies considerably among groups. Anadromous populations probably have the greatest uniformity from location to location.

In mature migrants, male and female, the basic colour pattern at spawning consists of an olive or brown dorsal and an orange-red ventral surface. The head is similar in colour to the dorsal surface except that, especially in males, the tip of the snout and the line of the lower jaw may be orange. The spots on the sides are brightly coloured and may be surrounded by a halo similar in colour to the dorsal surface but lighter. The dorsal, adipose, and caudal fins are also similar in colour to the dorsal surface. The leading edge of the latter is white. The anal fin and the paired fins are orange-red with an admixture of darker pigmentation. Each has a white leading edge, most distinct on the anal and pelvic fins, less so on the pectorals. Typically, spawning colouration is best developed in those fish actively involved in spawning and is considerably darker and more vivid in males than in females.

The spawning colouration of residual males associated with anadromous populations differs in several ways from the above. First, in most instances, parr marks are retained. The only exception to this appears to be the Kavik River, where residual males have an exceptionally fast growth rate and where parr marks are absent from some of the larger residual males (Craig 1977c). Second, the dorsal body surfaces and the head are very darkly pigmented, nearly black. This intensification of black pigment extends to the fins which are darker than those of migrant fish. The belly and lateral spots may be orange-red as they are in migrants or, more typically, a yellow colour.

Mature migrants and residuals also differ in the degree of development of male secondary sexual characters. Among these are: a dorsal ridge anterior to the dorsal fin, a kype (hooked lower jaw) with a corresponding notch at the tip of the upper jaw, and an enlargement of the teeth in the jaws. Each of these characters is best developed among migrant males and either absent or only slightly developed among residual males.

The spawning colouration of isolated, stream-resident populations is generally similar to that of residual males. In Shublik Springs and an unnamed spring described by McCart and Craig (1973), there is little sexual dimorphism among spawning fish and it was difficult to distinguish the sexes on the basis of external appearance. Mature fish are darkly pigmented on the head, back, sides, and fins, though less so in the unnamed spring than in Shublik Springs. Parr marks are retained even in mature fish. The ventral surface and lateral spots are bright orange as is the lateral surface of the lower jaw. There is almost no development of the dorsal ridge, kype, or enlarged teeth characteristic of anadromous males. A white leading edge is present on both the paired fins and the anal fin. The spawning colouration of other isolated stream-resident populations (e.g., in the Babbage River, Bain 1974) is very close to this though in some instances the belly and spots are more yellow than orange.

It appears that a dark spawning pigmentation and the retention of parr marks are general characteristics of stream-resident fish, whether residual males or isolated self-sustaining populations which mature totally in fresh water. Morrow (1973) mentions this as characteristics of isolated populations in the Brooks Range in the vicinity of Anaktuvak, Alaska.

The spawning colouration of lake-resident Arctic char is more variable than that of any other group. The most vividly coloured of those taken within the study area inhabit Campsite Lake (McCart et al. 1972). As the Campsite Lake char age, their parr marks gradually fade and the fish become silvery. The silver may be suffused with a faint pink or orange. As the fish mature, the

latter becomes more pronounced and at spawning the back, sides, and head of the most brightly coloured fish, males especially, are a vivid orange-red. This colour is nearly uniform over the whole body, without the marked differentiation between back and belly, which occurs in anadromous fish. Like other chars, the leading edges of the pectoral, pelvic, and anal fins are white.

There is little development of secondary sexual characteristics in lake-resident char. In some males the tip of the lower jaw is slightly upturned but there is no development of a notch in the upper jaw. There may be slight to moderate development of a dorsal ridge.

In other lake-resident populations, spawning colouration is generally less vivid than in Campsite Lake. The fish have a grey-green dorsal surface with silvery sides suffused with pink, red, or orange. The belly as well as the paired and anal fins range from pink to red-orange. In Big Lake, the slowest growing lake-resident population within the study area, fish retain parr-marks throughout life. This appears to be the only lake-resident population within the study area for which this is true.

SPAWNING SEASON

Data describing the spawning seasons of various populations of Arctic char are indicated in Table 27, along with information on water temperatures during spawning.

Few data are available for lake resident populations but spawning in Campsite Lake, CT-28 Lake, and Big Lake appears to peak during the month of September. At Lake 103, Yukon Territory (AEL file data), ripe males were taken as early as August 23, 1972, and two spawned-out females on September 8. No data are available describing water temperatures in lakes during the spawning period.

Spawning dates for isolated stream spawning populations vary considerably, probably largely in response to stream temperatures. Populations spawning in typical karst springs, which average approximately 4°C at their orifices throughout the year, have spawning periods similar to those of anadromous fish which also spawn in association with such springs. For example, Arctic char in the upper Babbage River spawn in September and October while those in Shublik Spring spawn from early November. At the other extreme are fish in warm springs such as Sadlerochit Spring and Cache Creek Spring where spawning is very late, probably in December or even later. At the high temperatures of Cache Creek Spring (14-16°C), eggs spawned in the early fall would probably produce emergent fry within a few months, during the period of continuous darkness when food supplies are likely to be inadequate. As it is, young-of-the-year in Cache Creek Spring are already well advanced at a time (early May) when fry in anadromous populations are just beginning to emerge and feed (McCart and Bain 1974).

The most complete data describing spawning season are those for anadromous fish. There seems to be considerable uniformity in their spawning seasons, typically beginning in mid to late August, peaking in September or early October, and completed by early November. There is some individual variation, however. For example, Yoshihara (1973) found that the proportion of ripe and spawned-out females among spawning Arctic char varied widely among four locations in the Sagavanirktok Drainage during the period September 19-29, 1972. In order, the proportions were 4.7% (N=107) at the Echooka River, 38.9% (N=72) at the Ribdon River, 74.7% (N=285) at Accomplishment Creek, and 85.1% (N=74) at the Lupine River spawning grounds. In each instance, the proportion of ripe and spawned-out males was high, 95.8 to 100%. Clearly, the spawning peaks at Accomplishment Creek and the Lupine River were earlier than those at the Echooka and Ribdon rivers. There may also be variation between years at the same location. Jessop and Lilley (1975), for example, note that in 1974, the spawning migration and, presumably, the spawning period were about two weeks later than in 1973.

As is typical of salmonids, males reach spawning condition before females. In the Firth River, for example (Fig. 34), the proportion of ripe and spawned-out males consistently exceeded that of females from early August until early October when the last samples were taken. In the sample taken at the end of August, during the middle of the sampling period, 88% of spawning males but only 10% of females were either ripe or spawned-out. The condition of females is a much better indication of the periodicity of egg deposition and the effective spawning period.

Bain (1974) found that in Fish Hole Creek, Y.T., residual males ripened at about the same time as anadromous males. Data for the Sagavanirktok River Drainage (McCart et al. 1972) and the Shaviovik Drainage (Craig 1977c) indicate the same.

AGE AT MATURITY

In Tables 28 through 31, data describing age at maturity are presented separately for anadromous fish, residual males, isolated stream-resident populations, and lake-resident populations. Among anadromous fish (Fig. 35), those which have spent some time at sea, males mature as early as age 2, their third summer. Most, however, do not mature until they are five years or older. By age 8 or 9, nearly all have matured. Anadromous females mature somewhat later than males. The youngest mature females are age 4 but by age 9, almost all, like the males, are mature.

Residual males associated with anadromous populations can mature as early as age 2 and by age 6 nearly all are mature (Fig. 35). They tend, therefore, to mature somewhat earlier than anadromous males from the same populations. Residual females are very rare. Data are available for only three-two five year old fish from the Kavik, and one 10 year old from the Canning River. All were mature.

Isolated stream resident populations are among the earliest maturing (Fig. 35). An average 29% of males are mature by age 2. Only 1% of females are mature by this age (all from Sadlerochit Spring), but by age 6, 100% of both sexes have matured.

Lake resident fish, as a group, are more variable than the others. The earliest maturing population is that in Lake CT-29, the only lake resident population of the western Arctic form which

has so far been identified. The data, though limited, suggest that in terms of age at maturity, this population is similar to isolated stream-resident populations (also examples of the western Arctic form) and both sexes are 100% mature by age 6. The other lake resident populations, all of them belonging to the eastern Arctic form, range from the relatively rapidly maturing populations in Big Lake, Alaska, in which some males and females mature by ages 3 and 4, respectively, and in which both sexes are 100% mature by age 9, to the Campsite Lake population, in which the youngest mature fish was a 9 year old female. Overall, lake resident fish of the eastern Arctic form are the slowest maturing of the four major groups (Fig. 35).

FECUNDITY

Fecundity data for anadromous, stream resident, and lake resident Arctic char are presented in Table 32. Where both the sample sizes and the range of lengths over which fish are available are sufficiently large, fecundity is positively correlated with both length (Fig. 36) and weight (Fig. 37) of fish. Fecundity-length (Fig. 36) data are more common, however, and it is these relationships that are presented in Table 32.

Because fecundity is positively correlated with length, the mean fecundity of populations is, in large part, determined by the size of mature females. Thus, isolated stream resident populations, which are the smallest at maturity (ranging from 117 to 251 mm for the fecundity complex) also have the lowest average fecundity, only 221 eggs as a means for the fecundity samples. Lake resident fish which are generally intermediate in length (averaging 309 mm for the fecundity samples) at maturity (Big Lake is a notable exception) have a fecundity averaging 751 eggs, while anadromous populations, the largest at maturity (498 mm for the fecundity) sample) have a fecundity averaging 3566 eggs. Length is not, however, the only factor affecting fecundity and there may be considerable differences between populations in their fecundity-length relationships. Other factors which might affect the fecundity-length relationship include egg size (where eggs are large, females might be expected to produce fewer per unit length) and the proportion of the total body weight devoted to gamete production (a proportionately large gonad would be expected to contain more eggs than a smaller one). In order to account for these additional variables, Yoshihara (1973) developed a formula to calculate the fecundity of mature anadromous Arctic char in the Sagavanirktok Drainage.

$$F = \frac{\left[\frac{0.85 + 0.76\ (W)}{-5.23 + 2.31\ (D)}\ (100)\right] + \left[-3285.58 + 14.90\ (L)\right]}{2}$$

where: F = calculated fecundity
W = fresh ovary weight (g)
D = mean ovum diameter (mm)
L = fork length of fish (mm)

Body weight was measured only to the nearest 100 g.

Fecundity data are available for only one residual female (Craig 1977c). This was a fish 268 mm fork length containing 2780 eggs, taken in the Kavik River.

OVARY WEIGHTS

Craig (1977a) presents some data describing the gonad weight to body weight relationships of both mature spawners and mature non-spawners among migrant females in the Canning River (Table 33). He found that among the former, the ovaries constituted a mean 17.8% of the total body weight just prior to spawning while those of the latter, mature females in the year or more between spawnings, constituted only 1.2% of total body weight.

EGG SIZE

The best data describing variations in egg size within the study area are for anadromous Arctic char. Most of these data are for fresh ova, removed from the ovary but not water-hardened. Yoshihara (1974) compared the diameters of fresh ova removed from the ovaries of ripe anadromous females with those of water-hardened eggs removed from spawning redds (Table 34). The mean diameter of the water-hardened ova was 4.8 mm compared with 4.2 mm for fresh ova, a 14% increase. If the eggs are considered to be spheres, then the calculated volumes of the fresh ova would have increased from 38.8 $mm^3$ to 57.9 $mm^3$ as the result of hardening, a 49% increase. Yoshihara (1973) demonstrated a strong (r=0.928) positive relationship between the diameter of fresh ova and their weight (Fig. 38) for anadromous females from the Sagavanirktok River drainage. McCart (unpublished data) demonstrated a positive correlation (r=0.45, N=56) between length of female and mean egg diameter in anadromous populations spawning in tributaries to the Sagavanirktok River (Fig. 39).

Craig (1977a) presents data (Fig. 40) describing seasonal changes in the diameter of eggs of three groups of anadromous females from the Canning River and adjacent coastal areas. The three groups were:

1. Spawners--those which would spawn in the fall of the year of capture;

2. Mature non-spawners--fish judged to have spawned in the past but which would not spawn in the year of capture, and

3. Immatures--juvenile fish which had never spawned and which would not spawn in the year of capture.

Craig (1977a) describes several trends. First, the egg sizes of spawners increase from approximately 2.0-3.0 mm in mid July to 3.5-4.5 mm at the time of spawning. Some females fitting into this pattern were collected in coastal waters. Second, the egg sizes of mature non-spawners remain in the 1.0-1.5 mm range throughout the sampling period. Many of these fish retained a few large eggs from a previous spawning, thus confirming that they were mature non-spawners rather than immatures. Third, the eggs of fish classified as immatures measured 0.5-1.2 mm. Similar data are available for char taken at Nunaluk Spit and in the Firth River (Griffiths et al. 1975).

It is more apparent from the Canning River data (Fig. 40) than those from char collected in other coastal areas (Griffiths et al. 1975, 1977) that at least some female spawners enter coastal waters during the same year in which they will spawn. One female with eggs 2.8 mm in diameter was taken in coastal waters as late as mid August.

It is apparent from Fig. 40, that early in the year it is sometimes difficult to distinguish spawning fish with small eggs from non-spawners or immature fish with relatively large ones. In an effort to distinguish potential spawners (i.e., those which would spawn in the fall of the year of capture) from non-spawners and immature fish among anadromous females, Yoshihara (1973) proposed using egg diameter together with a "maturity index" (ovary weight as a percentage of total body weight) (Fig. 41). He determined that most of the anadromous females with mean ovum diameters 2.6 mm or larger and with maturity indices 5.0% or greater were likely to spawn in the year of capture. All females with ova 2.8 mm or greater, having a maturity index 5.3% or greater were considered to be potential spawners. A second group, with mean ovum diameters 1.6 mm or less and maturity indices of 2.0% or less would definitely not spawn in the year of capture. The data suggest that there is an intermediate group, with mean egg diameters ranging from 1.7 to 2.5 mm whose status was unclear, presumably a mixture of fish with maturing ova taken very early in the season as well as some non-spawners and older immature fish.

Some further data describing seasonal changes in egg diameter are presented in Fig. 42. These show a generalized pattern combining data for four anadromous populations (the Sagavanirktok River, McCart et al. 1972; the Canning River, Craig 1977a; the Firth River, Glova and McCart 1974; and Fish Hole Creek, Bain 1974) along with individual data for three lake resident populations (Campsite Lake, McCart et al. 1972; Big Lake, Craig 1977a; and Lake 103, AEL file data) and three isolated stream resident populations (Shublik Spring, McCart and Craig 1973; Sadlerochit Spring, Craig 1977b; and the upper Babbage River, Bain 1974). The data are for mean egg diameters and indicate the following:

1. From early July, the eggs of lake resident fish develop rapidly and at spawning (late August and September) equal or exceed the upper range of mean egg diameters for anadromous char. This is true even for the small females inhabiting Big Lake.

2. The eggs of anadromous char develop most rapidly from mid June through July and early August then changes in mean egg diameter become asymptotic in late August, September, and October as spawning proceeds.

3. The eggs of isolated stream resident populations develop more slowly than either lake resident or anadromous fish probably both because the eggs are smaller at maturity than those of anadromous char and because the spawning season is generally later.

Egg size data are available for only two residual females: one a 240 mm fish, age 10, captured partially spawned (date unspecified) in the Canning River with eggs averaging 3.6 mm in diameter (Craig 1977a); and the second (length and age unspecified) taken in the Kavik River, August 23, with eggs also averaging 3.6 mm in diameter (Craig 1977c).

## TESTES WEIGHT

Craig (1977a) provides data describing the testis weight of both migrant, sea-run, and residual male char from the Canning River, Alaska. He found that, among migrant males, gonad weights were extremely variable ranging from 0.1 for an immature fish to 98.3 g for a mature adult (Fig. 43). The testes of mature migrant males generally weighed 20 g or more throughout the summer, averaging 4.4% of total body weight (Table 33) compared with 17.8% for mature females. Those of immature migrants and mature non-spawners generally weighed less than 5 g, the gonads of the latter averaging 0.3% of total body weight compared with 1.2% for mature non-spawning females. Thus, migrant females make a committment to gonad development which is approximately 4 times, by weight, that of migrant males.

Mature residual males had gonads which ranged in weight from 1.4 to 27.6 g (Fig. 44) reflecting in large part the wide range in size of mature males (112-331 mm). Their gonads averaged 6.7% of total body weight (Table 33), approximately 1.5 times greater proportionately than those of migrant males.

## FREQUENCY OF SPAWNING

There are no precise data describing the frequency of spawning of lake resident fish in the study area. It is apparent, however, that a large proportion of the females, at least, do not spawn every year. At Campsite Lake, four (40%) of a total sample of 10 mature females had retained eggs from previous spawning but had ovaries whose condition indicated they would not spawn in the year of capture (McCart et al. 1972). At Big Lake, 16 (38%) of a total sample of 43 mature females had retained eggs but would not have spawned in the year of capture.

Most of the isolated stream resident char in Shublik Spring and an Unnamed Spring (CT-41C) appear to spawn every year after attaining maturity (McCart and Craig 1973) as do those in Cache Creek Spring, Y.T. (McCart and Bain 1974). Bain (1974) does not explicitly state, but his data suggest, that the same is true of the isolated population inhabiting the upper Babbage River. All of 28 females captured between August 28 and September 3, 1972, which had retained eggs in their ovaries, would have spawned again in the year of capture. The data for Sadlerochit Spring are inconclusive (Craig 1977b).

Craig (1977a) found that almost all the mature stream resident residual male char in the Canning River spawn consecutively. Only a single non-spawner was found among 179 mature males. In this they appear to be similar to isolated stream resident males.

With regard to anadromous fish, there are repeated statements in reports (e.g., McCart et al. 1972; Yoshihara 1973; Glova and McCart 1974; Bain 1974; Craig 1977a) that (based on such evidence as retained eggs, the persistence of secondary sexual characteristics, and the occurrence of immature sex products in fish of advanced age) anadromous fish do not normally spawn in consecutive years. The only hard data, however, are those presented by Furniss (1975) based on the results of tagging studies in the Sagavanirktok Drainage (Table 35). His data indicate that only 1.3% of males and 5.9% of females (4.9% overall) spawned consecutively. The difference in the proportion of consecutive spawners between the sexes is significant ($X^2$=6.92, $P<0.05$) and unexpected as females must make a greater energy contribution to gonad development than males.

## SPAWNING BEHAVIOUR

There have been no detailed studies of the spawning behaviour of Arctic char in the study area. One aspect of this behaviour does, however, deserve special mention, the behaviour of residual males. Bain (1974) observed mature residual males in the Firth River in close association with mature anadromous females while the latter were in their nests and being actively courted by mature anadromous males. There is abundant evidence from other salmonid species that small residual males can successfully participate as accessory males in spawning acts involving larger males and females, e.g., *Salmo salar* (Jones and King 1952), *S. gairdneri* (Shapavalov and Taft 1954), and *Oncorhynchus nerka* (Hanson and Smith 1967; McCart 1970).

## ADVANTAGES OF ANADROMY

McCart (1970) has discussed the advantages and disadvantages of the anadromous pattern in the case of sockeye salmon and kokanee, the anadromous and freshwater resident forms, respectively, of *Oncorhynchus nerka*. Craig and McCart (1976) and Bain (1974) have applied many of McCart's arguments to Arctic char within the study area.

The major advantage to anadromous fish in the study area is that which results from their opportunity to utilize the greater resources of the marine environment. Their movement to the sea can be regarded as a feeding migration and the additional energy which they gain, as a marine subsidy to the freshwater environment. This is reflected in the greater lengths of anadromous individuals in comparison with same-age freshwater resident fish. This difference in size is even more impressive if it is expressed in terms of weight rather than length. At age 6, for example, anadromous Arctic char may be twice as long as same-age freshwater resident fish, but 11 to 13 times as heavy.

In species such as the Arctic char, larger size is associated with certain other advantages related to reproduction (McCart 1970). These features include greater fecundity (number of eggs produced); larger egg size, resulting in larger fry with presumably better survival; greater choice in spawning sites, because large fish are able to utilize a wider range of bottom materials and tolerate a greater range of water velocities; better preparation of the spawning nest with increased gravel permeabilities and, presumably, greater egg-to-fry survival; and greater success in securing mates.

The first four points apply exclusively to females, while the last is common to both sexes. It seems apparent that the major advantage of anadromy accrues to populations through the increased reproductive capacity of females. This may, in large part, explain the consistent tendency throughout the study area for a proportion of the male Arctic char to remain, mature, and die entirely in fresh water, while almost all females undertake a seaward migration. Small size is not necessarily detrimental to males. While they are unlikely to secure a position as a dominant male in spawning acts in competition with larger anadromous males, they can still fertilize at least a portion of the eggs of anadromous females by acting as satellite males.

A practical consequence of the disproportionately large number of females among those which migrate to sea is that any fishery which is concentrated on the larger, more desirable, migratory segment of Arctic char populations will differentially select females to the probable detriment of the reproductive capacity of the population. This applies to both marine and freshwater fisheries for migrant fish.

## IMPACT OF RESOURCE DEVELOPMENT IN THE STUDY AREA AND SOME MANAGEMENT IMPLICATIONS

The study area, though remote, is one in which resource development, mainly related to the petroleum industry, is proceeding at a high and increasing rate. In the following, the potential impacts of such development are discussed in general terms along with some of the implications for the management of Arctic char stocks in the Canadian portion of the study area.

Anadromous populations, which are the most numerous in the study area and which produce the largest and, therefore, the most desirable fish, are undoubtedly the most vulnerable to the effects of development. This is especially true during the freshwater phase of their life history when thousands of fish, in some cases what appear to be entire populations, may be crowded into one or a few pools in the vicinity of major groundwater sources. Such areas, in which char both spawn and overwinter, can be termed "critical areas". While in these areas Arctic char are extremely vulnerable to angling or to domestic fisheries and to major habitat disturbances. From the management point of view, this is a mixed blessing. On the one hand the fish are extremely vulnerable but on the other, such areas are easily identified (probably most of the major ones within the study area have already been located) so that regulations regarding access, disturbance, and fishing can be quite precisely defined in terms of geographic boundaries. In enforcing regulations regarding closures, management personnel need not cover large areas but can concentrate their efforts on those localities where major populations are known to occur.

Although anadromous species are most vulnerable to disturbance in critical areas in fresh water, their populations are to some extent adapted to withstand at least short-term fluctuations in the environment, natural or man-made. As a result of the great longevity, long period of maturity, and the habit of repeat spawning, there is great variation in the ages of fish spawning in any single year. This overlap means that populations are not dependent on the survival of any single year class. The failure of a year class (e.g., through sedimentation of spawning beds) will not necessarily result in any long-term hazard to populations.

Year class failures apparently occur among anadromous Arctic char in the study area under natural conditions and populations do recover. Furniss (1975), for example, reports that in the Sagavanirktok Drainage, the 1965 through 1967 year classes were very weak, but that subsequent year classes were strongly represented and the population appeared to have recovered from this temporary setback. The reasons for the loss of these year classes is not known but Furniss suggests, from the widespread nature of the phenomenon (it seemed

to affect all of the major spawning populations in the drainage), that it was probably related to weather conditions. Populations could presumably also recover from losses of one or a few year classes resulting from human activities.

More serious would be any disturbance which affects a wide range of year classes within a population, particularly if this occurs over a long term. Examples might be heavy fishing pressure continued over a period of years. Under such conditions, anadromous populations might be reduced to a level from which the population might not recover even if the factors causing the high mortality rates are removed, for example, by a closure to fishing. Studies of lake resident Arctic char in the eastern Arctic do suggest that these populations can, in fact, recover from extremely high rates of fishing exploitation once the fishery has terminated (Johnson 1976). Anadromous stream resident populations in the study area may have a similar resiliency but, thus far, no evidence is available concerning this point. If so, then closures of fisheries on endangered populations can be expected to be an effective management tool. In addition, such resiliency would allow the possibility of cyclic fisheries in which a population is heavily fished for a short period, then allowed to recover for several years before being fished again.

The multiplicity of year classes has been identified as a factor cushioning anadromous populations from short-term environmental change affecting year classes survival. An additional factor ensuring population survival in fresh water is the fact that for many anadromous populations (e.g., in the Sagavanirktok Drainage) there are major differences in the migration patterns of various life history stages, so that an entire population is not concentrated in a single locality during the course of the year. This reduces the possibility that an entire population can be destroyed by a single, localized event. For example, juveniles and non-spawning mature fish may overwinter in areas distinct from that of the spawning population, either elsewhere in the same drainage (McCart et al. 1972, Yoshihara 1973), or in some other drainage.

With regard to the effects of environmental disturbance to anadromous Arctic char during the marine phase of their life history, the following points bear emphasis.

First, at sea, Arctic char range widely along the coast reducing the probability that localized disturbances will have a major adverse effect on any individual population. Second, in contrast, Arctic char at sea remain very close to shore and any widespread disturbance affecting nearshore habitats could adversely affect Arctic char populations along long stretches of the Beaufort Sea coast. The obvious example of such a disturbance would be an oil spill originating from one of the drilling operations now in place in the Beaufort Sea off both the American and Canadian coasts.

This review concludes with a list of recommendations regarding the management of fisheries for anadromous Arctic char within the Canadian portion of the study area. These are, of necessity, general in nature because there have been no detailed studies of the effects of fisheries, whether sports, domestic, or commercial, on populations of anadromous char of the western Arctic form. As well, there appear to have been no studies among other salmonid species of the effects of fisheries exploitation on stocks which are heavily weighted in favour of females. The preponderance of females among migrant fish is a unique feature of anadromous populations in the study area and it is difficult to predict how they will react to exploitation. It would appear, however, that any fishery which significantly reduces the reproductive potential of a population by selecting against females will have a greater adverse impact on its well-being than one which affected the sexes equally or which selected against males.

1. Drainages should be systematically surveyed to enumerate existing populations of Arctic char. A prerequisite to the management of any fishery for anadromous fish and for the establishment of quotas is some estimate of the numbers of fish of exploitable age. At this time, the only stocks for which even visual estimates of population size are available are those in the Firth and Big Fish rivers. In the former, Glova and McCart (1974) observed a maximum of 32,000 migrant fish during aerial surveys in 1972. This figure is not, however, very precise and does not account for fish located upstream on the Alaskan side of the border, for fish occupying Joe Creek, a major tributary, or for errors in the estimate. In 1972, Stein et al. (1973) estimated that there were 12,000 to 17,000 migrant fish in the Big Fish River Drainage, all of them in its major tributary Cache Creek. Again, the estimate is not very precise. While these are probably the two largest anadromous populations within the study area in Canada, this cannot be stated with certainty because no comparable estimates have been made in other areas.

2. At least one representative anadromous population should be chosen for detailed studies of population dynamics. In particular, data are required concerning the actual numbers of fish within age groups and natural mortality rates for the anadromous and therefore exploitable segment of the population. Without such data, it will not be possible to determine with any degree of assurance the numbers of fish and the size and age classes that can be safely removed from stocks of Arctic char.

3. Existing levels of exploitation should be determined for the study area. While there appear, for example, to be considerable domestic fisheries on the Big Fish and, to a lesser extent, the Rat River, as well as an important sports fishery on the Firth River, the numbers and classes of fish taken are not known.

4. Certain populations should be selected for detailed study to determine how exploitation affects anadromous populations of western Arctic char. The population inhabiting Cache Creek, which has apparently been subjected to heavy exploitation in recent years (Stein et al. 1973 estimated that from 40 to 58% of the catchable char in this stream were taken by domestic fishermen in 1972) would seem a likely candidate. Consideration should also be given to the experimental manipulation of a small, presently unexploited population, to determine the effects of exploitation on growth rates, age at maturity, recruitment, sex ratios, etc. Such data would be used in developing appropriate fishing strategies (i.e. cyclic fisheries) and regulations.

5. Wherever feasible, fisheries should be concentrated in marine areas or near the mouths of streams. This has a number of advantages.

a) Fish would be subject to capture during a short period, not exceeding two months. Where fishing is allowed in spawning and overwintering areas, fish may be harassed throughout their freshwater residency of up to 10 months.

b) Fish are in prime condition, before spawning and before any weight loss as a result of the prolonged fast which appears to be typical of overwintering migrant fish.

c) Because the smaller fish generally remain at sea for a longer period than large ones, the fishery can be manipulated to concentrate on particular size ranges.

d) Fish due to spawn in the fall of the year either do not enter the sea or, if they do, return upstream after only a short period of marine residence. As a result, they are less susceptible to capture than either juvenile migrants or mature fish in the period between successive spawnings. Protection of these fish approaching spawning would maximize the reproductive potential of the population in any year.

6. Fishing methods should be encouraged which provide a reasonable representation of both the larger juvenile fish nearing the end of their logarithmic growth phase and of mature fish. This can be accomplished, in part, by adjusting the fishing season (5c and d above), through regulations governing the size of retained fish or through gear restrictions. With regard to the latter, some data are available regarding gillnet selectivity (Table 36 and Fig. 45). The 5.1 cm (2 in.) stretch mesh monofilament gillnet is the most efficient and captures fish over the same size range (300 to 580 mm fork length) as larger meshes. Smaller meshes (2.5 and 3.8 cm stretch mesh) are less efficient and take a greater range of very small fish.

7. Consideration should be given to prohibiting the use of helicopters in sports fishing. Helicopters have been used throughout the study area to transport fishermen to localities in which Arctic char are concentrated, principally spawning and overwintering areas. Arctic char are particularly vulnerable to this method of fishing because no area is safe from exploitation and because sports fishermen tend to concentrate on the larger, reproductively active fish. The effects of such practices might be expected to increase in future as resource development proceeds.

8. Development in the vicinity of critical areas should be strictly controlled. As indicated above, Arctic char in such areas are very vulnerable to major habitat disturbance and must be protected.

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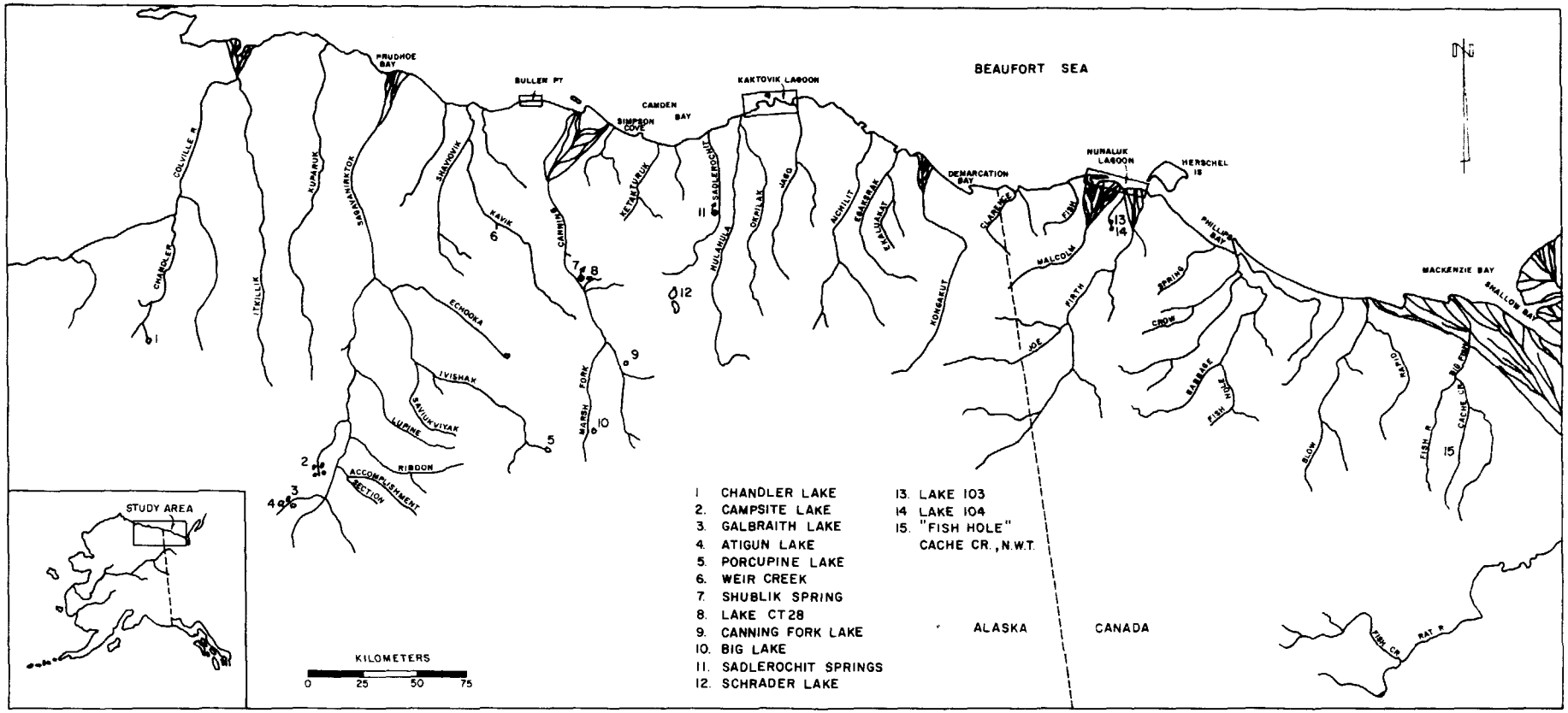


Fig. 1. Map of the study area.

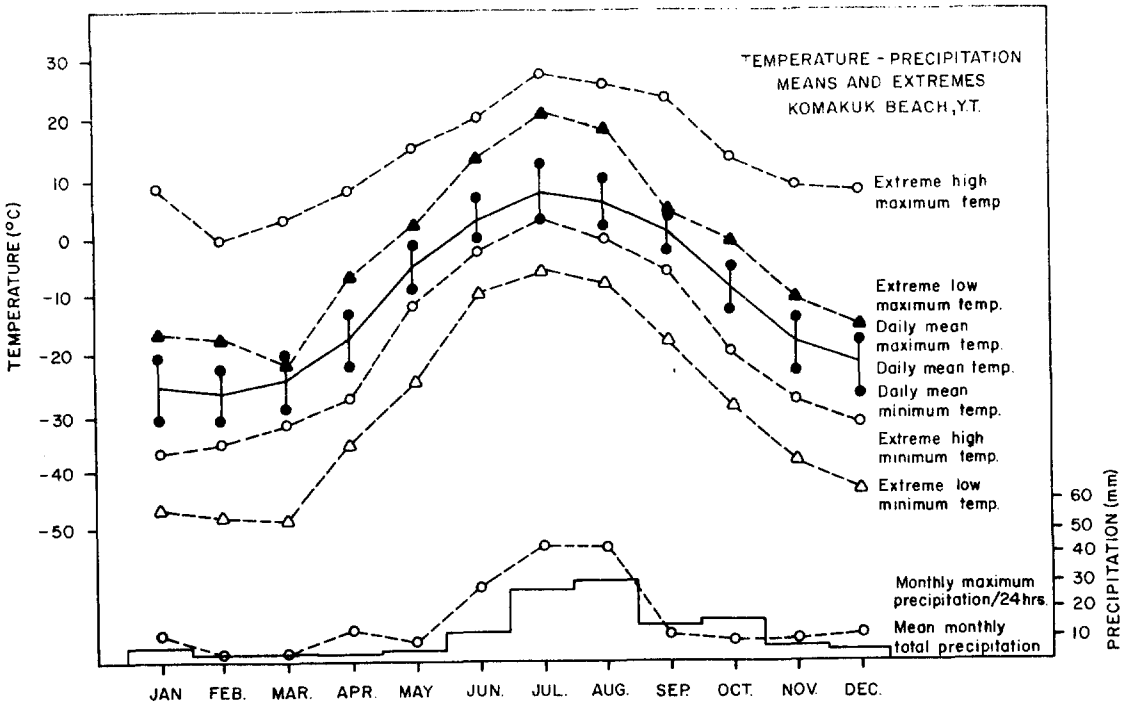


Fig. 2. Seasonal variation in air temperature and precipitation at Komakuk Beach (1958-1970). Modified from Burns (1973).

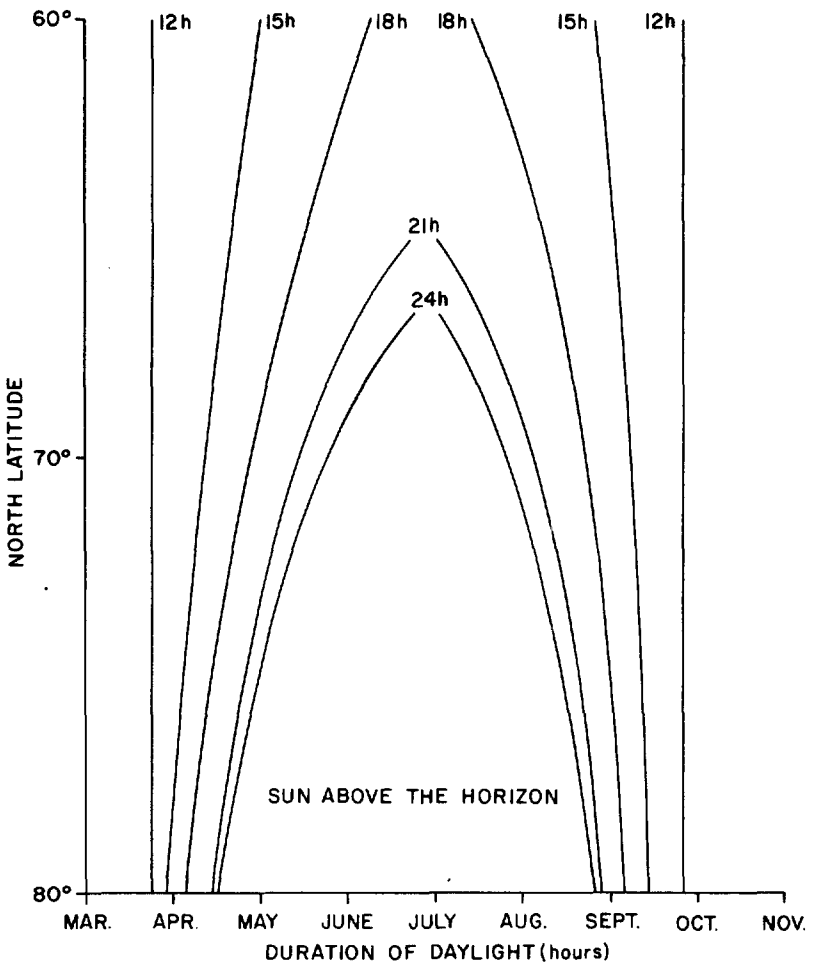


Fig. 3. Seasonal change in the number of daylight hours in Arctic latitudes From Griffiths et al. (1975).

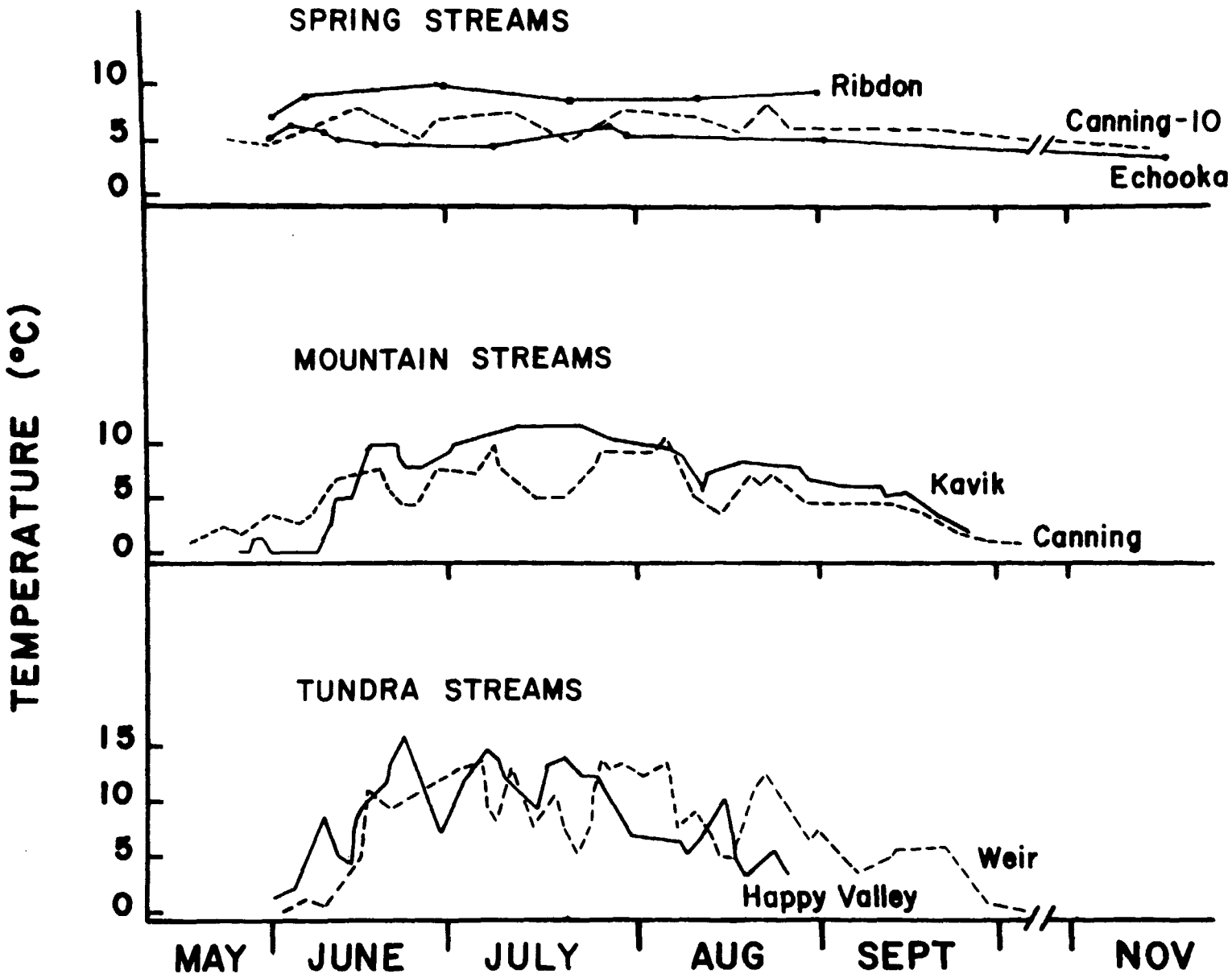


Fig. 4. Seasonal changes in temperature in the three stream types. From Craig and McCart (1975).

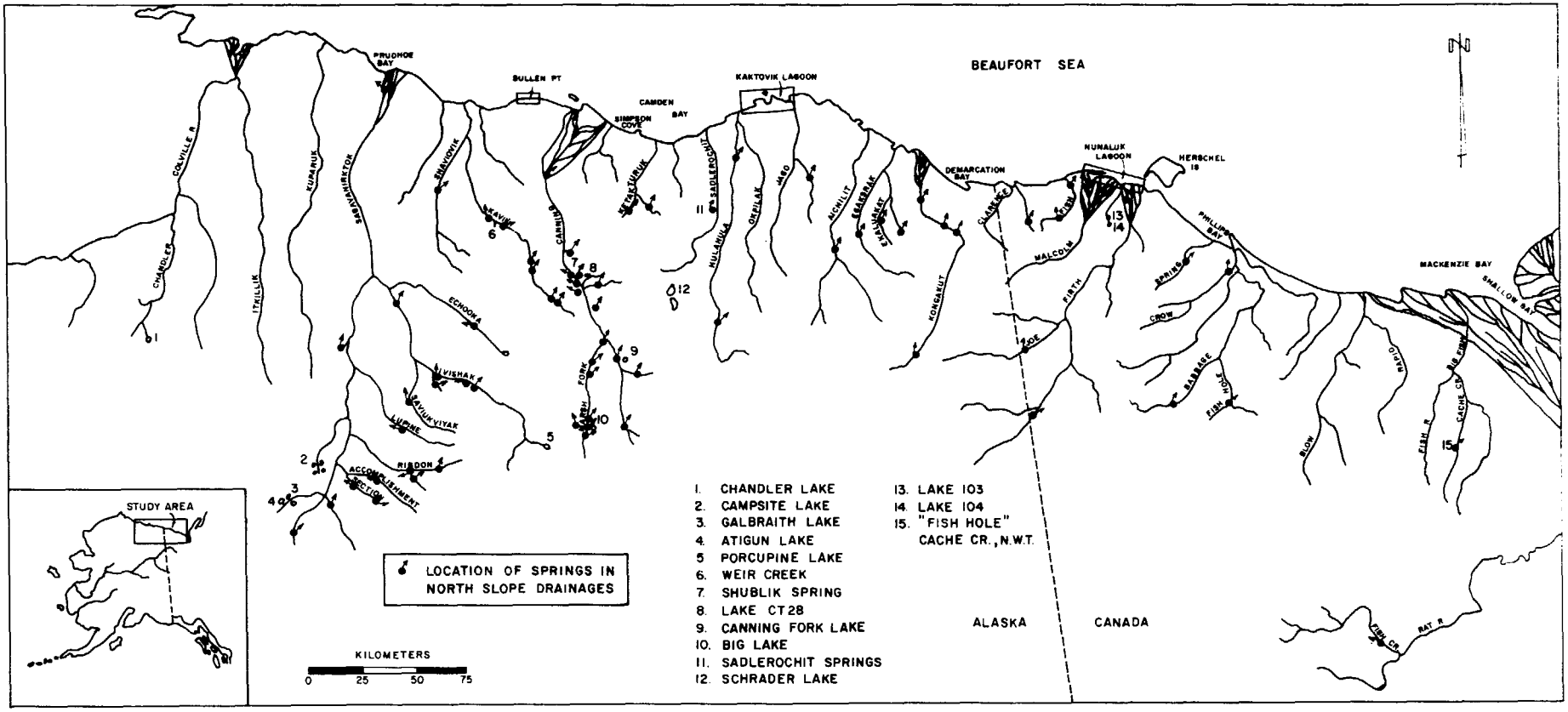


Fig. 5. Location of perennial springs in North Slope drainages.

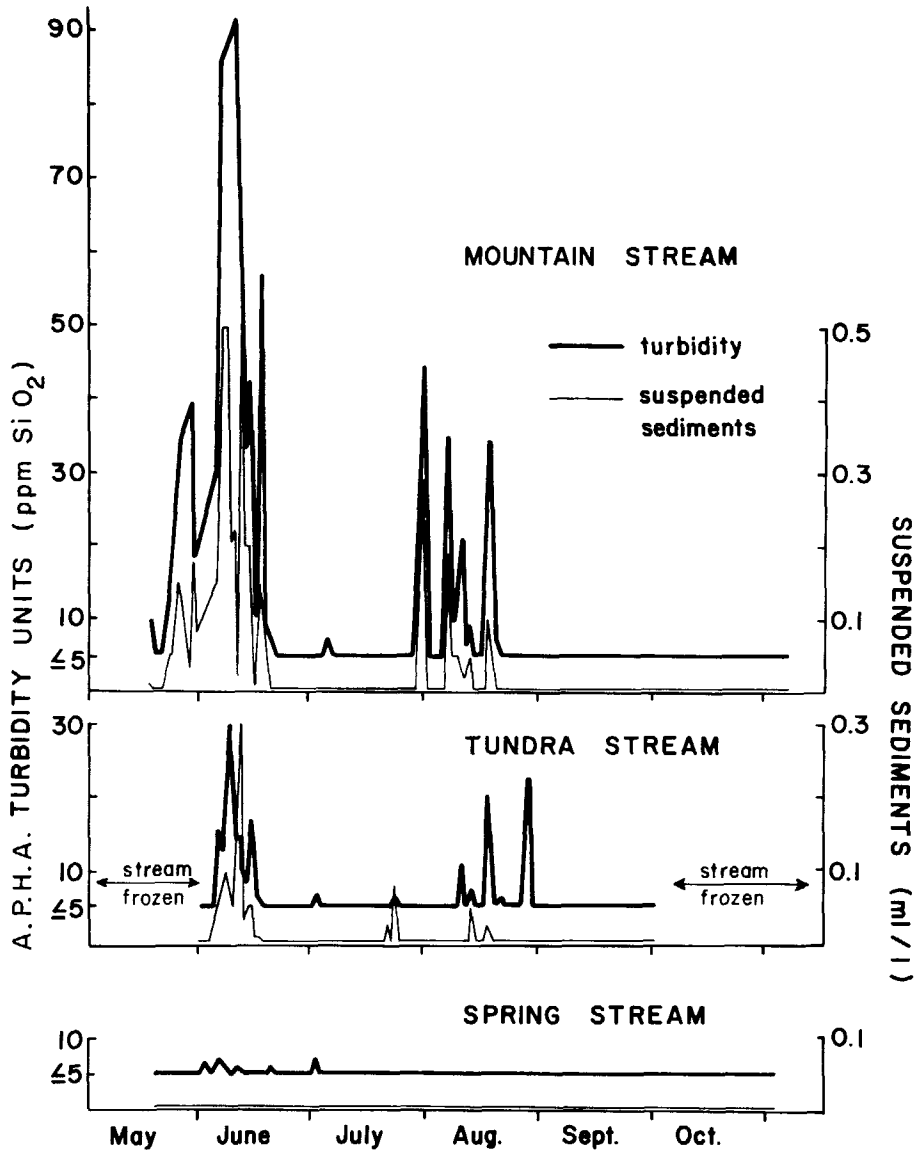


Fig. 6. Seasonal fluctuations in turbidity and suspended sediments in a Mountain Stream (Canning River), a Tundra Stream (Weir Creek), and a Spring Stream (Canning Spring 10) in 1973. From Craig and McCart (1975).

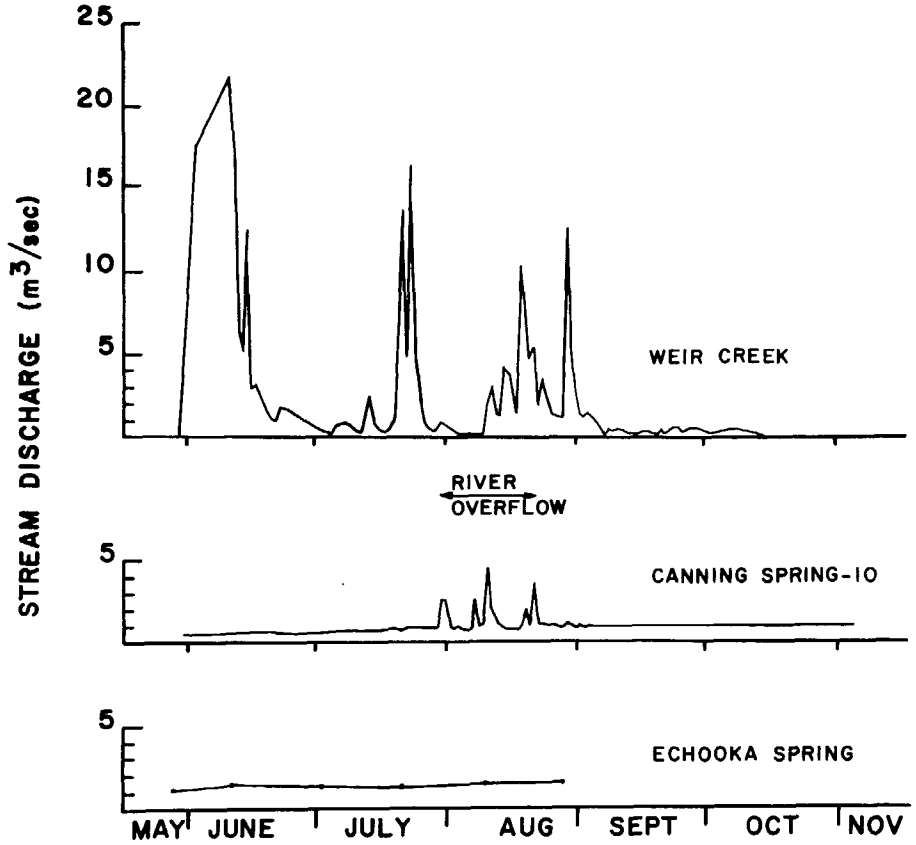


Fig. 7. Seasonal fluctuations in discharge in a Tundra Stream (Weir Creek) and two Spring Streams (Canning Spring 10, Echooka Spring). From Craig and McCart (1975).

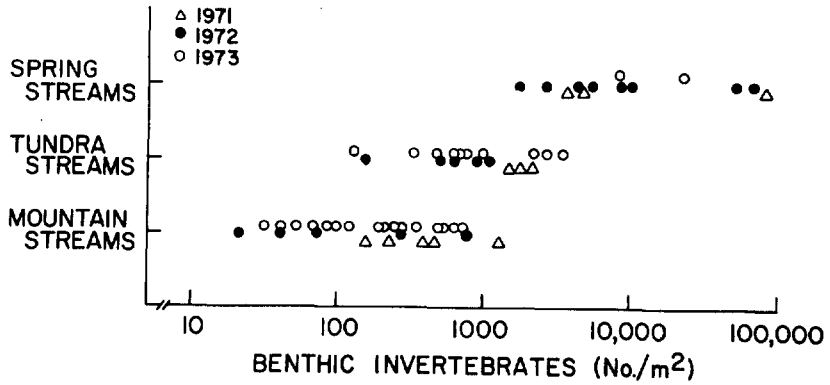


Fig. 8. Range of benthic invertebrate densities in three stream types in the study area. From Craig and McCart (1975).

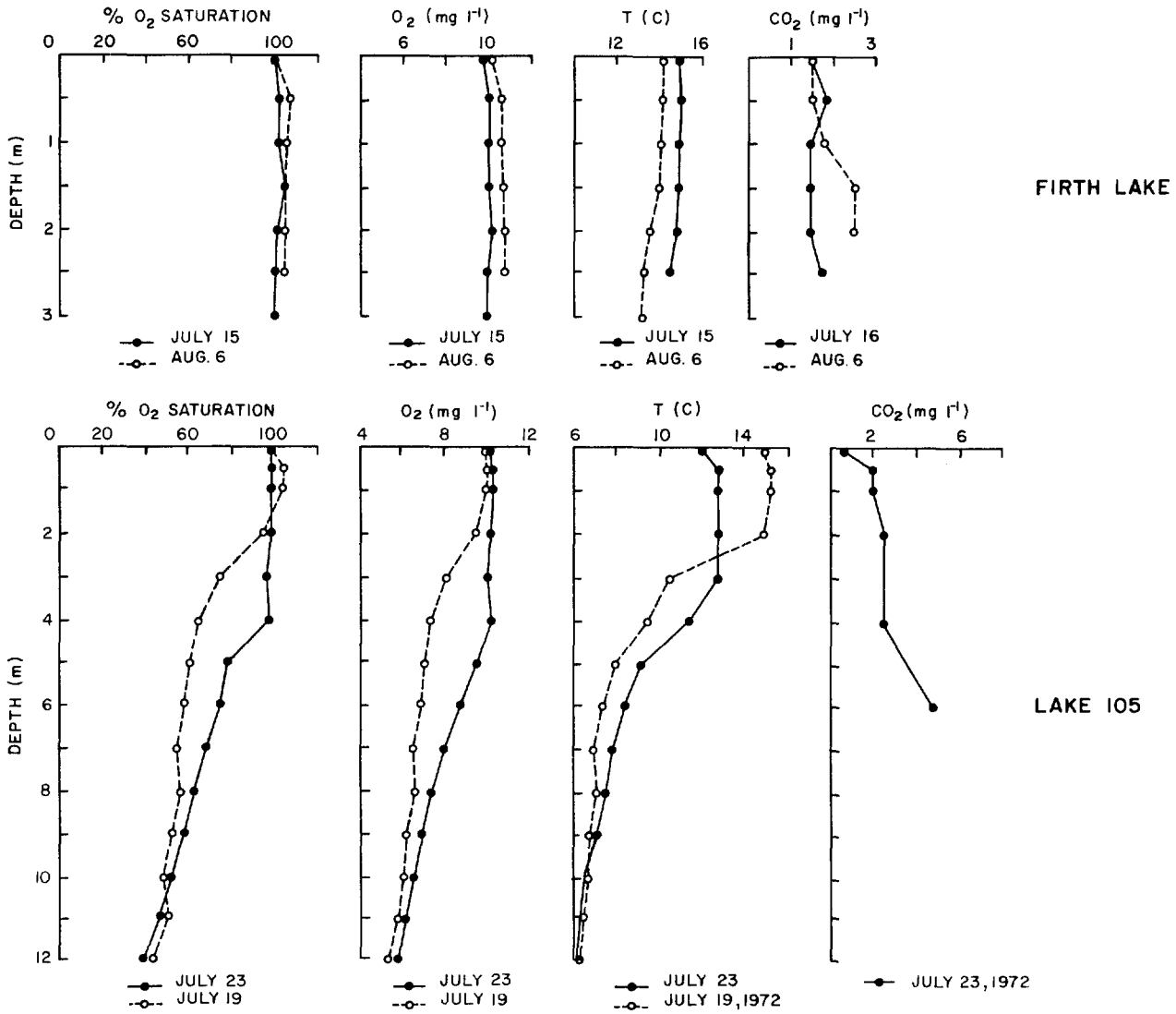


Fig. 9. Vertical distribution of oxygen, temperature, and carbon dioxide in Firth Lake and Lake 105. From McCart et al. (1975).

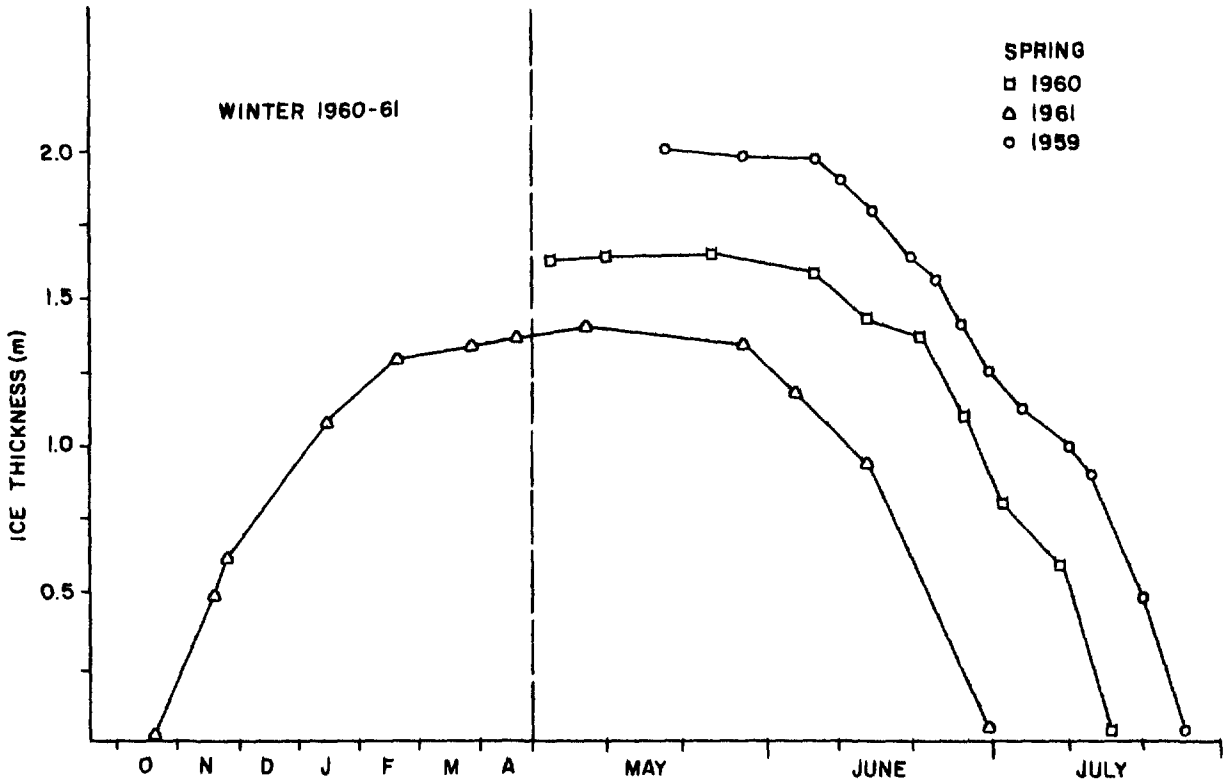


Fig. 10. Ice buildup at Lake Peters, Alaska, 1959 to 1961. From Hobbie (1962).

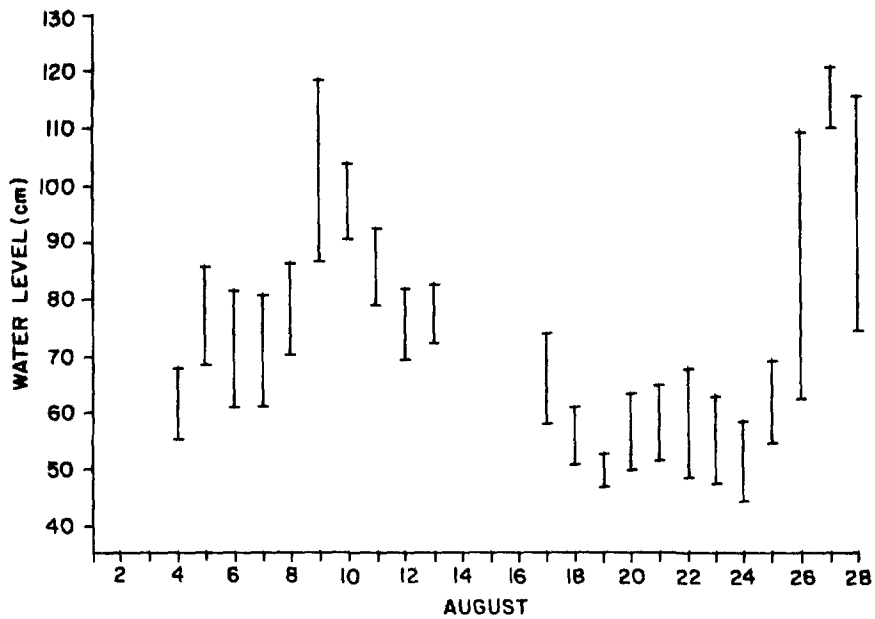


Fig. 11. Water level fluctuations in Pipsuk Bight in August 1975. Bars indicate approximate range of water levels. Changes in water levels are measured against an arbitrary reference point. From Griffiths et al. (1977).

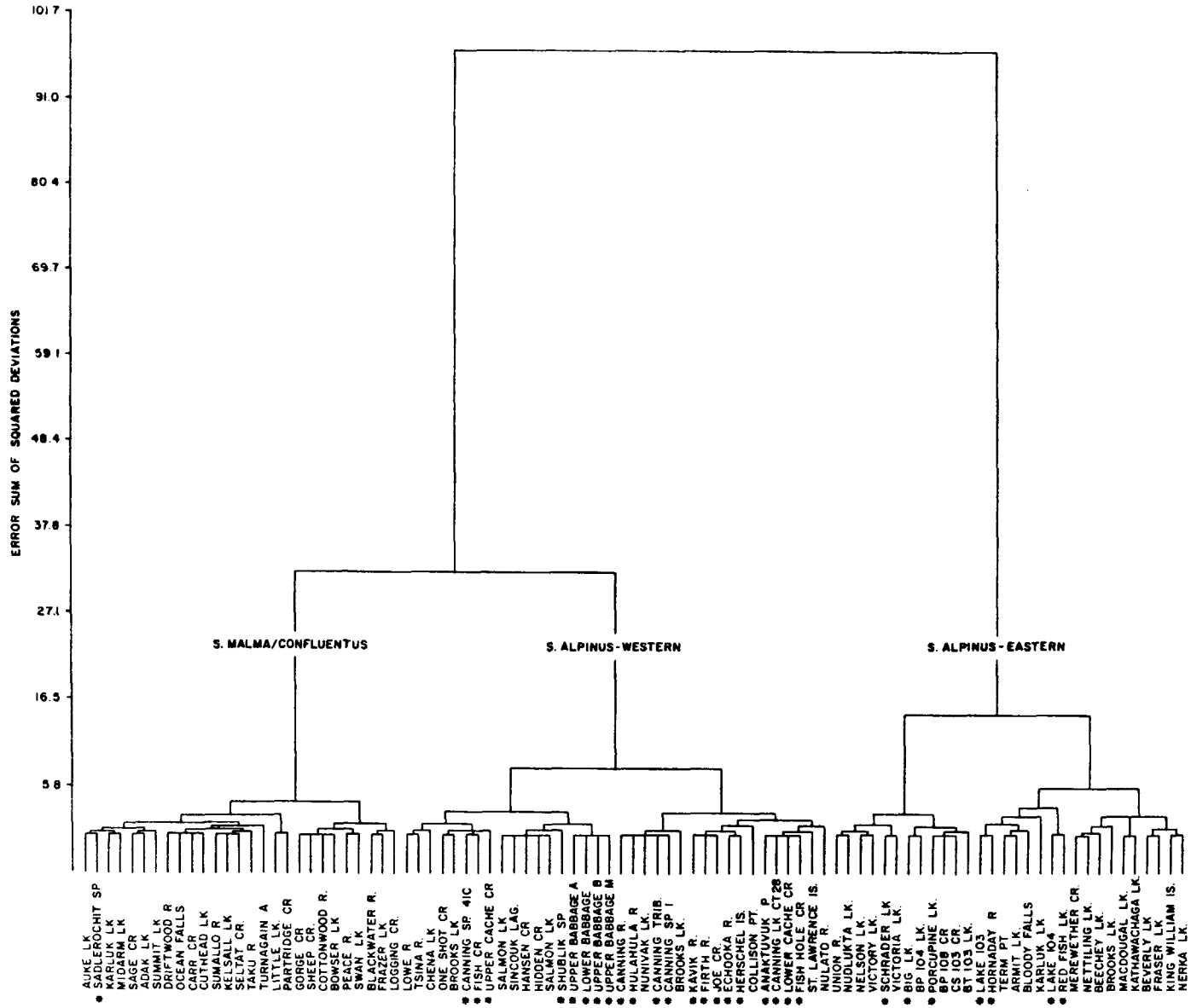


Fig. 12. Dendrogram describing four meristic variables for samples of char from 93 sites in western North America.

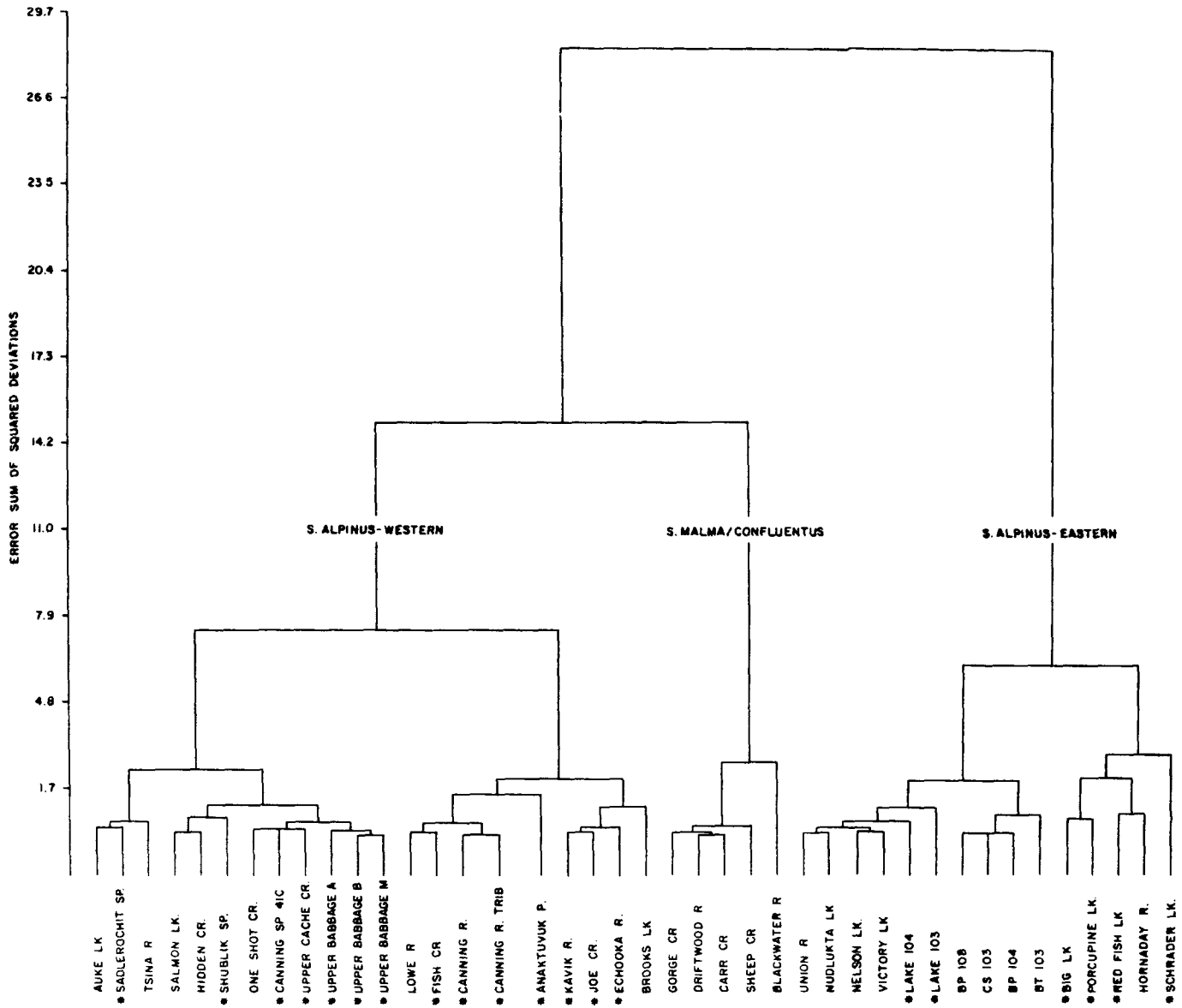


Fig. 13. Dendrogram describing eight meristic variables for samples of char from 42 sites in western North America.

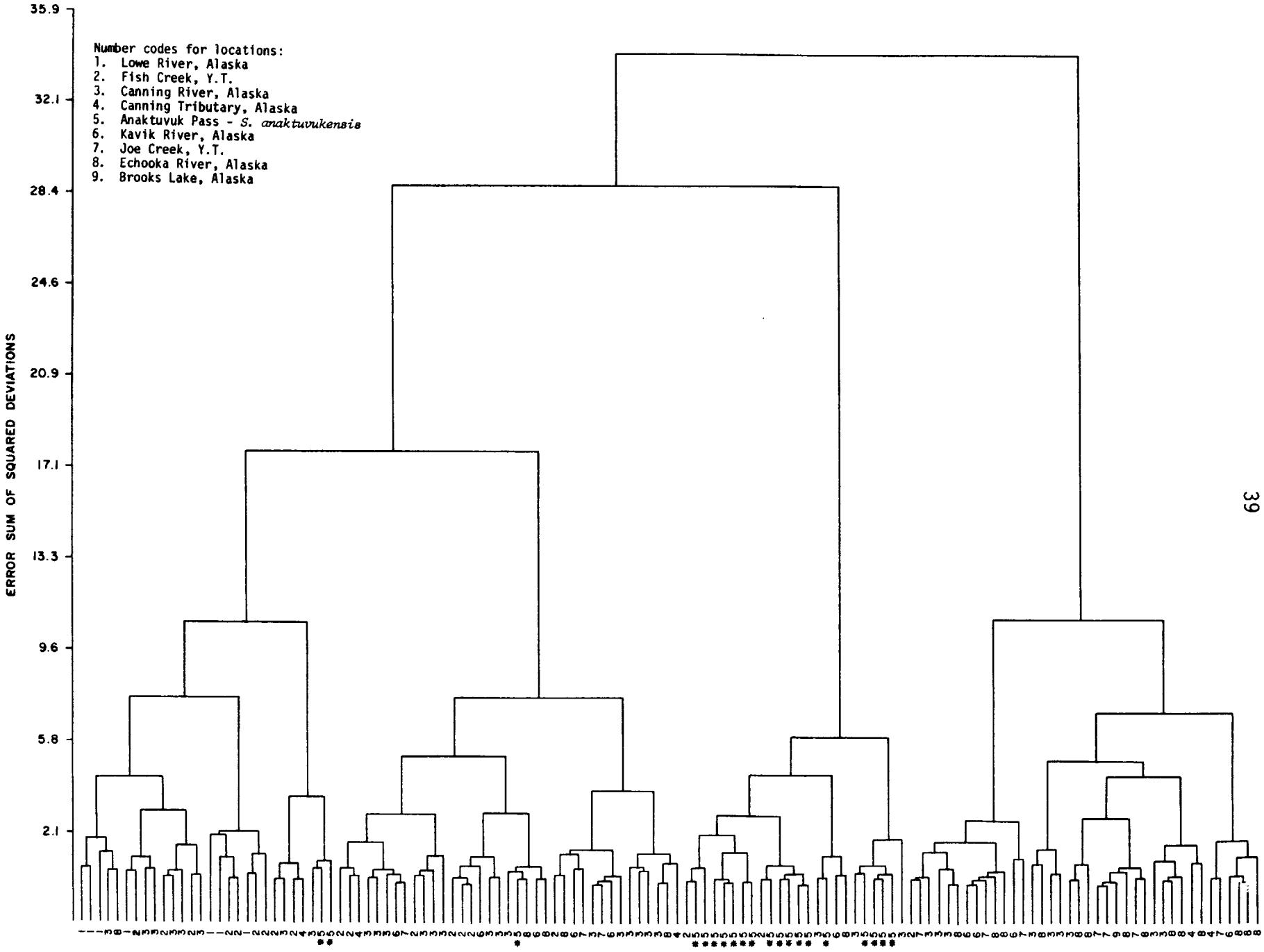


Fig. 14. Dendrogram for individual fish. *S. anaktuvukensis* indicated by asterisks.

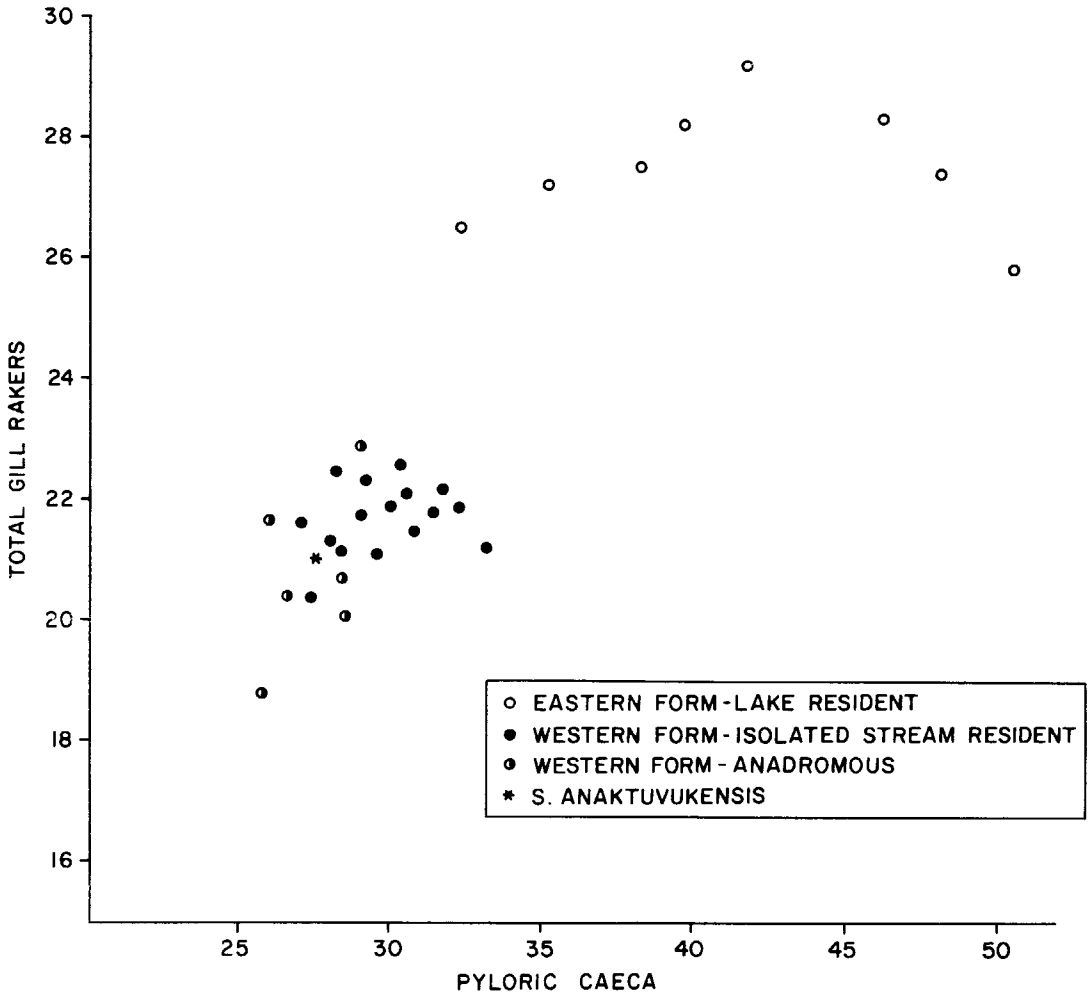


Fig. 15. Plots of total first arch gillraker counts against pyloric caeca counts for Arctic char in the study area and for *S. anaktuvukensis*.

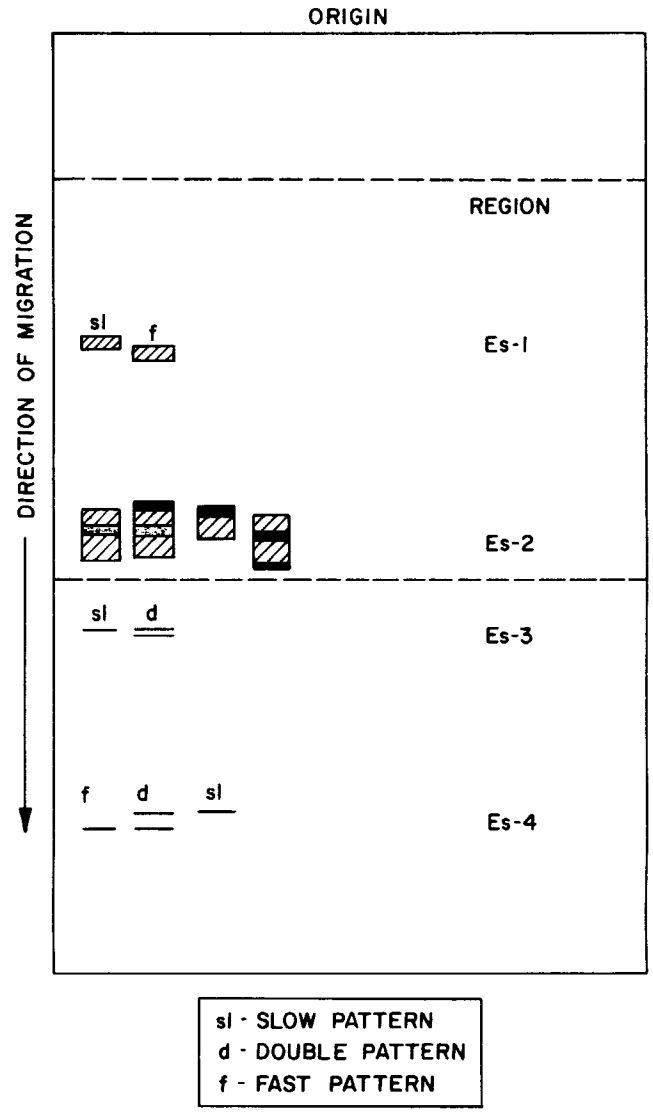


Fig. 16. Electrophoresis patterns for liver esterases.

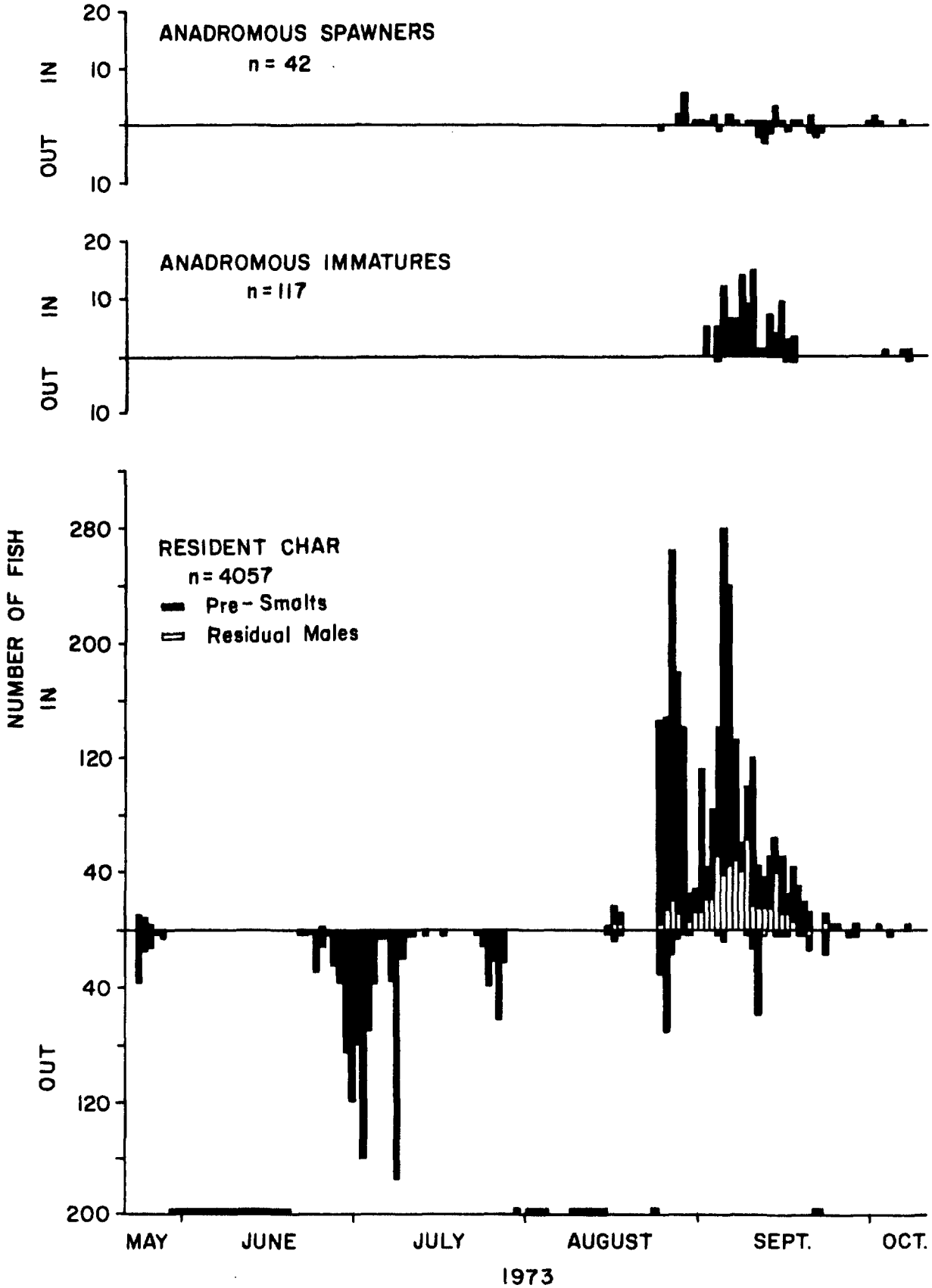


Fig. 17. Movements of Arctic char anadromous spawners, anadromous immatures, and freshwater residents (pre-smolts and residual males) into and out of Spring CS-10. Dark bars along abscissa indicate periods when the weir was not in operation. Note that ordinate scales differ. From Craig (1978).

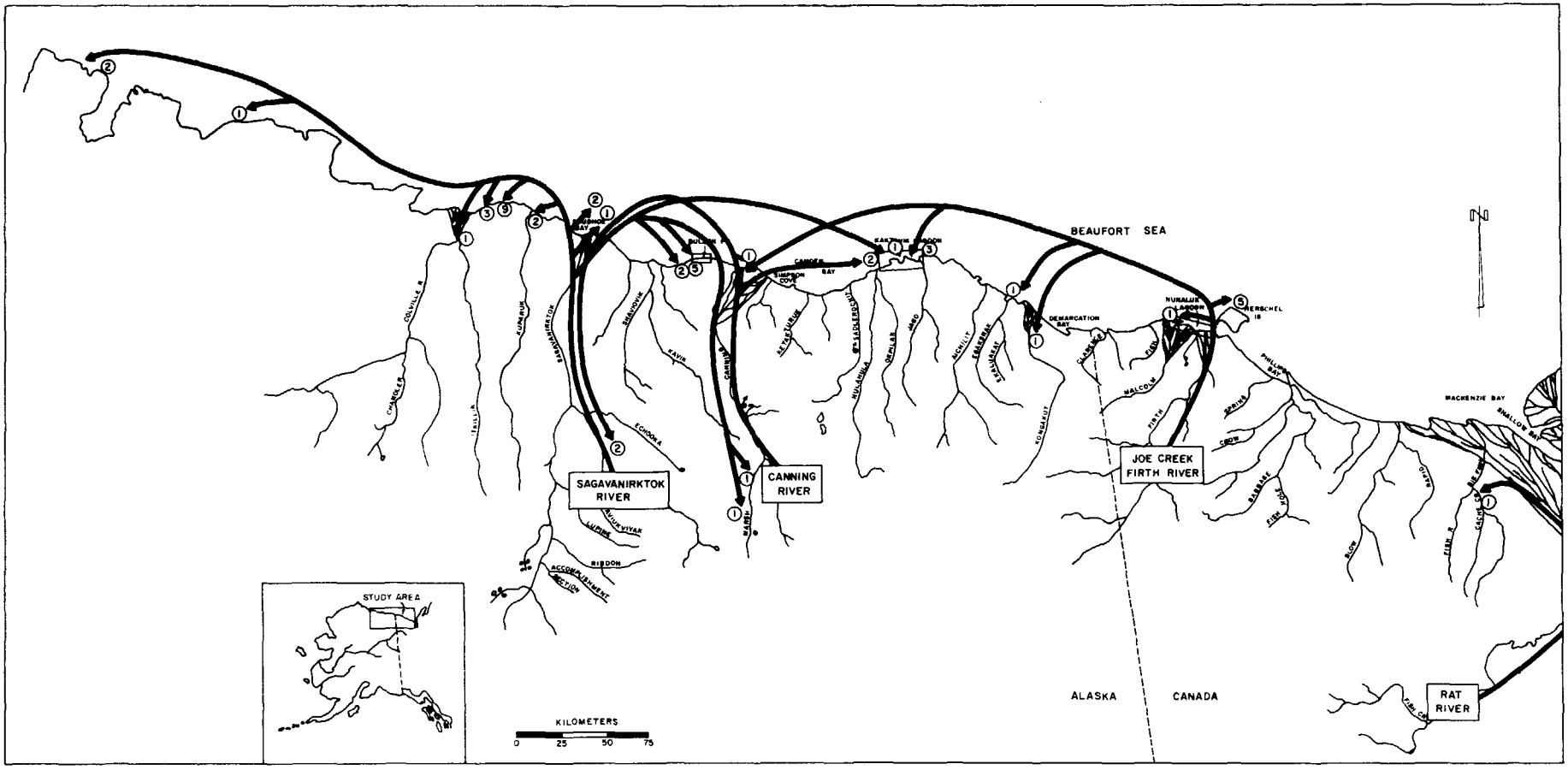


Fig. 18. Movements of tagged fish along the coast and between drainages in the study area. References given in the text.

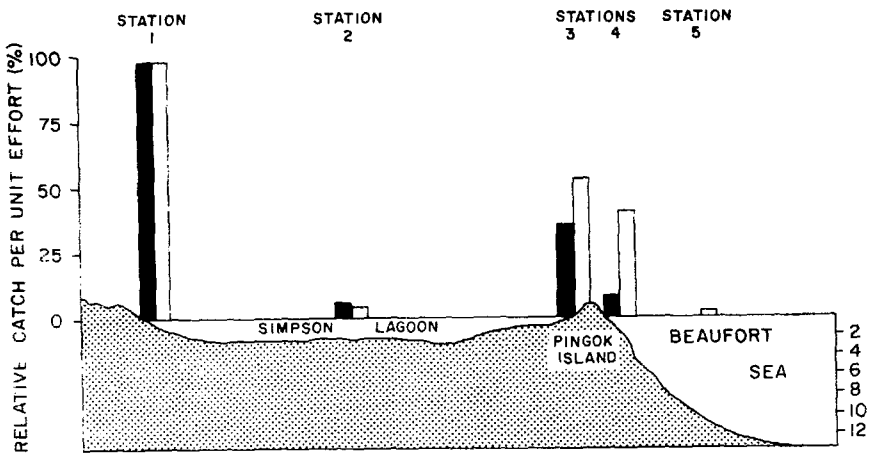


Fig. 19. Cross-section of Simpson Lagoon study area showing relative numbers of fish caught at five sampling stations, 1977. Black bars represent a seasonal average for combined species caught in a standardized 24 h gillnet set. Open bars are for Arctic char alone. From Craig and Haldorson (1980).

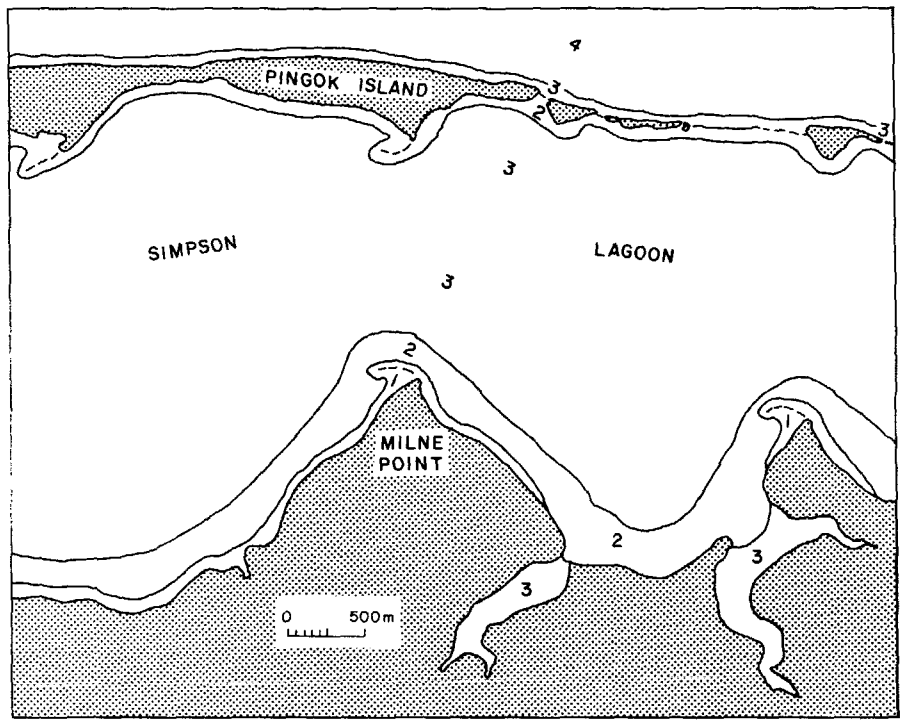


Fig. 20. Hypothetical density distribution of nearshore fishes in Simpson Lagoon. Relative densities range from 1 (high) to 4 (low). From Craig and Haldorson (1980).

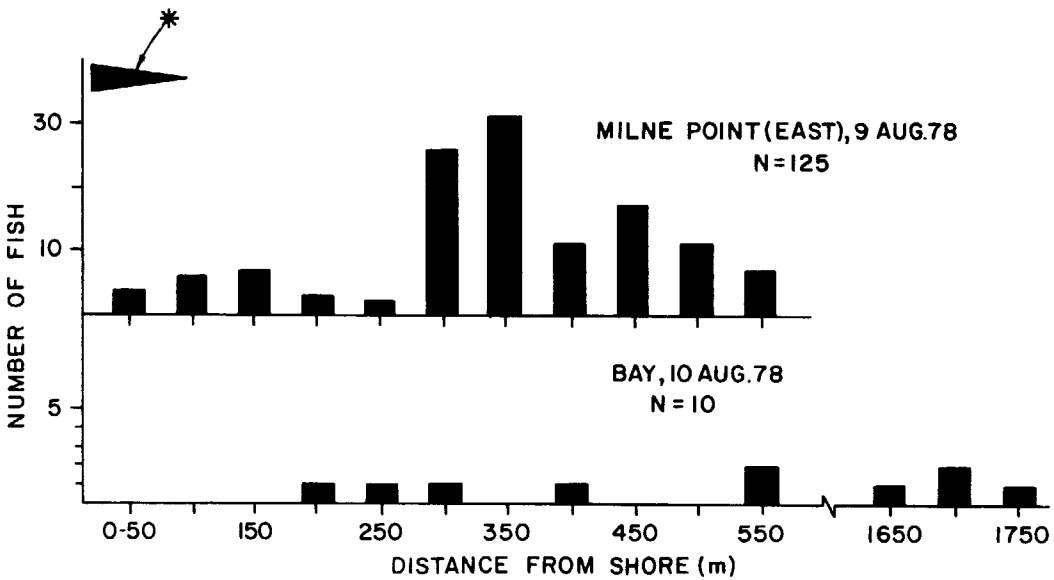


Fig. 21. Dispersed distribution of anadromous fish during stormy, rough-water conditions (top) and in a relatively shallow bay between Milne and Kavearak points (bottom; no sets were set between 550 and 1650 m). The usual location of the shoreline concentration of fish is indicated by an asterisk. From Craig and Haldorson (1980).

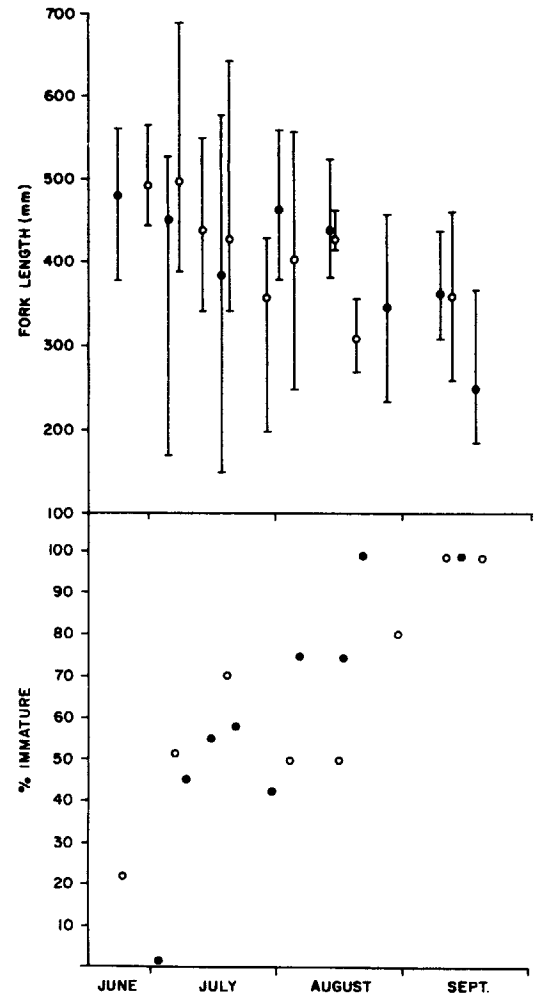


Fig. 22. Seasonal changes in the size and maturity of Arctic char at Kaktovik Lagoon (black circles, data from Griffiths et al. 1977) and at Nunaluk Spit (open circles, data from Griffiths et al. 1975).

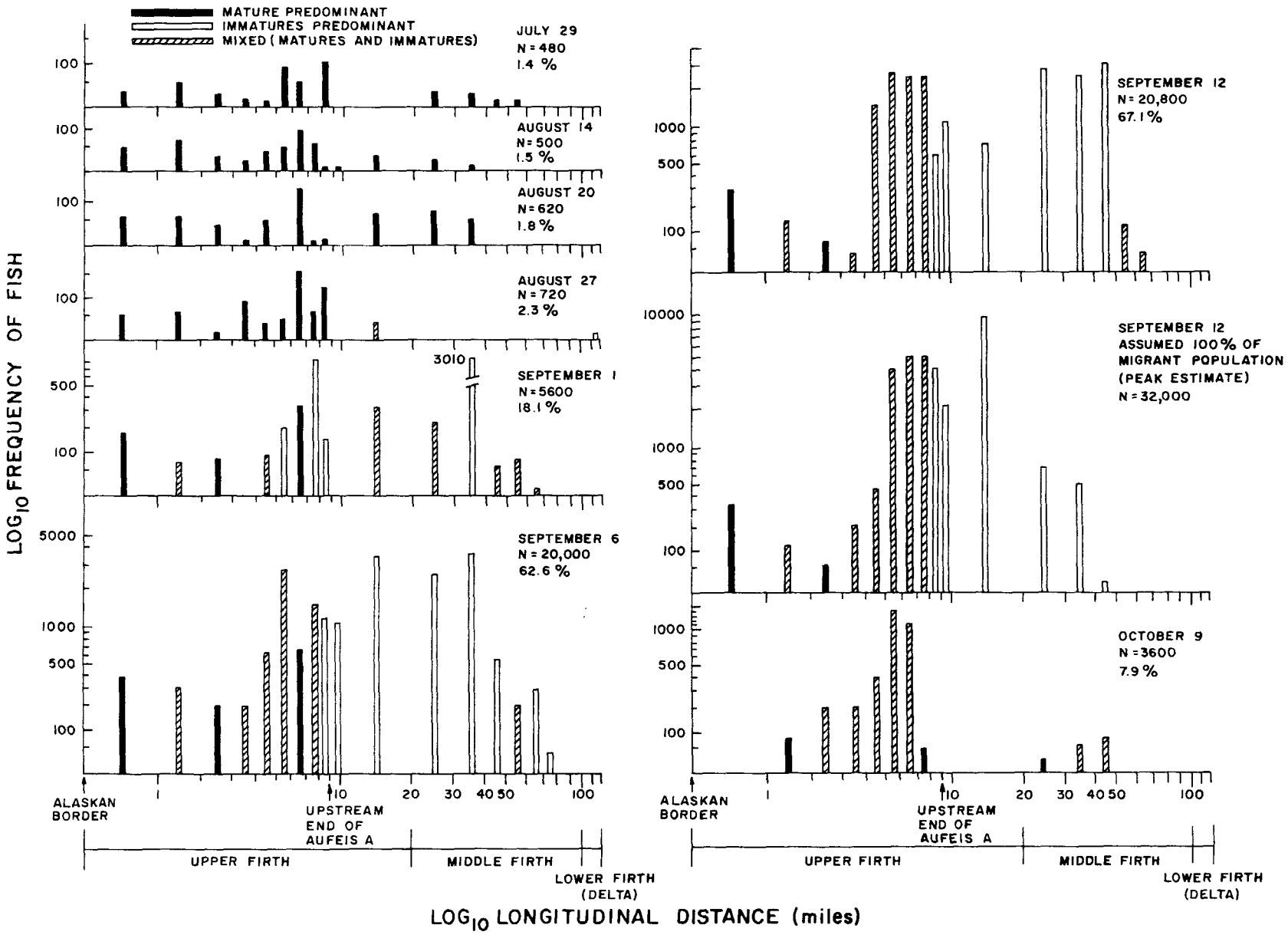


Fig. 23. Temporal changes in the longitudinal distribution and abundance of migrant Arctic char during the fall upstream migration, 1972. Percent of total population estimate (N=32,000) are shown for each time interval. From Glova and McCart (1974).

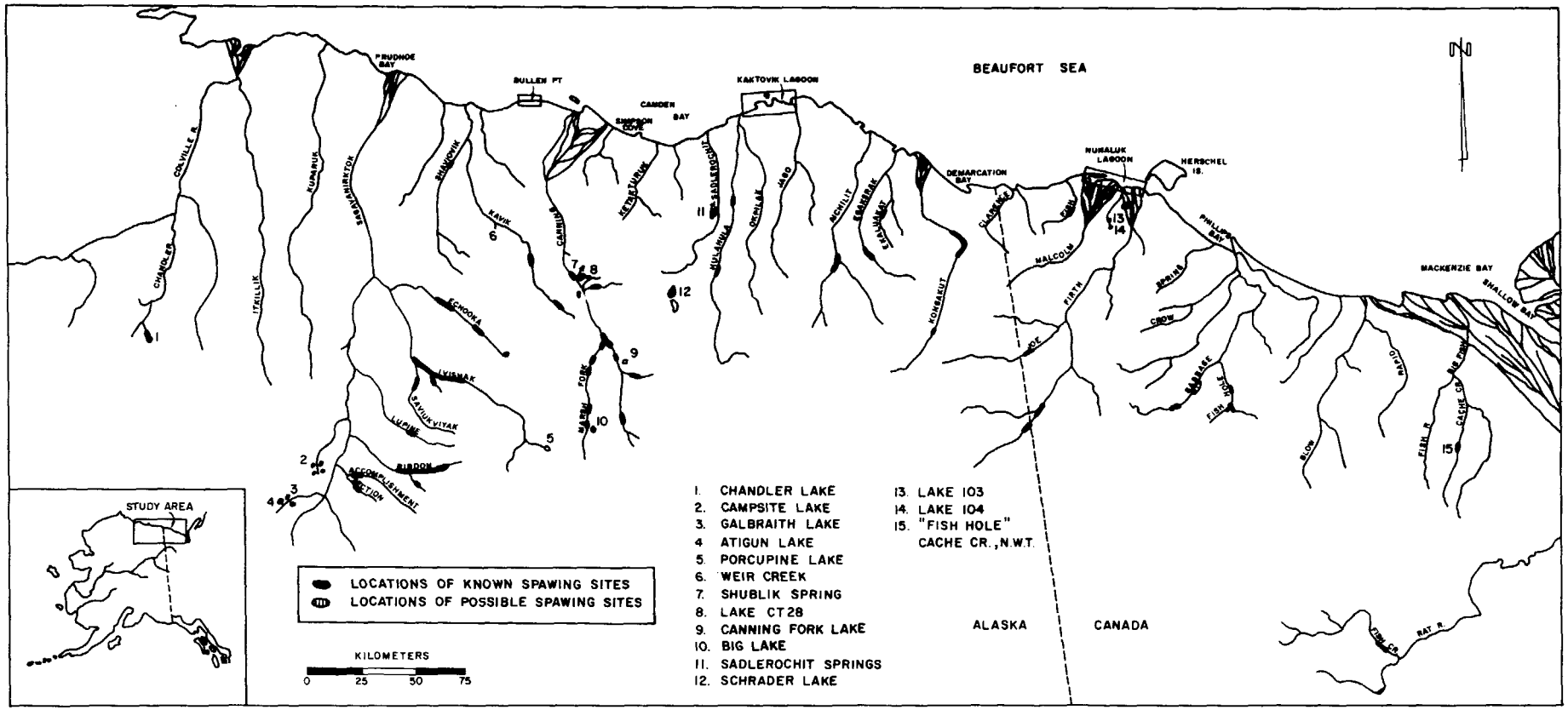


Fig. 24. Locations of known and possible spawning areas in the study area.

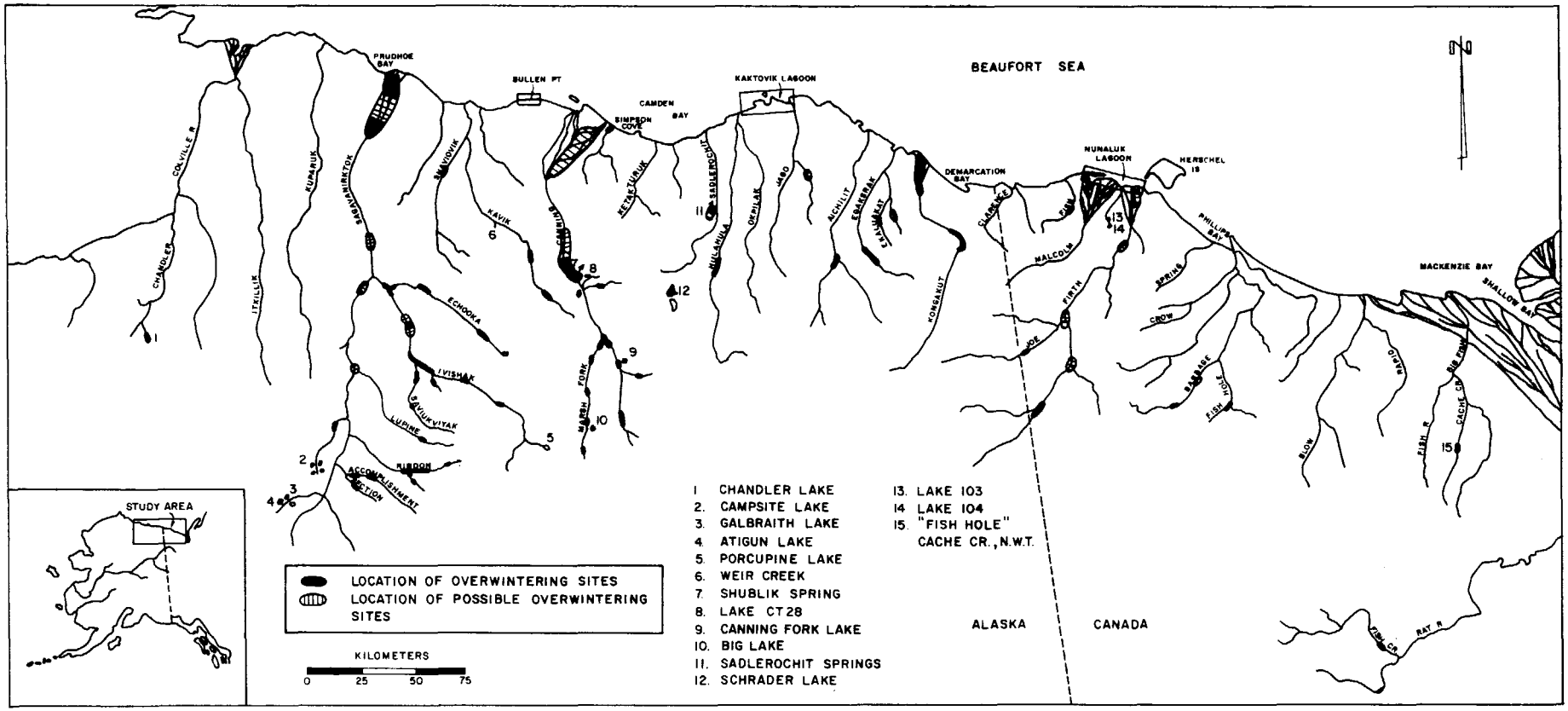


Fig. 25. Locations of Arctic char overwintering areas in the study area.

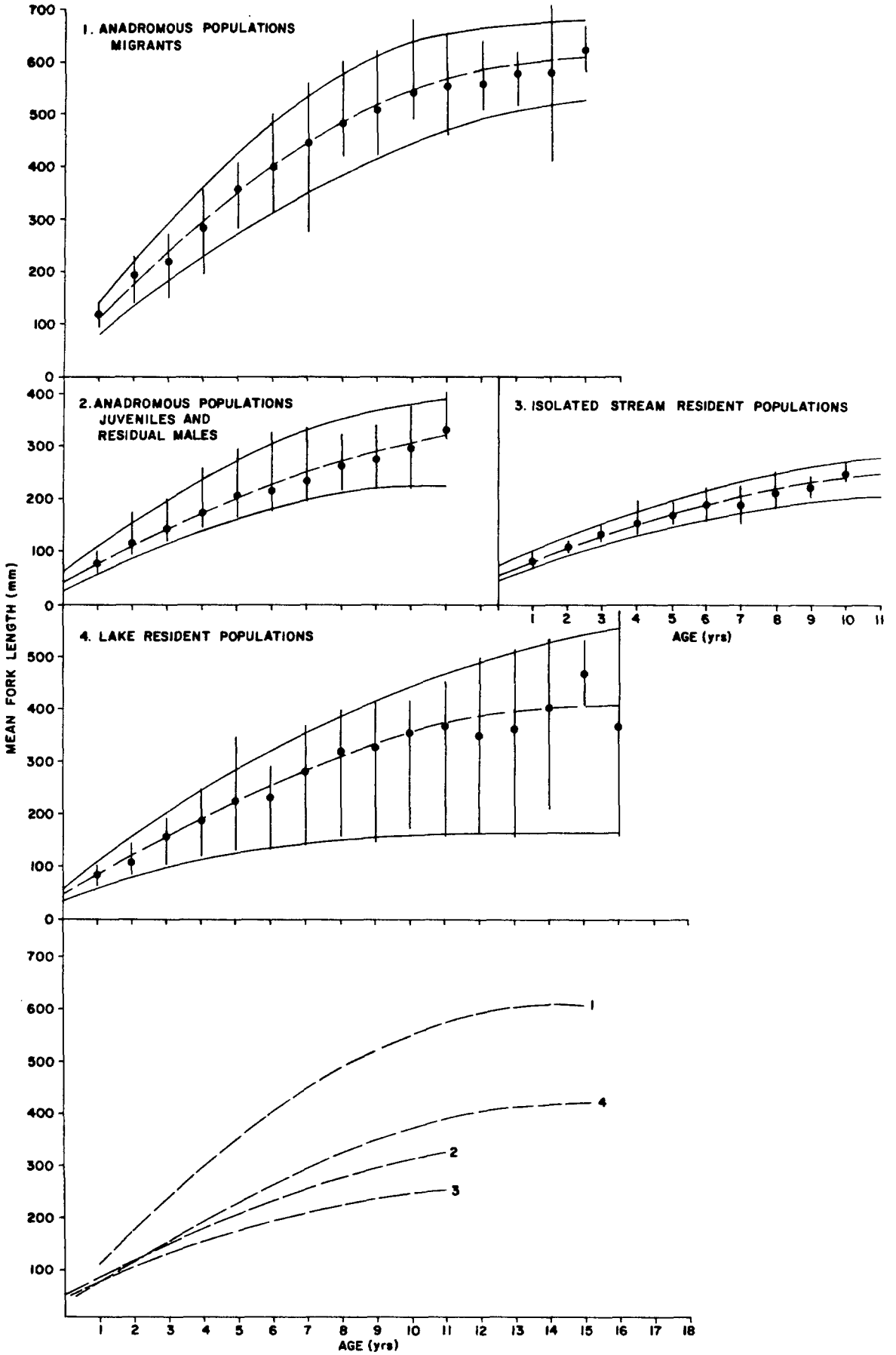


Fig. 26. Summary of length-age relationships for life history types of Arctic char from the study area. Large dots indicate means, vertical bars indicate ranges of means. Based on data in Table 13.

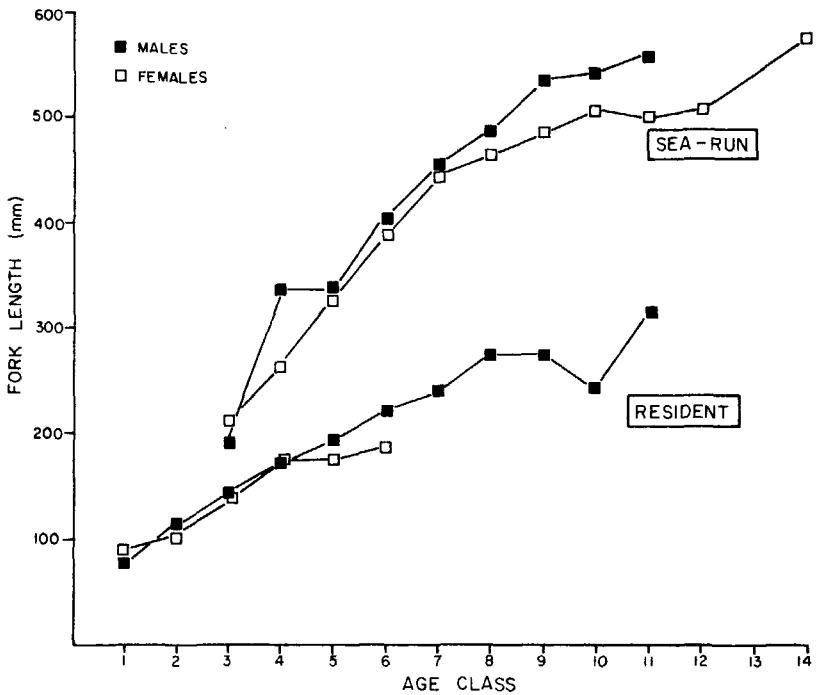


Fig. 27. Length-age comparison between male and female char for both sea-run and freshwater-resident samples from combined locations in the Canning drainage. From Craig (1977a).

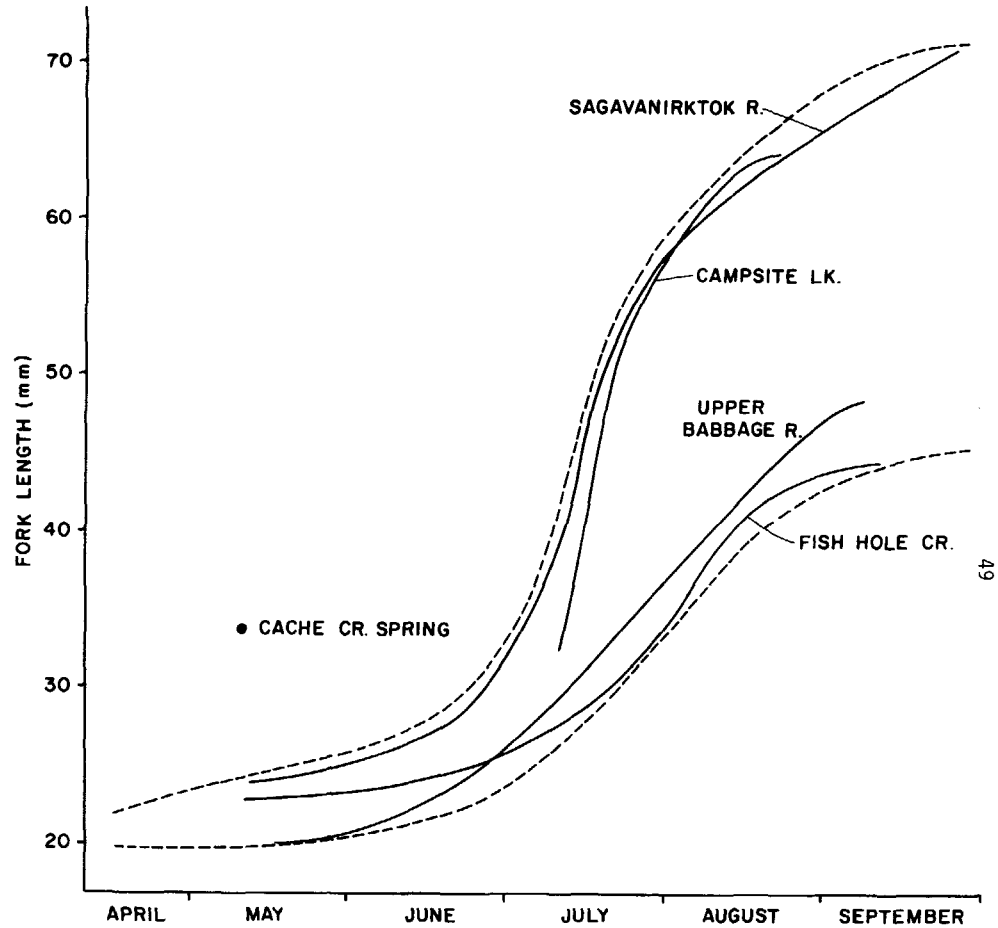


Fig. 28. Envelope of growth (dashed lines) enclosing means of fork lengths for young-of-the-year of anadromous populations. Also shown are individual growth curves for 1) the fastest (Sagavanirktok River) and slowest (Fish Hole Creek) growing fry of anadromous populations; 2) one isolated stream resident population (Upper Babbage River); 3) one lake resident population (Campsite Lake). Cache Creek Spring data are available for only one date (May 11).

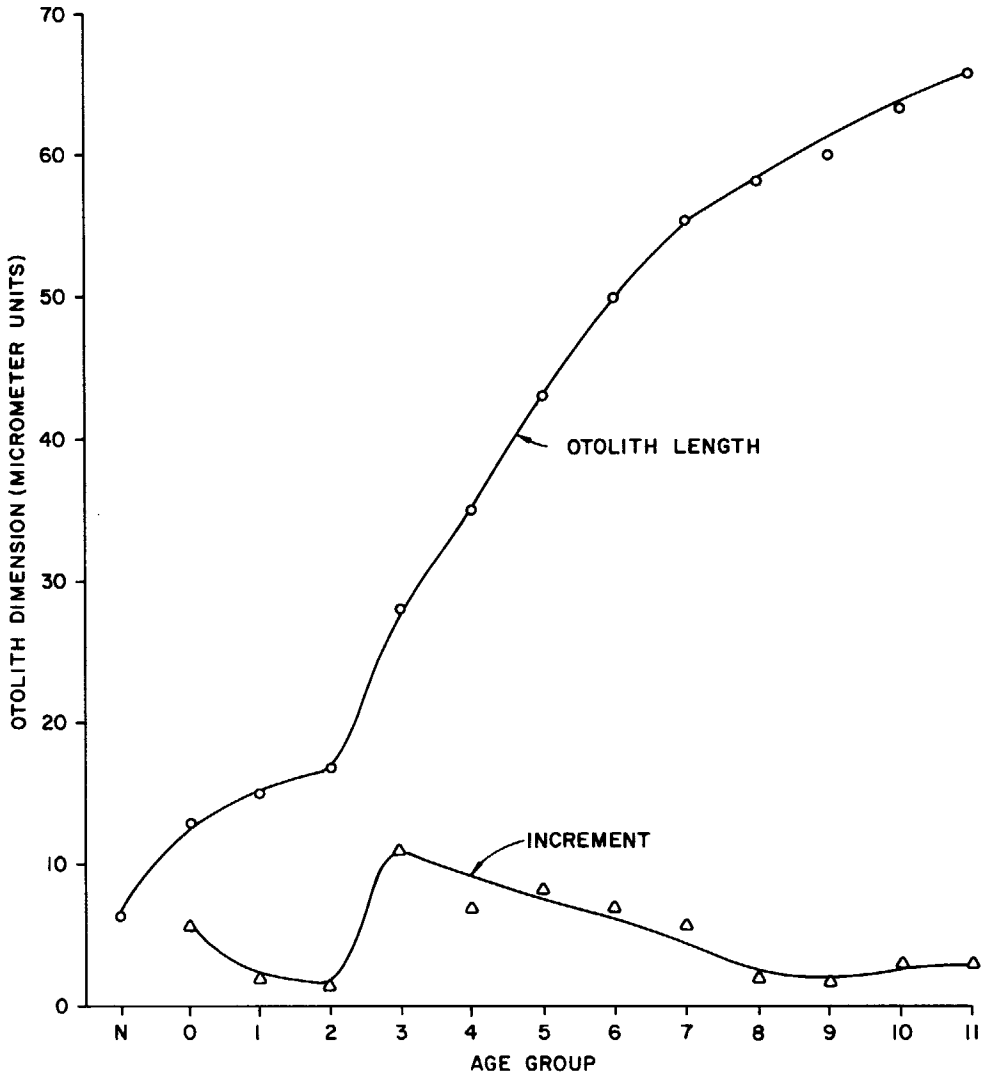


Fig. 29. Measurements of otolith length by age group for Arctic char from the Sagavanirktok drainage. Data from Yoshihara (1973).

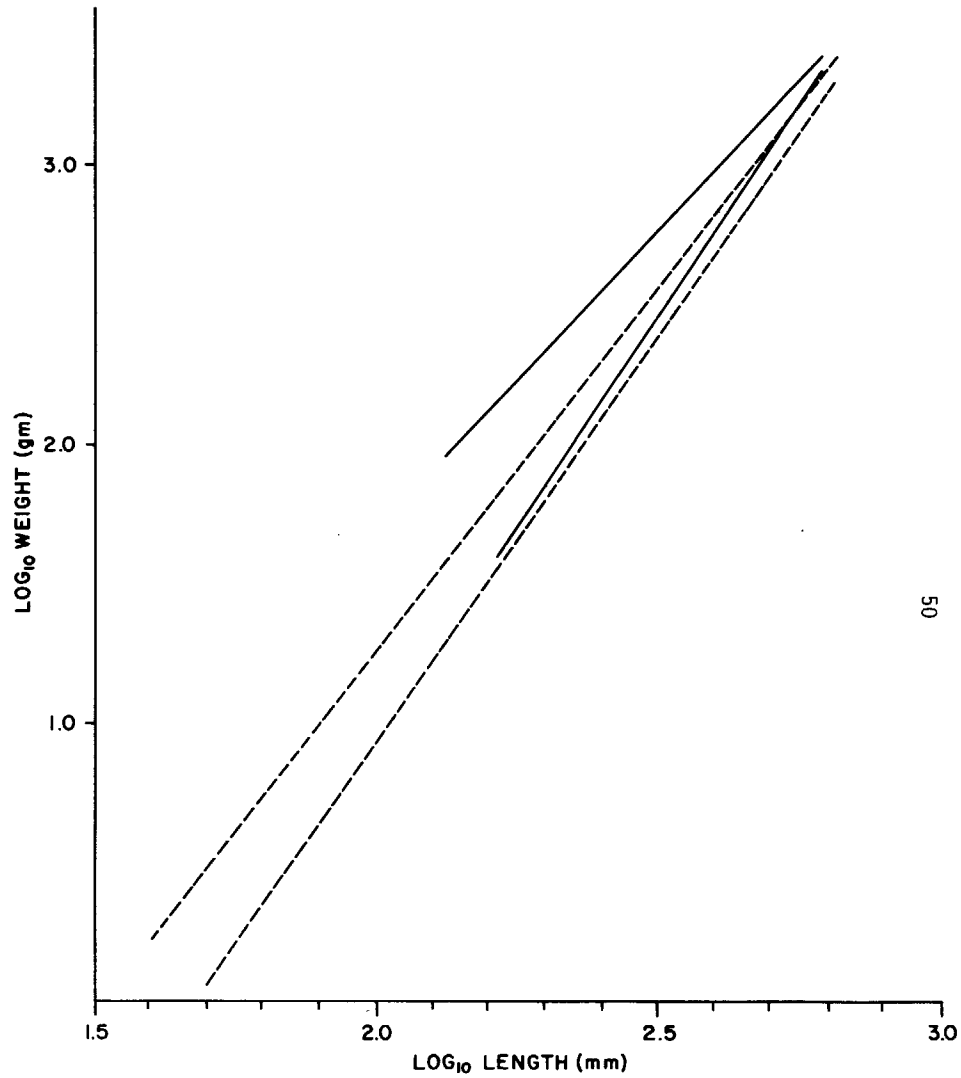


Fig. 30. Upper and lower ranges of weight-length relationships for freshwater resident char (dashed lines include lake resident, isolated stream resident, and juvenile and residual fish associated with anadromous populations) and migrant anadromous fish (solid lines). Detailed data in Table 19.

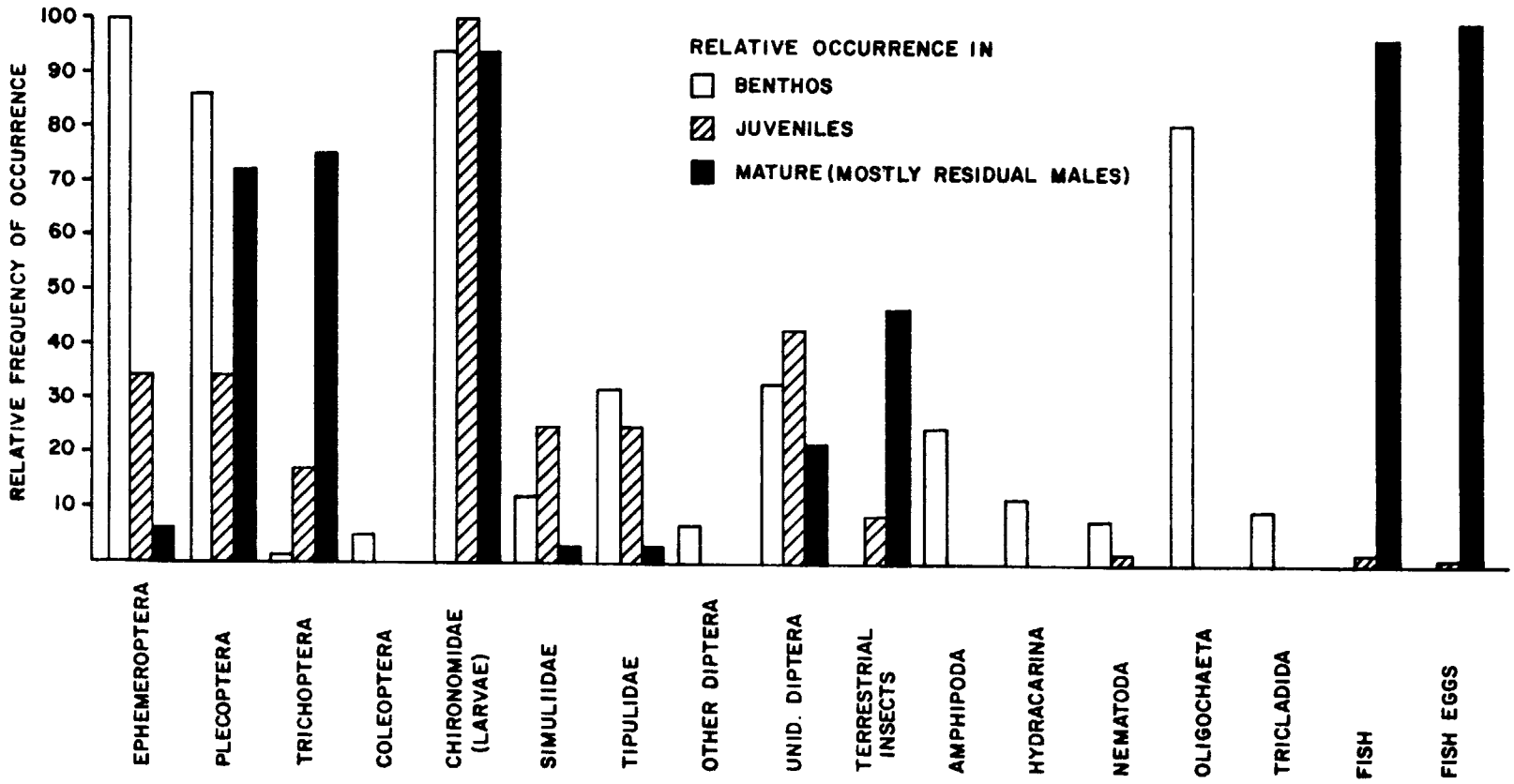


Fig. 31. Comparison of relative frequency of occurrence of food items in the stomachs of freshwater resident juvenile and mature (mostly male) residual fish, with frequency of the same organisms in the benthos.

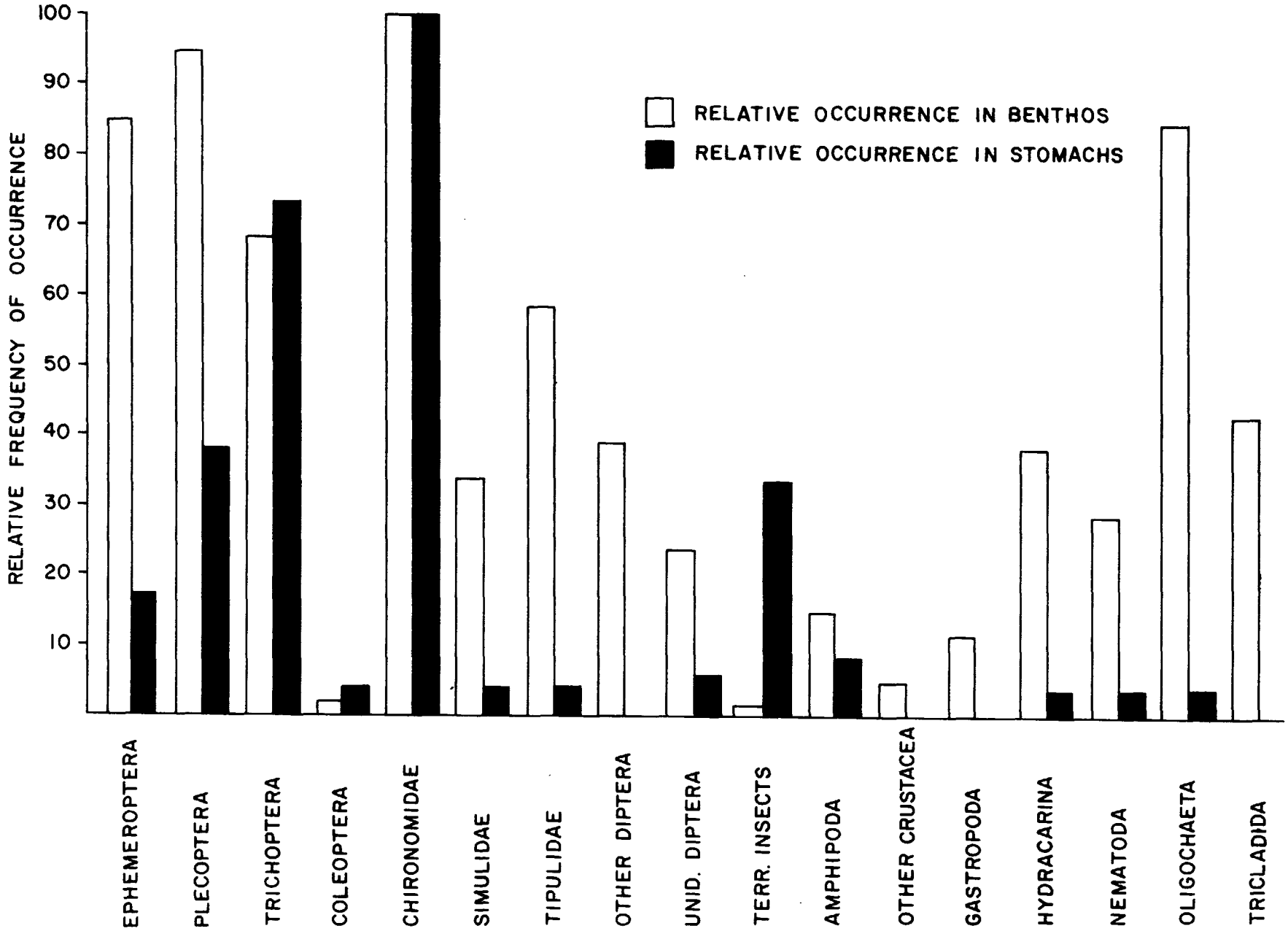


Fig. 32. Comparison of the relative occurrence of food items in the stomach contents of char from four isolated populations (upper Babbage Springs, Sadlerochit Springs, Shublik Springs, and Unnamed Spring) with the relative occurrence of the same items in the benthos of 13 springs within the study area.

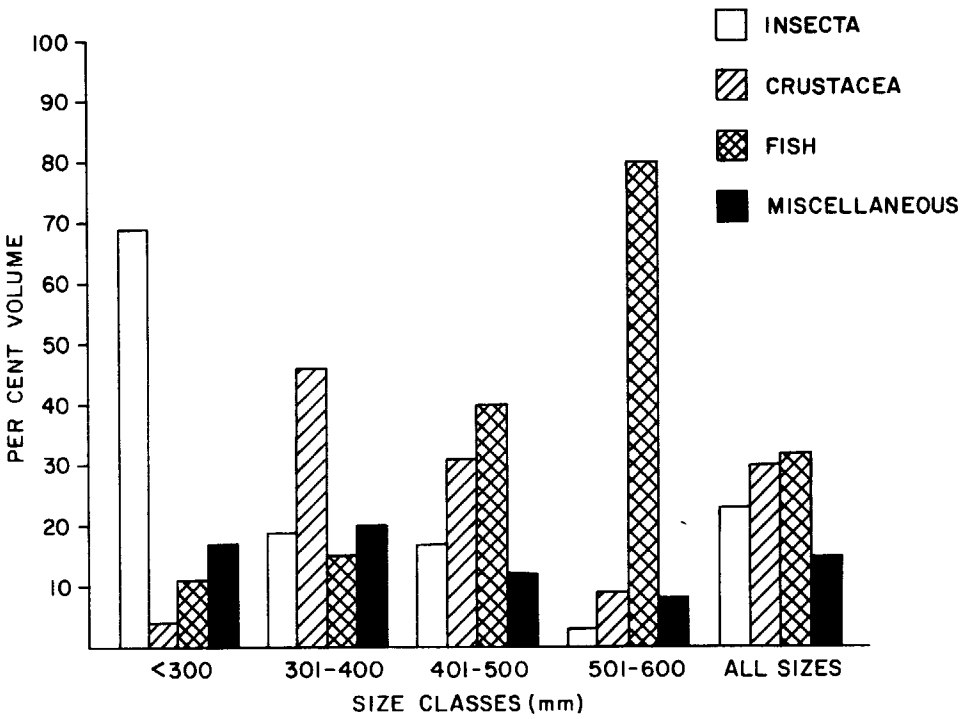


Fig. 33. Comparison of the percent volumes of four major groups of food items in the stomachs of Arctic char from Nunaluk Lagoon. Data from Griffiths et al. (1975).

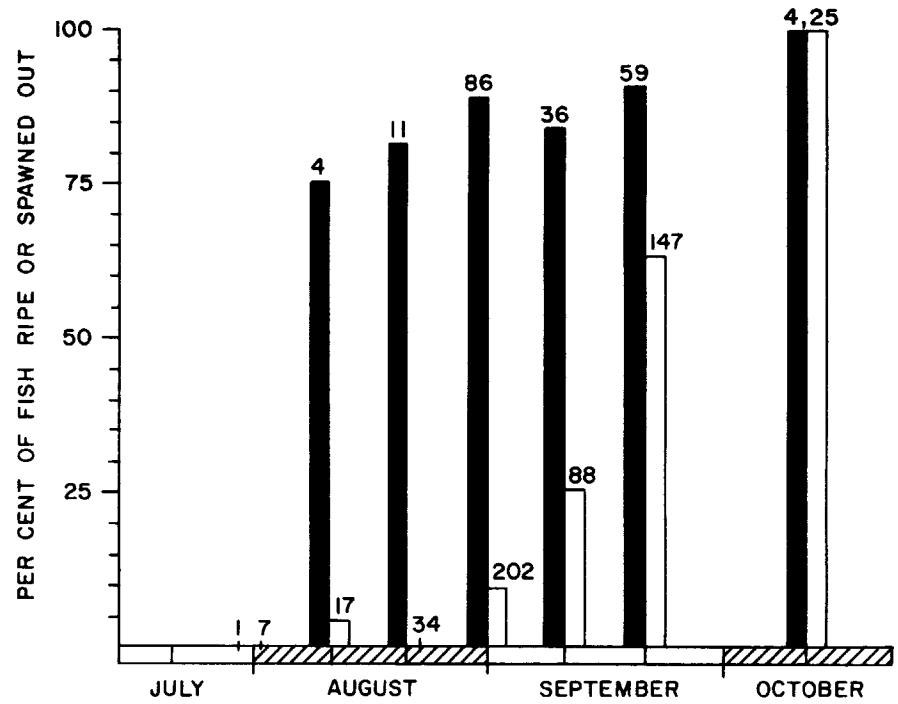


Fig. 34. Spawning condition of male (black bars) and female (open bars) anadromous Arctic char in the upper Firth River. Sample size and the percent of ripe or spawned-out fish are noted for each collection. From Glova and McCart (1974).

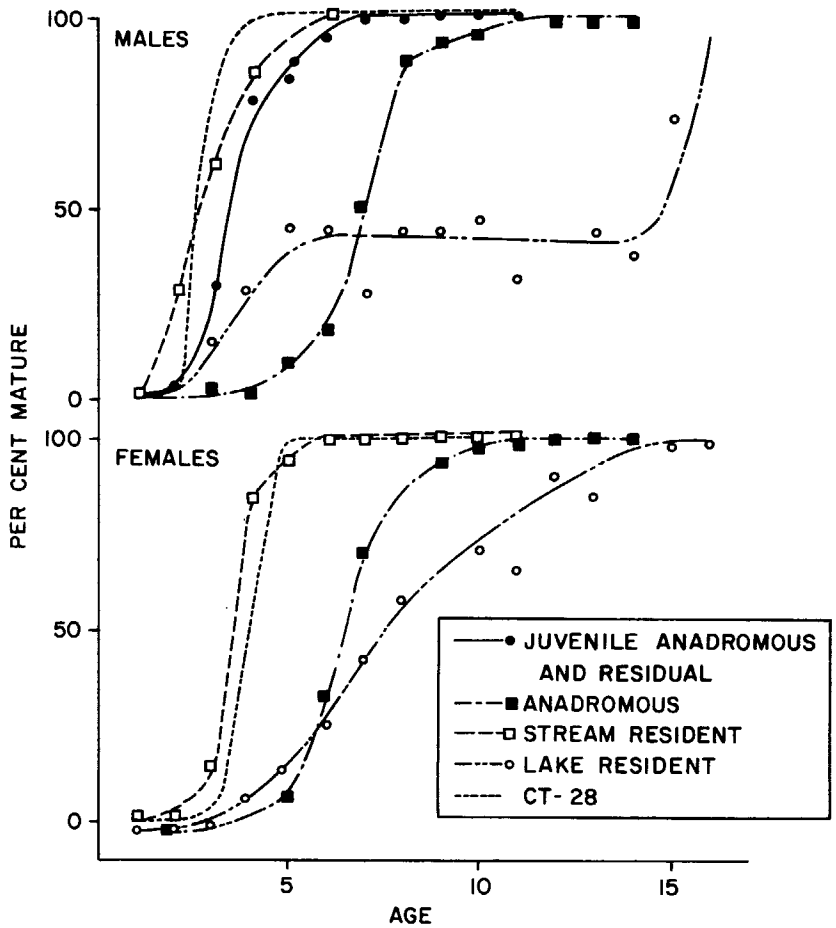


Fig. 35. Age at maturity for anadromous fish, residual males, isolated stream-resident populations, and lake-resident populations.

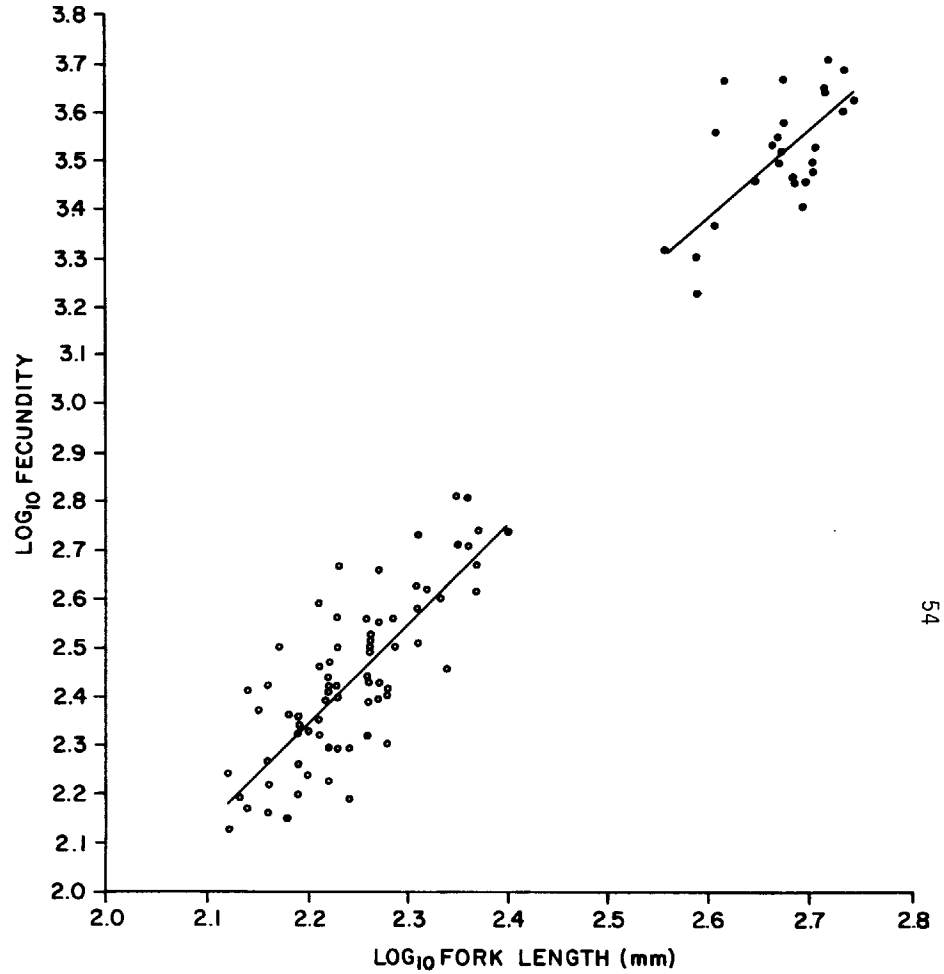


Fig. 36. Comparison of fecundity-length relationships for mature isolated females (open circles) from the upper Babbage River and mature anadromous females (closed circles) from Fish Hole Creek. From Bain (1974).

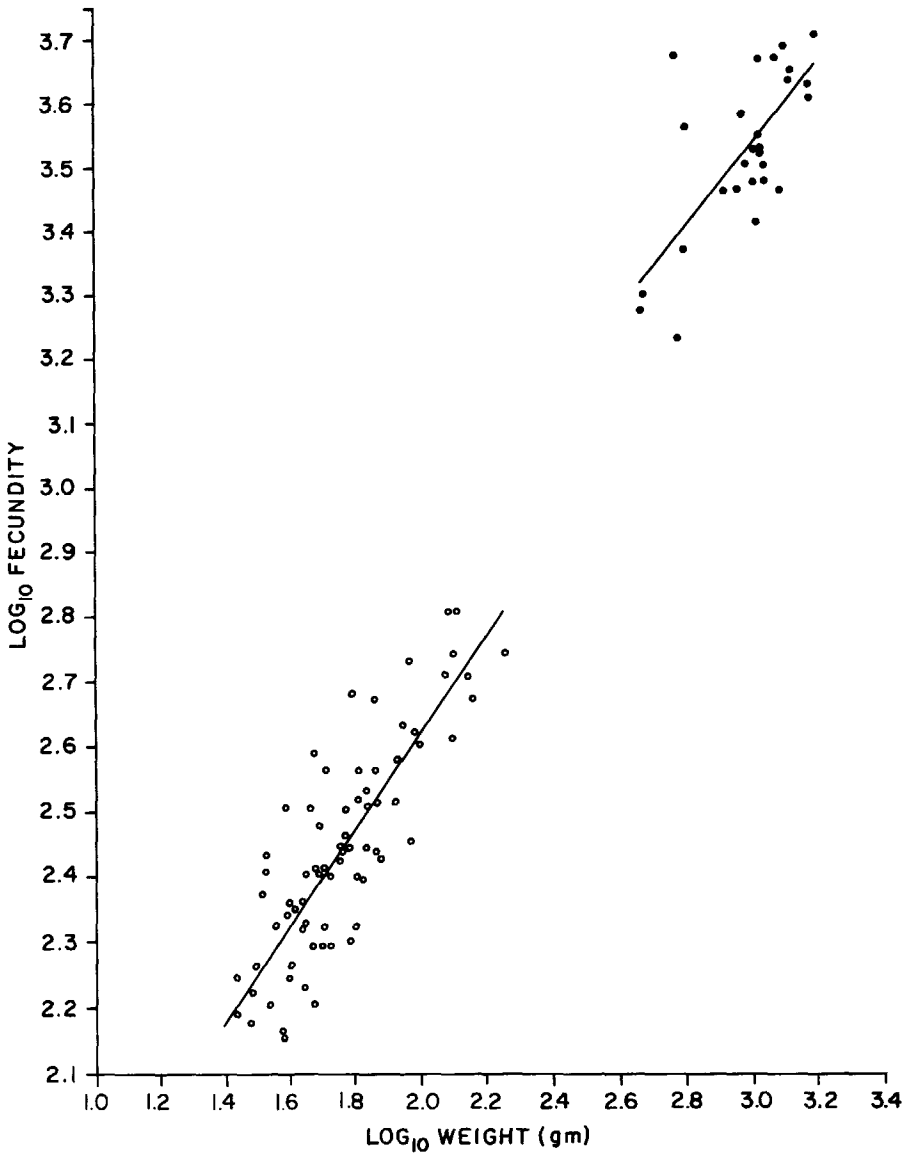


Fig. 37. Comparison of fecundity-weight relationships for mature isolated females (open circles) from the upper Babbage River and mature anadromous females (closed circles) from Fish Hole Creek. From Bain (1974).

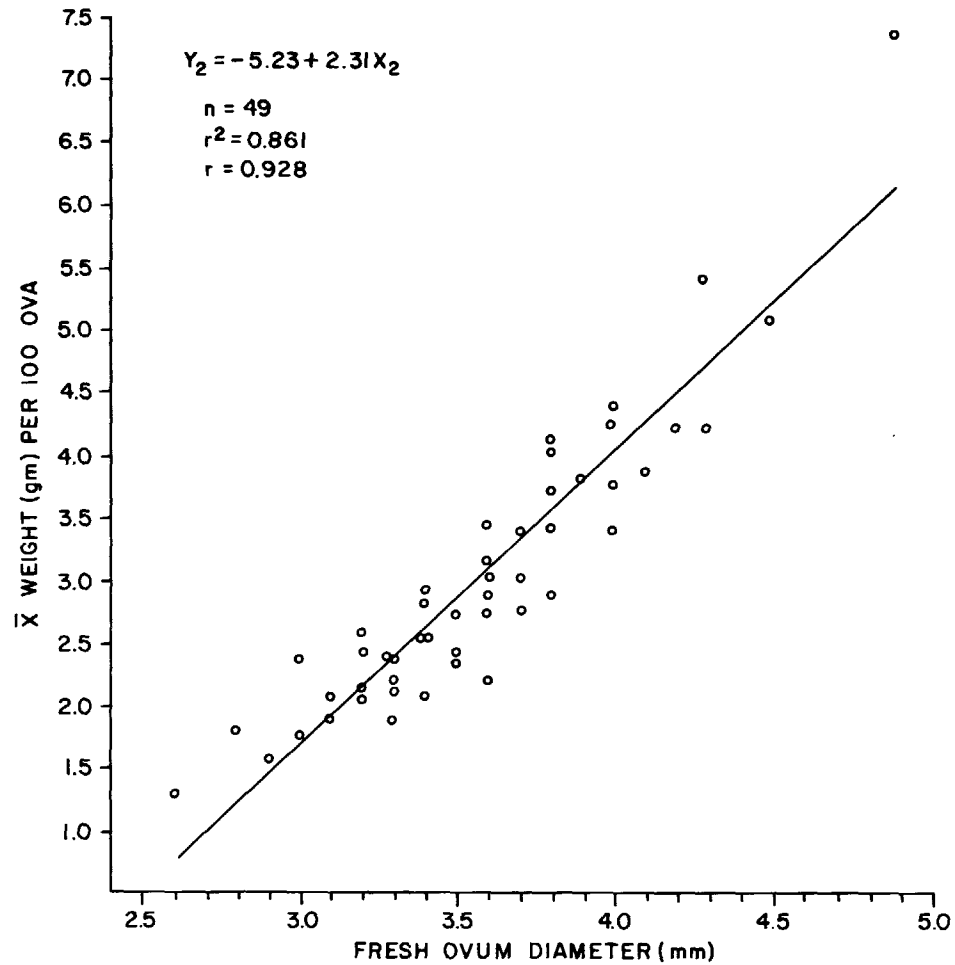


Fig. 38. Relationship between the mean diameter of fresh ova and mean weight of ova from samples of anadromous females from the Sagavanirktok River drainage, Alaska. From Yoshihara (1973).

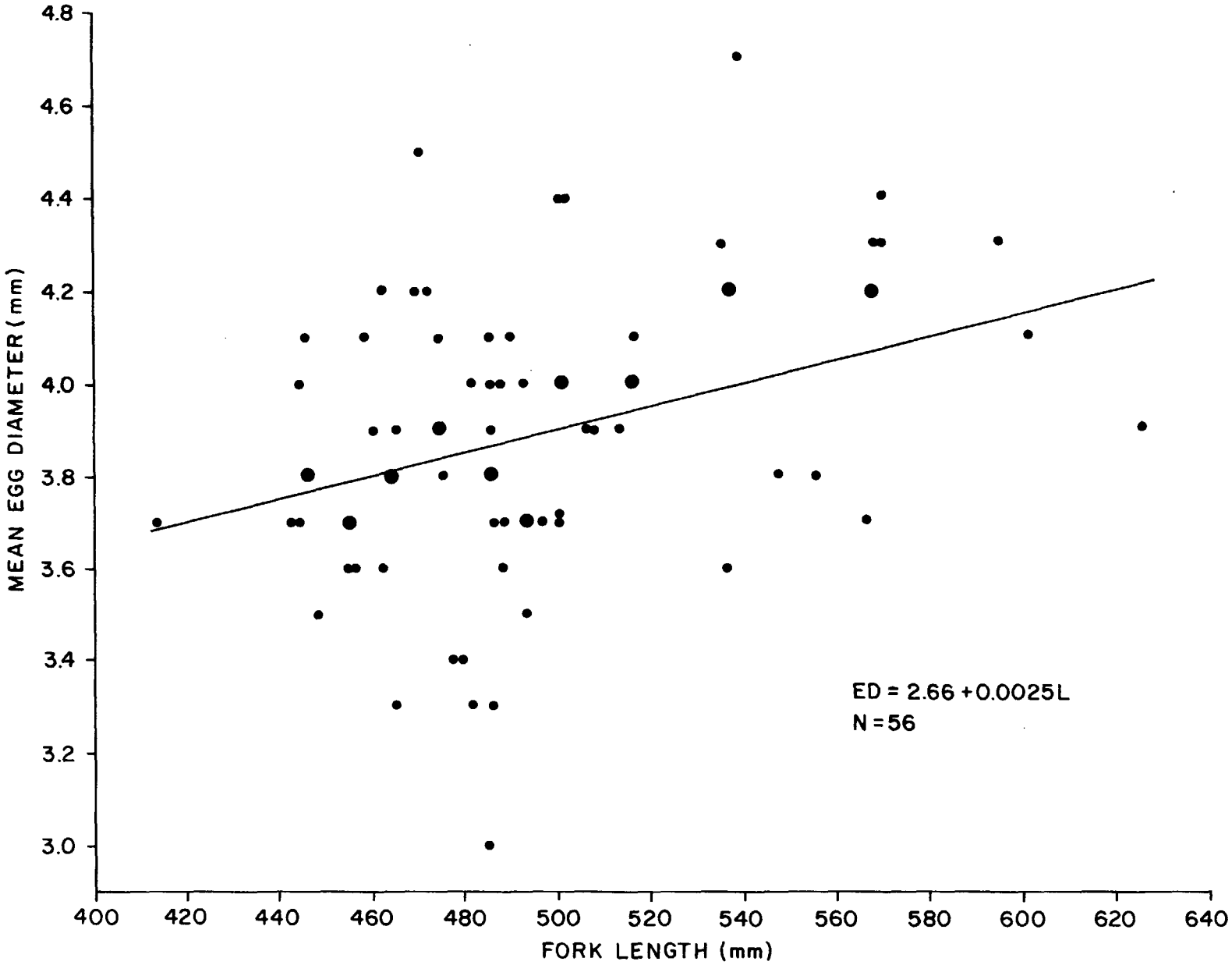


Fig. 39. Relationship of egg diameter and fork length for migrant female Arctic char classified as mature but green. Data for three streams (Accomplishment Creek, Section Creek, and Ribdon River) in the Sagavanirktok River Drainage combined. Small points, data for individual fish; large points, means for 10 mm length groups in which sample size is two or more. Unpublished data, Aquatic Environments Limited.

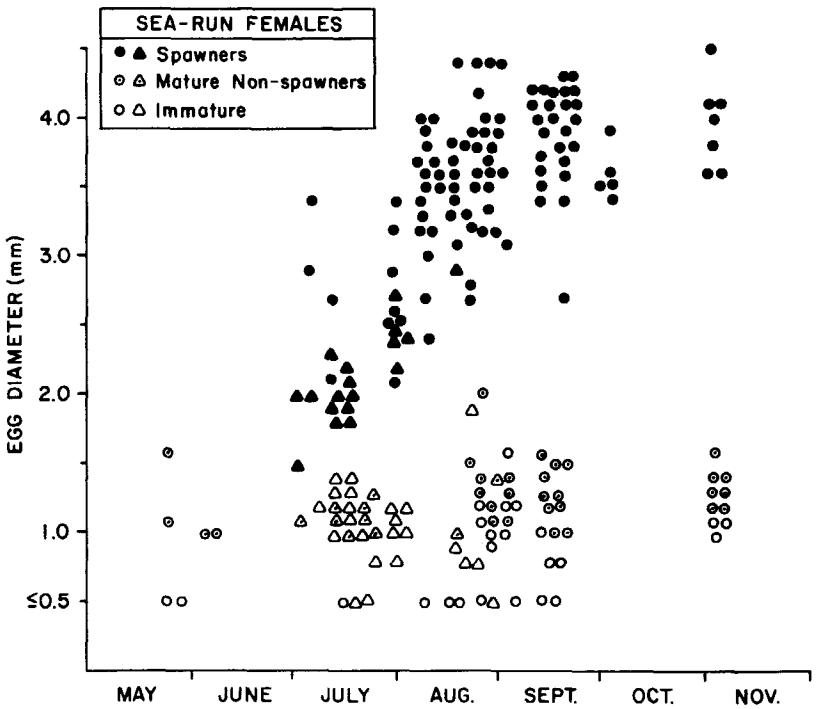


Fig. 40. Seasonal patterns of egg sizes for sea-run females caught in the Canning River (circles) and coastal waters (triangles). From Craig (1977a).

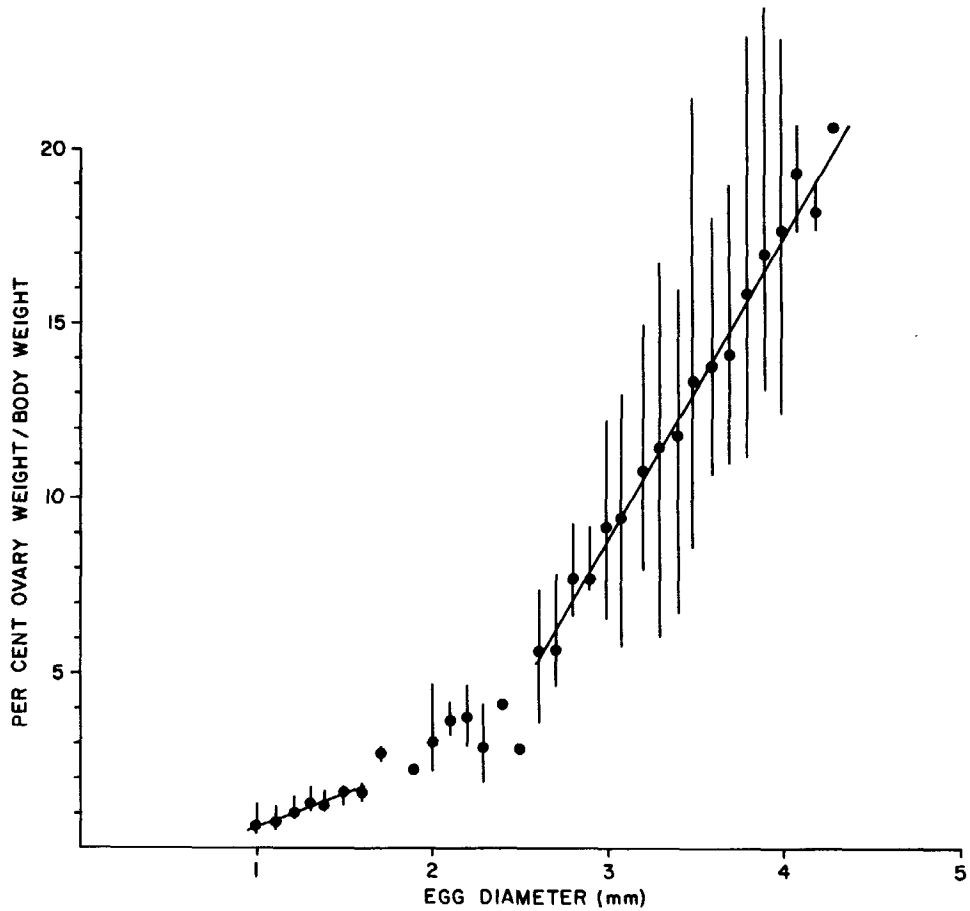


Fig. 41. Relationship of "maturity index" to egg diameter. From Yoshihara (1973).

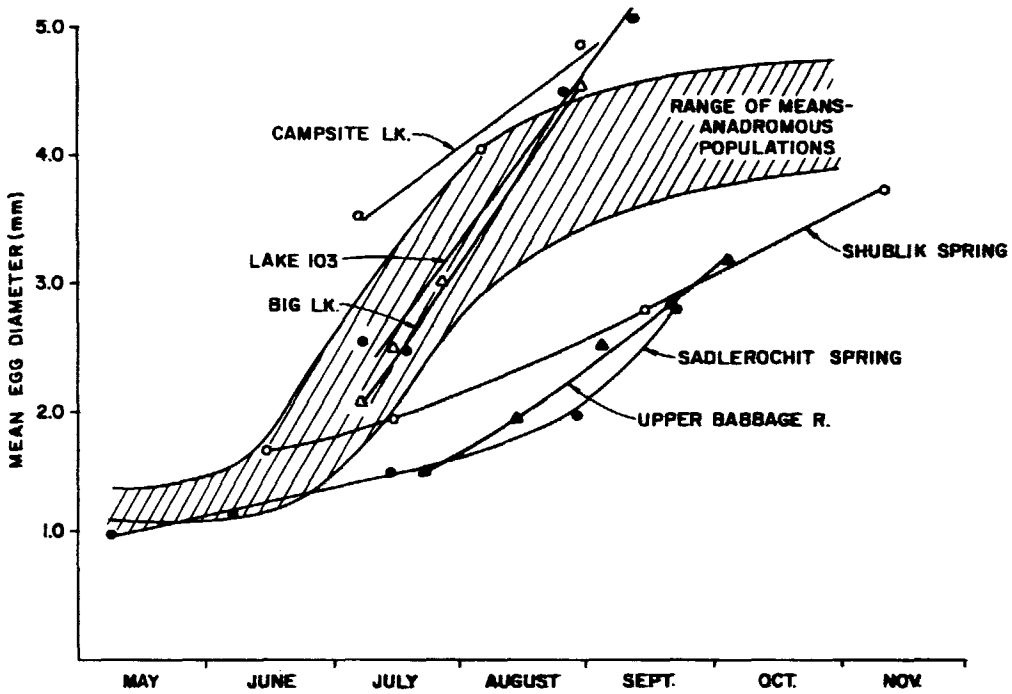


Fig. 42. Seasonal change in diameters of mature eggs. Further explanation in text.

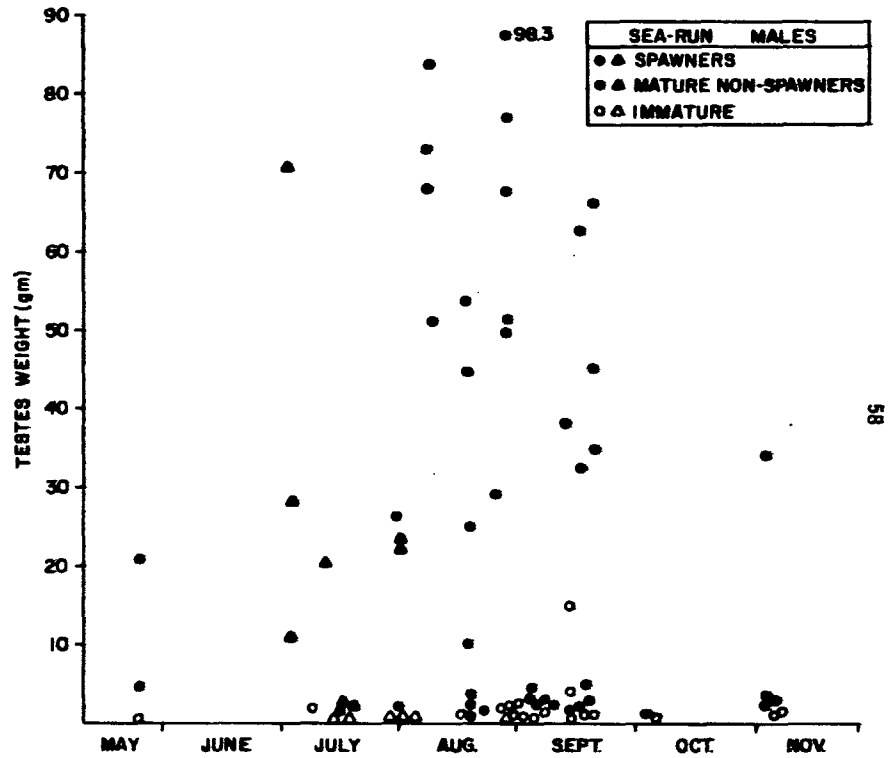


Fig. 43. Seasonal patterns of total gonad weight for sea-run males caught in the Canning River (circles) and coastal waters (triangles). From Craig (1977a).

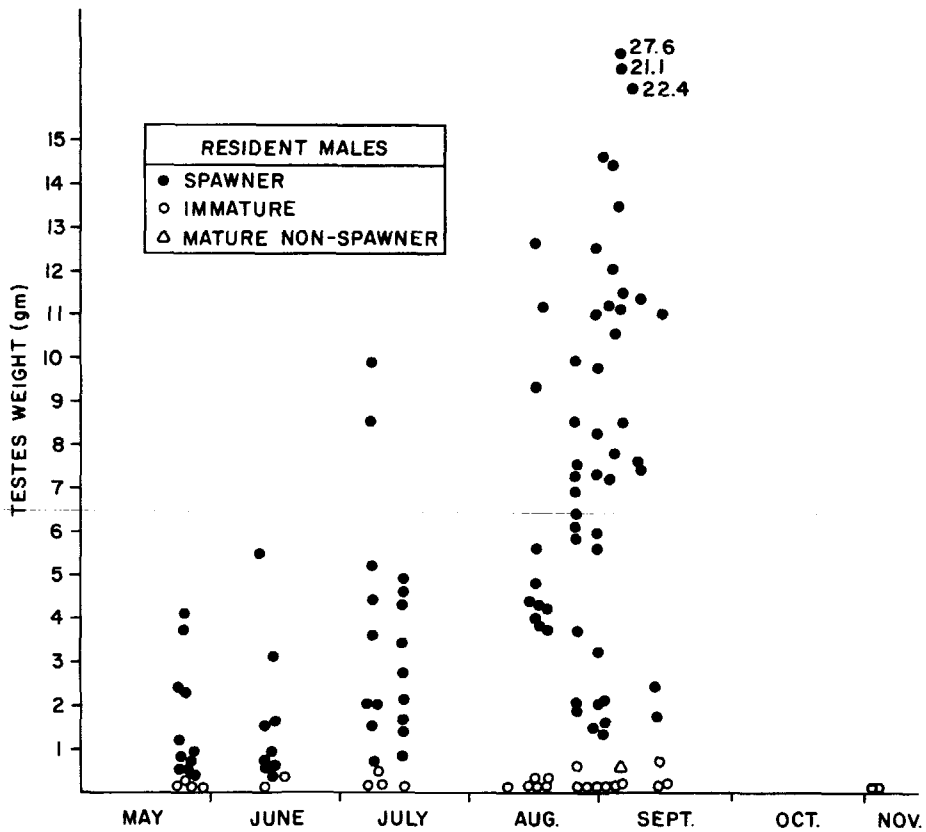


Fig. 44. Seasonal pattern of total gonad weight for resident males in the Canning River. From Craig (1977a).

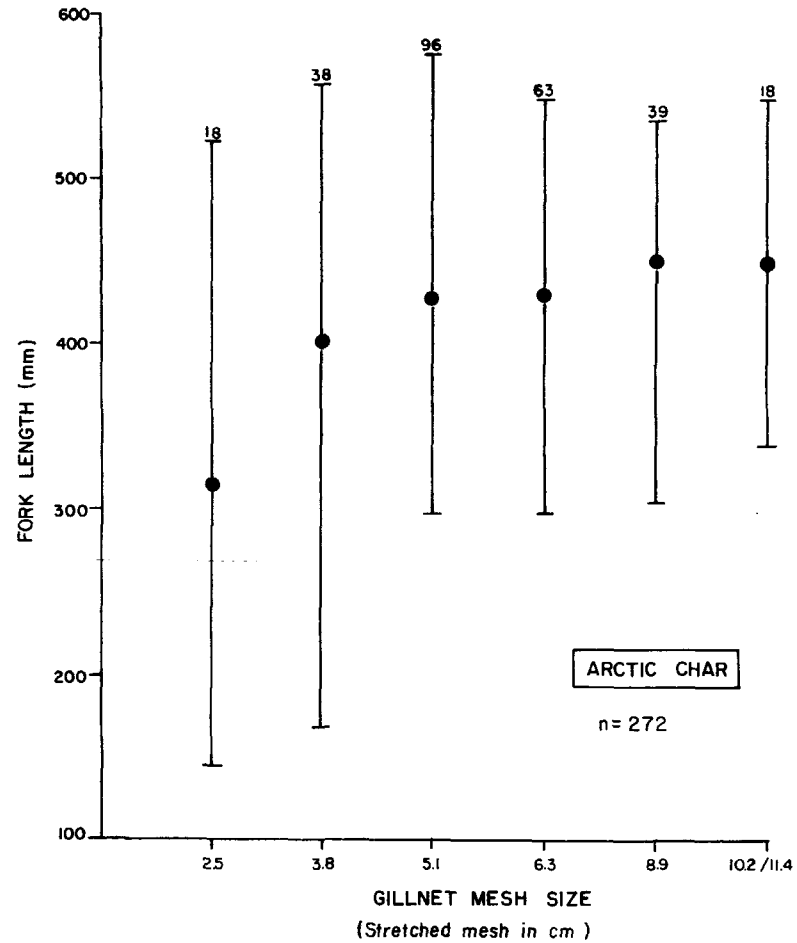


Fig. 45. Relationship between gillnet mesh size and the size of Arctic char caught. For each mesh size, the mean fork length (dot) and range (vertical bars) are indicated. From Griffiths et al. (1975).

Table 1. Comparison of conductivities, calcium concentrations, pH values, and benthic invertebrate densities in the three stream types. Student's t-test values are given for paired comparisons between Mountain Streams (MS), Spring Streams (SS), and Tundra Streams (TS). From Craig and McCart (1975).

| | Conductivity (μmhos/cm) | Ca (mg/L) | pH | Benthic Invertebrates (No./$m^2$) |
|---|---|---|---|---|
| Spring Streams | | | | |
| N | 12 | 13 | 13 | 13 |
| mean | 177.1 | 43.2 | 8.2 | 22011 |
| range | (140-240) | (36.3-52.6) | (7.5-8.5) | (1801-84377) |
| SD | 31.2 | 5.0 | 0.4 | 27071.0 |
| Tundra Streams | | | | |
| N | 14 | 6 | 17 | 18 |
| mean | 115.9 | 8.8 | 7.6 | 1024.6 |
| range | (17-230) | (2.8-15.6) | (6.4-8.5) | (126-2469) |
| SD | 64.8 | 4.22 | 0.62 | 673.9 |
| Mountain Streams | | | | |
| N | 25 | 8 | 25 | 26 |
| mean | 175.6 | 28.3 | 8.0 | 292.5 |
| range | (78-285) | (16.2-36.8) | (7.0-8.5) | (22-1270) |
| SD | 47.4 | 6.2 | 0.5 | 329.9 |
| T-Test | | | | |
| SSxTS | 2.9[b] | 13.9[c] | 2.6[a] | 3.18[b] |
| SSxMS | 0.09 | 5.8[c] | 0.92 | 3.98[c] |
| TSxMS | 3.21[b] | 6.2[c] | 2.4[a] | 4.7[c] |

[a] $P<0.05$.
[b] $P<0.01$.
[c] $P<0.001$.

Table 2. Chemical analysis of water samples from perennial groundwater sources[a]. From Craig and McCart (1975).

| | Springs: Karst | | | | Springs: Intermediate | | | | Springs: Mineral |
|---|---|---|---|---|---|---|---|---|---|
| | N | Mean | (Range) | SD | N | Mean | (Range) | SD | Cache Creek, N.W.T. |
| Temperature (°C) | 15 | 2.0 | (0-4.5) | 1.5 | 3 | 1.7 | (0.5-2.5) | 0.9 | 15.5 |
| pH | 15 | 7.9 | (7.5-8.2) | 0.2 | 3 | 7.8 | (7.3-8.2) | 0.4 | 7.8 |
| Conductivity (μmhos/cm @ 25°C) | 15 | 278.5 | (235-322) | 24.6 | 3 | 368.7 | (171-540) | 151.8 | 4546 |
| Ca | 15 | 43.3 | (36.3-52.6) | 4.8 | 3 | 45.8 | (21.5-66) | 18.4 | 95.0 |
| Mg | 15 | 7.4 | (4-12.9) | 2.2 | 3 | 10.7 | (4.1-16.8) | 5.2 | 22.1 |
| Na | 15 | 0.8 | (0.1-3.4) | 0.8 | 3 | 15.5 | (6.1-33) | 12.4 | 824.0 |
| K | 15 | 0.3 | (0.2-0.5) | 0.1 | 3 | 1.2 | (0.7-1.8) | 0.5 | 17.5 |
| Fe | 6 | 0.1 | (<0.05-0.12) | 0.1 | 2 | 0.005 | (0.05-0.06) | 0 | <0.05 |
| Mn | 6 | 0.007 | (<0.005-0.015) | 0 | 2 | 0.0065 | (0.005-0.008) | 0 | 0.008 |
| Cu | 6 | 0.002 | (<0.001-0.002) | 0 | 2 | 0.002 | (<0.002-0.002) | 0 | <0.002 |
| Pb | 6 | 0.006 | (<0.004-0.006) | 0 | 2 | 0.005 | (0.004-0.006) | 0 | <0.006 |
| Zn | 6 | 0.05 | (<0.002-0.19) | 0.7 | 2 | 0.08 | (0.001-0.15) | 0.1 | 0.56 |
| $HCO_3$ | 15 | 139.6 | (122-201.3) | 39.6 | 3 | 135.8 | (75.5-167.1) | 42.6 | 267.0 |
| $CO_3$ | 15 | 0.0 | | 0 | 3 | 0.0 | | 0 | 0 |
| $SO_4$ | 15 | 17.5 | (9.1-24.7) | 5.5 | 3 | 60.9 | (13.5-98.3) | 35.3 | 417.0 |
| Cl | 15 | 0.42 | (0.1-1.2) | 0.4 | 3 | 12.3 | (4.9-26.2) | 9.9 | 1036.0 |
| F | 15 | 0.2 | (<0.05-0.59) | 0.1 | 3 | 0.24 | (0.06-0.57) | 0.2 | 1.2 |
| $NO_3$ | 14 | 0.09 | (<0.01-0.23) | 0.1 | 3 | 0.08 | (0.08-0.09) | 0 | 0.04 |
| $PO_4$ | 9 | 0.004 | (<0.003-0.007) | 0 | 1 | 0.003 | | - | - |
| $SiO_2$ | 15 | 3.9 | (1.9-5.4) | 0.9 | 3 | 6.5 | (3.7-11) | 3.2 | 17.6 |
| Σ | 15 | 221.1 | (191.7-278.1) | 23.9 | 3 | 289 | (131.4-408.7) | 116.4 | 2698.1 |

[a]Fig. 5 shows spring locations, most of which are of the karst type. Springs with chemical values intermediate between the karst type and the mineral waters of Cache Creek Spring, N.W.T., are Sadlerochit Spring, Firth-2, and Spring River Spring. Units are mg/L except where noted otherwise.

Table 3. Percent occurrence of major taxonomic groups in the total number of Surber samples collected (N) in each stream type. From Craig and McCart (1975).

| Benthic Invertebrates | Spring Streams N=59 | Tundra Streams N=98 | Mountain Streams N=137 |
|---|---|---|---|
| Trichoptera | 68% | 21% | 1% |
| Plecoptera | 95 | 86 | 63 |
| Ephemeroptera | 85 | 93 | 73 |
| Diptera (unidentified) | 23 | 23 | 16 |
| Simulidae | 34 | 44 | 9 |
| Dolichopodidae | 2 | - | 1 |
| Tipulidae | 58 | 46 | 23 |
| Empididae | 25 | 2 | 3 |
| Chironomidae | 100 | 81 | 69 |
| Muscidae | 6 | 4 | 1 |
| Liriopeidae | 3 | - | - |
| Ceratopogonidae | 2 | - | - |
| Oligochaeta | 85 | 87 | 59 |
| Nematoda | 28 | 21 | 6 |
| Arachnida (mites) | 38 | 22 | 9 |
| Gastropoda | 12 | 9 | 1 |
| Tricladida | 43 | 22 | 7 |
| Amphipoda | 15 | 12 | 18 |
| Coleoptera larvae | 2 | 4 | 4 |
| Lepidoptera larvae | 2 | - | - |
| Copepoda | 2 | 3 | - |
| Concostracoda | 3 | - | - |
| Collembola | - | 1 | 1 |

Table 4. Primary production of planktonic algae in lakes in the study area (Firth, 105, Schrader, and Peters) compared with those of selected oligotrophic lakes.

| Lake | Reference | Location | Vertical Extinction Coefficient | Primary Production $mgC/m^{-3}/day^{-1}$ | Primary Production $mgC/m^{-2}/day^{-1}$ |
|---|---|---|---|---|---|
| Firth Lake (Yukon) | 1 | 69°N 139°W | 0.32-0.36 | 6.5 | 22.6 |
| Lake 105 (Yukon) | 1 | 69°N 139°W | 0.10-0.27 | 3.3 | 26.8 |
| Schrader Lake (Alaska) | 2 | 69°N 145°W | 0.25-0.50 | 4.1 | 40-60 |
| Lake Peters (Alaska) | 2 | 69°N 145°W | 0.25-0.75 | 3.1 | 5.0-10.0 |
| Eastern Great Bear Lake | 3 | 66°N 120°W | - | 1.0 | 30.0 |
| Tangle Lakes, Alaska | 4 | 63°N 146°W | 0.39-0.60 | 82 | 361 |
| Lake S-7 (Southampton Is.) | 5 | 63°N 85°W | - | 2.9 | 18 |
| McLeod Bay, Great Slave Lake | 3 | 62°N 112°W | - | 2.0 | 100 |
| Naknek Lake (Alaska) | 6 | 59°N 156°W | - | 10.8 | 173 |
| Becharof Lake (Alaska) | 6 | 58°N 156°W | - | 0.63 | - |
| Brooks Lake (Alaska) | 6 | 58°N 156°W | - | 3.5 | 158.3 |
| Eastern Lake Winnipeg | 3 | 52°N 98°W | - | 30 | 50 |
| Hillock Lake (Ontario) | 7 | 50°N 94°W | 0.537 | 87 | 850 |

References:
1 McCart et al. (1974).
2 Hobbie (1962).
3 Schindler and Holmgren (1971), Armstrong and Schindler (1971).
4 Barsdate and Alexander (1971).
5 Livingstone (1963).
6 Goldman (1960).
7 Schindler (1971), Schindler and Holmgren (1971), Sakamoto (1971).

Table 5. Relationship of mean depths and areas to fish populations of lakes along the Arctic Coastal Plain, Prudhoe Bay, Alaska, to Deep Creek, Yukon Territory. For 10 lakes, there was no information regarding fish populations. Data from Jones (1976).

| | N | Mean Depth (m) | Area (h) |
|---|---|---|---|
| Lakes with fish populations | 18 | 2.5 (1.1-4.0) | 116.5 (11.3-401.2) |
| Lakes without fish populations | 21 | 1.8 (1.2-2.9) | 105.1 (30.1-248.9) |
| All lakes | 49 | 2.1 (0.8-4.0) | 99.8 (11.3-401.2) |

Table 6. Summary of meristic data for *S. anaktuvukensis* (from Morrow 1973) and for isolated and anadromous populations of the western form of the Arctic char in the study area.

| | | Gillraker Upper | | | Gillraker Lower | | | Pyloric Caeca | | | Lateral Line Pores | | | Vertebrae | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | N | $\bar{x}$ | Range | N | $\bar{x}$ | Range | N | $\bar{x}$ | Range | N | $\bar{x}$ | Range | N | $\bar{x}$ | Range |
| *S. anaktuvukensis* | A | | 9 | (7-11) | | 11.5 | (9-13) | | 28 | (24-32) | | 135 | (127-152) | | 67 | (65-70) |
| | B | 21 | 9.1 | (7-11) | 21 | 12.0 | (11-13) | 20 | 27.6 | (24-31) | 21 | 135.8 | (130-140) | | | |
| ISOLATED: | | | | | | | | | | | | | | | | |
| Upper Babbage | | 159 | 8.4 | (6-12) | 159 | 11.7 | (9-14) | 149 | 28.5 | (20-39) | 58 | 129.6 | (121-146) | 58 | 67.4 | (65-70) |
| Lower Babbage | | 24 | 8.5 | (7-10) | 24 | 12.1 | (10-14) | 24 | 28.4 | (23-36) | 22 | 129.7 | (120-138) | 22 | 67.0 | (65-69) |
| Upper Cache Creek | | 25 | 9.7 | (8-14) | 25 | 11.8 | (9-14) | 25 | 26.0 | (21-32) | 25 | 131.8 | (122-138) | 24 | 64.7 | (58-67) |
| CT-41 Spring | | 18 | 8.3 | (7-9) | 18 | 12.1 | (11-13) | 59 | 26.6 | (16-35) | 18 | 133.3 | (122-141) | 18 | 67.8 | (66-70) |
| Shublik Spring | | 45 | 9.6 | (8-11) | 45 | 13.2 | (12-15) | 58 | 29.9 | (23-39) | 16 | 127.6 | (120-135) | 32 | 64.7 | (63-66) |
| Sadlerochit Spring | | 48 | 7.5 | (6-9) | 48 | 11.3 | (9-12) | 48 | 25.8 | (19-32) | 22 | 126.2 | (113-137) | 20 | 66.9 | (65-70) |
| | | 319 | 8.5 | (6-14) | 319 | 11.9 | (9-15) | 363 | 27.9 | (16-39) | 161 | 129.7 | (112-146) | 174 | 66.5 | (58-70) |
| | range $\bar{x}$ | | 7.5-9.7 | | | 11.3-13.2 | | | 25.8-29.9 | | | 126.2-133.3 | | | 64.7-67.8 | |
| ANADROMOUS | | | | | | | | | | | | | | | | |
| Hulahula River | | 29 | 9.1 | (6-11) | 29 | 12.4 | (10-14) | 29 | 30.8 | (22-32) | 9 | 135.7 | (126-140) | | | |
| Kavik River | | 43 | 9.9 | (8-13) | 43 | 12.4 | (9-14) | 43 | 29.2 | (22-38) | 20 | 139.2 | (135-142) | 10 | 68.3 | (57-70) |
| Kongakut River | | 26 | 9.1 | (8-12) | 26 | 12.0 | (10-13) | 26 | 29.5 | (20-38) | | | | | | |
| Echooka River | | 66 | 9.3 | (7-11) | 66 | 12.6 | (11-15) | 63 | 32.3 | (25-42) | 20 | 139.2 | (134-145) | 20 | 67.7 | (60-70) |
| Shaviovik River | | 5 | 9.0 | (8-11) | 5 | 12.5 | (12-13) | 4 | 27.0 | (20-30) | | | | | | |
| Canning River | | 96 | 9.2 | (7-11) | 96 | 12.6 | (10-18) | 97 | 31.4 | (18-45) | 40 | 133.2 | (125-141) | 40 | 67.8 | (66-70) |
| Canning Spring-1 | | 5 | 8.6 | (8-9) | 5 | 12.6 | (12-13) | 5 | 33.2 | (29-39) | 17 | 134.6 | (120-146) | 5 | 68.4 | (67-69) |
| Firth River | | 68 | 9.8 | (7-13) | 69 | 12.3 | (10-15) | 73 | 30.6 | (23-38) | 20 | 139.2 | (134-136) | | | |
| Fish Creek | | 95 | 8.7 | (7-11) | 95 | 11.7 | (9-14) | 95 | 27.4 | (19-40) | 35 | 133.7 | (122-144) | 30 | 68.9 | (67-71) |
| Fish Hole Creek | | 125 | 9.1 | (7-12) | 125 | 12.5 | (9-14) | 125 | 28.0 | (21-39) | 30 | 134.9 | (122-143) | 60 | 68.2 | (66-70) |
| Joe Creek | | 24 | 9.4 | (8-10) | 24 | 12.4 | (9-13) | 24 | 29.1 | (23-42) | 10 | 138.3 | (135-144) | 9 | 68.4 | (67-70) |
| Lower Cache Creek | | 35 | 8.9 | (7-11) | 35 | 12.3 | (9-14) | 34 | 28.3 | (22-35) | 14 | 136.4 | (132-141) | 27 | 67.1 | (66-69) |
| | | 617 | 9.2 | (6-13) | 168 | 12.3 | (9-18) | 618 | 29.6 | (18-45) | 215 | 135.9 | (122-145) | 201 | 68.0 | (60-70) |
| | range $\bar{x}$ | | 8.6-9.9 | | | 11.7-12.6 | | | 27.0-33.0 | | | 133.2-139.2 | | | 67.1-68.9 | |

(Continued)

Table 6. Concluded.

| | Pectoral Rays | | | Anal Rays | | | Dorsal Rays | | | Pelvic Rays | | | Parr Marks | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | $\bar{x}$ | Range | N | $\bar{x}$ | Range | N | $\bar{x}$ | Range | N | $\bar{x}$ | Range | N | $\bar{x}$ | Range |
| *C. anaktuvukensis* A | | 14 | (13-15) | | 14 | (13-15) | | 15 | (14-17) | | 10 | (9-10) | | | (9-15) |
| B | 21 | 14.3 | (14-15) | 21 | 13.4 | (12-15) | 21 | 15.2 | (14-16) | 21 | 9.9 | (9-10) | | | |
| ISOLATED | | | | | | | | | | | | | | | |
| Upper Babbage | 57 | 13.9 | (13-15) | 58 | 12.7 | (12-15) | 58 | 14.6 | (14-16) | 57 | 9.1 | (8-10) | | | |
| Lower Babbage | 22 | 14.0 | (13-15) | 22 | 12.9 | (12-15) | | | | 22 | 9.2 | (9-10) | | | |
| Upper Cache Creek | 25 | 13.6 | (13-15) | 25 | 12.9 | (12-14) | 25 | 14.5 | (14-16) | 25 | 9.0 | (8-9) | 31 | 15.1 | (13-17) |
| CT-41 Spring | 18 | 13.9 | (13-15) | 18 | 13.0 | (12-14) | 18 | 14.4 | (13-16) | 18 | 9.1 | (9-10) | 19 | 12.1 | (11-14) |
| Shublik Spring | 16 | 14.4 | (13-16) | 11 | 12.7 | (12-13) | 9 | 14.6 | (14-15) | 31 | 9.0 | (9-10) | 81 | 10.9 | (8-16) |
| Sadlerochit Spring | 20 | 13.6 | (13-15) | 22 | 12.4 | (12-13) | 22 | 14.2 | (13-15) | 40 | 8.9 | (8-9) | | | |
| | 158 | 13.9 | (13-16) | 156 | 12.8 | (12-15) | 132 | 14.5 | (13-16) | 193 | 9.1 | (8-10) | 131 | 12.1 | (8-17) |
| range $\bar{x}$ | 13.6-14.4 | | | 12.4-13.0 | | | 14.2-14.6 | | | 8.9-9.2 | | | 10.9-15.1 | | |
| ANADROMOUS | | | | | | | | | | | | | | | |
| Hulahula River | 9 | 14.8 | (13-16) | | | | | | | | | | | | |
| Kavik River | 20 | 14.5 | (14-15) | 20 | 12.8 | (12-14) | 20 | 14.5 | (13-16) | 10 | 9.1 | (9-10) | 1 | 11.0 | |
| Kongakut River | | | | | | | | | | | | | | | |
| Echooka River | 20 | 14.6 | (13-16) | 41 | 13.6 | (11-16) | 21 | 14.4 | (13-16) | 30 | 9.1 | (9-10) | 38 | 10.3 | (8-13) |
| Shaviovik River | | | | | | | | | | | | | | | |
| Canning River | 40 | 14.2 | (13-16) | 35 | 13.1 | (12-14) | 35 | 14.5 | (13-16) | 40 | 9.1 | (9-10) | 19 | 11.1 | (8-14) |
| Canning Spring-1 | 17 | 14.2 | (13-15) | 5 | 13.0 | (12-14) | 5 | 14.6 | (14-15) | 5 | 9.0 | (9-9) | 16 | 11.4 | (10-14) |
| Firth River | 20 | 14.3 | (13-15) | | | | | | | | | | | | |
| Fish Creek | 29 | 14.1 | (13-15) | 30 | 13.3 | (12-15) | 25 | 14.7 | (13-16) | 25 | 9.0 | (8-10) | | | |
| Fish Hole Creek | | | | | | | | | | | | | | | |
| Joe Creek | 10 | 14.5 | (14-16) | 10 | 12.9 | (12-14) | 10 | 14.1 | (13.15) | 10 | 8.9 | (8-9) | | | |
| Lower Cache Creek | 14 | 14.2 | (13-15) | | | | | | | 28 | 9.0 | (9-9) | 29 | 13.5 | (12-17) |
| | 179 | 14.3 | (13-16) | 141 | 13.2 | (11-16) | 116 | 14.5 | (13-16) | 148 | 9.0 | (8-10) | 103 | 11.5 | (8-17) |
| range $\bar{x}$ | 14.1-14.8 | | | 12.8-13.6 | | | 14.1-14.7 | | | 8.9-9.0 | | | 10.3-13.5 | | |

Table 7. Liver esterase patterns (Esterase-1) of Arctic char from the study area and from Redfish Lake.

| Location | N | Slow | Fast |
|---|---|---|---|
| EASTERN ARCTIC CHAR - LAKE RESIDENT | | | |
| Porcupine Lake | 16 | 0 | 16 |
| Schrader Lake | 2 | 0 | 2 |
| Big Lake | 41 | 0 | 41 |
| Redfish Lake | 9 | 0 | 9 |
| Lake 103 | 10 | 0 | 10 |
| Total | 78 | 0 | 78 |
| Percent | | 0 | 100 |
| WESTERN ARCTIC CHAR - LAKE RESIDENT | | | |
| CT-28 Lake | 9 | 9 | 0 |
| WESTERN ARCTIC CHAR - STREAM RESIDENT | | | |
| CT-41C | 15 | 15 | 0 |
| Shublik Springs | 10 | 10 | 0 |
| Sadlerochit Springs | 4 | 3 | 1 |
| Lower Babbage River | 24 | 24 | 0 |
| Upper Babbage River | 26 | 26 | 0 |
| WESTERN ARCTIC CHAR - ANADROMOUS | | | |
| Echooka River | 23 | 21 | 2 |
| Kavik River | 10 | 10 | 0 |
| Canning River | 26 | 26 | 0 |
| Canning Spring-1 | 16 | 16 | 0 |
| Ekaluakat River | 1 | 1 | 0 |
| Firth River | 10 | 10 | 0 |
| Fish Hole Creek | 38 | 38 | 0 |
| Total | 212 | 209 | 3 |
| Percent | | 98.6 | 1.4 |

Table 8. Relative abundance of mature and immature migrant Arctic char from seine samples at the three major spawning sites, upper Firth, 1972.

| Spawning Site | Date Sampled | N | Percent Matures | Percent Immatures |
|---|---|---|---|---|
| Site A | August 20 | 19 | 100.0 | 0.0 |
| | August 26 | 55 | 100.0 | 0.0 |
| | September 1 | 42 | 73.0 | 27.0 |
| | September 4 | 53 | 85.0 | 15.0 |
| | September 22 | 166 | 70.5 | 29.5 |
| | Total | 355 | 79.7 | 20.3 |
| Site B | August 20 | 23 | 100.0 | 0.0 |
| | September 1 | 33 | 100.0 | 0.0 |
| | September 11 | 77 | 100.0 | 0.0 |
| | September 21 | 31 | 100.0 | 0.0 |
| | Total | 164 | 100.0 | 0.0 |
| Site C | August 27 | 24 | 100.0 | 0.0 |
| | September 1 | 58 | 94.8 | 5.2 |
| | September 11 | 35 | 94.3 | 5.7 |
| | September 21 | 46 | 100.0 | 0.0 |
| | Total | 163 | 96.9 | 3.1 |

Table 9. Age-length relationship of lake resident populations of Arctic char. Age in years, length in mm, SD=standard deviation.

| | Chandler Lake[a] | | | | Campsite Lakes[b] | | | | Porcupine Lake[c] | | | | Schrader Lake[c] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Age | N | Mean | Length (Range) | SD | N | Mean | Length (Range) | SD | N | Mean | Length (Range) | SD | N | Mean | Length (Range) | SD |
| 0 | | | | | 18 | 57.4 | (47-69) | 7.8 | 3 | 41.3 | (35-40) | 7.0 | | | | |
| 1 | | | | | 23 | 99.3 | (68-166) | 21.0 | 2 | 81.0 | (76-86) | 7.1 | | | | |
| 2 | | | | | 23 | 144.4 | (96-215) | 21.9 | 1 | 90.0 | | | | | | |
| 3 | | | | | 4 | 189.8 | (155-215) | 10.9 | | | | | | | | |
| 4 | | | | | 3 | 248.0 | (173-311) | 56.9 | | | | | | | | |
| 5 | | | | | 4 | 347.8 | (321-381) | 23.5 | | | | | | | | |
| 6 | | | | | 2 | 285.5 | (245-326) | 40.5 | | | | | | | | |
| 7 | | | | | 2 | 365.0 | (353-377) | 12.0 | | | | | 3 | 310 | (290-322) | 14.0 |
| 8 | | | | | 6 | 396.2 | (374-433) | 21.2 | 1 | 205 | | | 3 | 338 | (309-370) | 25.0 |
| 9 | 1 | 372 | | | 6 | 412.3 | (374-449) | 25.6 | | | | | 6 | 347 | (332-358) | 9.5 |
| 10 | 2 | 424 | (416-432) | | 13 | 423.0 | (390-476) | 23.8 | | | | | 9 | 374 | (357-397) | 14.0 |
| 11 | 11 | 455 | (331-505) | | 17 | 432.1 | (375-480) | 27.1 | 1 | 167 | | | 5 | 377 | (358-448) | 29.0 |
| 12 | 6 | 499 | (485-510) | | 10 | 437.4 | (382-468) | 28.9 | 2 | 234 | (228-240) | 8.5 | 7 | 393 | (358-448) | 30.0 |
| 13 | 8 | 532 | (481-566) | | 6 | 464.8 | (410-562) | 48.6 | 1 | 248 | | | 4 | 378 | (356-410) | 22.0 |
| 14 | 4 | 537 | (508-552) | | 7 | 432.9 | (406-468) | 20.5 | 1 | 209 | | | 4 | 421 | (400-450) | 18.1 |
| 15 | 1 | 532 | | | 2 | 517.5 | (517-518) | 0.5 | | | | | 2 | 415 | (396-434) | 19.1 |
| 16 | 1 | 590 | | | 2 | 391.0 | (387-395) | 4.0 | 1 | 262 | | | 2 | 438 | (414-463) | 24.5 |
| 27 | | | | | 1 | 482 | | | | | | | | | | |
| Totals | 34 | | | | 149 | | | | 12 | | | | 45 | | | |

| | Big Lake[c] | | | | Lake CT-28[c] | | | | Lake 104[c] | | | | Lake 103[c] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Age | N | Mean | Length (Range) | SD | N | Mean | Length (Range) | SD | N | Mean | Length (Range) | SD | N | Mean | Length (Range) | SD |
| 0 | | | | | 25 | 41.7 | (31-52) | 5.7 | | | | | | | | |
| 1 | 8 | 63.5 | (59-72) | 4.2 | 2 | 82.5 | (77-88) | 7.8 | 3 | 89.3 | (87-91) | 1.7 | 6 | 86.2 | (83-94) | 3.8 |
| 2 | 20 | 81.0 | (76-97) | 7.3 | 3 | 90.0 | (83-102) | 10.4 | 17 | 123.3 | (113-144) | 7.5 | 6 | 114.0 | (106-120) | 4.5 |
| 3 | 25 | 106.0 | (74-126) | 13.5 | 12 | 154.9 | (107-177) | 21.4 | 2 | 187.0 | (178-196) | 9.0 | 14 | 133.6 | (115-173) | 15.0 |
| 4 | 43 | 119.0 | (95-138) | 9.1 | 15 | 189.9 | (159-232) | 21.9 | 13 | 105.1 | (167-256) | 30.1 | 13 | 169.2 | (129-197) | 32.0 |
| 5 | 28 | 132.0 | (119-168) | 9.3 | 4 | 193.0 | (168-215) | 0.7 | 33 | 251.5 | (172-336) | 38.6 | 18 | 207.0 | (168-277) | 32.6 |
| 6 | 23 | 126.0 | (83-160) | 15.3 | 3 | 241.0 | (220-252) | 14.8 | 40 | 291.0 | (215-387) | 40.0 | 24 | 223.9 | (173-332) | 51.1 |
| 7 | 26 | 144.0 | (93-179) | 16.2 | | | | | 29 | 316.8 | (233-389) | 37.8 | 12 | 271.3 | (185-370) | 60.1 |
| 8 | 8 | 160.0 | (135-189) | 16.3 | 3 | 347.0 | (336-361) | 11.0 | 6 | 317.8 | (290-387) | 33.7 | 11 | 355.4 | (282-395) | 31.2 |
| 9 | 10 | 149.0 | (134-178) | 14.0 | 2 | 337.0 | (315-359) | 71.0 | | | | | 4 | 361.0 | (316-405) | 33.6 |
| 10 | 7 | 171.0 | (151-184) | 11.5 | 4 | 391.0 | (360-430) | 16.0 | 1 | 387 | | | 9 | 344.1 | (174-407) | 66.7 |
| 11 | 3 | 157.0 | (132-181) | 20.0 | | | | | | | | | 2 | 408.5 | (397-420) | 11.5 |
| 12 | 3 | 167.0 | (161-177) | 7.1 | | | | | | | | | 6 | 370.7 | (340-403) | 21.9 |
| 13 | 4 | 156.0 | (131-182) | 18.1 | | | | | 2 | 391.0 | (359-423) | 52.0 | 1 | 368 | | |
| 14 | | | | | | | | | 2 | 427.0 | (393-461) | 34.0 | 3 | 403.3 | (375-422) | 20.4 |
| 15 | | | | | | | | | | | | | 1 | 415 | | |
| 16 | 1 | 160 | | | | | | | | | | | | | | |
| Totals | 209 | | | | 73 | | | | 148 | | | | 130 | | | |

[a]Furniss 1974.
[b]McCart et al. 1974.
[c]AEL file data.

Table 10. Age-length relationships of isolated stream resident populations of Arctic char. Age in years, length in mm, SD=standard deviation.

| | Shublik Springs[a] | | | | Unnamed Spring[a] | | | | Sadlerochit Spring[b] | | | | Upper Babbage River[c] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Age | N | Mean | Length (Range) | SD | N | Mean | Length (Range) | SD | N | Mean | Length (Range) | SD | N | Mean | Length (Range) | SD |
| 0 | 14 | 50.1 | | 9.7 | 42 | 53.8 | | 10.2 | 17 | 71.0 | (40-90) | | 58 | 46.1 | (31-69) | 9.0 |
| 1 | 22 | 75.0 | | 12.1 | 21 | 85.7 | | 14.0 | 11 | 91.5 | (75-114) | 8.8 | 29 | 73.1 | (55-99) | 12.2 |
| 2 | 21 | 102.8 | | 14.0 | 22 | 113.0 | | 12.4 | 37 | 114.3 | (89-166) | 17.4 | 78 | 108.0 | (80-149) | 13.9 |
| 3 | 46 | 128.9 | | 18.7 | 26 | 121.7 | | 9.2 | 25 | 139.5 | (109-190) | 18.9 | 86 | 132.8 | (78-184) | 18.5 |
| 4 | 22 | 151.7 | | 12.9 | 21 | 133.3 | | 8.9 | 23 | 151.7 | (132-175) | 9.5 | 99 | 156.3 | (131-226) | 17.5 |
| 5 | 29 | 165.1 | | 16.0 | 4 | 148.8 | | 14.2 | 14 | 169.3 | (147-210) | 15.5 | 86 | 172.5 | (131-232) | 17.0 |
| 6 | 3 | 164.7 | | 8.1 | 3 | 156.7 | | 1.5 | 3 | 180.7 | (166-196) | 12.3 | 44 | 185.9 | (151-232) | 20.4 |
| 7 | 4 | 193.3 | | 26.9 | 2 | 148.5 | | 5.0 | 1 | 153 | | | 13 | 203.9 | (165-235) | 22.4 |
| 8 | 4 | 202.5 | | 34.9 | | | | | | | | | 3 | 191.7 | (178-208) | 15.2 |
| 9 | | | | | | | | | | | | | 1 | 231 | | |
| 10 | | | | | | | | | | | | | 2 | 272.0 | (250-294) | 31.1 |
| 11 | | | | | | | | | | | | | 1 | 355 | | |
| Totals | 165 | | | | 141 | | | | 142 | | | | 500 | | | |

| | Lower Babbage River[c] | | | | Lower Babbage River[c] | | | | Cache Creek Above Falls[d] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Age | N | Mean | Length (Range) | SD | N | Mean | Length (Range) | SD | N | Mean | Length (Range) | SD |
| 0 | 87 | 58.3 | (46-67) | 4.6 | | | | | | | | |
| 1 | 64 | 93.6 | (69-115) | 10.3 | | | | | | | | |
| 2 | 36 | 114.6 | (89-145) | 12.0 | | | | | 16 | 102.9 | | 9.1 |
| 3 | 9 | 130.0 | (116-149) | 10.4 | 1 | 145 | | | 5 | 132.2 | | 10.8 |
| 4 | 4 | 153.0 | (148-162) | 5.5 | 2 | 195.5 | (172-219) | 23.5 | 9 | 161.1 | | 8.2 |
| 5 | | | | | 8 | 191.5 | (172-205) | 11.4 | 9 | 170.8 | | 36.6 |
| 6 | | | | | 3 | 220.3 | (205-241) | 15.2 | 15 | 206.1 | | 14.2 |
| 7 | | | | | 1 | 205 | | | 9 | 223.9 | | 16.2 |
| 8 | | | | | | | | | 4 | 250.3 | | 19.5 |
| 9 | | | | | 1 | 205 | | | 1 | 237 | | |
| 10 | | | | | | | | | 2 | 241.0 | | 3.0 |
| Totals | 200 | | | | 16 | | | | 70 | | | |

[a]McCart and Craig 1973.
[b]Craig 1977b.
[c]Bain 1974.
[d]McCart and Bain 1974.

Table 11. Age-length relationships of anadromous populations of Arctic char--juveniles and residual males. Age in years, length in mm, SD= standard deviation.

| | Accomplishment Creek[a] | | | | Section Creek[a] | | | | Section Creek[b] | | | | Kavik River[c] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Age | N | Mean | Length (Range) | SD | N | Mean | Length (Range) | SD | N | Mean | Length (Range) | SD | N | Mean | Length (Range) | SD |
| 0 | 3 | 56.8 | (50-69) | | 8 | 53.5 | (49-59) | | 14 | 59 | (34-74) | | | | | |
| 1 | 20 | 81.6 | (61-111) | | 41 | 67.7 | (46-85) | | 13 | 79 | (67-99) | | 36 | 96 | (45-171) | 38.5 |
| 2 | 5 | 102.6 | (83-125) | | 19 | 93.3 | (72-117) | | 28 | 111 | (78-144) | | 67 | 173 | (100-221) | 32.6 |
| 3 | 1 | 123 | | | 10 | 144.9 | (128-165) | | 17 | 143 | (128-168) | | 31 | 204 | (155-235) | 18.1 |
| 4 | | | | | 16 | 160.3 | (124-209) | | 13 | 163 | (148-178) | | 17 | 261 | (205-301) | 27.7 |
| 5 | 3 | 209.0 | (198-221) | | 5 | 188.8 | (155-204) | | 5 | 175 | (170-191) | | 20 | 293 | (261-337) | 23.6 |
| 6 | 1 | 225 | | | 11 | 208.5 | (154-250) | | 2 | 200 | (186-214) | | 3 | 331 | (300-352) | 27.2 |
| 7 | 1 | 239 | | | 3 | 214.7 | (202-231) | | 2 | 217 | (206-228) | | 2 | 338 | (311-364) | 37.5 |
| 8 | | | | | 2 | 245.5 | (231-260) | | 2 | 220 | (205-235) | | 1 | 324 | | |
| 9 | | | | | 3 | 260.0 | (222-305) | | 2 | 221 | (213-228) | | 3 | 341 | (310-376) | 33.2 |
| 10 | | | | | | | | | 2 | 233 | (218-249) | | 1 | 380 | | |
| Totals | 62 | | | | 118 | | | | 100 | | | | 182 | | | |

| | Weir Creek[d] | | | | Canning Tributaries[e] | | | | Spring CS-10[e] | | | | Spring CS-1[e] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Age | N | Mean | Length (Range) | SD | N | Mean | Length (Range) | SD | N | Mean | Length (Range) | SD | N | Mean | Length (Range) | SD |
| 0 | | | | | | | | | | | | | | | | |
| 1 | 1 | 87 | | | 10 | 77 | (59-92) | 10 | 23 | 88 | (63-113) | 13 | 27 | 80 | (55-105) | 14 |
| 2 | 28 | 139 | (100-205) | 29.2 | 24 | 103 | (77-135) | 14 | 17 | 112 | (97-133) | 11 | 36 | 99 | (66-135) | 19 |
| 3 | 16 | 180 | (55-223) | 18.7 | 7 | 123 | (102-145) | 13 | 17 | 146 | (117-198) | 21 | 14 | 140 | (123-154) | 9 |
| 4 | 7 | 204 | (181-235) | 15.7 | 10 | 156 | (134-213) | 23 | 14 | 180 | (146-231) | 27 | 9 | 155 | (132-178) | 14 |
| 5 | 2 | 252 | (205-300) | 47.0 | 4 | 170 | (145-200) | 20 | 12 | 201 | (157-252) | 36 | 3 | 183 | (178-190) | 5 |
| 6 | | | | | 9 | 202 | (166-283) | 35 | 12 | 245 | (177-296) | 33 | 3 | 172 | (167-175) | 4 |
| 7 | | | | | 1 | 194 | | | 14 | 242 | (211-280) | 26 | | | | |
| 8 | | | | | 1 | 315 | | | 5 | 281 | (225-318) | 37 | | | | |
| 9 | | | | | | | | | 4 | 274 | (240-331) | 35 | | | | |
| 10 | | | | | | | | | | | | | | | | |
| 11 | | | | | | | | | 1 | 315 | | | | | | |
| Totals | 54 | | | | 66 | | | | 119 | | | | 92 | | | |

(Continued)

Table 11. Concluded.

| Age | Firth River[f] N | Firth River[f] Length Mean | Firth River[f] Length (Range) | Firth River[f] SD | Fish Hole Creek[g] Residual Males N | Fish Hole Creek[g] Residual Males Length Mean | Fish Hole Creek[g] Residual Males Length (Range) | Fish Hole Creek[g] Residual Males SD | Fish Hole Creek[g] Juveniles N | Fish Hole Creek[g] Juveniles Length Mean | Fish Hole Creek[g] Juveniles Length (Range) | Fish Hole Creek[g] Juveniles SD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | | | | | | | 31 | 51.5 | (37-64) | 5.7 |
| 1 | 108 | 74.9 | (48-116) | | | | | | 47 | 79.0 | (54-107) | 12.2 |
| 2 | 76 | 106 | (78-153) | | | | | | 11 | 115.6 | (80-153) | 17.6 |
| 3 | 17 | 129 | (105-156) | | 8 | 162.1 | (128-184) | 16.5 | 21 | 157.0 | (109-187) | 16.5 |
| 4 | 5 | 158 | (134-185) | | 17 | 184.0 | (156-207) | 17.3 | 7 | 158.6 | (131-168) | 15.0 |
| 5 | 2 | 270 | | | 14 | 197.1 | (167-235) | 18.2 | 5 | 182.8 | (150-204) | 18.5 |
| 6 | 2 | 196 | (192-200) | | 18 | 212.1 | (184-236) | 12.8 | | | | |
| 7 | 2 | 229 | (190-268) | | 9 | 209.0 | (174-249) | 21.1 | | | | |
| 8 | 1 | 243 | | | 2 | 228.5 | (228-229) | 0.5 | | | | |
| 9 | 3 | 317 | (266-390) | | | | | | | | | |
| 10 | 1 | 220 | | | 2 | 373.5 | (352-395) | 21.5 | | | | |
| 11 | 2 | 404 | (390-418) | | | | | | | | | |
| Totals | 219 | | | | 70 | | | | 122 | | | |

[a]McCart unpublished data.
[b]Van Wyhe 1971.
[c]Craig 1977c.
[d]Craig and Poulin 1974.
[e]Craig 1977a.
[f]Glova and McCart 1974.
[g]Bain 1974.

Table 12. Age-length relationships of anadromous populations of Arctic char--migrant fish. Age in years, length in mm, N=sample size, SD=standard deviation.

| | Colville River Delta[a] | | | | Colville River[b] | | | | Thetis Island[a] | | | | Simpson Lagoon[c] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Age | N | Mean | Length (Range) | SD | N | Mean | Length (Range) | SD | N | Mean | Length (Range) | SD | N | Mean | Length (Range) | SD |
| 0 | | | | | | | | | | | | | | | | |
| 1 | | | | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | | 14 | 233 | (181-315) | 34 |
| 4 | | | | | | | | | 5 | 344 | (305-395) | | 31 | 254 | (189-329) | 35 |
| 5 | | | | | | | | | 8 | 382 | (345-440) | | 18 | 298 | (238-364) | 33 |
| 6 | 2 | 501.5 | (453-550) | | | | | | 13 | 397 | (330-455) | | 5 | 356 | (305-473) | 70 |
| 7 | 2 | 470.0 | (435-505) | | 4 | 462.5 | (440-470) | | 12 | 440 | (370-530) | | 5 | 390 | (298-454) | 63 |
| 8 | 3 | 519.3 | (430-600) | | | | | | 8 | 420 | (355-510) | | 5 | 507 | (473-539) | 30 |
| 9 | 5 | 587.6 | (550-610) | | 2 | 477.0 | (476-478) | | 3 | 422 | (370-525) | | 9 | 524 | (475-614) | 47 |
| 10 | 4 | 630.0 | (555-695) | | 2 | 519.0 | (502-536) | | 3 | 504 | (405-576) | | 21 | 554 | (480-640) | 42 |
| 11 | 1 | 590.0 | | | | | | | 1 | 605 | | | 12 | 586 | (527-662) | 46 |
| 12 | | | | | 1 | 569.0 | | | | | | | 6 | 582 | (542-680) | 51 |
| 13 | | | | | | | | | | | | | 5 | 608 | (520-703) | 79 |
| 14 | | | | | | | | | | | | | 2 | 643 | (595-690) | 67 |
| 15 | | | | | | | | | | | | | 1 | 668 | | |
| Totals | 17 | | | | 9 | | | | 53 | | | | 134 | | | |

| | Prudhoe Bay[d] | | | | Lupine River[a] | | | | Ribdon River[e] | | | | Accomplishment Creek[f] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Age | N | Mean | Length (Range) | SD | N | Mean | Length (Range) | SD | N | Mean | Length (Range) | SD | N | Mean | Length (Range) | SD |
| 0 | | | | | | | | | | | | | | | | |
| 1 | | | | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | | | | |
| 3 | 3 | 148 | (136-155) | | | | | | | | | | | | | |
| 4 | 11 | 194 | (154-265) | | | | | | | | | | | | | |
| 5 | 10 | 360 | (331-393) | | | | | | | | | | | | | |
| 6 | 10 | 380 | (346-410) | | | | | | | | | | | | | |
| 7 | 5 | 431 | (401-460) | | 1 | 560 | | | 1 | 448 | | | | | | |
| 8 | | | | | 1 | 600 | | | 2 | 462.0 | (443-481) | | 2 | 527 | (479-575) | |
| 9 | 2 | 488 | (465-510) | | 3 | 619.7 | (561-670) | | 3 | 518.0 | (453-581) | | 17 | 528 | (469-588) | |
| 10 | 23 | 503 | (450-538) | | 2 | 660.0 | (645-675) | | 2 | 552.0 | (536-568) | | 34 | 536 | (467-605) | |
| 11 | 6 | 541 | (535-549) | | 4 | 650.8 | (620-663) | | 1 | 522 | | | 17 | 555 | (507-616) | |
| 12 | 6 | 563 | (503-620) | | | | | | | | | | 2 | 572 | (562-582) | |
| 13 | | | | | | | | | 1 | 517 | | | 3 | 564 | (530-592) | |
| 14 | | | | | | | | | 2 | 571.5 | (568-575) | | | | | |
| 15 | | | | | | | | | | | | | 1 | 583 | | |
| Totals | 76 | | | | 11 | | | | 12 | | | | 76 | | | |

(Continued)

Table 12. Continued.

| Age | Accomplishment Creek[e] N | Length Mean | Length (Range) | SD | Section Creek[e] N | Length Mean | Length (Range) | SD | Section Creek[g] N | Length Mean | Length (Range) | SD | Kavik River[h] N | Length Mean | Length (Range) | SD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | | 3 | 143 | (126-154) | 15.1 |
| 2 | | | | | | | | | | | | | 15 | 207 | (180-261) | 24.7 |
| 3 | | | | | | | | | | | | | 20 | 244 | (189-291) | 28.9 |
| 4 | | | | | | | | | | | | | 8 | 310 | (272-354) | 37.3 |
| 5 | | | | | | | | | | | | | 4 | 376 | (332-438) | 44.4 |
| 6 | 2 | 473.0 | (458-488) | | | | | | 1 | 433 | | | 2 | 430 | (415-444) | 20.5 |
| 7 | 10 | 471.4 | (429-500) | | 2 | 467.0 | (463-471) | | 4 | 428 | (390-455) | | 11 | 466 | (437-483) | 16.0 |
| 8 | 29 | 480.3 | (442-554) | | 5 | 461.6 | (378-515) | | 5 | 499 | (448-570) | | 22 | 461 | (419-525) | 24.9 |
| 9 | 5 | 524.8 | (477-575) | | | | | | 1 | 498 | | | 15 | 504 | (409-626) | 58.0 |
| 10 | 2 | 511.5 | (488-535) | | | | | | 1 | 529 | | | 9 | 499 | (430-549) | 36.9 |
| 11 | 4 | 567.7 | (547-622) | | 3 | 586.3 | (540-625) | | 4 | 543 | (512-568) | | 2 | 546 | (500-592) | 65.0 |
| 12 | 4 | 585.5 | (538-657) | | 1 | 569 | | | | | | | | | | |
| 13 | | | | | 1 | 620 | | | | | | | | | | |
| Totals | 56 | | | | 12 | | | | 16 | | | | 111 | | | |

| Age | Bullen Point, 1973[i] N | Length Mean | Length (Range) | SD | Arctic Wildlife Range[j] N | Length Mean | Length (Range) | SD | Canning-Coastal Waters[k] N | Length Mean | Length (Range) | SD | Canning River[k] N | Length Mean | Length (Range) | SD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | | | | | | | | | | | | | | |
| 1 | | | | | | | | | | | | | | | | |
| 2 | | | | | | | | | 1 | 229 | | | | | | |
| 3 | | | | | 4 | 164 | (125-208) | | 8 | 249 | (184-285) | 38 | 4 | 206 | (183-253) | 32 |
| 4 | 1 | 241 | | | 2 | 267 | (265-268) | | 10 | 275 | (191-402) | 70 | 14 | 275 | (197-381) | 59 |
| 5 | | | | | 9 | 329 | (210-415) | | 6 | 392 | (370-420) | 19 | 18 | 341 | (255-434) | 48 |
| 6 | 1 | 358 | | | 15 | 358 | (318-447) | | 10 | 405 | (335-447) | 37 | 21 | 400 | (286-442) | 34 |
| 7 | 5 | 473 | (454-483) | 11.2 | 9 | 418 | (358-500) | | 14 | 453 | (392-488) | 33 | 63 | 449 | (386-513) | 32 |
| 8 | 3 | 483 | (468-500) | 16.0 | 13 | 444 | (409-500) | | 17 | 486 | (414-581) | 40 | 84 | 480 | (408-547) | 30 |
| 9 | 4 | 503 | (485-514) | 13.4 | 8 | 459 | (390-496) | | 16 | 512 | (460-620) | 34 | 50 | 501 | (431-620) | 41 |
| 10 | 2 | 613 | (587-638) | 36.1 | 2 | 495 | (461-528) | | 5 | 565 | (502-638) | 55 | 17 | 516 | (476-570) | 28 |
| 11 | | | | | 2 | 459 | (406-511) | | 4 | 515 | (473-568) | 63 | 9 | 527 | (473-575) | 39 |
| 12 | | | | | 3 | 530 | (506-545) | | 1 | 532 | | | 4 | 508 | (483-540) | 24 |
| 13 | | | | | | | | | | | | | | | | |
| 14 | 1 | 593 | | | | | | | 1 | 593 | | | 2 | 573 | (554-592) | 27 |
| Totals | 17 | | | | 67 | | | | 93 | | | | 286 | | | |

(Continued)

Table 12. Concluded.

| Age | Canning Tributaries[k] N | Length Mean | Length (Range) | SD | Spring CS-10[k] N | Length Mean | Length (Range) | SD | Barter Island[i] N | Length Mean | Length (Range) | SD | Nunaluk Lagoon[l] N | Length Mean | Length (Range) | SD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | | | | | | | | | | | | | | |
| 1 | | | | | | | | | | | | | 1 | 90.0 | | |
| 2 | | | | | | | | | | | | | 4 | 140.0 | (108-180) | 32.2 |
| 3 | | | | | | | | | 225 | | (190-225) | | 12 | 185.8 | (144-296) | 49.5 |
| 4 | 1 | 217 | | | 1 | 299 | | | 285 | | (240-320) | | 9 | 286.4 | (190-386) | 66.5 |
| 5 | | | | | 5 | 288 | (267-312) | 16 | 345 | | (245-390) | | 19 | 373.1 | (304-444) | 35.4 |
| 6 | 2 | 318 | (208-318) | | 4 | 336 | (286-416) | 49 | 385 | | (330-420) | | 94 | 425.7 | (330-530) | 37.7 |
| 7 | 1 | 279 | | | 16 | 441 | (352-463) | 25 | 420 | | (360-550) | | 80 | 458.2 | (379-556) | 32.9 |
| 8 | 1 | 426 | | | 14 | 471 | (440-505) | 21 | 435 | | (390-490) | | 10 | 503.0 | (447-570) | 38.1 |
| 9 | | | | | 3 | 533 | (521-545) | 10 | 470 | | (415-505) | | 10 | 514.4 | (456-557) | 31.6 |
| 10 | | | | | 2 | 496 | (478-514) | 18 | 505 | | (430-560) | | 8 | 516.9 | (492-566) | 26.9 |
| 11 | | | | | 1 | 532 | | | 570 | | (500-635) | | 3 | 533.7 | (477-576) | 51.0 |
| 12 | | | | | | | | | 560 | | (495-680) | | 2 | 518.5 | (515-522) | 4.9 |
| 13 | | | | | | | | | | | | | | | | |
| 14 | 1 | 409 | | | | | | | | | | | | | | |
| Totals | 6 | | | | 46 | | | | | | | | 252 | | | |

| Age | Firth River[m] N | Length Mean | Length (Range) | SD | Phillips Bay[n] N | Length Mean | Length (Range) | SD | Fish Hole Creek[o] N | Length Mean | Length (Range) | SD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | | | | | | | | | | |
| 1 | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | |
| 3 | 29 | 272 | (125-305) | | | | | | 11 | 272.1 | (225-298) | 29.3 |
| 4 | 56 | 336 | (244-407) | | 4 | 360 | (315-405) | | 18 | 303.3 | (233-372) | 42.0 |
| 5 | 66 | 368 | (167-522) | | 12 | 405 | (275-535) | | 25 | 360.9 | (279-470) | 56.3 |
| 6 | 30 | 432 | (310-525) | | 16 | 430 | (310-535) | | 22 | 451.2 | (343-560) | 51.0 |
| 7 | 25 | 471 | (373-578) | | 4 | 490 | (460-545) | | 17 | 478.7 | (405-546) | 45.0 |
| 8 | 34 | 522 | (429-618) | | 3 | 455 | (435-500) | | 8 | 520.5 | (475-556) | 32.6 |
| 9 | 16 | 541 | (420-632) | | 2 | 525 | (520-530) | | 4 | 497.3 | (470-513) | 17.0 |
| 10 | 10 | 537 | (434-665) | | 1 | 680 | | | 6 | 531.3 | (474-629) | 64.6 |
| 11 | 4 | 610 | (582-638) | | | | | | 1 | 559 | | |
| 12 | 3 | 637 | (588-685) | | | | | | | | | |
| 13 | 3 | 597 | (575-636) | | | | | | | | | |
| 14 | 3 | 709 | (701-720) | | | | | | | | | |
| 15 | 2 | 624 | (615-633) | | | | | | | | | |
| Totals | 281 | | | | 42 | | | | 112 | | | |

[a]Roguski and Winslow 1970.
[b]Kogl 1971.
[c]Craig and Griffiths 1978.
[d]Furniss 1975.
[e]McCart unpublished data.
[f]Furniss 1974.
[g]Van Wyhe 1971.
[h]Craig 1977c.
[i]Griffiths et al. 1977.
[j]Roguski and Komarek 1971.
[k]Craig 1977a.
[l]Griffiths et al. 1975.
[m]Glova and McCart 1974.
[n]Kendel et al. 1974.
[o]Bain 1974.

Table 13. Summary of age/length data for major life history types. NP indicates number of populations represented in each age group, NI indicates number of individuals. Mean values are the mean of means calculated from data presented in Tables 9 through 12; ranges are ranges of means from the same tables.

| | Lake Resident | | | | Isolated Stream Resident | | | | Juveniles and Residual Males | | | | Migrant | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Length | | | | Length | | | | Length | | | | Length | |
| Age | NP | NI | Mean | (Range) | NP | NI | Mean | (Range) | NP | NI | Mean | (Range) | NP | NI | Mean | (Range) |
| 0 | 3 | 46 | 46.8 | (41.3-57.4) | 5 | 218 | 55.9 | (46.1-71) | 4 | 84 | 55.2 | (51.5-59) | | | | |
| 1 | 6 | 44 | 83.6 | (63.5-99.3) | 5 | 158 | 83.8 | (73.1-93.6) | 10 | 326 | 81.0 | (67.7-96) | 2 | 4 | 116.5 | (90-143) |
| 2 | 6 | 70 | 107.1 | (81 -144.4) | 6 | 210 | 109.3 | (102.8-114.6) | 10 | 311 | 115.5 | (93.3-173) | 3 | 20 | 192.0 | (140-229) |
| 3 | 5 | 57 | 154.3 | (106 -189.8) | 7 | 198 | 132.9 | (121.7-145) | 11 | 159 | 150.2 | (123 -204) | 10 | 116 | 219.9 | (148-272.1) |
| 4 | 5 | 87 | 186.2 | (119 -248) | 7 | 180 | 157.5 | (133.3-195.5) | 10 | 115 | 178.0 | (155 -261) | 15 | 169 | 283.1 | (194-360) |
| 5 | 5 | 87 | 226.3 | (132 -347.8) | 6 | 150 | 169.7 | (148.8-191.5) | 11 | 75 | 211.1 | (170 -293) | 13 | 207 | 355.2 | (288-405) |
| 6 | 5 | 92 | 233.5 | (126 -291) | 6 | 71 | 185.7 | (156.7-220.3) | 9 | 61 | 221.3 | (172 -331) | 18 | 234 | 398.3 | (318-501.5) |
| 7 | 5 | 72 | 281.4 | (144 -365) | 6 | 30 | 187.9 | (148.5-223.9) | 8 | 34 | 235.3 | (194 -338) | 22 | 291 | 447.0 | (279-560) |
| 8 | 6 | 38 | 319.1 | (160 -396.2) | 3 | 11 | 214.8 | (191.7-250.3) | 7 | 14 | 265.3 | (220 -324) | 21 | 269 | 483.9 | (420-600) |
| 9 | 6 | 29 | 329.7 | (149 -412.3) | 3 | 3 | 224.3 | (205 -237) | 5 | 15 | 282.6 | (221 -341) | 21 | 178 | 511.8 | (422-619.7) |
| 10 | 7 | 45 | 359.2 | (171 -424) | 2 | 4 | 256.5 | (241 -272) | 4 | 6 | 301.6 | (220 -380) | 21 | 156 | 545.4 | (495-680) |
| 11 | 5 | 38 | 365.9 | (157 -455) | 1 | 1 | | | 3 | 4 | 371.7 | (315 -404) | 19 | 78 | 557.8 | (459-650.8) |
| 12 | 6 | 34 | 350.2 | (167 -499) | | | | | | | | | 12 | 33 | 560.5 | (508-637) |
| 13 | 7 | 26 | 362.5 | (156 -532) | | | | | | | | | 5 | 13 | 581.2 | (517-620) |
| 14 | 6 | 21 | 405.0 | (209 -537) | | | | | | | | | 7 | 12 | 584.5 | (409-709) |
| 15 | 4 | 6 | 469.9 | (415 -532) | | | | | | | | | 3 | 4 | 625 | (583-668) |
| 16 | 5 | 7 | 368.2 | (160 -590) | | | | | | | | | | | | |
| 27 | 1 | 1 | 482 | | | | | | | | | | | | | |

Table 14. Age composition and fork lengths of juvenile migrant char, Foggy Island, Alaska, June-August, 1972. Data from Yoshihara (1973).

| | First Time Migrants | | | | Second Time Migrants | | | | Third Time Migrants | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Percent of | Length | | | Percent of | Length | | | Percent of | Length | |
| Age | N | Total | Mean | Range | N | Total | Mean | Range | N | Total | Mean | Range |
| 2 | 1 | 0.7 | 145 | | | | | | | | | |
| 3 | 61 | 40.3 | 152.4 | (132-226) | | | | | | | | |
| 4 | 83 | 55.0 | 165.6 | (140-241) | 8 | 30.8 | 258.6 | (217-282) | | | | |
| 5 | 4 | 4.0 | 195.2 | (180-217) | 15 | 57.7 | 277.1 | (240-301) | 8 | 38.1 | 339.1 | (311-374) |
| 6 | | | | | 3 | 11.5 | 256.3 | (231-298) | 12 | 57.1 | 369.2 | (323-404) |
| 7 | | | | | | | | | 1 | 4.8 | 393.0 | |
| Totals | 151 | | 161.3 | (132-241) | 26 | | 269.0 | (217-301) | 21 | | 358.9 | (311-404) |

Table 15. Lengths of pre-emergent and newly emergent fry of Arctic char from the study area.

| Location | Life History Type | Length (mm) Mean | Range | Date | Reference |
|---|---|---|---|---|---|
| Sagavanirktok Drainage | Anadromous | 19.8 | (17-21) | April 21 | Yoshihara 1973 |
| | | 23.1 | (19-27) | May 15 | |
| | | 23.2 | (21-26) | May 28 | |
| | | 24.3 | (22-27) | June 13 | |
| | | 25.0 | (24-26) | July 2 | |
| Accomplishment and Section creeks | Anadromous | 23.7 | (20-27) | May 18 | McCart et al. 1972 |
| Canning Spring CS-1 | Anadromous | 22 | (19-24) | April 11 | Craig 1977a |
| Canning Spring CS-10 | Anadromous | 21 | (20-26) | April 11 | Craig 1977a |
| Joe Creek | Anadromous | 26 | (22-32) | May 22 | Glova and McCart 1974 |
| Fish Hole Creek | Anadromous | 22.7 | (16-26) | May 11 | Bain 1974 |
| Upper Babbage River | Isolated Freshwater Resident | 20.3 | (19-21) | May 11 | Bain 1974 |

Table 16. Date specific comparisons of mean fork lengths of Arctic char fry, 1972-1973. From Bain (1974).

| | | | | |
|---|---|---|---|---|
| Upper Babbage (28 July 1972) $\bar{x} \pm$ (SD) | Upper Babbage (25 July 1973) $\bar{x} \pm$ (SD) | d.f. | t-value | Probability |
| 38.6 $\pm$ (4.29) | 34.7 $\pm$ (4.51) | 65 | 3.541 | P<0.01 |
| Fish Hole Creek (28 August 1972) $\bar{x} \pm$ (SD) | Fish Hole Creek (27 August 1973) $\bar{x} \pm$ (SD) | d.f. | t-value | Probability |
| 45.9 $\pm$ (5.49) | 42.7 $\pm$ (6.65) | 67 | 2.075 | P<0.05 |
| Lower Babbage (28 August 1972) $\bar{x} \pm$ (SD) | Lower Babbage (29 August 1973) $\bar{x} \pm$ (SD) | d.f. | t-value | Probability |
| 57.3 $\pm$ (3.96) | 57.2 $\pm$ (3.52) | 40 | 0.068 | P>0.05 |
| Upper Babbage (3-9 September 1972) $\bar{x} \pm$ (SD) | Upper Babbage (12 September 1973) $\bar{x} \pm$ (SD) | d.f. | t-value | Probability |
| 57.5 $\pm$ (5.77) | 49.5 $\pm$ (3.91) | 42 | 4.917 | P<0.01 |

$\bar{x}$ = mean fork length.
SD = standard deviation.
d.f. = degree of freedom.

Table 17. Age at first seaward migration determined from otoliths. Sagavanirktok data from McCart et al. (1972); Fish Hole Creek data from Bain (1974).

| Age at Migration | Sagavanirktok Drainage Males | Females | Total | (%) | Fish Hole Creek Males | Females | Total | (%) | Total | (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | - | 4 | 4 | (7) | 2 | 5 | 7 | (9) | 11 | (8) |
| 2 | 9 | 22 | 31 | (55) | 12 | 23 | 35 | (43) | 66 | (48) |
| 3 | 1 | 12 | 13 | (23) | 10 | 18 | 28 | (35) | 41 | (30) |
| 4 | 1 | 6 | 7 | (13) | 2 | 8 | 10 | (12) | 17 | (12) |
| 5 | 1 | - | 1 | (2) | 1 | - | 1 | (1) | 2 | (2) |
| Totals | 12 | 44 | 56 | (100) | 27 | 54 | 81 | (100) | 137 | (100) |

Table 18. Age specific sex ratios of juvenile and residual Arctic char from nine anadromous populations in the study area. Sources various.

| Age | Sample Size | Percent Male | Chi Square | Populations Where Age Group Represented | Age | Sample Size | Percent Male | Chi Square | Populations Where Age Group Represented |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 232 | 50.9 | 0.1 | 7 | 7 | 38 | 97.4 | 34.1 | 8 |
| 2 | 326 | 46.0 | 2.1 | 8 | 8 | 17 | 100.0 | - | 7 |
| 3 | 178 | 55.6 | 2.2 | 9 | 9 | 18 | 100.0 | - | 6 |
| 4 | 130 | 77.7 | 39.9 | 8 | 10 | 7 | 85.7 | 3.6 | 5 |
| 5 | 83 | 84.3 | 39.1 | 9 | 11 | 4 | 100.0 | - | 3 |
| 6 | 74 | 97.3 | 66.2 | 8 | 12 | 1 | 100.0 | - | 1 |

Table 19. Weight-length relationships of Arctic char found in study area.

| Location | N | Length (mm) Mean | Length (mm) (Range) | Weight (g) Mean | Weight (g) (Range) | Weight-Length Relationship | r | Reference |
|---|---|---|---|---|---|---|---|---|
| LAKE RESIDENT POPULATIONS | | | | | | | | |
| Chandler Lake | 34 | 492.6 | (372-590) | 1284.0 | (569-1808) | $Log_{10}$ W = -4.06 + 2.65 $Log_{10}$ L | 0.99 | Furniss 1974 |
| Campsite Lakes | 133 | - | - | - | - | $Log_{10}$ W = -4.89 + 2.95 $Log_{10}$ L | 0.99 | McCart et al. 1972 |
| Big Lake | 149 | - | (60-189) | - | - | $Log_{10}$ W = -3.73 + 2.37 $Log_{10}$ L | 0.91 | Craig 1977a |
| Lake CT-28 | 56 | 189.3 | (44-430) | 156.0 | (1.3-995) | $Log_{10}$ W = -4.87 + 2.98 $Log_{10}$ L | 0.99 | AEL data |
| Schrader Lake | 45 | 297.0 | (27-436) | 423.8 | (0.3-955.5) | $Log_{10}$ W = -5.10 + 3.04 $Log_{10}$ L | 0.99 | AEL data |
| Lake 103 | 86 | 270.5 | (83-422) | 227.9 | (5.9-655.5) | $Log_{10}$ W = -4.66 + 2.83 $Log_{10}$ L | 0.99 | AEL data |
| Lake 104 | 147 | 260.5 | (87-461) | 207.0 | (6.7-761.9) | $Log_{10}$ W = -4.88 + 2.94 $Log_{10}$ L | 0.99 | AEL data |
| Overall | 650 | 302.0 | (27-590) | 459.7 | (0.3-1808) | | | |
| STREAM RESIDENT POPULATIONS | | | | | | | | |
| Sadlerochit River | 74 | - | (40-210) | - | - | $Log_{10}$ W = -5.11 + 3.05 $Log_{10}$ L | 0.98 | Craig 1977b |
| Lower Babbage River | 76 | - | - | - | - | $Log_{10}$ W = -5.12 + 3.05 $Log_{10}$ L | 0.99 | Bain 1974 |
| Upper Babbage River | 237 | - | - | - | - | $Log_{10}$ W = -4.87 + 2.96 $Log_{10}$ L | 0.94 | Bain 1974 |
| Overall | 387 | | (40-210) | | | | | |
| ANADROMOUS POPULATIONS - JUVENILES AND RESIDUAL MALES | | | | | | | | |
| Kavik River | 109 | - | (45-321) | - | - | $Log_{10}$ W = -3.89 + 2.50 $Log_{10}$ L | 0.93 | Craig 1977c |
| Canning River | 171 | - | (55-331) | - | - | $Log_{10}$ W = -4.97 + 2.98 $Log_{10}$ L | 0.99 | Craig 1977a |
| Firth River | 471 | - | - | - | - | $Log_{10}$ W = -4.59 + 2.79 $Log_{10}$ L | 0.99 | Glova and McCart 1974 |
| Fish Hole Creek[a] | 47 | - | - | - | - | $Log_{10}$ W = -4.15 + 2.63 $Log_{10}$ L | 0.98 | Bain 1974 |
| Fish Hole Creek[b] | 58 | - | - | - | - | $Log_{10}$ W = -4.76 + 2.90 $Log_{10}$ L | 0.99 | Bain 1974 |
| Overall | 856 | | (45-331) | | | | | |
| ANADROMOUS POPULATIONS - MIGRANTS | | | | | | | | |
| Prudhoe Bay | 76 | 400.9 | (136-620) | 962.0 | (23-2666) | $Log_{10}$ W = -5.42 + 3.16 $Log_{10}$ L | 0.99 | Furniss 1975 |
| Sagavanirktok River | 1331 | 444.1 | (212-600) | 947.0 | (90-2005) | $Log_{10}$ W = -5.09 + 3.03 $Log_{10}$ L | 0.99 | Yoshihara 1973 |
| Sagavanirktok River | 326 | - | - | - | - | $Log_{10}$ W = -3.83 + 2.55 $Log_{10}$ L | 0.99 | McCart et al. 1972 |
| Kavik River | 76 | - | (186-626) | - | - | $Log_{10}$ W = -4.82 + 2.92 $Log_{10}$ L | 0.99 | Craig 1977c |
| Canning R.-coastal area | 113 | - | (184-638) | - | - | $Log_{10}$ W = -5.10 + 3.03 $Log_{10}$ L | 0.98 | Craig 1977a |
| Canning River | 162 | - | (232-592) | - | - | $Log_{10}$ W = -5.00 + 2.99 $Log_{10}$ L | 0.98 | Craig 1977a |
| Spring CS-10 | 118 | 215.7 | (52-545) | 185.5 | (0.8-1537.1) | $Log_{10}$ W = -5.17 + 3.07 $Log_{10}$ L | 0.99 | AEL data |
| Nunaluk Lagoon | 75 | - | (108-576) | - | - | $Log_{10}$ W = -5.34 + 3.08 $Log_{10}$ L | 0.99 | Griffiths et al. 1975 |
| Firth River | 279 | - | - | - | - | $Log_{10}$ W = -4.53 + 2.81 $Log_{10}$ L | 0.99 | Glova and McCart 1974 |
| Fish Hole Creek | 107 | - | - | - | - | $Log_{10}$ W = -4.82 + 2.93 $Log_{10}$ L | 0.98 | Bain 1974 |
| Cache Creek | 18 | 376.2 | (299-434) | 556.6 | (263.2-840.2) | $Log_{10}$ W = -4.19 + 2.69 $Log_{10}$ L | 0.92 | AEL data |
| Rat River | 240 | - | (301-590) | - | - | ln W = -9.51 + 2.69 ln L | | Jessop et al. 1973 |
| Rat River | 17 | - | (460-570) | - | - | ln W =-12.80 + 3.16 ln L | | Jessop et al. 1973 |
| Overall | 2938 | 359.2 | (52-638) | 662.8 | (0.8-2666) | | | |

[a]Equation refers to residual males.
[b]Equation refers to juveniles.

Table 20. Sex ratios of samples of Arctic char from the study area. Asterisks indicate P<0.05.

| Location | N | % Male | $X^2$ | Reference |
|---|---|---|---|---|
| LAKE RESIDENT POPULATIONS | | | | |
| Chandler Lake | 34 | 67.7 | 4.2* | Furniss 1974 |
| Campsite Lakes | 111 | 62.2 | 6.6* | McCart et al. 1972 |
| Schrader Lake | 46 | 54.4 | 0.3 | AEL file data |
| Big Lake | 159 | 45.3 | 1.4 | AEL file data |
| Lake CT-28 | 41 | 56.1 | 0.6 | AEL file data |
| Lake 104 | 141 | 32.0 | 18.4* | AEL file data |
| Lake 103 | 130 | 45.4 | 1.1 | AEL file data |
| Total | 662 | 47.7 | 1.4 | |
| ISOLATED STREAM RESIDENT POPULATIONS | | | | |
| Shublik Springs | 142 | 42 | 3.4 | McCart and Craig 1973 |
| Unnamed Springs | 90 | 47 | 0.4 | McCart and Craig 1973 |
| Sadlerochit Springs | 142 | 42 | 3.4 | Craig 1977b |
| Upper Babbage River | 444 | 45.5 | 3.6 | Bain 1974 |
| Lower Babbage River | 129 | 49.6 | <0.1 | Bain 1974 |
| Cache Creek, above falls | 70 | 46 | 0.5 | McCart and Bain 1974 |
| Total | 1017 | 45.2 | 8.1* | |
| ANADROMOUS POPULATIONS - JUVENILES | | | | |
| Sagavanirktok River | 208 | 52.4 | 0.5 | McCart et al. 1972 |
| Accomplishment Creek | 6 | 67 | 0.7 | McCart 1972 (unpublished) |
| Section Creek | 37 | 59.5 | 1.3 | McCart 1972 (unpublished) |
| Section Creek | 90 | 43.3 | 1.6 | Van Wyhe 1971 |
| Kavik River | 164 | 57.9 | 4.1* | Craig 1977c |
| Kavik River, Weir Creek | 64 | 45 | 0.6 | Craig and Poulin 1975 |
| Canning River | 215 | 58.6 | 6.4* | Craig 1977a |
| Firth River | 208 | 52.4 | 0.5 | Glova and McCart 1974 |
| Fish Hole Creek | 94 | 57.5 | 2.1 | Bain 1974 |
| Total | 1086 | 54.1 | 7.1* | |
| ANADROMOUS POPULATIONS - RESIDUALS | | | | |
| Sagavanirktok River | 22 | 100 | - | McCart et al. 1972 |
| Accomplishment Creek | 12 | 100 | - | McCart 1972 (unpublished) |
| Section Creek | 19 | 100 | - | McCart 1972 (unpublished) |
| Section Creek | 10 | 90 | 6.4* | Van Wyhe 1971 |
| Kavik River | 11 | 100 | - | Craig 1977c |
| Canning River | 53 | 96.2 | 45.3* | Craig 1977a |
| Firth River | 11 | 100 | - | Glova and McCart 1974 |
| Fish Hole Creek | 70 | 100 | - | Bain 1974 |
| Total | 198 | 98.5 | 186.1* | |
| ANADROMOUS POPULATIONS - MIGRANTS (Taken in Marine Locations) | | | | |
| Colville River Delta | 17 | 52.9 | 0.1 | Roguski and Winslow 1970 |
| Thetis Island | 148 | 44.0 | 2.2 | Roguski and Winslow 1970 |
| Simpson Lagoon | 143 | 29 | 26.0* | Craig and Griffiths 1978 |
| Prudhoe Bay | 127 | 37.0 | 8.6* | Furniss 1975 |
| Bullen Point, 1975 | 17 | 45.5 | 0.1 | Griffiths et al. 1977 |
| Bullen Point, 1973 | 11 | 35.3 | 0.8 | Griffiths et al. 1977 |
| Arctic Wildlife Range | 173 | 34.7 | 16.2* | Roguski and Komarek 1971 |
| Kaktovik Lagoon | 133 | 37.6 | 8.2* | Griffiths et al. 1977 |
| Nunaluk Lagoon | 272 | 40.2 | 10.7 | Griffiths et al. 1975 |
| Herschel Island | 191 | 36.6 | 9.3 | Kendel et al. 1974 |
| Total | 1232 | 37.6 | 76.0* | |

(Continued)

Table 20. Concluded.

| Location | N | % Male | $X^2$ | Reference |
|---|---|---|---|---|
| ANADROMOUS POPULATIONS - MIGRANTS (Taken on Spawning Grounds) | | | | |
| Echooka Springs | 241 | 28.2 | 45.7* | Furniss 1975 |
| Echooka Springs | 6 | 33 | 0.7 | Furniss 1974 |
| Echooka Springs | 131 | 18.3 | 52.6* | Yoshihara 1973 |
| Ivishak Spawning Site | 202 | 22.8 | 59.9* | Furniss 1975 |
| Ivishak Spawning Site | 2 | 0 | - | Furniss 1974 |
| Ivishak Spawning Site | 379 | 23.0 | 110.9* | Yoshihara 1974 |
| Saviukviayak River | 210 | 23.8 | 57.6* | Furniss 1975 |
| Lupine River | 156 | 23.7 | 43.1* | Furniss 1975 |
| Lupine River | 84 | 26 | 19.0* | Furniss 1974 |
| Lupine River | 114 | 35.1 | 5.9* | Yoshihara 1974 |
| Ribdon River | 12 | 17 | 5.3* | McCart 1972 (unpublished) |
| Ribdon River | 96 | 25.0 | 24.0* | Yoshihara 1973 |
| Accomplishment Creek | 318 | 12.0 | 184.2* | Furniss 1975 |
| Accomplishment Creek | 92 | 16 | 41.8* | Furniss 1974 |
| Accomplishment Creek | 109 | 11 | 66.3* | McCart 1972 (unpublished) |
| Accomplishment Creek | 392 | 27.3 | 80.8* | Yoshihara 1974 |
| Section Creek | 12 | 17 | 5.3* | McCart 1972 (unpublished) |
| Fish Hole Creek | 444 | 45.5 | 3.6 | Bain 1974 |
| Total | 3000 | 25.9 | 697.0* | |
| ANADROMOUS POPULATIONS - MIGRANTS (Taken at Overwintering Locations) | | | | |
| Ivishak River | 1920 | 37.8 | 74.4* | Furniss 1975 |
| Ivishak River | 71 | 27 | 15.3* | Furniss 1974 |
| Total | 1991 | 37.4 | 126.1* | |
| ANADROMOUS POPULATIONS - MIGRANTS (Taken at Unspecified Freshwater Locations) | | | | |
| Colville River | 9 | 11.1 | 5.4* | Kogl 1971 |
| Sagavanirktok River | 16 | 18.8 | 6.2* | Van Wyhe 1971 |
| Sagavanirktok River | 345 | 25 | 86.7* | McCart et al. 1972 |
| Kavik River | 111 | 27 | 23.4* | Craig 1977c |
| Canning River | 427 | 26 | 98.4* | Craig 1977a |
| Firth River | 481 | 40.2 | 18.8* | Glova and McCart 1974 |
| Rat River | 279 | 42.7 | 6.0* | Jessop et al. 1973 |
| Total | 1668 | 32.6 | 201.7* | |
| ANADROMOUS POPULATIONS - MIGRANTS (Combined) | | | | |
| Total | 7891 | 32.2 | 999.9* | |

Table 21. Localities, incidence, and intensity of helminth and arthropod parasites collected from *Salvelinus alpinus* in Yukon Territory and Alaska. From Mudry and McCart (1976).

| Locality and Parasite | Number of Fish Infected/ Examined | Infection Intensity Range (Mean) | Infection Site | Host Life History Type[a] |
|---|---|---|---|---|
| Porcupine Lake, Alaska (68°47'N, 146°30'W) | | | | FWR Eastern |
| *Crepidostomum farionis* | 4/7 | 1-2 (1.2) | Intestine | |
| *Bunodera luciopercae* | 7/7 | 107-289 (196) | Intestine | |
| *Cyathocephalus truncatus* | 4/7 | 1-34 (13) | Pyloric caeca | |
| *Metchinorhynchus salmonis* | 7/7 | 31-95 (60) | Intestine | |
| "Campsite Lake", Alaska (Unnamed headwater lake, 68°36'N, 149°06'W) | | | | FWR Eastern |
| *Phyllodistomum* sp. | 4/4 | 22-71 (54) | Kidney | |
| *Eubothrium* sp. | 3/4 | 1 (1) | Pyloric caeca | |
| "Big Lake", Alaska (Unnamed headwater lake, 68°49'N, 145°47'W) | | | | FWR Eastern |
| *Bunodera luciopercae* | 5/12 | 2-27 (10) | Intestine | |
| *Proteocephalus* sp. | 9/12 | 2-98 (18) | Pyloric caeca | |
| Unnamed Lake on tributary to Canning River, Alaska (69°26'N, 146°00'W) | | | | FWR Western |
| *Crepidostomum farionis* | 4/5 | 9-33 (19) | Intestine | |
| *Bunodera luciopercae* | 4/5 | 38-163 (128) | Intestine | |
| *Cyathocephalus truncatus* | 3/5 | 2-3 (2.3) | Pyloric caeca | |
| Shublik Spring, Alaska (69°27'N, 146°11'W) | | | | FWR Western |
| *Bulbodacnitis alpinus* | 12/12 | 1-23 (6.4) | Pyloric caeca | |
| Babbage River, Yukon (68°38'N, 139°20'W) | | | | FWR Western |
| *Tetraonchus alaskensis* | 3/29 | 1-2 (1.3 | Gills | |
| *Bulbodacnitis alpinus* | 19/29 | 1-75 (13) | Pyloric caeca | |
| *Salmincola edwardsii* | 2/29 | 1-2 (1.5) | Gills | |
| Joe Creek, Yukon (68°53'N, 140°59'W) | | | | ANAD Western |
| *Tetraonchus alaskensis* | 3/41 | 1-4 (2.3) | Gills | |
| *Brachyphallus crenatus* | 4/41 | 1-2 (1.7) | Intestine | |
| *Cyathocephalus truncatus* | 2/41 | 1 (1) | Pyloric caeca | |
| *Proteocephalus* sp. | 5/41 | 1-3 (1.6) | Pyloric caeca | |
| *Bulbodacnitis alpinus* | 27/41 | 1-132 (24) | Pyloric caeca | |
| *Cystidicola stigmatura* | 25/41 | 1-410 (63) | Swim bladder | |
| *Salmincola edwardsii* | 2/41 | 1-2 (1.5) | Gills | |
| *Salmincola carpionis* | 5/41 | 1 (1) | Gills | |
| Upper Firth Delta, Yukon (69°28'N, 139°30'W) | | | | ANAD Western |
| *Tetraonchus alaskensis* | 1/13 | 23 (23) | Gills | |
| *Brachyphallus crenatus* | 1/13 | 2 (2) | Intestine | |
| *Salmincola edwardsii* | 1/13 | 1 (1) | Gills | |
| "Kavik Tributary", Alaska (69°37'N, 137°03'W) | | | | ANAD Western |
| *Bunodera luciopercae* | 1/3 | 1 (1) | Intestine | |
| *Bothrimonus sturionis* | 1/3 | 6 (6) | Pyloric caeca | |
| *Proteocephalus* sp. | 1/3 | 4 (4) | Pyloric caeca | |
| *Bulbodacnitis alpinus* | 1/3 | 38 (38) | Pyloric caeca | |
| *Salmincola edwardsii* | 1/3 | 1 (1) | Gills | |
| Shaviovik River, Alaska (69°49'N, 147°37'W) | | | | ANAD Western |
| *Proteocephalus* sp. | 1/1 | 5 (5) | Pyloric caeca | |
| *Cystidicola stigmatura* | 1/1 | 3 (3) | Swim bladder | |
| *Salmincola edwardsii* | 1/1 | 11 (11) | Gills | |
| *Salmincola carpionis* | 1/1 | 2 (2) | Gills | |
| Echooka Springs, Alaska (69°16'N, 147°27'W) | | | | ANAD Western |
| *Bulbodacnitis alpinus* | 1/1 | 159 (159) | Pyloric caeca | |

[a]FWR, freshwater resident population; ANAD, anadromous population.

Table 22. List of references which include data describing the food habits of Arctic char.

| | Reference | Locality | | Reference | Locality |
|---|---|---|---|---|---|
| 1. | AEL file data | Various | 11. | Furniss 1975 | Prudhoe Bay |
| 2. | Bain 1974 | Babbage River | 12. | Glova and McCart 1974 | Firth River |
| 3. | Bendock 1977 | Prudhoe Bay | 13. | Griffiths et al. 1975 | Nunaluk Lagoon |
| 4. | Bryan et al. 1973 | Fish Hole Creek | 14. | Griffiths et al. 1977 | Kaktovik Lagoon |
| 5. | Craig 1977a | Canning River Spring, CT-28, Big Lake | 15. | Jessop et al. 1973 | Rat River |
| | | | 16. | Kogl 1971 | Colville River |
| 6. | Craig 1977b | Sadlerochit River | 17. | McCart and Craig 1973 | Shublik and Unnamed Springs |
| 7. | Craig 1977c | Kavik River | 18. | McCart et al. 1972 | Sagavanirktok River |
| 8. | Craig and Griffiths 1978 | Simpson Lagoon | 19. | Stein et al. 1973 | Mackenzie River |
| 9. | de Graaf and Machniak 1977 | Mackenzie River | 20. | Yoshihara 1973 | Sagavanirktok River |
| 10. | Furniss 1974 | Chandler Lake | | | |

Table 23. Food items eaten by Arctic char resident in lakes in the study area. All values are percent occurrence and refer only to those stomachs containing food. NNST+ninespine stickleback. References as listed in Table 22.

| Location: | Lake 103 | | | | | Lake 104 | | | | Schrader | Big | CT-28 | Porcupine | Campsite | Atigun | Galbraith | Chandler | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Reference: | 1 | | | | | | | | | 1 | 5 | 5 | 1 | 18 | 1 | 1 | 10 | Percent |
| Length Range (mm): | 83-94 | 106-199 | 201-299 | 309-422 | Total | 87-196 | 203-297 | 301-461 | Total | 290-463 | 61-189 | 77-430 | 203-248 | 196-490 | 463-503 | 422-523 | 331-590 | Occurrence |
| Insecta | | | | | | | | | | | | | | | | | | |
| Ephemeroptera | | | | 3 | 1 | | | | | | | | | | | | | <1 |
| Plecoptera | | | | 3 | 1 | | | | | 7 | 7 | 28 | 20 | | | | 10 | 4 |
| Trichoptera | | 33 | 33 | 40 | 34 | 75 | 42 | 18 | 47 | 13 | 17 | 21 | | 11 | | | 4 | 26 |
| Orthoptera | | | | | | | | | | | 1 | | | | | | 4 | <1 |
| Hymenoptera | | | | | | | | | | 33 | 4 | | | | | | 14 | 4 |
| Coleoptera | | | | 5 | 2 | | 2 | | 1 | 4 | 2 | | | 3 | | | 17 | 3 |
| Chironomidae larvae | | 2 | 24 | 23 | 13 | | 9 | 4 | 6 | 89[a] | 34[a] | 31[a] | 100 | 1 | | | | 22 |
| pupae | | | | | | | | | | | 27[a] | | | | | | | 6 |
| adults | | | | | | | | | | | 41[a] | 3[a] | | | | | | 9 |
| Culicidae larvae | | | | | | | | | | | | | | | | | 90 | 5 |
| pupae | | | | | | | | | | | | | | | | | 55 | 3 |
| Simuliidae | | | | | | | | | | 24 | 8 | 17 | | | | | | 5 |
| Tipulidae | | | | | | | | | | 13 | 2 | | | | | | | 2 |
| Unidentified diptera | | | | | | 4 | 3 | | 2 | | | | | | | | 41 | 3 |
| Terrestrial insects | | 10 | 19 | 3 | 8 | | 5 | 16 | 8 | 11 | | | | 20 | | | 10 | 8 |
| Crustacea | | | | | | | | | | | | | | | | | | |
| Amphipoda | | | | | | | | | | | 1 | 62 | 60 | | | | | 4 |
| Cladocera | 100 | 47 | 10 | | 27 | | | 1 | 1 | | 14 | | | 10 | | | | 10 |
| Conchostraca | | | | | | | | | | | 4 | | | | | | | 1 |
| Copepoda | | | | | | | | | | | 4 | | | | | | | 1 |
| Aranea | | | | | | | | | | | 5 | | | | | | | 1 |
| Hydracarina | | | 5 | | 1 | | | | | | 24 | 3 | | | | | | 6 |
| Mollusca | | | | | | | | | | | | | | | | | | |
| Gastropoda | | 24 | 14 | 30 | 23 | | 20 | 24 | 18 | | 7 | | 20 | 62 | 100 | 100 | 4 | 19 |
| Pelecypoda | | | | | | 11 | 20 | 20 | 18 | | 1 | | | 1 | | | | 5 |
| Fish - NNST | | | 29 | 33 | 16 | 4 | 22 | 37 | 24 | | | | | | | | | 9 |
| Miscellaneous | | | | | | | | | | | | | | | | | | |
| Unidentified organic | | 4 | 14 | 5 | 6 | 18 | 12 | 14 | 14 | | | | | | | | | 5 |
| Plant material | | | | | | | | | | 2 | 2 | | 60 | | | | 7 | 1 |
| Debris | | | 5 | 5 | 3 | | | | | 17 | 19 | | | | | | | 6 |
| No. Stomachs Examined | 6 | 59 | 23 | 42 | 130 | 30 | 65 | 51 | 146 | 46 | 140 | 37 | 8 | 94 | 7 | 6 | 29 | 643 |
| Percent Empty Stomachs | 0 | 14 | 9 | 5 | 9 | 7 | 0 | 4 | 3 | 0 | 11 | 22 | 38 | 25 | 86 | 83 | 0 | 12 |

[a]Predominantly Chironomidae, but also includes other Diptera.

Table 24. Food items eaten by stream resident Arctic char (includes pre-smolt, juvenile, residual males, and fish inhabiting isolated springs). All values calculated as percent occurrence and refer only to stomachs containing food. Length ranges in brackets represent entire life history samples where the length range of the stomach samples is not indicated separately in the original reference. juv=juveniles, res=residual males, mat=mature, iso=isolated. References are as listed in Table 22.

| Location: | Mackenzie River | Rat River | Fish Hole Creek | | Upper Babbage River | | Lower Babbage River | | Firth River | | Sadlerochit Springs | Shublik Springs | Unnamed Springs | Canning River | | Canning Spring-10 | | Kavik River | Sagavanirktok Drainage | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Reference: | 19 | 15 | 2 | | 2 | | 2 | | 12 | | 6 | 17 | 17 | 5 | | 1 | | 7 | 18 | |
| Length Range (mm): | juv 35-132 | juv 50-57 | juv (37-204 | res (128-395 | juv-mat (31-294) | | juv (46-162) | mat (145-241) | juv 42-71 | juv 48-390 | iso (40-210) | iso (40-237) | iso (44-164) | fry 34-70 | juv-res (55-331) | juv 63-198 | res 157-331 | juv-res (45-321) | juv-res (23-347) | Mean Percent Occurrence |
| Insecta | | | | | | | | | | | | | | | | | | | | |
| Ephemeroptera nymphs | | | 9 | 5 | | | 37 | | 4 | 14 | 13 | 31 | 4 | 2 | 4 | | | 3 | | 8 |
| adults | | | | | | | | | | | | 1 | 4 | | | | | 4 | | 1 |
| Plecoptera nymphs | 54 | | 12 | 8 | 3 | 5 | | | 9 | 12 | 38 | 48 | 13 | 51 | 20 | 79 | 47 | 30 | 12 | 19 |
| adults | | | | 3 | | | | | | | 6 | 7 | 9 | 2 | 5 | | | 2 | 4 | 2 |
| Trichoptera larvae | | | 17 | 40 | 33 | 61 | 2 | 13 | | 4 | 49 | 26 | 25 | | | | 3 | 12 | 16 | 20 |
| adults | | | | 3 | | | | | | 1 | | 2 | 3 | | 12 | | | | | 1 |
| Hymenoptera | | | | | | 2 | | | | | 2 | 2 | 19 | | 1 | | | 4 | | 2 |
| Coleoptera | | | | | 1 | 5 | | | | | | 5 | 4 | | 2 | | | 8 | 4 | 2 |
| Chironomidae larvae | 92 | 100 | 53 | 42 | 55 | 34 | 62 | 25 | 43[a] | 52[a] | 36 | 59[a] | 70[a] | 81[a] | 42[a] | 35 | 17 | 68[a] | 52 | 52 |
| pupae | | | 18 | 32 | 28 | 1 | 2 | | 8[a] | 13[a] | | 13[a] | 20[a] | 2[a] | 23[a] | | | 4[a] | 6 | 13 |
| adults | | | 6 | 11 | 3 | | | | 11[a] | 3[a] | 2 | 10[a] | 19[a] | 9[a] | 6[a] | | | 15[a] | | 6 |
| Simuliidae | | | | 3 | | 1 | 37 | | | 1 | | 7 | 3 | | | | | 2 | | 3 |
| Tipulidae | 8 | | 19 | 3 | 4 | | 10 | | 21 | 10 | 4 | 2 | 1 | 13 | 4 | | | 22 | 11 | 8 |
| Unidentified Diptera | 69 | | 44 | 13 | 7 | 1 | 4 | | | | | | | | | | 1 | | 6 | 6 |
| Terrestrial Insects | 8 | | 2 | 5 | 17 | 11 | 4 | 25 | 9 | 10 | | 7 | | | | 15 | 23 | 2 | 20 | 8 |
| Crustacea | | | | | | | | | | | | | | | | | | | | |
| Amphipoda | | | | | 1 | 3 | | | 4 | 4 | 4 | | 19 | | 1 | | | | | 2 |
| Hydracarina | 8 | | | | 1 | 5 | | | | | | 2 | 4 | | 1 | | | | | 1 |
| Oligochaeta | | | | | 4 | | | | | | | | | | | | | | | 1 |
| Nematoda | | | | | 1 | 2 | 2 | | | | | | | | | | | | | <1 |
| Fish | | | | | | | | | | | | | | | | | | | | |
| Fish remains | | | 3 | 16 | | 2 | | 50 | | 4 | | | | | 4 | | 43 | 11 | 5 | 4 |
| Fish eggs | | | 1 | 66 | | | | | | 1 | | | | | 3 | | | 4 | 14 | 3 |
| Miscellaneous | | | | | | | | | | | | | | | | | | | | |
| Unidentified organic | | | 5 | 3 | 33 | 7 | 33 | 27 | | | | | | | | 3 | 3 | | | 8 |
| Plant material | | | 5 | 5 | 1 | | | | | | | 3 | 4 | | 3 | 9 | | 4 | 2 | 2 |
| Debris | | | | | 1 | | | | 1 | 32 | 15 | 21 | 24 | 23 | 40 | 9 | 7 | 32 | | 12 |
| No. Stomachs Examined | 13 | 4 | 110 | 53 | 253 | 143 | 125 | 15 | 79 | 209 | 58 | 123 | 81 | 48 | 121 | 45 | 64 | 171 | 101 | 1816 |
| Percent Empty Stomachs | 0 | 0 | 5 | 26 | 11 | 15 | 38 | 27 | 4 | 25 | 19 | 2 | 3 | 2 | 6 | 26 | 52 | 34 | 17 | 18 |

[a]Predominantly Chironomidae but includes other Diptera.

Table 25. Food items eaten by anadromous and unspecified but probably anadromous Arctic char collected in fresh water (includes juveniles, non-spawning adults, and spawning adults). All values calculated as percent occurrence (except those from reference 4 which are percent volume) and refer only to stomachs containing food. Length ranges in brackets represent entire life history samples where the length range of the stomach samples is not separately indicated in the original reference. anad.=anadromous; n.s.=not specified; mat=mature; juv=juvenile; nsp=non-spawner, spw=spawner. References are as listed in Table 22.

| Location: | Mackenzie River | Mackenzie River | Rat River | | Cache Creek | Fish Hole Creek | | Fish Hole Creek | Babbage River | Firth River | Firth River | Kongakut River | Egaksrak River | Ekaluakat River |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Reference: | 19 | 9 | 15 | | 1 | 2 | | 4 | 4 | 4 | 12 | 1 | 1 | 1 |
| | anad. mat | anad. | anad. nsp | anad. spw | anad. | anad. juv | anad. mat | | n.s. | | anad. | anad. | anad. | anad. |
| Length Range (mm): | 228-545 | 261-440 | 301-590 | 460-572 | 299-434 | | (347-629) | 451-593 | 198-504 | 418-720 | 237-720 | 425-620 | 210-485 | 203-584 |
| Insecta | | | | | | | | | | | | | | |
| Ephemeroptera | | | | 13 | | | 22 | | | 17 | 8 | | | |
| Plecoptera nymphs | | | 6 | 88 | | | | | <1 | 11 | 15 | 8 | | 9 |
| adults | | | | | | | | | | | | | | |
| Trichoptera | | | 18 | | | 9 | 11 | | | | 8 | | | |
| Heteroptera | | | 6 | | | | | | | | | | | |
| Coleoptera | | | 12 | | | | | | <1 | | | | | |
| Chironomidae larvae | | | 42 | 38 | | 36 | 11 | 23 | 1 | 11 | 49[a] | | 25 | 18 |
| pupae | | | | | | | 22 | | | | 28[a] | | | |
| adults | | | | | | 9 | | | | | 7[a] | | | |
| Tipulidae | | | | 13 | | | 11 | | | | 8 | | | |
| Unidentified diptera | | | 30 | | | | | | <1 | 18 | | 50 | 25 | 9 |
| Terrestrial insects | | | 12 | | | 9 | 11 | | | | 3 | | | |
| Unidentified insects | | | 24 | | | | | | 2 | 39 | | | | |
| Crustacea | | | | | | | | | | | | | | |
| Amphipoda | | | | | | | | | | | 10 | | | |
| Other crustacea | | | | | | | | | | | | | | |
| Hydracarina | | | | | | | | | | | | | | |
| Fish | | | | | | | | | | | | | | |
| Fish remains | | | | 63 | | 27 | | 77 | 96 | 4 | 10 | 42 | | 36 |
| Fish eggs | | | | | | | 44 | | <1 | | 3 | | 75 | 27 |
| Miscellaneous | | | | | | | | | | | | | | |
| Unidentified organic | | | | | | | | | | | | | | |
| Plant material | | | | | | | | | | | | | | |
| Debris | | | | | | | | | | | 33 | | | |
| No. Stomachs Examined | 21 | 7 | 192 | 11 | 18 | 60 | 70 | 22 | 10 | 37 | 294 | 73 | 10 | 32 |
| Percent Empty Stomachs | 100 | 100 | 91 | 27 | 100 | 82 | 87 | 91 | 50 | 62 | 79 | 84 | 60 | 66 |

(Continued)

Table 25. Concluded.

| Location: | Canning River | Canning Spring | | Kavik River | Sagavanirktok Drainage | Sagavanirktok Drainage | Colville River | | |
|---|---|---|---|---|---|---|---|---|---|
| Reference: | 5 | 10 | 1 | 7 | 20 | 18 | 16 | Mean Percent Occurrence | Mean Percent Volume |
| | anad. | anad. | anad. | anad. | n.s. | anad. mat | anad. mat | | |
| Length Range (mm): | (232-592) | 195-335 | 440-545 | (186-626) | (210-710) | (378-657) | 440-569 | | |
| Insecta | | | | | | | | | |
| Ephemeroptera | | | | 3 | | 9 | | 2 | 11 |
| Plecoptera nymphs | 27 | | | 40 | | 9 | | 11 | 7 |
| adults | 2 | | | 3 | | 5 | | 1 | - |
| Trichoptera | 2 | | | | 1 | 14 | | 4 | - |
| Heteroptera | | | | | | | | <1 | - |
| Coleoptera | | | | 3 | 4 | | | 2 | <1 |
| Chironomidae larvae | 36[a] | | | 50[a] | 17 | 9 | | 27 | 10 |
| pupae | | | | 6[a] | | | | 5 | - |
| adults | 5[a] | | | 3[a] | | | | 2 | - |
| Tipulidae | 7 | | | 13 | | | | 4 | - |
| Unidentified diptera | | | 50 | | 5 | 14 | | 4 | 12 |
| Terrestrial insects | | | | | 7 | 14 | | 5 | - |
| Unidentified insects | | | | | 44 | | 100 | 21 | 26 |
| Crustacea | | | | | | | | | |
| Amphipoda | 7 | | | | | | | 2 | - |
| Other Crustacea | 2 | | | | | | | <1 | - |
| Hydracarina | 2 | | | | | | | <1 | - |
| Fish | | | | | | | | | |
| Fish remains | 16 | | 75 | 31 | 11 | 23 | | 16 | 33 |
| Fish eggs | 5 | | | 19 | 3 | 23 | | 7 | <1 |
| Miscellaneous | | | | | | | | | |
| Unidentified organic | | | | | 3 | | | 1 | - |
| Plant material | 4 | | | 3 | 40 | | | 18 | - |
| Debris | 11 | | | 22 | | | | 8 | - |
| No. Stomachs Examined | 341 | 8 | 9 | 96 | 802 | 138 | 9 | 2191 | 69 |
| Percent Empty Stomachs | 84 | 100 | 56 | 67 | 76 | 84 | 78 | 80 | 70 |

[a]Predominantly Chironomidae, but includes other Diptera.

Table 26. Food items eaten by anadromous Arctic char collected in coastal waters. Percent by volume determined by the Points Method and refers only to fish with food in their stomachs. Data for percent occurrence also refer only to those fish with food in their stomachs. NNST=ninespine sticklebacks, ARCD=Arctic cod, ARCS=Arctic cisco, FHSC=fourhorn sculpin, CHAR=Arctic char, GRAY=grayling, STBY=stout eel blenny, WTSP=whitefish sp. Length ranges in brackets represent entire life history samples where the length range of the stomach sample is not separately indicated in the original reference. Bracketed value based on subsample of 1518 fish. References as listed in Table 22.

| Location: | Nunaluk Lagoon | | | | | Kaktovik Lagoon | Vicinity Canning R. Mouth | Bullen Point | | Sagavanirktok River | | Prudhoe Bay | Prudhoe Bay | Simpson Lagoon | Means | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Reference: | 13 | | | | | 14 | 5 | 14 | | 20 | | 11 | 3 | 8 | | |
| | | | | | | | | 1973 | 1975 | delta area | coastal area | | | | | |
| Length Range (mm): | <300 | 301-400 | 401-500 | 501-600 | all sizes | (190-685) | (184-638) | (241-638) | (392-538) | (130-610) | | (136-620) | (154-685) | (120-703) | | |
| Method of Calculation: | * | * | * | * | * | * | ** | * | * | ** | ** | ** | ** | * | ** | * |
| Insecta | | | | | | <1 | | | | | | | | | | <1 |
| Plecoptera | 5 | 5 | 4 | 2 | 3 | | | | | | 2 | | | | 1 | 1 |
| Trichoptera | | | | | <1 | | | | | | | | | | | <1 |
| Coleoptera | | | | | | | | | | | | 3 | | | <1 | |
| Chironomidae | 58 | 5 | 8 | <1 | 14 | | | | | 1 | 1 | | | | 1 | 3 |
| Other Diptera | 6 | 9 | 6 | 1 | 6 | | | | | | 1 | 26 | | | 2 | 1 |
| Unidentified Insects | | | | | | | | | | 2 | <1 | 5 | | | 1 | |
| Crustacea | | | | | | | | | | | | | | | | |
| Amphipoda | 4 | 24 | 15 | 2 | 15 | 56 | 51 | 7 | 35 | 5 | 14 | 45 | 95 | 55 | 32 | 34 |
| Copepoda | | 10 | 1 | 7 | 4 | <1 | 4 | | | | | | | 3 | <1 | 1 |
| Isopoda | | 10 | 14 | | 9 | <1 | 9 | | 5 | 12 | 17 | 45 | 11 | <1 | 15 | 3 |
| Mysidacea | | 2 | 2 | | 1 | 29 | 47 | 21 | 41 | 54 | 41 | 24 | 32 | 32 | 42 | 25 |
| Other Crustacea | | | | | | | | | 1 | 2 | 13 | | | 2 | 6 | 1 |
| Mollusca | | | | | | <1 | 1 | | | | | | | | <1 | <1 |
| Fish | | | | | | | | | | | | | | | | |
| ARCS | | | 3 | 6 | 2 | | | | | | | | | | | <1 |
| ARCD | | | | | | | | | | | | 42 | | | 7 | |
| CHAR | | | 3 | 12 | 2 | | | | | | | | | | | <1 |
| FHSC | 11 | 13 | 20 | 33 | 17 | 7 | | | 4 | | | | | | | 6 |
| GRAY | | | | 4 | <1 | | | | | | | | | | | <1 |
| NNST | | 1 | 6 | 2 | 3 | | | | | | | | | | | 1 |
| STBY | | | | | | 3 | | | | | | | | | | 1 |
| WTSP | | | | | | <1 | | | | | | | | | | <1 |
| Fish Remains | | 2 | 9 | 23 | 7 | 2 | 42 | 60 | | 26 | 12 | 37 | | 5 | 18 | 15 |
| Fish Eggs | | | | | | | | | | | | 5 | | | <1 | |
| Miscellaneous | | | | | | | | | | | | | | | | |
| Unidentified Organic | 17 | 20 | 12 | | 13 | 3 | | 12 | 15 | 7 | 17 | | | 2 | 9 | 9 |
| Plant Material | | | 1 | | 1 | | 1 | | | 1 | 1 | 8 | | | 1 | <1 |
| Sand and Stones | | | | 8 | 1 | | | | | | | | | | | <1 |
| No. Stomachs Examined | 17 | 57 | 112 | 20 | 206 | 137 | 102 | 12 | 18 | 621 | 427 | 52 | 210 | 30 | 1715 | |
| Percent Empty Stomachs | 0 | 0 | 0 | 0 | 33 | 0 | 21 | 0 | 0 | 70 | 31 | 27 | 44 | 0 | (46) | |

* Percent Volume.
**Percent Occurrence.

Table 27. Spawning dates of Arctic char in lakes and streams within the study area, arranged by drainage.

| Drainage | Location | Spawning Dates | Water Temperature (°C) | Reference |
|---|---|---|---|---|
| LAKE RESIDENT | | | | |
| Sagavanirktok River | Campsite Lake | Late August through September | | McCart et al. 1972 |
| Canning River | Lake CT-28 | From mid September | | Craig 1977a |
| Canning River | Big Lake | From early September | | Craig 1977a |
| Firth River | Lake 103 | September | | AEL unpublished data |
| ISOLATED STREAM RESIDENT | | | | |
| Canning River | Shublik Springs | From early November | 3.5 | McCart and Craig 1973 |
| Sadlerochit River | Sadlerochit Springs | From early December | 11-14 | Craig 1977b |
| Babbage River | Upper Babbage River | September to mid October | 3.5 | Bain 1974, Craig and McCart 1974 |
| Big Fish River | Cache Creek Springs | Late fall or early winter | 14-16 | McCart and Bain 1974 |
| ANADROMOUS | | | | |
| Sagavanirktok River | Echooka River | September into November | 4.5 | McCart et al. 1972, Yoshihara 1972, 1973 |
| Sagavanirktok River | Ivishak River | Last week August to November | 4.0 | Yoshihara 1972, 1973 |
| Sagavanirktok River | Saviukviayak River | September | 5.0 | Yoshihara 1973 |
| Sagavanirktok River | Lupine River | Early August through September | 4.0 | McCart et al. 1972, Yoshihara 1972, 1973 |
| Sagavanirktok River | Ribdon River | September | 3.5-7.0 | Yoshihara 1973 |
| Sagavanirktok River | Accomplishment Creek | Mid August into November | 0-3.3 | McCart unpublished ms., McCart et al. 1972, Yoshihara 1972 |
| Sagavanirktok River | Section Creek | Mid September into November | | McCart unpublished ms. |
| Shaviovik River | Kavik River | Late July to early November | 0.0 | Craig 1977c |
| Canning River | Mainstem | Late August to late December | | Craig 1977a |
| Canning River | Confluence of Marsh Fork and Mainstem | Late August to November | | Craig and McCart 1974 |
| Canning River | Marsh Fork | Late August to November | 6-11 | Craig 1977a, Craig and McCart 1974 |
| Hulahula River | Mainstem | September | | Craig and McCart 1974 |
| Fish Creek | Mainstem | October | | Craig and McCart 1974 |
| Firth River | Upper Mainstem | Mid August to early October | 1.5 | Craig and McCart 1974, Glova and McCart 1974 |
| Firth River | Joe Creek | September through October | | Glova and McCart 1974 |
| Babbage River | Fish Hole Creek | September | | Bryan et al. 1973, Bain 1974 |
| Big Fish River | Cache Creek "Fish Hole" | September through October | 0-5 | Dryden et al. 1973, Jessop et al. 1974, Jessop and Lilley 1975, Stein et al. 1973a |
| Rat River | Fish Creek | Mid August to early October | 3-8 | Dryden et al. 1972, Jessop et al. 1973, 1974, Jessop and Lilley 1975, Stein et al. 1973a, 1973b. |

Table 28. Age at maturity, lake resident populations of Arctic char.

| Location: | | Campsite | | Schrader | | Big Lake | | Lake CT-28 | | Lake 104 | | Lake 103 | | Combined Locations Except Lake CT-28 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Source: | | McCart et al. 1972 | | AEL File Data | | Craig 1977a | | Craig 1977a | | AEL File Data | | AEL File Data | | | |
| Age | Sex | N | Percent Mature | N | Percent Mature | N | Percent Mature | N | Percent Mature | N | Percent Mature | N | Percent Mature | N | Percent Mature |
| 1 | M | 7 | 0 | | | | | 2 | 0 | | | 3 | 0 | 10 | 0 |
| | F | 8 | 0 | | | | | 1 | 0 | | | 3 | 0 | 11 | 0 |
| 2 | M | 7 | 0 | | | | | 1 | 0 | 4 | 0 | 1 | 100 | 12 | 8 |
| | F | 4 | 0 | | | | | 1 | 0 | 13 | 0 | 5 | 0 | 22 | 0 |
| 3 | M | 3 | 0 | | | 17 | 12 | 6 | 83 | | | 7 | 29 | 27 | 15 |
| | F | 1 | 0 | | | 8 | 0 | 4 | 0 | 2 | 0 | 7 | 0 | 18 | 0 |
| 4 | M | 3 | 0 | | | 20 | 35 | 10 | 100 | 5 | 40 | 8 | 13 | 36 | 28 |
| | F | | | | | 16 | 13 | 6 | 50 | 8 | 0 | 5 | 0 | 29 | 7 |
| 5 | M | 1 | 0 | | | 10 | 40 | | | 8 | 38 | 12 | 58 | 31 | 45 |
| | F | 3 | 0 | | | 23 | 35 | 1 | 100 | 25 | 0 | 6 | 0 | 57 | 14 |
| 6 | M | | | | | 9 | 56 | 1 | 100 | 17 | 0 | 15 | 87 | 41 | 44 |
| | F | 2 | 0 | | | 14 | 64 | 2 | 100 | 22 | 9 | 9 | 22 | 47 | 28 |
| 7 | M | 1 | 0 | 2 | 0 | 5 | 80 | | | 6 | 0 | 4 | 25 | 18 | 28 |
| | F | 1 | 0 | 1 | 100 | 10 | 90 | | | 19 | 11 | 8 | 63 | 39 | 41 |
| 8 | M | 3 | 0 | 1 | 100 | 2 | 100 | | | | | 1 | 0 | 7 | 43 |
| | F | 3 | 0 | 2 | 50 | 4 | 75 | 5 | 100 | 3 | 33 | 10 | 80 | 22 | 59 |
| 9 | M | 4 | 0 | 5 | 20 | 6 | 100 | | | | | 1 | 0 | 16 | 44 |
| | F | 2 | 50 | 2 | 100 | 5 | 100 | 1 | 100 | | | 3 | 100 | 12 | 92 |
| 10 | M | 7 | 14 | 4 | 75 | 2 | 100 | 2 | 100 | | | 2 | 50 | 15 | 47 |
| | F | 5 | 0 | 2 | 100 | 3 | 100 | 1 | 100 | 1 | 100 | 8 | 100 | 19 | 74 |
| 11 | M | 12 | 17 | 2 | 50 | 1 | 100 | | | | | 1 | 100 | 16 | 31 |
| | F | 1 | 0 | | | 2 | 100 | | | | | | | 3 | 67 |
| 12 | M | 9 | 0 | 3 | 100 | 1 | 100 | | | | | 2 | 100 | 15 | 40 |
| | F | 2 | 50 | 3 | 100 | 2 | 100 | | | | | 4 | 100 | 11 | 91 |
| 13 | M | 4 | 0 | 2 | 100 | | | | | 1 | 100 | | | 7 | 43 |
| | F | 3 | 67 | 1 | 100 | 1 | 100 | | | 1 | 100 | 1 | 100 | 7 | 86 |
| 14 | M | 4 | 0 | 3 | 67 | | | | | | | 1 | 100 | 8 | 38 |
| | F | | | | | | | | | 1 | 100 | 2 | 100 | 3 | 100 |
| 15 | M | 2 | 50 | 1 | 100 | | | | | | | 1 | 100 | 4 | 75 |
| | F | 1 | 100 | | | | | | | 2 | 100 | | | 3 | 100 |
| 16 | M | 1 | 100 | 1 | 100 | | | | | | | | | 2 | 100 |
| | F | 1 | 100 | | | | | | | | | | | 1 | 100 |

Table 29. Age at maturity, isolated freshwater resident populations of Arctic char.

| Location: | | Shublik Springs | | Unnamed | | Sadlerochit | | Upper Babbage | | Lower Babbage | | Cache Creek, Y.T. | | Combined | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Source: | | ---- McCart and | | Craig 1973--- | | Craig 1977b | | Bain 1974 | | Bain 1974 | | McCart, Bain 1974 | | | |
| Age | Sex | N | Percent Mature | N | Percent Mature | N | Percent Mature | N | Percent Mature | N | Percent Mature | N | Percent Mature | N | Percent Mature |
| 1 | M | 8 | 0 | 4 | 0 | | | 17 | 0 | 34 | 0 | | | 63 | 0 |
| | F | 8 | 0 | 10 | 0 | | | 12 | 0 | 31 | 0 | | | 61 | 0 |
| 2 | M | 9 | 22 | 12 | 50 | 21 | 26 | 36 | 31 | 14 | 0 | 8 | 62 | 100 | 29 |
| | F | 9 | 0 | 8 | 0 | 16 | 7 | 42 | 0 | 22 | 0 | 8 | 0 | 105 | 1 |
| 3 | M | 15 | 47 | 16 | 88 | 12 | 73 | 47 | 55 | 4 | 25 | 4 | 100 | 98 | 62 |
| | F | 31 | 3 | 10 | 10 | 13 | 38 | 39 | 18 | 6 | 0 | 1 | 0 | 100 | 14 |
| 4 | M | 8 | 63 | 8 | 100 | 8 | 88 | 42 | 90 | 4 | 25 | 4 | 100 | 74 | 85 |
| | F | 14 | 79 | 13 | 100 | 15 | 80 | 57 | 89 | 2 | 100 | 5 | 40 | 106 | 86 |
| 5 | M | 13 | 100 | 2 | 100 | 3 | 100 | 33 | 91 | 5 | 25 | 5 | 80 | 61 | 87 |
| | F | 16 | 100 | 2 | 100 | 11 | 91 | 53 | 96 | 4 | 100 | 4 | 25 | 90 | 93 |
| 6 | M | 1 | 100 | | | 1 | 100 | 17 | 100 | 2 | 100 | 6 | 100 | 27 | 100 |
| | F | 2 | 100 | | | 2 | 100 | 27 | 100 | 1 | 100 | 9 | 100 | 41 | 100 |
| 7 | M | 3 | 100 | | | | | 6 | 100 | | | 3 | 100 | 12 | 100 |
| | F | 1 | 100 | | | 1 | 100 | 7 | 100 | 1 | 100 | 6 | 100 | 16 | 100 |
| 8 | M | 3 | 100 | | | | | 1 | 100 | | | 2 | 100 | 6 | 100 |
| | F | 1 | 100 | | | | | 2 | 100 | | | 2 | 100 | 5 | 100 |
| 9 | M | | | | | | | | | | | | | | |
| | F | | | | | | | 1 | 100 | | | 1 | 100 | 2 | 100 |
| 10 | M | | | | | | | 1 | 100 | 1 | 100 | | | 2 | 100 |
| | F | | | | | | | 1 | 100 | | | 1 | 100 | 2 | 100 |
| 11 | M | | | | | | | 1 | 100 | | | | | 1 | 100 |
| | F | | | | | | | 1 | 100 | | | | | 1 | 100 |

Table 30. Age at maturity, anadromous populations of Arctic char: juveniles and residuals.

| Location: | | Kavik | | Canning | | Glova, | | Firth | | Fish Hole | | Combined | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Source: | | Craig 1977c | | Craig 1977a | | McCart 1974 | | Bain 1973 | | | | | |
| Age | Sex | N | Percent Mature | N | Percent Mature | N | Percent Mature | N | Percent Mature | N | Percent Mature | N | Percent Mature |
| 1 | M | 10 | 0 | 16 | 0 | 60 | 0 | 24 | 0 | 110 | 0 | | |
| | F | 19 | 0 | 18 | 0 | 48 | 0 | 20 | 0 | 105 | 0 | | |
| 2 | M | 33 | 9 | 41 | 5 | 38 | 0 | 11 | 0 | 123 | 4 | | |
| | F | 34 | 0 | 43 | 0 | 38 | 0 | 3 | 0 | 118 | 0 | | |
| 3 | M | 19 | 32 | 26 | 58 | 71 | 14 | 18 | 44 | 134 | 29 | | |
| | F | 12 | 0 | 19 | 0 | 10 | 0 | 11 | 0 | 52 | 0 | | |
| 4 | M | 15 | 100 | 30 | 67 | 4 | 75 | 21 | 81 | 70 | 79 | | |
| | F | 2 | 0 | 2 | 0 | 1 | 0 | 3 | 0 | 8 | 0 | | |
| 5 | M | 18 | 94 | 18 | 83 | | | 19 | 74 | 55 | 84 | | |
| | F | 2 | 100 | 1 | 0 | 2 | 0 | | | 5 | 40 | | |
| 6 | M | 3 | 100 | 22 | 95 | 2 | 100 | 18 | 100 | 45 | 98 | | |
| | F | | | 3 | 33 | | | | | 3 | 33 | | |
| 7 | M | 2 | 100 | 15 | 100 | 2 | 100 | 9 | 100 | 28 | 100 | | |
| | F | | | | | | | | | | | | |
| 8 | M | 1 | 100 | 6 | 100 | 1 | 100 | 2 | 100 | 10 | 100 | | |
| | F | | | | | | | | | | | | |
| 9 | M | 3 | 100 | 4 | 100 | 3 | 100 | | | 10 | 100 | | |
| | F | | | | | | | | | | | | |
| 10 | M | 1 | 100 | | | 1 | 100 | 2 | 100 | 4 | 100 | | |
| | F | | | 1 | 100 | | | | | 1 | 100 | | |
| 11 | M | 1 | 100 | 1 | 100 | 2 | 100 | | | 4 | 100 | | |
| | F | | | | | | | | | | | | |

Table 31. Age at maturity, anadromous and searun populations of Arctic char.

| Location: | | Simpson Lagoon | | Prudhoe Bay | | Kavik | | Canning Coastal | | Canning River | | Nunaluk Lagoon | | Firth | | Fish Hole | | Combined[a] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Source: | | Craig, Griffiths 1978 | | Furniss 1972 | | Craig 1977c | | Craig 1977a | | Craig 1977a | | Griffiths et al. 1975 | | Glova, McCart 1974 | | Bain 1974 | | | |
| Age | Sex | N | Percent Mature | N | Percent Mature | N | Percent Mature | N | Percent Mature | N | Percent Mature | N | Percent Mature | N | Percent Mature | N | Percent Mature | N | Percent Mature |
| 1 | M | | | | | 1 | 0 | | | | | | | | | | | 1 | 0 |
| | F | | | | | 2 | 0 | | | | | | | | | | | 2 | 0 |
| 2 | M | | | | | 6 | 17 | 1 | 0 | | | 2 | 0 | | | | | | |
| | F | | | | | 9 | 0 | | | | | 2 | 0 | | | | | 11 | 0 |
| 3 | M | 5 | 0 | 3 | 0 | 6 | 17 | 8 | 0 | 1 | 0 | 4 | 0 | 15 | 0 | 3 | 0 | 34 | 3 |
| | F | 9 | 0 | | | 14 | 0 | | | 3 | 0 | 5 | 0 | 14 | 0 | 8 | 0 | 53 | 0 |
| 4 | M | 9 | 0 | 11 | 0 | 6 | 0 | 9 | 0 | 2 | 0 | 5 | 0 | 24 | 4 | 5 | 0 | 51 | 2 |
| | F | 19 | 0 | | | 2 | 0 | | | 13 | 0 | 4 | 0 | 32 | 3 | 13 | 0 | 83 | 1 |
| 5 | M | 7 | 0 | 10 | 0 | 1 | 0 | 6 | 0 | 12 | 0 | 11 | 0 | 27 | 11 | 9 | 44 | 67 | 10 |
| | F | 11 | 0 | | | 3 | 33 | | | 13 | 0 | 28 | 4 | 39 | 3 | 16 | 25 | 110 | 6 |
| 6 | M | 3 | 0 | 10 | 0 | | | 10 | 10 | 7 | 0 | 35 | 17 | 14 | 7 | 9 | 67 | 68 | 19 |
| | F | 2 | 0 | | | 2 | 100 | | | 16 | 25 | 59 | 27 | 16 | 0 | 13 | 92 | 108 | 32 |
| 7 | M | 0 | 0 | 5 | 100 | 1 | 100 | 14 | 36 | 14 | 50 | 35 | 51 | 6 | 33 | 6 | 67 | 62 | 52 |
| | F | 5 | 40 | | | 10 | 100 | | | 64 | 81 | 44 | 59 | 19 | 42 | 11 | 90 | 153 | 71 |
| 8 | M | | | | | 2 | 100 | 17 | 71 | 22 | 90 | 8 | 88 | 13 | 85 | 1 | 100 | 46 | 89 |
| | F | 5 | 100 | | | 20 | 100 | | | 77 | 96 | 2 | 100 | 21 | 48 | 7 | 100 | 132 | 89 |
| 9 | M | 1 | 100 | 2 | 100 | 5 | 100 | 16 | 100 | 17 | 100 | 5 | 100 | 6 | 60 | | | 33 | 94 |
| | F | 8 | 100 | | | 10 | 100 | | | 36 | 100 | 5 | 100 | 11 | 55 | 4 | 100 | 74 | 93 |
| 10 | M | 7 | 100 | 23 | 100 | 1 | 100 | 5 | 100 | 6 | 100 | 1 | 100 | 5 | 80 | 2 | 100 | 22 | 96 |
| | F | 14 | 100 | | | 8 | 100 | | | 13 | 100 | 7 | 100 | 5 | 80 | 4 | 100 | 51 | 100 |
| 11 | M | 3 | 100 | 6 | 100 | 1 | 100 | 4 | 100 | 4 | 100 | 1 | 100 | 2 | 100 | | | 11 | 100 |
| | F | 9 | 100 | | | 1 | 100 | | | 6 | 100 | 2 | 100 | 2 | 100 | 1 | 100 | 21 | 100 |
| 12 | M | 2 | 100 | 6 | 100 | 1 | 100 | 1 | 100 | | | 1 | 100 | | | | | 5 | 100 |
| | F | 4 | 100 | | | | | | | 4 | 100 | 1 | 100 | 3 | 100 | | | 12 | 100 |
| 13 | M | 2 | 100 | | | | | | | | | | | 1 | 100 | | | 3 | 100 |
| | F | 3 | 100 | | | | | | | | | | | 2 | 100 | | | 5 | 100 |
| 14 | M | 1 | 100 | | | | | | | | | | | 1 | 100 | | | 2 | 100 |
| | F | 1 | 100 | | | | | 1 | 100 | 2 | 100 | | | 2 | 100 | | | 5 | 100 |

[a]Except data where males and females were combined.

Table 32. Fecundity-length relationships for Arctic char.

| Location | N | Length (mm) Mean | Length (mm) Range | Fecundity Mean | Fecundity Range | Fecundity-Length Relationship | r | P | Reference |
|---|---|---|---|---|---|---|---|---|---|
| LAKE RESIDENT | | | | | | | | | |
| Campsite Lake | 11 | 409.0 | 374-445 | 802 | 554-1229 | - | - | - | McCart et al. 1972 |
| Big Lake | 18 | 152.0 | 122-184 | 88 | 54-152 | $Log_{10}$ F = 2.365 $Log_{10}$ L - 3.234 | 0.87 | 0.01 | Craig 1977a |
| Lake CT-28 | 8 | 297.8 | 188-390 | 1036 | 290-1750 | Not significantly correlated | 0.24 | 0.05 | AEL file data |
| Lake 104 | 5 | 346.4 | 297-377 | 886 | 653-1252 | Not significantly correlated | 0.75 | 0.05 | AEL file data |
| Lake 103 | 3 | 341.7 | 320-376 | 942 | 693-1304 | Not significantly correlated | 0.99 | 0.05 | AEL file data |
| Total | 45 | 309.4 | 122-445 | 750.8 | 54-1750 | | | | |
| ISOLATED STREAM RESIDENT | | | | | | | | | |
| Shublik Springs | 18 | 154.2 | 117-183 | 143 | 84-199 | Not significantly correlated | 0.08 | 0.05 | McCart and Craig 1973 |
| Unnamed Spring | 17 | 137.5 | 121-158 | 113 | 42-187 | Not significantly correlated | 0.39 | 0.05 | McCart and Craig 1973 |
| Lower Babbage River | 7 | - | - | 334 | - | Not significantly correlated | 0.70 | 0.05 | Bain 1974 |
| Upper Babbage River | 78 | - | 132-251[a] | 294 | 132-605[a] | $Log_{10}$ F =2.02 $Log_{10}$ L - 2.08 | 0.76 | 0.01 | Bain 1974 |
| Total | 120 | | 117-251 | 221.3 | 42-605 | | | | |
| ANADROMOUS | | | | | | | | | |
| Sagavanirktok River | 66 | 449.0 | - | 3670 | 2100-5500[a] | $Log_{10}$ F = 2.03 $Log_{10}$ L - 1.91 | 0.70 | 0.01 | McCart et al. 1972 |
| Sagavanirktok River | 49 | 499.2 | 424-630 | 4154 | 2698-6326 | Y = 3285.58 + 14.90 X | - | - | Yoshihara 1973 |
| Kavik River | 28 | 477.0 | 366-516 | 3737 | 2140-5840 | $Log_{10}$ F = 2.15 $Log_{10}$ L - 2.19 | 0.67 | 0.01 | Craig 1977c |
| Canning River | 96 | - | 415-554 | 3177 | 1760-6600 | Not significantly correlated | 0.10 | 0.05 | Craig 1977a |
| Canning Spring 10 | 8 | 491.0 | 440-532 | 3874 | 3050-5570 | $Log_{10}$ F = 3.89 $Log_{10}$ L - 6.91 | 0.96 | 0.01 | AEL file data |
| Upper Firth River | 20 | 529.6 | - | 4955 | - | $Log_{10}$ F = 2.82 $Log_{10}$ L - 4.01 | 0.84 | 0.01 | Glova and McCart 1974 |
| Fish Hole Creek | 27 | - | 355-525[a] | 3468 | 1700-5100[a] | $Log_{10}$ F = 1.74 $Log_{10}$ L - 1.12 | 0.69 | 0.01 | Bain 1974 |
| Cache Creek | 7 | 491.0 | 357-422 | 1493 | 1120-2120 | $Log_{10}$ F = 3.07 $Log_{10}$ L - 4.80 | 0.76 | 0.05 | AEL file data |
| Total | 301 | 497.8 | 355-630 | 3566 | 1120-6600 | | | | |

[a]Taken from graph.

Table 33. Proportion of total gonad weight to body weight of mature sea-run and freshwater-resident char prior to spawning. In each category (spawners and mature non-spawners for the three life history patterns) 10 fish were randomly selected in or about the month of September. From Craig (1977a).

| | SEA-RUN FEMALES | | | | SEA-RUN MALES | | | | RESIDUAL MALES | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Spawners | | Mature Non-Spawners | | Spawners | | Mature Non-Spawners | | Spawners | |
| Sample Number | Body(g) | %Gonad | Body(g) | %Gonad | Body(g) | %Gonad | Body(g) | %Gonad | Body(g) | %Gonad |
| 1 | 1505 | 9.7 | 1347 | 0.9 | 1648 | 6.0 | 2288 | 0.1 | 350 | 7.9 |
| 2 | 1019 | 20.9 | 1378 | 1.0 | 1354 | 4.9 | 1662 | 0.1 | 150 | 6.5 |
| 3 | 958 | 17.8 | 1591 | 0.8 | 904 | 3.6 | 1820 | 0.2 | 33 | 4.2 |
| 4 | 852 | 15.2 | 1354 | 1.2 | 1222 | 5.8 | 1696 | 0.2 | 37 | 5.7 |
| 5 | 1020 | 23.4 | 1046 | 0.9 | 1311 | 5.2 | 1589 | 0.2 | 51 | 4.7 |
| 6 | 1109 | 25.8 | 1193 | 1.4 | 1592 | 3.1 | 1321 | 0.3 | 149 | 8.4 |
| 7 | 844 | 15.6 | 1085 | 1.8 | 1905 | 2.7 | 860 | 1.3 | 164 | 8.9 |
| 8 | 931 | 15.8 | 813 | 1.5 | 727 | 5.2 | 1630 | 0.1 | 152 | 7.6 |
| 9 | 724 | 16.6 | 881 | 1.3 | 978 | 3.5 | 1518 | 0.2 | 398 | 5.3 |
| 10 | 916 | 17.9 | 1216 | 1.5 | 1192 | 3.8 | 1265 | 0.3 | 104 | 7.3 |
| Averages | | 17.8% | | 1.2% | | 4.4% | | 0.3% | | 6.7% |

Table 34. Comparison of the diameters of fresh ova from ripe females with those of water-hardened ova removed from spawning redds in streams tributary to the Sagavanirktok River, Alaska. Data from Yoshihara (1973).

| OVA FROM RIPE FEMALES<br>Spawning Ground | Females (N) | Diameter (mm)<br>Mean | Range |
|---|---|---|---|
| Accomplishment Creek | 44 | 4.2 | 3.5-4.6 |
| Ribdon (main branch) | 30 | 4.2 | 3.8-4.7 |
| Lupine River | 19 | 4.2 | 3.9-4.5 |
| | 93 | 4.2 | 3.5-4.7 |

| OVA FROM REDDS<br>Spawning Ground | Redds (N) | Diameter (mm)<br>Mean | Range |
|---|---|---|---|
| Accomplishment Creek | 5 | 4.7 | 4.5-4.9 |
| Ribdon (main branch) | 7 | 4.8 | 4.6-5.0 |
| Ribdon (south branch) | 10 | 4.8 | 4.5-5.2 |
| Lupine River | 16 | 4.7 | 4.4-5.0 |
| | 38 | 4.8 | 4.4-5.2 |

Table 35. Frequency of spawning determined from tagging studies in the Sagavanirktok River Drainage, Alaska. Data from Furniss (1975).

| | Males | | Females | | Sexes Combined | |
|---|---|---|---|---|---|---|
| | N | % | N | % | N | % |
| Sample Size | 79 | | 305 | | 384 | |
| Consecutive Spawners | 1 | 1.3 | 18 | 5.9 | 19 | 4.9 |
| Non Consecutive: | | | | | | |
| Alternate Year | 36 | 45.6 | 197 | 64.6 | 233 | 60.7 |
| Undetermined | 42 | 53.1 | 90 | 29.5 | 132 | 34.4 |
| Total | 78 | 98.7 | 187 | 94.1 | 365 | 95.1 |

Table 36. Selectivity of gillnet size for Arctic char captured at Nunaluk Spit in 1974. Data for two largest mesh sizes combined. From Griffiths et al. (1975).

| Mesh Size (Stretched) cm | in | Catch N | % | Mesh Size (Stretched) cm | in | Catch N | % |
|---|---|---|---|---|---|---|---|
| 2.5 | 1.0 | 18 | 6.4 | 6.3 | 2.5 | 63 | 22.5 |
| 3.8 | 1.5 | 38 | 13.6 | 8.9 | 3.5 | 39 | 13.9 |
| 5.1 | 2.0 | 103 | 36.8 | 10.2 & 11.4 | 4 & 4.5 | 19 | 6.8 |
| Total | | | | | | 280 | 100.0 |

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