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Chapter 3b   Alaska Arctic Marine Fish Species Accounts

Chapter 3. Alaska Arctic Marine Fish Species Accounts

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Abstract

Species accounts provide brief, but thorough descriptions about what is known, and not known, about the natural life histories and functional roles of marine fishes in the Arctic marine ecosystem. Information about human influences on traditional names and resource use and availability is limited, but what information is available provides important insights about marine ecosystem status and condition, seasonal patterns of fish habitat use, and community resilience. This linkage has received limited scientific attention and information is best for marine species occupying inshore and freshwater habitats. Some species, especially the salmonids and coregonids, are important in subsistence fisheries and have traditional values related to sustenance, kinship, and barter. Each account is an autonomous document providing concise information about a species zoogeography, western and Alaska Native taxonomy, life history, niches, and life requirements. Each account is fully referenced with the identification of the most critical literature for Alaska and a more comprehensive listing of referencing from which biological and ecological information was drawn. New-to-science narratives, distributional maps, and vertical profiles, provide quick, reliable sources of information about fish life history and habitat requirements for this segment of the Arctic fauna.

Purpose and Design of Species Accounts

Individual species accounts were prepared for 104 of the 109 confirmed marine fishes for which adequate biological information was available from the U.S. Chukchi and Beaufort Seas. These descriptions are an important source of documentation about Arctic Alaska's marine fish fauna. Although tailored to address the specific needs of BOEM Alaska OCS Region NEPA analysts, the information presented in each species account also is meant to be useful to other users including state and Federal fisheries managers and scientists, commercial and subsistence resource communities, and Arctic residents. Readers interested in obtaining additional information about the taxonomy and identification of marine Arctic fishes are encouraged to consult the *Fishes of Alaska* (Mecklenburg and others, 2002) and *Pacific Arctic Marine Fishes* (Mecklenburg and others, 2016). By design, the species accounts enhance and complement information presented in the *Fishes of Alaska* with more detailed attention to biological and ecological aspects of each species' natural history and, as necessary, updated information on taxonomy and geographic distribution.

Each species account includes a concise summary of the natural history, population dynamics, functional roles, and traditional and economic values of the marine fish found off Alaska. An initial organizational task was to create a standard format for effective information delivery. The species descriptions by Ehrlich and others (1988) were provided to the USGS by BOEM as an example of a creative template for information transfer. Four pilot species accounts, representing well known to poorly known species, were developed, reviewed, and repeatedly revised for improvements, interagency approval, and selection of the final layout and design. Final decisions about content represented the priority needs of BOEM.

More than 1,200 individual scientific publications relevant to Arctic marine fishes were reviewed in preparation of the species accounts. In each species account, the most relevant literature for each species is cited. A shorter list (about 5–10 articles) identifies key Alaskan information sources that, in our opinion, have had the greatest scientific effect on understanding the species of the Arctic area of the United States.

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Limitations of Data

The species accounts reveal many gaps in the biological information needed to conduct vulnerability assessments of the marine fishes of the Beaufort and Chukchi Seas to human interventions. Part of this problem relates to the geographic coverage of existing research and surveys in Alaska as, in many instances, we were required to incorporate the results of investigations conducted outside the region. This raises an important caution because, even though the best available information was used in preparing the species accounts, our reliance on data and information from outside Alaska will introduce uncertainty to EIS expectations. Ideally, and with respect to oil and gas activities, baseline information for fishery resources should be collected from the potentially affected environment to appropriately evaluate the potential effects of oil spills or other possible industrial-related disturbances. However, as has been widely noted (for example, Bluhm and others, 2011), systematic and methodologically comparable data typically are not available from Arctic Alaska marine ecosystems. Evaluating change in populations and communities from natural and anthropogenic stressors is limited by the variable quality and lack of quantitative reports on abundance, distribution, community structure, and demographics for Arctic marine fishes.

In each species account, an attempt was made to incorporate the most reliable baseline information available and offer impressions of information needs. Important ongoing studies sponsored by BOEM, and others, may be addressing some of these needs. The needs assessments for this study considered these efforts to the extent that oral and (or) written communications and preliminary results allowed. The focus of this study was on impressions of the population parameters (Williams and others, 2002) and environmental measurements needed to detect changes in marine fish populations (Reist and others, 2006; Wassmann and others, 2011) and their resilience to a variable and rapidly changing environment (Holland-Bartels and Pierce, 2011). For key marine fish species, examples might include changes in range, community structure, abundance, phenology, behavior, and population growth and survival.

Each species account is designed as a self-contained article; therefore, no references to other accounts are included. Additionally, to reduce complexity in the presentations, only common names were used to identify the major predator and prey species for the marine fish described. Because this document was meant to be a companion document to the *Fishes of Alaska* (Mecklenburg and others, 2002), interested readers are encouraged to consult this book or Page and others (2013) and Mecklenburg and others (2016) for more complete information about the scientific authorities and literature citations associated with the original descriptions of each species. Readers are directed to the references cited in each species account for additional information on the species.

Operational Definitions

In chapter 1, several concepts about the temporal and spatial habitat requirements for Arctic marine fish were introduced. More information is presented in this chapter to explain the vertical distribution and the location of shelf break, as used in this report.

Vertical Distribution

The conceptual design of the species depth profiles (vertical structure by life history stage) was patterned after the "coastal marine life zones" of Allen and Smith (1988). The goal of the profiles is to visualize what is known about a species occurrence and reproductive ecology by depth and location. An idealized characterization of Arctic shelves was designed to visualize these relationships. Additional detail about origins of data was included in the depth profiles to reflect Alaskan records or collections from other Arctic regions. This is important because actual field collections and observations are limited from this region. In many instances, the actual presence of a life stage remains unverified by field sampling. Thus, for many of species, the depth of a fish's life cycle should be considered untested hypotheses in need of additional testing.

Location of Shelf Break

Early versions of the depth profiles were modified at the request of BOEM with respect to the depiction of the continental shelf break. As a special effect for the Arctic, the species depth profiles were redrawn to depict the change in bathymetry that typically occurs at depths of about 75 m throughout the Chukchi and western Beaufort Seas. This depiction is not an attempt to redefine the oceanographic definition of shelf break. Instead, it highlights the relatively sharp gradient in depths that often occurs near 70- to 80-m contours over much of the region. Although species depth profiles in this report depict an apparent "break" at 75-m, three factors were considered: (1) this is a generalization and the actual shelf break may be geographically close but at a slightly greater depth; (2) shelf edge effects on fish distribution at depths occurring between 75-, 150-, or 200-m are likely negligible due to the gradient and area involved; and (3) the conceptual depictions of depth distributions by life history stage are consistent with accepted oceanographic conventions for continental shelf and slope (despite the magnified view at 75-m) and thus are compatible to the import of biological data obtained elsewhere.

Keystone Species

The concept of keystone species describes the critical role certain organisms are perceived to have in maintaining the structure of biological communities and resilience of ecosystem dynamics (Paine, 1966). Arctic Cod (*Boreogadus saida*) are widely distributed in the Arctic Ocean and by virtue of their abundance and intermediate trophic position between invertebrates and higher-level predators are integral to the movement of nutrients in marine food webs. For this reason, Arctic Cod are considered a keystone species in the Arctic marine (Bradstreet and others, 1986; Walkusz and others, 2011). Arctic Cod are common in United States waters of the Beaufort and Chukchi Seas being considered for energy exploration and development and are an ecological focus of BOEM fishery studies to understand potential effects on the species (Maule and Thorsteinson, 2012).

Outline of Species Accounts

The species accounts are scientifically accurate descriptions of the life histories, populations, habitats, and community values of individual species in the Arctic marine ecosystem. The mix of quantitative and qualitative information presented reflects state-of-the-art knowledge, a faunal assessment of information gaps, and prioritization of priority needs for population and process understanding. Limited information for many Alaskan species required that relevant observations from other geographic locales be included. Each species account attempts to be clear about the geographic origins of data and information, through scientific referencing or special notations in graphics. As an example, *italics* are used in the species accounts to highlight data collections from the Alaska study area. In several instances, species information was so lacking that inferences from a closely related species were required.

The generic species account includes a comprehensive accounting of scientific and cultural information in a standard format. The scientific information addresses multiple disciplinary areas including taxonomy, life history and habitats, ecological relationships including predator-prey interactions and environmental preferences, and population ecology. The population information is critical to evaluations of population status and health, resilience, and vulnerability to natural and anthropogenic changes in the marine environment. Each species account includes a photograph of an adult specimen (or line drawing if an image was not available); distribution maps (horizontal and vertical); and concise descriptions of abundance, life history, and ecology (11 life history categories); major stressors; research needs; and key references. To assist users, a suite of easily recognized icons was developed to provide quick access to specific life history information. In addition, some species attributes regarding life history, population dynamics, and biological interactions are defined in the Glossary (chapter 7).

Information presented in each species account is outlined and described as:

Taxonomic—Scientific and Common Names

The format of the species accounts was, by design, intended to link the biologic and ecologic information presented in this document directly to the species identification guides contained in the "*Fishes of Alaska*." This connection was established by adherence to naming conventions as described by Mecklenburg and others, 2002 (p. 25 and 26). The common names of each marine fish are presented first, followed by scientific and family names. Each scientific name includes a reference to the name of the person (author) who formally described and named the species in the ichthyological literature. The bibliographic data for the authors and dates of publication of scientific names can be found in Eschmeyer's Catalog of Fishes online (http://researcharchive.calacademy.org/research/ichthyology/catalog/fishcatmain.asp) and are not reported here. In some instances, a *Note* (italicized) has been included to describe exceptional details about existing biological data, morphology, nomenclature, taxonomic status, life history strategy, or occurrence of a species in the United States Chukchi and Beaufort Seas.

Iñupiat Name

The existence of colloquial Iñupiat (Iñupiaq) names for the Arctic's marine fish fauna by indigenous peoples is an important component of traditional ecological knowledge. Relatively few marine fish species are abundant or susceptible enough to subsistence fisheries to have received special names. For those species having Iñupiat names, this information is reported to assure that a common vocabulary can facilitate future exchanges of ideas and knowledge across disciplinary boundaries. In this manner, colloquial names can provide a cultural link between local marine resources and science supporting sustainability of Arctic communities and ecosystems.

Ecological Role

Fishes play a pivotal role in marine ecosystems as secondary and higher-level consumers in many marine food webs. In many instances, information about predator-prey relationships is so limited that only preliminary, qualitative assessments of the relative role of each species are possible. The ecological niche describes how an organism or population responds to resources and competitors. Importance or significance descriptors do not diminish the fact that all organisms contribute in ways large or small to the provision of ecosystem goods and services. These descriptors however, may provide useful information about the relative importance of a particular species as an indicator of ecosystem condition and trajectories of change associated with climate change, habitat fragmentation, ecosystem stress, effect of pollutants, or other anthropogenic effects.

Physical Description/Attributes

A brief physical description of the species is summarized from information presented by Mecklenburg and others, (2002) in the *Fishes of Alaska*; the relevant page number is included for quick referral to more comprehensive morphological information. An image of the adult form of each fish is presented with appropriate attribution. High-quality images were selected to highlight the key identifying features of a particular species.

Information about the presence of a swim bladder and antifreeze glycoproteins is included because of its relevance to geo-seismic oil and gas exploration, climate change issues, and evolutionary life history.

Range

The geographic occupancy of the species in United States sectors of Chukchi and Beaufort Seas and adjacent waters is presented in brief narratives and depicted on maps. Known occurrence in the Arctic OCS Planning Areas is highlighted by symbols indicating locations of valid species identifications from properly archived voucher specimens on each map. Although the symbols on the maps may suggest that some of the species are rare in the region, the study of historical collections from the United States and Canadian sectors of the Beaufort Sea, as well as the collections from BOEM surveys in the Beaufort in 2011 and 2012, is still in progress and may reveal that these species are more abundant in deep sectors of the study area than the maps suggest. Definitions of zoogeographic pattern are from the Online Resource 1 (electronic supplemental to Mecklenburg and others, 2011), Mecklenburg and Steinke (2015), and Mecklenburg and others (2016) and relate to ranges of population viability (see chapter 2).

Depth profiles in each species account graphically summarize existing information about the benthic and reproductive distributions of each marine fish. In both depth profiles, the width of areas depicted confers species information about horizontal (onshore-offshore) patterns of distribution. The italicized captions in the depth profiles highlight species information germane to the study area. Areas in the graphs denoted by the orange coloration represent understanding from data collection within the United States Chukchi and Beaufort Seas; olive colors represent data collection outside the study area. For benthic distributions, solid lines in the depth profiles represent species for which no specific information is available about its preferred depth range. Solid lines represent a synthesis of understanding that includes information not necessarily specific to the study area. In some instances, only one record of a species occurrence by depth was available and coding in orange was not meaningful. In these cases, an explanatory comment, in italicized font, with a line pointing to the appropriate depth was included in the graph (for example, see the species account for *Megalocottus platycephalus*). Highlighted depths as indicated through “bolded” (dark black) and dashed segments, represent most common depths where the species has been detected, and depth distribution as has been reported throughout the species range, respectively. Areas denoted with diagonal cross-hatching represents depth distribution of juveniles (immature); adult distributions are not cross-hatched and age-related habitat overlaps, are informed by captioning in the figures.

For reproductive distribution, eggs and larvae (pre-juvenile life stages) of marine fishes are represented with respect to depth and distance from the coast. Orange areas in the reproductive distribution profiles represent data collection in the study area. In many instances, information about spawning habitats and egg and larval distributions is summarized from information reported from throughout a species range. In these cases, dark blue represents species distributions in spawning habitats; light blue represents the geographic distributions of eggs and larvae; and light green is used to highlight areas of substantial habitat overlap (for example, see the species account for *Hippoglossus stenolepsis*). Distribution patterns of eggs and larvae are symbolized by “dots” and “horizontal dashes,” respectively, in the graphs. As for benthic distribution, solid lines represent species-specific information from data collections from throughout the species entire range. Highlighted (dark black lines) segments of solid lines indicate the most common depths where egg and larvae samples have been collected. Dashed lines represent areas of hypothesized distributions for species for which no information is available about egg or larval occurrence. In these instances the hypothesized distributions are based on known patterns for closely related species; the lack of data is stated in captions above the graph.

Relative Abundance

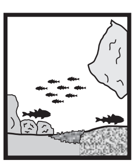
Relative abundance refers to the contribution a species makes to the total abundance of the fishery community. It is a measure that provides an index of the number of individuals present, but not the actual numbers. Relative abundance terms, such as “common,” “uncommon,” or “rare” often are used to express the general population status of a given species, but are most useful when they are defined by something that is measured or estimated in a manner that makes comparison meaningful.

Depth Range

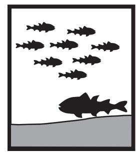
Benthic distribution refers to the spatial arrangement of a particular species at different depths over continental shelf and slope waters. The life cycle of fishes occurs in multiple dimensions in time and space and generally reflects genetically determined life history or behavior that has evolved to maximize fitness (life time reproductive success, see Gross [1987]). Benthic distribution profiles for each species represent the location of important habitats as they are presently known for juvenile and marine fishes. Reproductive distributions depict important habitats for spawning and early life history development.

Life History, Population Dynamics, and Biological Interactions

Life history theory holds that the schedule and duration of key events in a species' lifetime are shaped by natural selection to produce the largest possible number of surviving offspring. These events, notably juvenile development, age of sexual maturity, first reproduction, number of offspring and level of parental investment, senescence, and death, depend on the abiotic and biotic environment of the organism. Specific information about these traits informs understanding of a species' adaptive capacity including major influences on population abundance. A number of fisheries models use basic length-weight and age-at-size relationships to describe the growth and dynamics of fishery populations (for example, von Bertalanffy and Gompertz, growth models and derivatives [Ricker, 1975]). Ecological models estimate transfer of energy or matter along the trophic chain (Gamito, 1998). The parameters that are estimated in these models are individually important indicators of population condition and may be used with other indicators to derive quantitative information about compensatory responses and resilience. Much of this information, including population parameters, has been compiled in FishBase for the Arctic marine fish (Froese and Pauly, 2012).



Habitats and Life History—Basic information about the life history (for example, body size, reproductive ecology, growth) and ecology (for example, mobility, growth, habitat) of a species and the environmental area inhabited by that species is foundational to effective resource management. Habitat is the natural environment that influences and is used by a species population. Information about abiotic (that is, temperature, salinity, other physiochemical factors, depth, and substrate types) and biotic (that is, type and abundance of food, presence of other biota) often are used to describe fish habitats and provide insights about a species environmental preferences and habitat associations (for example, water masses). Maximum body size often is reported and can be an important surrogate of different life history traits (for example, age at maturity, growth, and reproductive output). In population dynamics studies, the relationships between length and weight and size and age form the basis for population growth and production models and quantitative analysis of environmental effects. Length measurements are reported as standard length (SL), total length (TL), and fork length (FL) in fisheries studies.



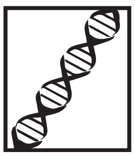
Behavior (see also Glossary [chapter 7]).—Behavior is the manner in which a fish operates or functions within its environment (that is, home range, territoriality, and many others) to procure food, orient to specific locations, or relate to other organisms. Knowing how individuals respond to the environment (physical, chemical, and biological cues) is critical to understanding population processes such as distribution, survival, and reproduction and recruitment and for managing fisheries. Many behaviors are evolutionary adaptations to the physiological and reproductive requirements for a species' survival. For example, migration involves the regular movement of animals between different geographic locations. Migrations can be extensive in terms of time and distance involved (anadromous model) or seasonal (amphidromous and marine models). Each of these models reflects a life strategy adapted for age and growth at sea. Diel relates to daily changes in water column position due to changes in light, temperature, and food supply.

Migratory behaviors are rooted in physiological requirements for food, growth, reproductive, and survival ("scope for growth"). Movement behaviors are more tactical responses to local environmental conditions (for example, variable hydrographic conditions in the nearshore Beaufort Sea). Fish movement can be active or passive and involve large distances in search of suitable habitats and foods. The seasonal nature of migration and movement behaviors are typically related to life history stage, predator-prey distributions, or energetic requirements for growth.

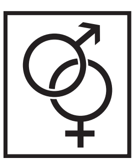
Schooling (that is, social structure of fish of the same species moving in more or less harmonious patterns in the sea) often is related to survival and reproduction. Schooling confers physical benefits to fish movement, safety against predators, search behaviors (for example, foods), population immunology, and reproduction.

The functional feeding morphology of a fish relates to its anatomical adaptations (for example, body size, gape sizes, shape, and body form) to environmental conditions especially food preferences. The adage "function determines morphology and morphology determines way of life" is an important evolutionary concept as it applies to fish feeding behavior, dietary preferences, habitat selection, and trophic stature. Trophic position (within categories of trophic levels) expresses the "tendency of larger (less abundant) fishes feeding on smaller (more abundant) fishes, which themselves feed on zooplankton and all these animals resting upon primary producers" (from Pauly and Watson, 2005). Categories of trophic levels are:

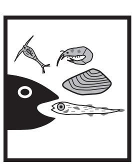
- Trophic level 1 (T1), plants and animals make their own food and are called primary producers;
- Trophic level 2 (T2), herbivores eat plants and are called primary consumers;
- Trophic level 3 (T3), carnivores eat herbivores and are called secondary consumers;
- Trophic level 4 (T4), carnivores eat other carnivores and are called tertiary consumers; and
- Trophic level 5 (T5), apex consumers, which have no predators, are at the top of the food chain.



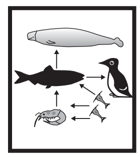
Populations or Stocks—A population often is defined as a group of organisms of the same species occupying a particular space at a particular time with the potential to breed with each other (Williams and others, 2002). Stocks are subpopulations of a particular species of fish that result from reproductive isolation and subdivisions within the biological range. The current state of knowledge about local stocks and their genetic population structure is reported. Grossberg and Cunningham (2001) described the combined effects of demographic, behavioral, genetic, oceanographic, climate, and tectonic processes as major determinants of population structure. These mechanisms act across a range of temporal and spatial scales to determine the rates and patterns of dispersal of different life stages of marine fishes. Dispersal, combined with the successful reproduction and survival of immigrants, control the scale and rate of processes that build or erode structure within and among groups of individuals.



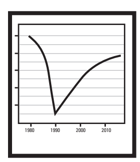
Reproduction Mode—Little information is available about the spawning times and locations, mating behaviors (breeders or nonbreeders), and genetic diversity of Arctic marine fishes. What is known is drawn largely from observations from populations studied outside the United States. For most Arctic marine fish species, there is no information about population or stock structure (for example, age structure, reproductive behavior, sex ratios, age-at-maturity, fecundity, and genetic). These are key population parameters needed for understanding reproductive ecology, population dynamics (for example, growth, survival, and mortality), and assessments of resiliency (response to disturbance).



Food and Feeding—Dietary information is summarized from literature and, unless in italics, is reported from other regions. Fish communities can affect the ecological characteristics of marine ecosystems in response to productivity and abundance patterns, the mobility and migratory behavior of species, and through food influences in different habitats (for example, Grebmeier and others, 2006b). Trophic Index (T) values are reported from FishBase (Froese and Pauly, 2012). The T values for Arctic marine fishes are largely derived from stomach contents analyses, which have correlated well with stable isotopes of nitrogen in tissues. The fractional values (between 1 and 5) realistically address complexities of consumer feeding behaviors (omnivory and feeding across multiple trophic levels) and predator-prey relationships. For example, the mean T value for Blackline Prickleback (*Acantholumpenus mackayi*) is 3.1 (±0.31). This mid food web value is indicative of a primary carnivore that feeds across trophic levels, in this case on lower level herbivores.



Biological Interactions.—The effects organisms in a community have on one another. Competition and consumption (predation, herbivory, or cannibalism) are the best known of the major ecological processes affecting resource abundance, community composition, and ecosystem function. Competition involves interactions between individuals of the same species (intraspecific) or different species (interspecific) in which the fitness of one is lowered by the presence of another. Competition often is related to food and habitat requirements and reproductive behavior. Interspecific competition for foods is greatest for species occupying similar trophic positions in relatively short food chains and for animals living in regions of low biological productivity.

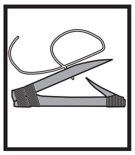


Resilience—In ecology, resilience traditionally refers to the ability of a population or biotic community to sustain or return to its former state after a disturbance. The rate of recovery is a measure of resilience determined by the population processes involved in restoring abundance to healthy, sustainable, or pre-disturbance levels. Four categories of productivity (high, medium, low, and very low) are used to classify reliance in marine fish populations (Musick, 1999). These categories are based on a combination of population parameters for intrinsic rate of growth, growth coefficient, fecundity, age at maturity, and maximum age. Because population parameters were unavailable, resiliency is defined here based on estimated population doubling time where high = <15 months, medium = 1.4–4.4 years, and low = 4.5–14 years.

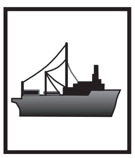
Traditional, Cultural, and Economic Values

In August 2009, the U.S. Secretary of Commerce approved a Fishery Management Plan for the Arctic Management Area. The plan covers U.S. Arctic waters in the

Chukchi and Beaufort Seas, and acknowledges that changing climate may potentially favor the development of commercial fisheries. However, until adequate fisheries resource assessments are completed, the region remains closed to commercial fishing in federal waters. A small salmon fishery exists in Kotzebue Sound; in 2010, a small commercial fishery for Arctic Ciscoes in the Colville River was terminated.



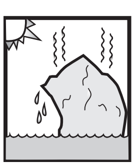
Traditional and Cultural Importance.— Several species of nearshore marine fishes are important in subsistence fisheries. The protection of traditional lifestyles and economies, including these subsistence fisheries, is a responsibility of the Federal government. Subsistence relates to resource use patterns (for example, seasonal round) and values (that is, sustenance, kinship, and barter) in coastal communities of northern Alaska.



Commercial Fisheries.—Currently (2016) there are no offshore marine fisheries in the U.S. Chukchi and Beaufort seas. Changing Arctic environmental conditions and shifting distributions of species in response to warming suggest that there may be fisheries in the future. A precautionary approach by fishery managers has been adopted that requires the collection of reliable baseline information for decision-making and ecosystem management (North Pacific Fishery Management Council [North Pacific Fishery Management Council, 2009; Wilson and Ormseth, 2009]).

Climate Change

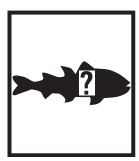
Alaska's climate is changing at more than twice the rate of the rest of the United States (Mellilo and others, 2014). Year-to-year and regional variability in air temperatures are evident and the warming trend currently is being moderated by large-scale cooling associated with the Pacific Decadal Oscillation. Even so, climate effects are pronounced and are being seen in changes in sea ice, timing of snowmelt, widespread glacier retreat, and changes in hydrology (runoff) and coastal processes, such as erosion (Markon and others, 2012). The effects of rising ocean temperatures and ocean acidification on marine food webs are of growing regional concern with respect to the condition and trends in marine ecosystems and human community resilience are of concern. Climate changes potentially can affect marine fish in numerous ways, leading to distributional changes, increased or decreased mortality rates, changes in growth rates, and by altering the timing in reproduction (Clow and others, 2011).



Potential Effects of Climate Change.—A pole-ward shift of many fish distributions is possible as is a reduction or extinction of species that are narrowly adapted to Arctic environments. Generally, the species are expected to increase in abundance if they are currently present in the Bering Sea and decrease if they have very low tolerance for temperatures greater than 1.5–2.0 °C. However, it is hypothesized in current climate projections that temperatures near the ocean floor in the northern Bering Sea will remain cold (<2 °C) due to persistence of winter sea ice (Sigler and others, 2011). Cold-water conditions and other marine ecosystem effects related to seasonal sea ice extent and timing of retreat may effectively block northward migrations and production of exploitable quantities of species, such as pollock and cod, for several decades. Shifts in range and other possible climate-related effects, such as increased predation or competition for food, are identified in the species accounts. Only "loose qualitative generalizations" are presently possible (Reist and others, 2006).

Research Needs

The compilation and review of species information for species in U.S. Arctic waters revealed many gaps in life history understanding and environmental relations. These are evaluated on the basis of a species current fishery and community values and ecological significance in marine ecosystem structure and function. The needs reflect the researcher's perceptions and their understanding that new fishery information is becoming available for the Arctic region and that, although Arctic research is currently a national priority, some aspects of population ecology will take many years of data collection to accurately assess.



Areas for Future Research.—The preparation of individual accounts led to the identification of many information gaps in knowledge about the biology and ecology of marine species including life history, population dynamics, and community associations. Generally, species life history and ecology gaps are most pronounced with respect to: (1) depth and location of pelagic larvae; (2) depth, location, and timing of young-of-the-year habitats; (3) preferred depth ranges for juveniles and adults; (4) spawning seasons; (5) seasonal and ontogenetic movements; (6) population genetics and dynamics; (7) prey–predator relationships and food web relationships; and (8) environmental health (multiple stressor effects on fitness). Behavioral studies for all life stages are virtually non-existent. New information is being developed and, for the lesser-known species, gaps may be slowly addressed over time. Priority needs, for species having special significance in subsistence fisheries and marine food webs or that may be indicator species are emphasized in the species accounts. One of two categories of identified research need is identified for each species. The meaning of the categories **[A]** and **[B]** is as follows:

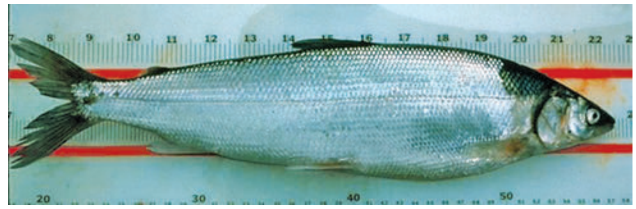
- **[A]** Many gaps in our understanding of the species life history and ecology remain in Alaska (for example, research areas 1 through 8). These are high profile species in terms of ecological, subsistence, or potential fisheries values. Specific research priorities are briefly discussed.
- **[B]** Most aspects of the species life history and ecology are unknown for Alaska (for example, research areas 1 through 8). Species information will likely accumulate over time and focused studies are not warranted at this time.

References Cited and Bibliography

A thorough review of scientific literature was done in the preparation of the species account. A list of references (References Cited [chapter 8]) is provided for each species for readers seeking additional information. This list identifies key sources of information that make the greatest contributions to current knowledge (2014) and understanding. The Bibliography section provides a full accounting of all scientific literature cited in each species account. For a small number of species from the family Cottidae, only a Bibliography was possible to provide and this is indicative of the lack of information available. Citations are not always in numerical order in species accounts because new information became available during the production phase of this publication and were incorporated into the species accounts as appropriate.

Arctic Cisco (*Coregonus autumnalis*)
(Pallas, 1776)

Family Salmonidae



Arctic Cisco (*Coregonus autumnalis*). Photograph by Kirk Waggoner, MJM Research LCC.

Colloquial Name: Iñupiat: *Qaatag, Qaaktaq* [1]; *Qaaqtaq* [2].

Ecological Role: As one of the most common and widely distributed coregonids found in Alaskan Beaufort Sea coastal waters during summer [3], this species is a prominent member of the nearshore fish assemblage. Arctic Cisco is an important subsistence resource.

Physical Description/Attributes: Slender body with a dark brown to green back, silver belly, and pale (almost colorless) anal, pectoral, and pelvic fins. Unlike other ciscoes, does not have black spots on back or white spots on fins. Lower jaw does not protrude beyond upper jaw. Very closely resembles Bering Cisco. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 183) [4]. Swim bladder: Present [5]. Swim bladder ruptures have been documented when exposed to explosive-based instantaneous pressure change [6]. Antifreeze glycoproteins in blood serum: Unknown.

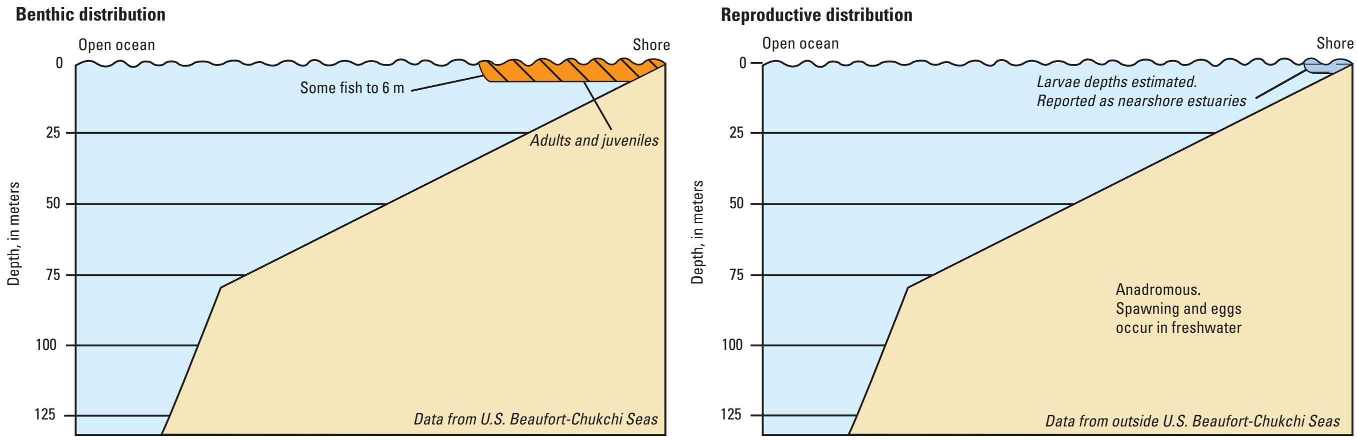
Range: *U.S. Beaufort Sea westward to northeastern Chukchi Sea at Point Lay* [7]. Worldwide, along coasts from the White Sea east through Siberia and to Mackenzie River, Canada [8].

Relative Abundance: *Rare from Barrow to Point Lay in U.S. Chukchi Sea* [7, 11]. Common *along coast of U.S. Beaufort Sea eastward from at least Colville River* [12]. Common at least as far east as Coppermine River mouth in Coronation Gulf, Canada [13].

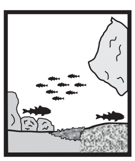
Geographic distribution of Arctic Cisco (*Coregonus autumnalis*) at sea within Arctic Outer Continental Shelf Planning Areas [9] based on review of published literature and specimens from historical and recent collections [4, 8, 10].

Depth Range: *Nearshore, rarely deeper than about 6 m. Common within a few hundred meters from shore*. [12, 14–19]. However, in Canadian Beaufort Sea, juveniles have been taken near the surface as far as 50 km offshore [20].

Coregonus autumnalis
Arctic Cisco



Benthic and reproductive distribution of Arctic Cisco (*Coregonus autumnalis*).



Habitats and Life History

Anadromous. *There appear to be some landlocked populations* [15].

Eggs—Size: 0.5–1.3 mm [21]. Time to hatching: Unknown. Habitat: Gravel beds in fast flowing freshwater rivers [15, 22].

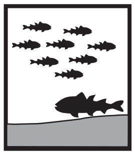
Larvae—Size at hatching: As small as 19 mm FL [15, 22]. Size at juvenile transformation: *About 45–54 mm FL* [12, 15, 23]. Days to juvenile transformation: Unknown. Habitat: Freshwater rivers to nearshore estuaries [22, 24, 25].

Juveniles—Age and size: 0–5 years and 4.5–32.8 cm FL [21, 23]. Habitat: Nearshore brackish or marine waters [22, 24, 25]. *Occasionally, juveniles have been found well upstream in some river systems (for example, Colville and Babbage Rivers)* [15, 26].

Adults—Age and size at first maturity: As young as 5 years in Russia, where males mature about 1 year earlier than females [27]. *North American fish mature at a wide range of ages. A few mature as early as 5 years, many at 6–8 years, and some at perhaps 11 years or older. A few are mature by 32.8 cm FL and virtually all by about 40.0 cm FL* [15, 21, 26, 28–30]. Length-weight relationships appear to be similar along much of the species' range. Male and female growth rates are similar [31], but females are larger at older ages than males and may also be heavier at length [30]. *Fish weigh less at length during years of cold water and heavy ice packs* [32]. Maximum age: At least 21 years [33]. Males and females may have similar life spans [26, 27]. Maximum size: 64 cm TL [4]. Habitat: Pelagic, nearshore brackish or marine waters and freshwater rivers [22, 24, 25]. *Adults generally re-enter fresh water only to spawn and then return to estuarine coastal waters* [22, 24, 25].

Substrate—Gravel for spawning [15, 22]. *Taken over sand-gravel in Chukchi Sea* [34].

Physical/chemical—Temperature:*–1.–13.5 °C* [12]. Salinity: *0–30.0 parts per thousand* [15, 35], *mainly in 10–25 parts per thousand except when spawning in fresh water* [15, 21]. Prefers relatively warm and brackish conditions [16, 35–38] but tolerant of cold and saline waters [17, 32, 39–41]. *May grow faster in warm and low-salinity water* [37].



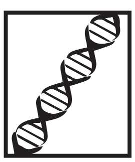
Behavior

Diel—Unknown.

Seasonal—Spawning occurs in autumn and eggs hatch during spring in MacKenzie River, Canada [15, 22]. Yolk-sac larvae are flushed downstream into the river delta in late May or early June [15, 22]. *Migrations to either east or west are passive, depending on strength and direction of winds and currents.* The predominant westerly winds tend to propel fish along Tuktoyaktuk Peninsula, Canada (at least as far as Liverpool Bay, near the Anderson River) [15]. *Strong easterlies assist their wind-aided migration westward, often to Colville River area,* although many are carried only as far as the Yukon Territory coast [39, 42]. *Successful year classes that reach the Colville River Delta are associated with summers when easterly winds are strong and more-or-less continuous, often of 5 km/h or more* [17, 29, 43, 44]. Eastward-moving juveniles often stay within 100 m of shore although more offshore migrations may occur [15, 17, 45]. Young-of-the-year first occurs off Yukon coast (Phillips Bay) between early July and September, and *recruit to the Prudhoe Bay-Colville River-Simpson Lagoon area between mid-August and late September* [12, 15, 23].

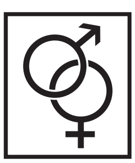
Juveniles migrate to overwintering grounds as autumn approaches. In Alaska, most fish winter under ice in brackish, deep channels of the Colville River, and some in lower parts of the Sagavanirktok River [15, 24, 46]. *However, the Sagavanirktok River may not provide sufficient annual winter refuge to sustain long-term populations* [40]. *An estimated 1.2–1.8 million individuals larger than 250 mm FL overwinter in the Colville River Delta* [46]. To the east, wintering grounds are in the Mackenzie River Delta (perhaps as far west as Herschel Island), as well as in bays and lagoons along the Tuktoyaktuk Peninsula, in Tuktoyaktuk Harbour, and as far east as at least the Anderson River [22, 25, 31, 47, 48].

Juveniles leave overwintering grounds in summer when waters warm and disperse to feed in the nearshore, some moving at an average rate of 2.9 km/d [12]. Younger fish tend to remain in brackish waters and do not venture far [39]. *Older juveniles migrate farther during summer and are able to tolerate more saline conditions. Regardless of size, juveniles always begin to return to overwintering grounds after a few months and are usually in place by September* [12, 15, 49]. *At least in Arctic National Wildlife Refuge region, larger fish tend to move back to overwintering grounds earlier than do smaller ones* [16].



Populations or Stocks

Fish utilizing different Mackenzie River tributaries may form different genetic stocks [50].



Reproduction

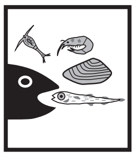
Mode—Iteroparous [26].

Spawning season—September to early October in Mackenzie River tributaries [15, 51], and September–December in Russia.

Fecundity—11,316–30,267 eggs in North America [30] and 7,700–52,000 eggs in Russia [15, 28].

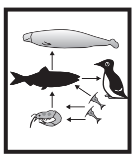
Reproductive—Upon maturity, their life cycle is dominated by migrations to and from spawning sites. Adults migrate back to the Mackenzie River, spending less time than usual in coastal waters. Autumn spawners enter the river from May to early August [22]. Little is known about spawning behaviors or specific conditions. Spawning occurs in fast waters over gravel [27, 52]. Most females spawn every other year [21, 26, 27, 51]. Post-spawning fish move downstream and overwinter in the Mackenzie River Delta [22, 52]. *During the next spring and summer they will disperse, with some exceptions, as far westward as Barter Island and at least as far eastward as the Anderson River* [15, 22, 26]. *The presence of a few older individuals (10–15 years) along the North Slope as far west as Simpson Lagoon implies that older fish will occasionally make more extensive migrations* [12, 16, 18, 32].

Although common along much of the Beaufort Sea coast, most, or perhaps all Arctic Cisco are believed to spawn in Mackenzie River tributaries such as Great Bear, Arctic Red, Peel, and Liard Rivers, the latter being more than 1,700 km from the Beaufort Sea [15, 42, 53]. Evidence for limited spawning in other waterways is discussed in the section, "Remarks." Intertidal or subtidal spawning in estuaries and perhaps the sea has been reported in Russian waters [27] but has not been observed in North America.
Schooling—*Forms schools, often in groups of tens to several hundreds. Sometimes schools with Dolly Varden* [12, 18, 26]. *Individuals may stay together in same school for months at a time (specifically, several fish tagged on same date at Simpson Lagoon were recaptured together several months later)* [12].
Feeding—*Opportunistic feeders. Feed under ice during winter (at a reduced rate)* [46], *although food habits may change, reflecting differences in food availability* [12]. Rarely feeds during spawning migrations [48, 51, 52, 54].



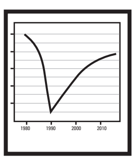
Food and Feeding

Food items—*A wide variety of benthic and water column prey. Important prey include various crustaceans (for example, amphipods, copepods, mysids, and cladocerans), insects (particularly chironomids), snails, clams, polychaetes, fishes* (for example, Fourhorn Sculpin and Arctic Cisco), fish eggs, and occasionally plant material [12, 31, 35, 54].
Trophic level—3.57 (standard error 0.56) [55].



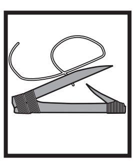
Biological Interactions

Predators—Dolly Varden, Arctic Smelt, and Arctic Cisco [21, 26].
Competitors—Shallow, nearshore species such as Dolly Varden, Arctic Cod, other whitefishes, and sculpins.



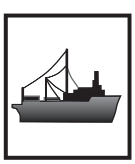
Resilience

Low, minimum population doubling time is 4.5–14 years (t_m=6; Fecundity=2,000) [55].



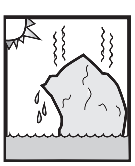
Traditional and Cultural Importance

Arctic Cisco are widely taken in subsistence fisheries along much of the U.S. Beaufort Sea coast. Juvenile Arctic Cisco in particular form the basis for major subsistence in the Colville River Delta. Most of the fish are captured under the ice by gill nets during the autumn. Currently, the principal fishing areas on the Colville River are in the lower delta and near the village of Nuiqsut [29, 56, 57]. *Part of this catch is distributed to other parts of Alaska* [12]. *The summer fishery at Kaktovik may catch newly matured fish as they migrate back to the Mackenzie River* [1, 58]. Annual catch records have been collected since 1968.



Commercial Fisheries

A small commercial fishery for Arctic Cisco in the Colville River Delta was terminated in 2010. Currently, there is no commercial fishing for Arctic Cisco.



Potential Effects of Climate Change

Unknown, as the effect of climate change on the Mackenzie River system and on the wind patterns that control juvenile movements, are unclear. However, von Biela and others (2011) [59] determined that young-of-the-year growth increased during years of stronger east winds, as well as reduced sea-ice concentration and Mackenzie River discharge, and that there was a time lag of one or 2 years. Generally, Durand and others (2011) [60] predict that, at least for anadromous fishes in subarctic rivers, shifts in biology will be effected by spring ice break-up and resultant peak flows and surrounding permafrost processes: both of which affect the supply of nutrients and (or) sediment to the watershed of climate change on spring break-up intensity.

Areas for Future Research [A]

Although it is clear that Arctic Cisco frequently use nearshore, shallow waters for feeding and migration, the role, if any, of offshore waters has not been completely investigated. The physiological tolerance of young-of-the-year fish to cold, high salinity water has been suggested but not confirmed in laboratory studies and may be an important constraint to recruitment in Alaskan waters. Environmental tolerance experiments including effects of different temperature and salinity regimes on the growth and survival of Arctic Cisco are needed to assess the species vulnerability to climatic changes. In addition, the location and significance of important habitats in the Mackenzie River and the potential for isolated spawning stocks should also be explored. Studies to describe the genetic relationships between Arctic and Bering Cisco are needed. Coastal monitoring at key reference locations should be designed to track changes in population health (growth, survival, recruitment, and condition).

Remarks

Although it is clear that most, if not all, Beaufort Sea Arctic Cisco spawn in the Mackenzie River, there is evidence that spawning may occur on other grounds. Colonell and Gallaway (1997) [53] provide indirect evidence for some spawning west of the Colville River. They noted that some subsistence fishermen near Barrow stated that they captured mature Arctic Cisco in their autumn fishery. The Colonell and Gallaway (1997) indicated that on several occasions strong westerly winds, anticipated to lead to poor recruitment of young Arctic Cisco in the Colville River area (through poor transport from the Mackenzie River to the east), led instead to large recruitment. This would imply that westerly currents from some spawning waters west of the Colville River carried young fish to the study site. Colonell and Gallaway (1997) [53] also cited three genetic studies that posit a genetically differentiated group of Arctic Cisco in western Alaska. Bond and Erickson (1997) [22] reported on the capture of young-of-the-year Arctic Cisco at the mouth of the Anderson River in early July. They suggested that these captures were too early in the season to be fish that had hatched in the Mackenzie River and then carried eastward for hundreds of kilometers. They also noted that capture in Wood Bay (into which the Anderson River empties) of hybrid Arctic Cisco-other coregonids; captures that imply that Arctic Cisco were mating with fishes in that region. *Lastly, Bickham and others (1997)* [61] *determined that some Arctic Cisco from the western Beaufort Sea carried mitochondrial DNA of Bering Cisco* (C. laurettae). *As Bering Cisco are unknown from the Mackenzie River (the putative site of all Arctic Cisco spawning) it appears that some Arctic Cisco spawn to the west of the MacKenzie River.*

Arctic Cisco are closely related to Lake Cisco (*Coregonus artedi*) and Bering Cisco (*C. laurettae*) [62]. In the Northwest Territories, they occasionally hybridize with Least Cisco and Humpback Whitefish [63].

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Bering Cisco (*Coregonus laurettae*)

Bean, 1881

Family Salmonidae

Bering Cisco (*Coregonus laurettae*). Photograph by R.J. Brown, U.S. Fish and Wildlife Service.

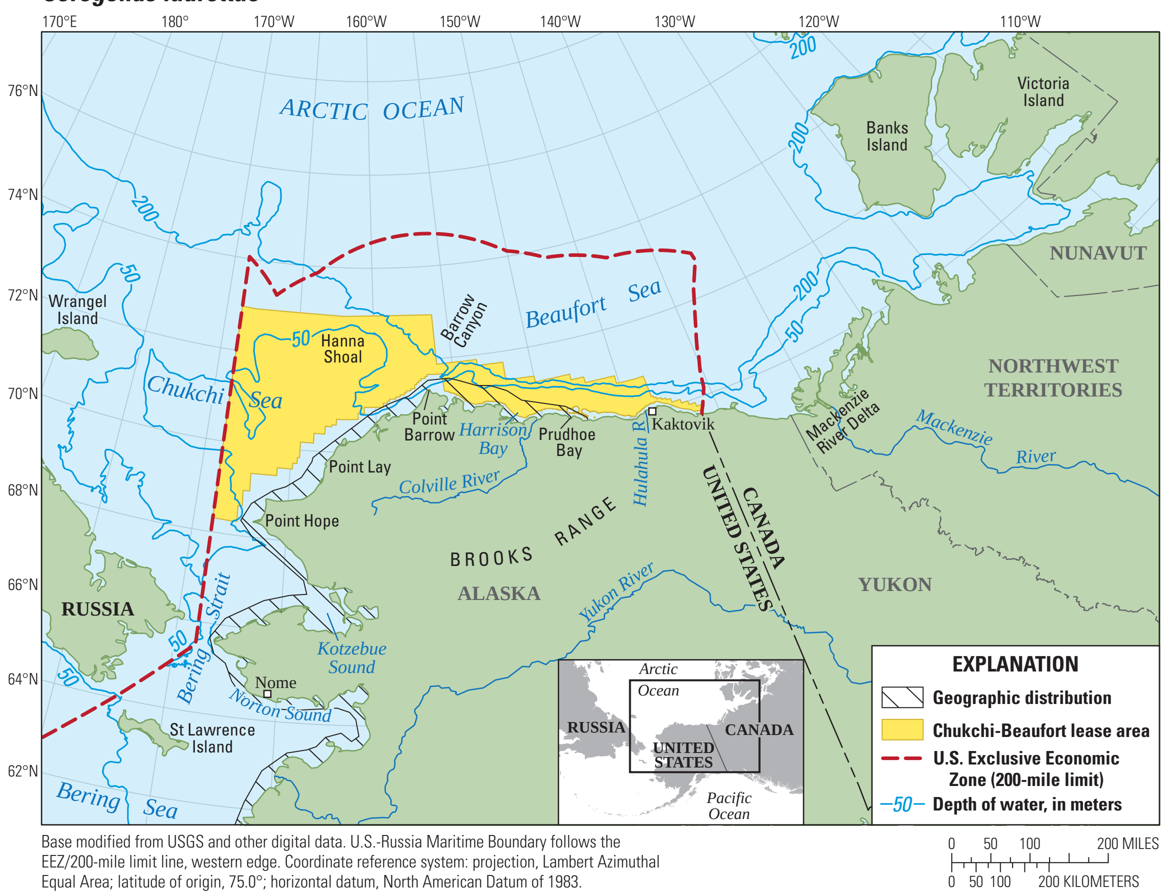
Colloquial Name: Iñupiat: *Qaaktaq, tipuk* [1].

Ecological Role: Although data are lacking, this is a schooling species, and may be of some ecological importance in the nearshore of the U.S. Chukchi Sea and perhaps western part of U.S. Beaufort Sea.

Physical Description/Attributes: Elongate, slightly compressed body with brownish to dark green back and silvery belly. There may be black dots with faint halos on the body, or white spots on the fins, or both. The anal, pectoral, and pelvic fins are pale. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 184) [2]. Swim bladder: Present [3]. Antifreeze glycoproteins in blood serum: Unknown.

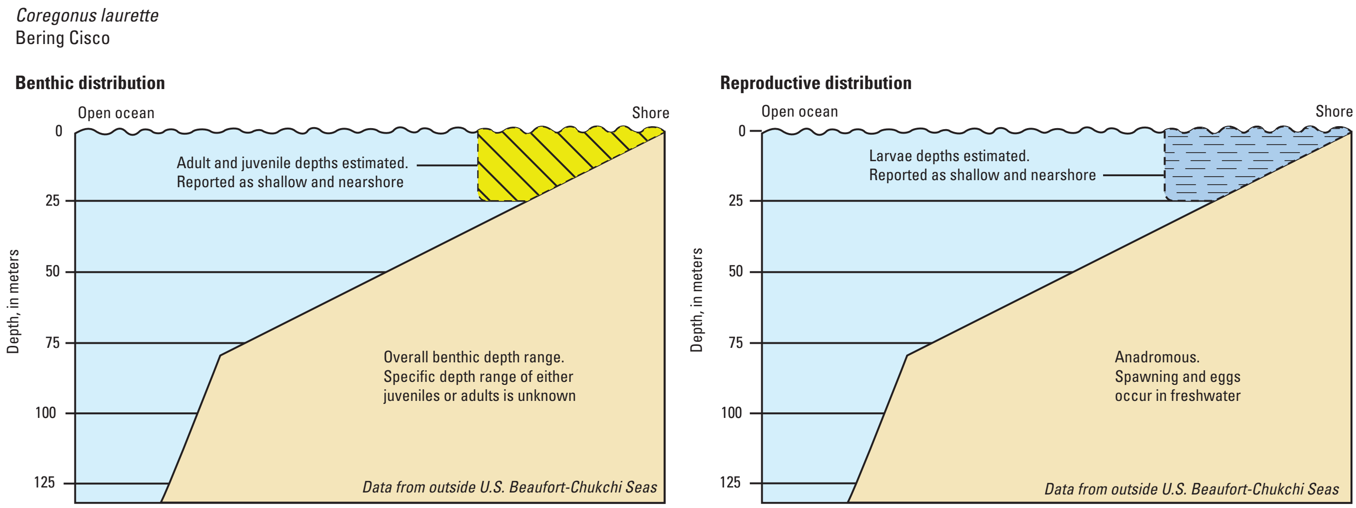
Range: *U.S. Chukchi Sea east to U.S. Beaufort Sea at Oliktok Point (just east of the Colville River).* Elsewhere in Alaska, southward to the Kenai Peninsula, northern Gulf of Alaska. Worldwide, Chukotka Peninsula, eastern Siberia, Russia [2].

Relative Abundance: *Patchily abundant (common on rare occasions) as far eastward as the Colville River, as well as such locations as the Barrow, Wainwright, and Kotzebue regions* [7–9].

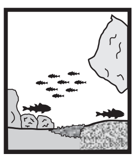


Geographic distribution of Bering Cisco (*Coregonus laurettae*) at sea within 2008–09 lease areas [4] based on review of published literature and specimens from historical and recent collections [5, 6].

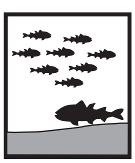
Depth Range: Mainly shallow nearshore waters, although taken as much as 20–30 km offshore in Yukon River plume [10, 11].



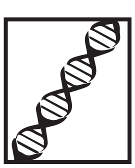
Benthic and reproductive distribution of Bering Cisco (*Coregonus laurette*).



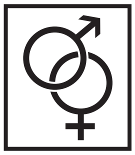
Habitats and Life History
Anadromous [12].
Eggs—Size: Specific size unknown. 2.3–3.0 mm for whitefish in general [12]. Time to hatching: Specific time unknown. 150–200 days for northern whitefish in general [12]. Habitat: Benthic, in gravel beds of fast-flowing rivers [11, 12].
Alevins (larvae)—Size at hatching: Unknown. Size at juvenile transformation: Unknown. Days to juvenile transformation: Unknown. Habitat: Pelagic, in freshwater rivers to nearshore estuaries [11].
Juveniles—Age and size: Minimum size unknown. Matures at about 4 years and 310 mm [11, 13]. Habitat: Nearshore marine and brackish waters [11].
Adults—Age and size at first maturity: 4 years and as small as 310 mm (Yukon River) [11, 13]. Maximum age: At least 13 years [12], *and at least 8 years in Colville River area* [9]. Maximum size: 48 cm [2]. Habitat: Pelagic, mainly in marine and estuarine nearshore waters. Fast-flowing rivers for spawning [11].
Substrate—Sand and gravel for spawning [11, 12].
Physical/chemical—Temperature: Unknown. Salinity: Fresh to full seawater. The most marine-tolerant of all coregonids within the study area range [13].



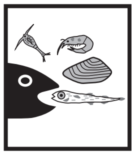
Behavior
Diel—Unknown.
Seasonal—Eggs hatch in spring. Alevins (larvae) likely move downstream soon after and enter coastal waters where they spend their first years [11]. Upon maturity, adults migrate up river. Anadromous fish, probably on spawning runs, have been found at least 2,000 km [14] or perhaps as much as 2,150 km [15] upstream in the Yukon River. Spawning occurs in Yukon, Kuskokwim, and Susitna Rivers [11, 12, 16]. Yukon River spawning migrations are continuous throughout the summer with major pulses varying from year to year [12]. Spawning occurs in autumn [11]. *Juveniles and adults overwinter beneath ice of river deltas and other coastal waters* [7, 11, 17].
Reproductive—Spawns annually [12]. Broadcast spawners over gravel beds in fast-flowing rivers [11]. Returns to sea after spawning [11].
Schooling—Forms schools [11].
Feeding—Feeding likely occurs in nearshore waters, especially near river mouths and brackish estuaries [11]. Does not feed during spawning migrations [11].



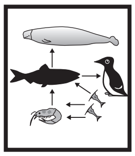
Populations or Stocks
There have been no studies within the study area.



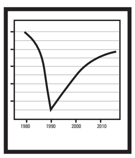
Reproduction
Mode—Gonochoristic, oviparous, iteroparous with external fertilization [11].
Spawning season—Autumn; early to mid-October in Yukon and Kuskokwim River drainages [11, 12].
Fecundity—In Yukon River, 20,210–34,166 orange, non-adhesive eggs [12].



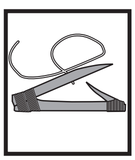
Food and Feeding
Food items—Mysids as well as harpacticoid copepods, isopods, gammarid amphipods, crangonid shrimps, insects, and small fishes [18].
Trophic level—3.79 (standard error 0.59) [19].



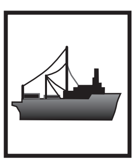
Biological Interactions
Predators—Unknown.
Competitors—Unknown.



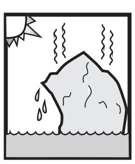
Resilience
Medium, minimum population doubling time: 1.4–4.4 years (Preliminary *K* or Fecundity) [19].



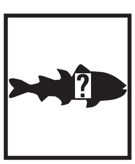
Traditional and Cultural Importance
There are subsistence fisheries for Bering Cisco wherever the species is found. *The species is most important near Wainwright* [20] *and Kotzebue Sound* [7], *although occasional anomalously large runs are known from the Colville River region* [8]. *Bering Cisco are taken during open water seasons and under the ice by gillnets and hook and line* [20, 21]. *This very oily species is most often roasted, salted, or frozen* [7].



Commercial Fisheries
Currently, Bering Cisco are not commercially harvested. Historically, there has been no commercial fishery for this species [22] until 2008, when a fishery was initiated at the mouth of the Yukon River to supply a New York kosher market with smoked fish [12].



Potential Effects of Climate Change
Unknown. However, Durand and others (2011) estimate that, at least for anadromous fishes in sub-arctic rivers various biological shifts will be caused by the timing of spring ice break-up (and thus peak flow timing) and various permafrost processes that influence nutrient and sediment supply [23]



Areas for Future Research [B]
Little is known about the ecology and life history of this species in the study area. Research needs include: (1) depth, location, and timing of spawning; (2) size and age of fish at hatching and transformation; (3) preferred depth ranges and locations for juveniles and adults; (4) spawning season; (5) seasonal and ontogenetic movements; (6) population studies; (7) prey; and (8) predators.

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Broad Whitefish to Dolly Varden

Broad Whitefish (*Coregonus nasus*)
(Pallas, 1776)

Family Salmonidae

Broad Whitefish (*Coregonus nasus*). Photograph by R.J. Brown, U.S. Fish and Wildlife Service.

Colloquial Name: *Iñupiat—Aanaakliq, Aanaaliq* [1, 2]; *Qalupiaq, Qausriluk, Qausiluk, Sigguilaq, Siyyuilaq* [3, 57].

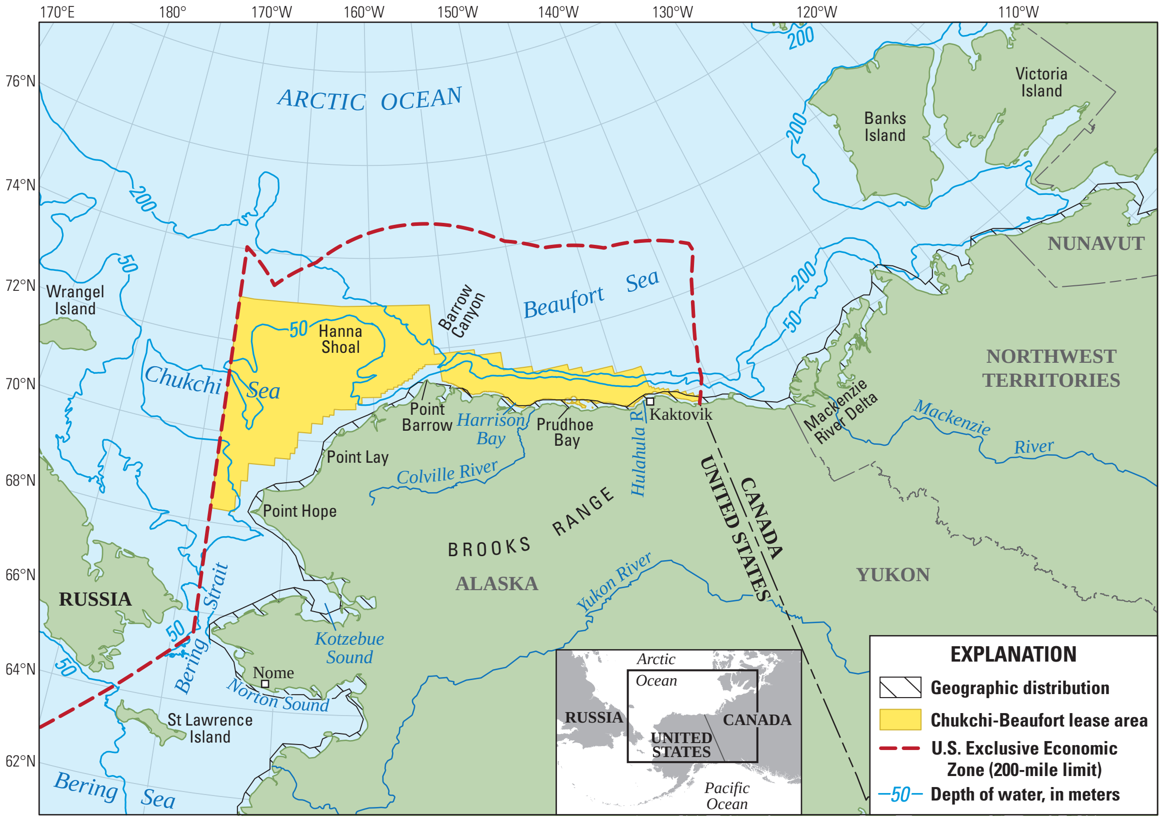
Ecological Role: This species rarely ventures into marine waters, preferring fresh and nearshore brackish conditions. It is one of the most prominent members of the coastal fish community and is important in seasonal food webs during ice-free periods.

Physical Description/Attributes: Laterally compressed with a rounded to flat head, a broad maxilla, short and blunt gill rakers, and very thick scales. These scales develop prominent tubercles during the spawning season. Colors are olive-brown to nearly black on back, silvery, and white to yellowish belly. Fins of small fish are pale and in older individuals are dark [3, 4]. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 185) [4]. Swim bladder: Present [5]. Antifreeze glycoproteins in blood serum: Unknown.

Range: *U.S. Chukchi and Beaufort Seas* [4]. Elsewhere in Alaska, found in Bering Sea drainages south to Kuskokwim Bay, southwestern Alaska. Worldwide, Arctic coasts from Siberia eastward to the Perry River, Nunavut, eastern Canada [4].

Relative Abundance: *Common in parts of U.S. Beaufort Sea and southward in U.S. Chukchi Sea to at least the Kotzebue Sound* [3, 9]. *Relatively rare nearshore between Smith Bay and Cape Halkett in Beaufort Sea* [10], *along ANWR* and Yukon coasts [11–16], *and along northeast Chukchi Sea coast* [17], reflecting this species' intolerance of cold and saline waters. Elsewhere, common eastward in Canadian Beaufort Sea to at least the Coppermine River [18].

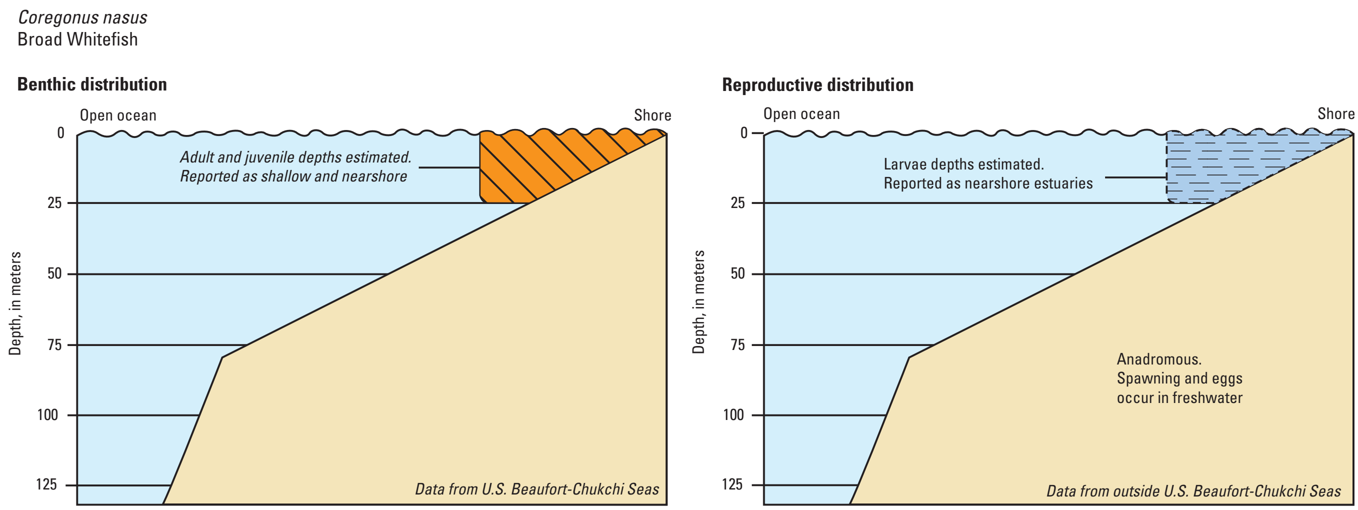
Broad Whitefish
Coregonus nasus



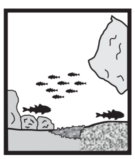
Base modified from USGS and other digital data. U.S.-Russia Maritime Boundary follows the EEZ/200-mile limit line, western edge. Coordinate reference system: projection, Lambert Azimuthal Equal Area; latitude of origin, 75.0°; horizontal datum, North American Datum of 1983.

Geographic distribution of Broad Whitefish (*Coregonus nasus*), at sea within Alaska Outer Continental Shelf Planning Areas [6] based on review of published literature and specimens from historical and recent collections [4, 7, 8].

Depth Range: *Shallow, nearshore waters* [4, 19, 20].



Benthic and reproductive distribution of Broad Whitefish (*Coregonus nasus*).



Habitats and Life History

Exhibits a wide range of life history strategies. Anadromous, migrating from fresh to brackish waters for a few months in summer, to lacustrine, never leaving fresh water [21–24]. Migratory fish have been variously termed “facultative anadromous” [14], “semi-anadromous” [23], and “diadromous” [25]. *Those entering U.S. Chukchi and Beaufort seas are primarily freshwater residents, only using the coastal zone as a migration corridor and an alternate feeding habitat under suitable (low-salinity) conditions* [26]. *This account focuses on those fish that migrate into the shallow waters of the Chukchi and Beaufort Seas.* Lacustrine and riverine types are discussed elsewhere [23, 27–29]. The early life history of this species is best known for fish produced in the Mackenzie River watershed, however even here there are some uncertainties.

Eggs—Size: 1.7–2.3 mm [30]. Time to hatching: Specific time unknown; 150–200 days for northern whitefish in general [31]. *Spawning is in autumn and eggs hatch during spring* [3, 27, 32, 33]. Habitat: *Gravel beds in fast-flowing freshwater rivers* [27].

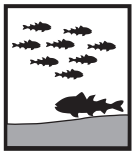
Fry—Size at hatching: Unknown. Days to juvenile transformation: Unknown. Habitat: *Freshwater rivers to nearshore estuaries* [14, 16, 27, 34].

Juveniles—Age and size: 0–5 years and 4.5–32.8 cm [35, 36]. Habitat: Primarily freshwater rivers and lakes to nearshore estuaries [14, 16, 34]. In the Mackenzie River, when young-of-the-year fish are flushed out of the river, they mainly are carried eastward along the Tuktoyaktuk Peninsula; some move into the outer or inner delta regions or eastward along the Yukon coast. Those reaching the Tuktoyaktuk Peninsula ascend rivers and spend up to 4 years in lakes. Larger, but still immature, fish may over winter in lakes or coastal waters, and use the coast, creeks, and lakes of the Tuktoyaktuk Peninsula as summer feeding grounds [12, 13, 16, 23, 27, 37]. Outcome of fish not transported along the Tuktoyaktuk Peninsula is unknown; although those carried westward along the Yukon coast may not survive due to its cold and highly saline waters [12, 13, 16, 23, 27, 37].

Adults—Age and size at first maturity: Highly variable throughout its range; *from 3 to at least 21 years, mostly at 6–9 years (30–40 cm long)* [13, 20, 22, 23, 27, 29, 37, 38]. Maximum age: Between 30 and 38 or more years [2, 27]. Maximum size: 83.5 cm [2]. Habitat: Pelagic, in fresh and nearshore brackish (rarely marine) waters [21, 23, 24, 26, 28].

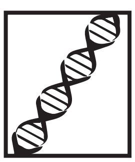
Substrate—Sand and gravel beds for spawning [27, 31].

Physical/chemical—Temperature: At least 0–16 °C [24]. Spawning occurs at about 0 °C [13]. Salinity: *0–30 parts per thousand, but rare in higher salinity waters. Juveniles cope with salinities greater than 15–20 parts per thousand for only short periods, whereas larger fish are more tolerant of brackish conditions* [20, 22, 26, 39].



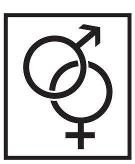
Behavior

Diel—Unknown. Seasonal—*In spring eggs hatch under ice (perhaps in April and May)* [23, 27] and young-of-the-year are flushed out of the river into the river's estuary during break-up [12, 13, 16, 23, 27, 37]. *In June fish migrate into the smaller estuarine river deltas of the U.S. Beaufort Sea* [19] [20], *and generally do not migrate far* [12, 40, 41]. *For instance, Sagavanirktok River fish remain in the river delta until they are at least 3 years old* [41]. *In that population, the somewhat older fish are more tolerant of saline conditions and may migrate farther along coasts, typically moving between the Sagavanirktok and Colville Rivers* [25]. *At the extreme, a fish tagged in Prudhoe Bay was recaptured in Kaktovik Lagoon, 175 km to the east* [42]. *However, once mature, many adult fish also exhibit restricted movements* [26]. At least in the Mackenzie River, once a fish has spawned it remains within the river's influence for the rest of its life and never returns to its Tuktoyaktuk Peninsula nursery grounds [23]. *Fish destined to spawn begin to enter rivers mostly in July and August* [19, 27, 38]. *Mature fish preparing to spawn tend to move to staging areas in river mouths earlier than do mature, non-spawning individuals. Regardless of maturation state, by September all broad whitefish have returned to rivers, with spawning fish migrating earliest* [27, 37]. Fish overwinter in a wide range of habitats. Depending on location, overwintering grounds include nearshore brackish waters, river deltas, deep pools in rivers, and a variety of lakes [16, 19, 23, 27, 43]. In Alaska, overwintering in nearshore waters is not known to occur.
Reproductive—Spawning occurs in fresh water, likely in their natal streams [23]. In some river systems, fish may travel great distances to spawning sites. For instance, Yukon River fish may migrate at least 1,700 km [44]. In the Mackenzie River, fish first congregate in the river delta for a few months before moving upstream to the spawning grounds, perhaps waiting for water temperatures to be to near 0 °C before migrating [13, 23, 27]. *In U.S. Chukchi and Beaufort Seas, spawning occurs in many rivers, from the Sagavanirktok River to at least the Meade River* [12, 19], *and in the Kobuk and Selawik Rivers in the Kotzebue region [3]. In most northern Alaskan rivers, spawning occurs in the lower parts of the waterways in deeper pools* [19, 27], *except the Colville River where fish may spawn a significant distance from the mouth* [27]. *With the possible exception of the Canning River, none of the "mountain" rivers or streams of the eastern Alaskan and Yukon coasts harbor spawning populations* [12, 25, 45]. However, scattered non-spawning fish have been captured in a number of Canadian rivers west of the Mackenzie River [12]. Upon reaching maturity, spawning may occur annually or every other year [31]. Broad Whitefish are broadcast spawners that release gametes into the water column over gravel beds; eggs sink to the bottom after fertilization [27, 46].
Schooling—Unknown.
Feeding—*Opportunistic predators* [27]. Adults undertaking spawning migrations only occasionally feed [47]. Mature individuals or current-year spawners spend the summer prior to spawning feeding in delta habitats, peninsula lakes, or brackish water environments [23]. In the Alaska Beaufort Sea, nearshore brackish habitats are annually colonized by a rich benthic invertebrate community that forms the base of the coastal food web.



Populations or Stocks

Information about population sizes of Broad Whitefish occurring in U.S. Chukchi and Beaufort Sea drainages does not exist. However, life history parameters have been developed for fish found in the Sagavanirktok and Colville Rivers. Genetic distinctions among fish from the Mackenzie River and its tributaries appear likely. Groups of fish may have both distinct spawning and overwintering grounds [16]. Fish of the Mackenzie River Basin also likely are genetically distinct from those living in other watersheds [32, 48–50]. Investigators have reported genetic differences in fish found in the Sagavanirktok and Colville Rivers.

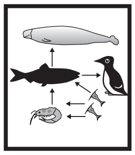


Reproduction

Mode—Gonochoristic, oviparous, and iteroparous with external fertilization [27].
Spawning season—*Mainly in October and November, at freeze-up under the ice* [3, 21, 23, 27].
Fecundity—10,070–117,687 pale-colored eggs [3, 33].

Food and Feeding

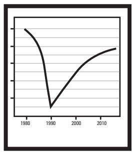
Food items—*Zooplankton, for young-of-the-year; a wide range of invertebrates including chironomids and other insects, clams, amphipods, snails, polychaetes, oligochaetes, mysids, isopods, and plants for larger individuals* [27, 28, 47, 51, 52].
Trophic level—3.28 (standard error 0.44) [53].



Biological Interactions

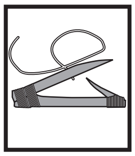
Predators—*Not well understood.* Ringed seals are probably a major predator; brown bears in the Mackenzie River occasionally feed on them [54].

Competitors—Likely other opportunistic feeders, such as other whitefish species, Dolly Varden, Arctic Cisco, Least Cisco, Bering Cisco, Humpback Whitefish, Arctic Flounder, Fourhorn Sculpin, and Arctic Cod.



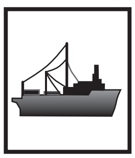
Resilience

Low, minimum population doubling time 4.5–14 years (*K*=0.10–0.30; t_m=7; t_{max}=15; Fecundity=10,000) [53].



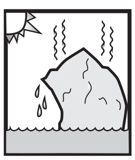
Traditional and Cultural Importance

Among the most important food fishes in the Arctic, taken in large numbers in the Kotzebue region on the Chukchi Sea, and from about Barrow, Alaska, to the Coppermine River, Northwest Territories, Canada, in the Beaufort Sea [1–3, 18, 37, 55]. *Depending on location, and apparently on local preferences, most Broad Whitefish are frozen and either aged or dried* [2, 3, 55].



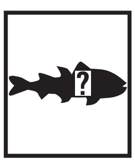
Commercial Fisheries

Currently, Broad Whitefish are not commercially harvested. *Repeated efforts to create viable, large-scale commercial fisheries for this species have failed, although they were caught and sold as by-catch in the Arctic Cisco fishery on the Colville River* [20, 39]. The Iñupiat currently harvest and sale in Barrow under the subsistence barter and trade category rather than as an actual commercial fishing operation.



Potential Effects of Climate Change

Unknown. Generally, Durand and others (2011) [60] predict that, at least for anadromous fishes in subarctic rivers, shifts in biology will be effected by spring ice break-up and resultant peak flows and surrounding permafrost processes: both of which affect the supply of nutrients and (or) sediment to the watershed of climate change on spring break-up intensity.



Areas for Future Research [A]

The Broad Whitefish is a dominant species in brackish waters of the Alaska Beaufort Sea and has been well studied in the central Beaufort Sea near Prudhoe Bay. Population parameters including condition factors, genetic information, and habitat use are reasonably well known for this area. Coastal monitoring of populations should be continued to track population growth, survival, and recruitment patterns and changes in the coastal fish assemblage as indicators of environmental change.

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Humpback Whitefish (*Coregonus pidschian*)
(Gmelin, 1789)

Humpback Whitefish (*Coregonus pidschian*). Photograph by R.J. Brown, U.S. Fish and Wildlife Service.

Family Salmonidae

Colloquial Name: Iñupiat—*Piqutuuq, Pikuktuuq* [1]; *Ikkuiyiq, Iqalupiaq, Iqalutchiaq, Qaalgiq* [2].

Note: *American biologists have generally referred to anadromous and Alaska-dwelling individuals of this species as "humpback" whitefish* (Coregonus pidschian)*. Anadromous fish in northern Canada usually have been called "lake" whitefish* (C. clupeaformis)*, by Canadian researchers. Based on both morphological and genetic studies, McDermid and others (2005)* [3] *determined that, in North America, individuals of this group could be assigned to one of three subspecies (1) Humpback Whitefish* (Coregonus clupeaformis pidschian)*, (2) Mississippian Lake Whitefish* (Coregonus clupeaformis clupeaformis)*, and (3) Alaska Whitefish* (Coregonus clupeaformis nelsonii)*. In particular, fish referable to the Humpback Whitefish subspecies were found in waters from the Alaska Peninsula through the U.S. Chukchi and Beaufort Sea drainages, and eastward to at least the lower Mackenzie River. For geographic ranges of all three subspecies, see McDermid and others (2005)* [3]*. In this account, data are included only from populations living within those ranges.*

Taxonomy: *The correct species name for this complex is pidschian, because it is the oldest name, used by Gmelin in 1789 when naming and describing the species. The name clupeaformis is more recent, used by Mitchill in 1818. In zoological nomenclature the oldest name has priority*.

Ecological Role: This species rarely ventures into marine waters, and prefers freshwaters and nearshore brackish waters. It likely is of considerable ecological importance only within this relatively proscribed area.

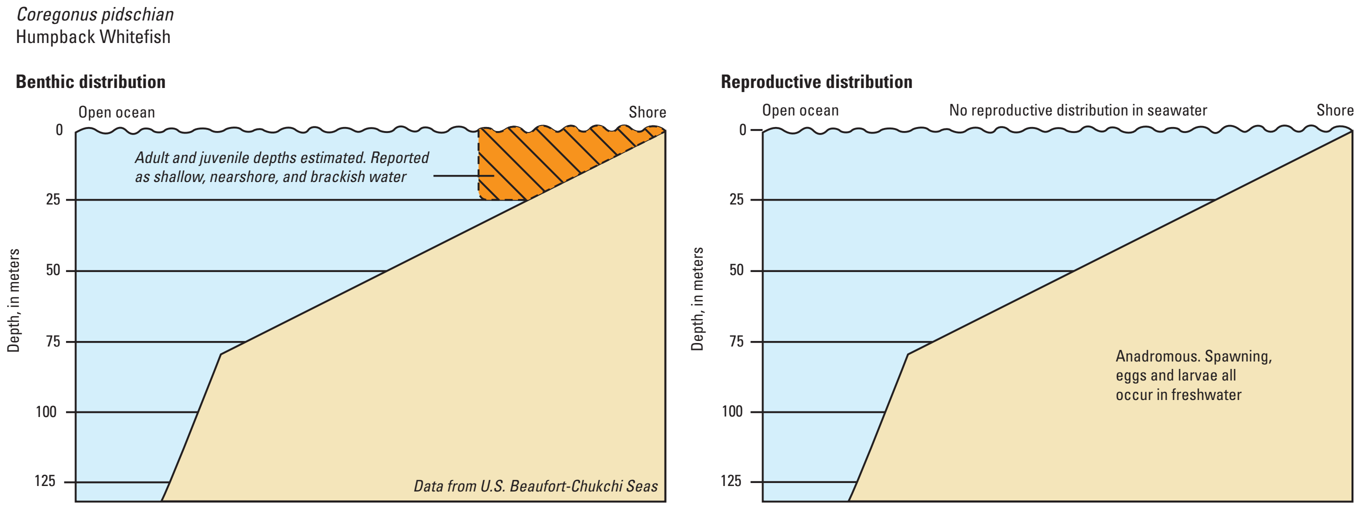
Physical Description/Attributes: Dark brown to dark blue back, silver sides, and white belly prominent nuchal hump [4]. Both sexes (more prominently in males) develop "nuptial tubercles" on head and scales [2]. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 188) [4]. Swim bladder: Present [5]. Antifreeze glycoproteins in blood serum: Unknown.

Range: *Coastal waters of U.S. Chukchi and Beaufort Seas*. Elsewhere in Alaska, found in Bering Sea south to Bristol Bay [6]. Worldwide, along Arctic coasts from Siberia, Russia, west to Kara Sea, and eastward along Alaskan and Canadian coasts to Hudson Bay and New England (as *C. clupeaformis* of Canadian authors) [4, 7].

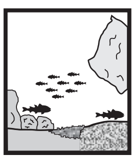
Relative Abundance: *Common in coastal waters of southeastern U.S. Chukchi Sea, but is uncommon in northeastern Chukchi Sea* [8]. *Common in coastal waters of U.S. Beaufort Sea, except is uncommon between about Smith Bay and Cape Halkett* [9] *and off the Arctic National Wildlife Refuge* [10, 11]. Elsewhere, fairly common in Canadian Beaufort Sea along the outer Mackenzie River Delta [12].

Geographic distribution of Humpback Whitefish (*Coregonus pidschian*), at sea within Arctic Outer Continental Shelf Planning Areas [13] based on review of published literature and specimens from historical and recent collections [4, 14, 15].

Depth Range: *Shallow, nearshore waters* [16, 17].



Benthic and reproductive distribution of Humpback Whitefish (*Coregonus pidschian*).



Habitats and Life History

Populations are amphidromous and freshwater [18, 19]. Amphidromous fish tend to remain in estuaries, within the influence of freshwater drainages [12, 16, 17].

Eggs—Size: 1.2–1.6 mm [20] and 144–257 eggs per gram ovary weight [21]. Time to hatching: About 6 months, based on autumn spawning and late winter to spring hatching [22, 23]. Size of eggs: Unhatched. Habitat: Freshwater; gravel beds in shallow and moderately swift waters [24].

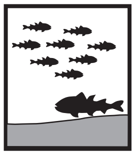
Larvae—Size at hatching: Unknown. Size at juvenile transformation: Unknown. Days to juvenile transformation: Unknown. Habitat: Freshwater [18].

Juveniles—Age and size: *On average, to about 6 years and about 30.0 cm* [16, 18, 23, 25, 26]. *Habitat: Fresh and brackish waters* [23, 26]; *tend to remain in estuaries, within the influence of freshwater drainages* [12, 16, 17].

Adults—Age and size at first maturity: *Primarily at 7–10 years* [16, 18, 23, 25]. *However, in some populations, maturation occurs at a later age. For example, in Dease Inlet/Admiralty Bay region, 50 percent of fish are mature at about 11 years and not all fish mature until perhaps 14 years* [26, 27]. *Most fish are mature between 300 and 350 mm* [23, 26, 28]. Maximum age: 37 years [23]. Maximum size: 54 cm [39]. Habitat: *Pelagic, in fresh and nearshore brackish waters; tend to remain in estuaries, within the influence of freshwater drainages* [12, 16, 17].

Substrate—Gravel to sand and silt for spawning [24, 29].

Physical/chemical—Temperature: 0–16 °C [19]. Salinity: *At least 0–28 parts per thousand* [17].



Behavior

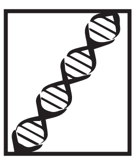
Diel—Unknown.

Seasonal—*Young fish are carried downstream to lower parts of rivers and into brackish coastal waters* [22, 23]. *Smaller fish tend to stay in or near river mouths, whereas larger individuals are able to tolerate somewhat colder and more saline waters and venture somewhat farther along the coast* [23, 26]. *However, most fish tend to remain within the brackish water lens* [17, 24]. In Mackenzie River area (including the Tuktoyaktuk Peninsula), juvenile fish may remain in coastal channels, lakes, and other quiet waters for several years before returning to the river [24]. *Mature fish return to rivers beginning in June and this migration perhaps peaks in August* [25, 30, 31].

Reproductive—Although spawning may occur within a few kilometers of river mouths [23], spawning migrations may be quite extensive (as far as 1,700 km from the mouth in the Yukon River) [32]. Spawning tends to occur in relatively slow- or moderate-moving rivers (that is, Colville River, Alaska, and Mackenzie River, Canada). *In Beaufort Sea drainages, most spawning takes place between Barrow and the Sagavanirktok River* and in the Mackenzie River [18, 23, 33]. *Although Humpback Whitefish have been captured in most of the rivers flowing into the Beaufort Sea, it is not known whether fish spawn in such fast-flowing rivers as the Canning River, Alaska, or if these are only seasonal visits. Similarly, in the Chukchi Sea, Humpback Whitefish have not been found in numerous rivers, including the Kokolik, Utukok, Kukpowruk, and Kuk, Alaska* [23], *although they do spawn in the Kobuk River* [2]. Spawning occurs over gravel or sand, in shallow waters. Eggs are broadcast over the river floor and lodge in crevices [24]. *After spawning, mature fish migrate down river and overwinter in brackish waters of river mouths and perhaps in fresh water* [18, 24, 34].

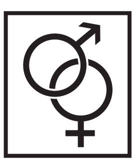
Schooling—Unknown.

Feeding—Unknown.



Populations or Stocks

At least some distinct populations may exist among drainages running into the Beaufort and Chukchi Seas [3].



Reproduction

Mode—Gonochoristic, oviparous, and iteroparous with external fertilization [23].

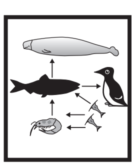
Spawning season—*Primarily September–October, but may extend into November and December* [2, 22, 29]. *At least some mature individuals spawn only every other year* [19, 26].

Fecundity—5,000–122,000 *eggs, with higher numbers in larger fish* [21, 26, 27, 29].

Food and Feeding

Food items—*Benthic and epibenthic prey including clams, crustaceans (for example, isopods, amphipods, copepods, and mysids), insects, snails, fishes, and plants* [26, 28].

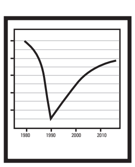
Trophic level— 3.2 (standard error 0.40) [35].



Biological Interactions

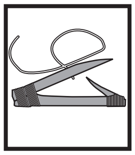
Predators—Unknown.

Competitors—Likely other benthic and epibenthic predators including other whitefish species, sculpins, Arctic Flounder, and Dolly Varden.

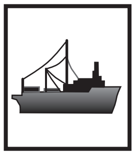


Resilience

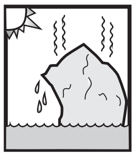
Low, minimum population doubling time 4.5–14 years (t_m=3–14; t_{max}=14; Fecundity=8,000) [35].



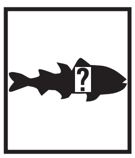
Traditional and Cultural Importance
A very important part of several subsistence fisheries, particularly those in the Kotzebue Sound [2]. Humpback Whitefish also are taken in some numbers in the Barrow area and in the lower Colville River [36, 37]. In Kotzebue Sound, their ease of scaling and lower oil content makes them a preferred species for paniqtuq (dried fish) and also for the aged and frozen product (quaq). Most fish are taken in seines or gillnets, but many are captured in ditches (qargisat) that are dug to divert migrating fish [2].



Commercial Fisheries
Currently, Humpback Whitefish are not commercially harvested.



Potential Effects of Climate Change
Unknown. Generally, Durand and others (2011) [60] predict that, at least for anadromous fishes in subarctic rivers, shifts in biology will be effected by spring ice break-up and resultant peak flows and surrounding permafrost processes: both of which affect the supply of nutrients and (or) sediment to the watershed of climate change on spring break-up intensity.



Areas for Future Research [A]
Research needs for this species in the study area include: spawning behavior, spawning locations and early life histories, as well as studies on populations and predators. The vulnerability of the species to climate change effects on hydrology, timing of key life history events, and habitat use requires investigation. The projected expansion of brackish water habitats could greatly change this species occurrence in nearshore areas.

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Least Cisco (*Coregonus sardinella*)
Valenciennes, 1848

Family Salmonidae

Least Cisco (*Coregonus sardinella*). Photograph by R.J. Brown, U.S. Fish and Wildlife Service.

Colloquial Name: Iñupiat—*Iqalusaaq* [1]; *Anuutituuq, Qalusraaq, Qalutchiaq* [2].

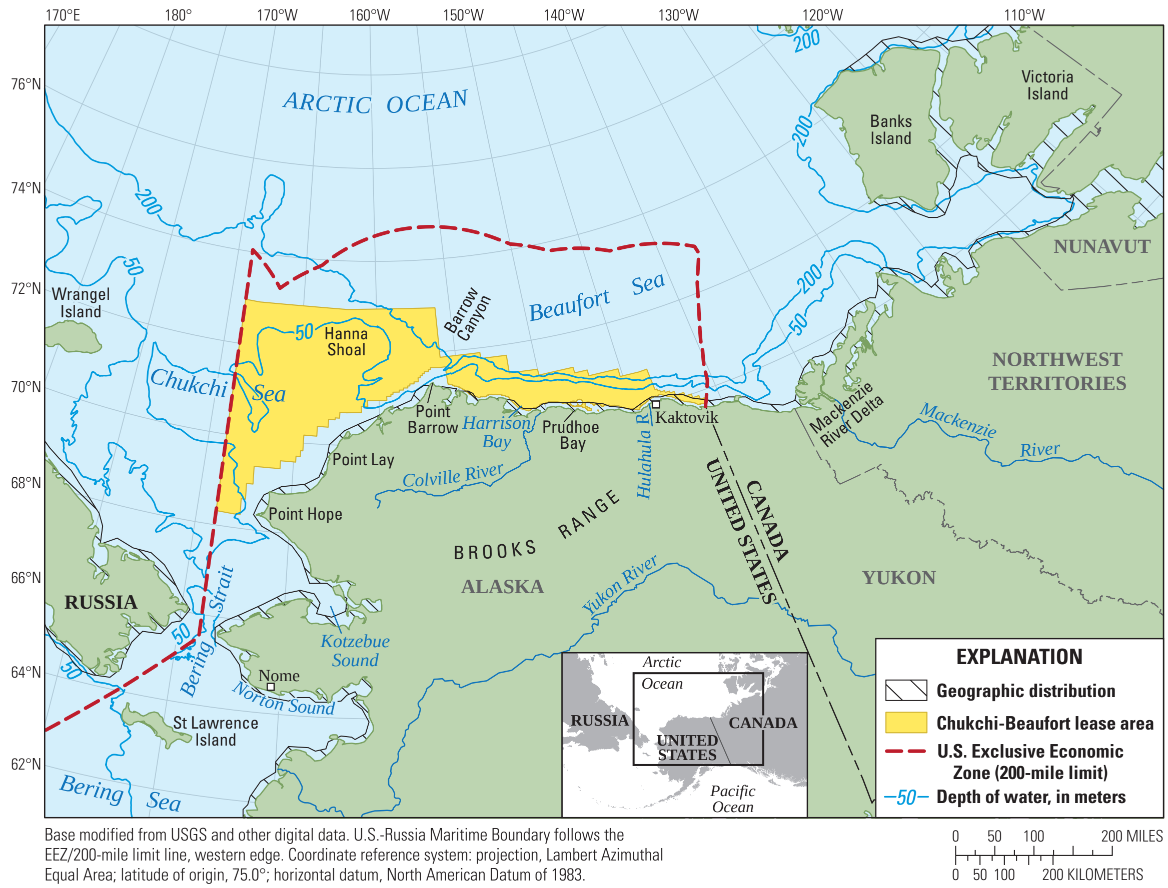
Ecological Role: This species rarely ventures into marine waters, preferring fresh and nearshore brackish conditions. Least Cisco are seasonally common in nearshore waters and are important in coastal food webs.

Physical Description/Attributes: Brownish to dark green back and silvery belly; back and dorsal fin have dark spots and fish more than 15 cm long and have dusky or black pelvic fins. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 182) [3]. Swim bladder: Present [4]. Antifreeze glycoproteins in blood serum: Unknown.

Range: *U.S. Chukchi and Beaufort Seas. Along U.S. Chukchi Sea, found at least in Utukok, Kokolik, Kuk, Kukpowruk, and Utukok Rivers* [5] *and rivers running into Kotzebue Sound [2]. In U.S. Beaufort Sea, found in most rivers of North Slope region, from Inaru to Canning River, but are not presumed to live in or enter the rivers between Canning River* and Babbage River in Yukon Territory [6–10]. Elsewhere in Alaska, south to Bristol Bay in eastern Bering Sea [3, 11]. Worldwide, Siberia, Russia, west to the White Sea and east to Southampton Island, Hudson Bay, Canada, northeast to Viscount Melville Sound, Beaufort Sea [12].

Relative Abundance: Common *in U.S. Chukchi and Beaufort Sea coastal waters north from at least Kotzebue Sound* [2] *but relatively uncommon along some of the northeastern Chukchi Sea coast and in U.S. Beaufort Sea between Smith Bay and Cape Halkett, and between Canning River–Camden Bay region and near Phillips Bay, reflecting this species' tendency to avoid high salinity and cold marine waters* [5, 6, 16–20]. Common in Canadian Beaufort Sea east to as close as the Tuktoyaktuk Peninsula, Canada [21].

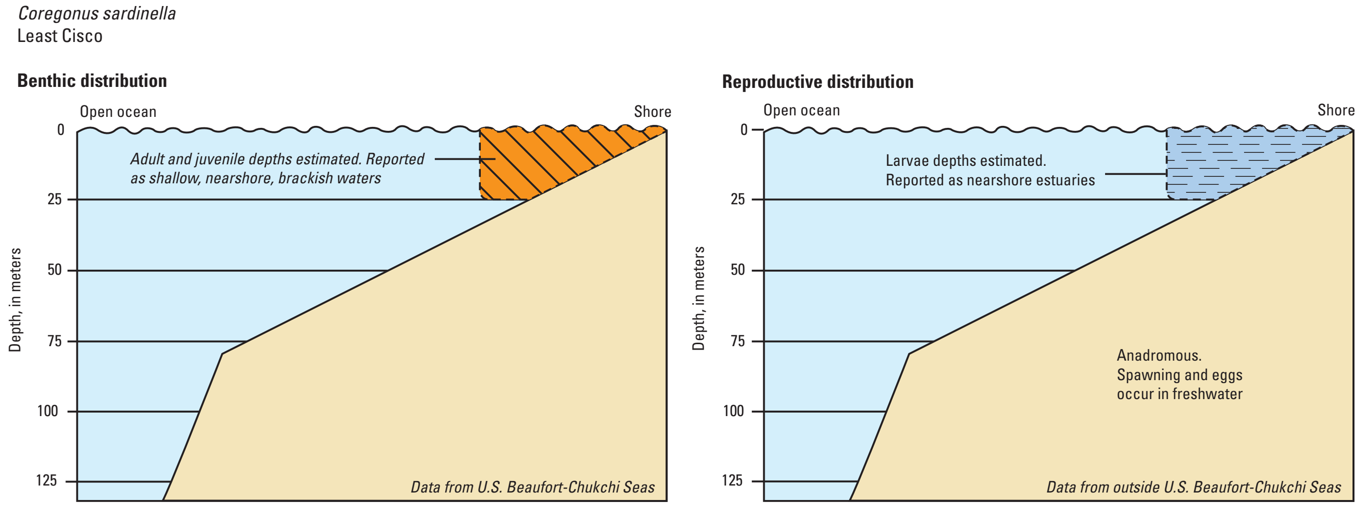
Least Cisco
Coregonus sardinella



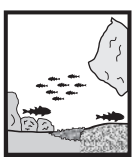
Base modified from USGS and other digital data. U.S.-Russia Maritime Boundary follows the EEZ/200-mile limit line, western edge. Coordinate reference system: projection, Lambert Azimuthal Equal Area; latitude of origin, 75.0°; horizontal datum, North American Datum of 1983.

Geographic distribution of Least Cisco (*Coregonus sardinella*), at sea within Arctic Outer Continental Shelf Planning Areas [13] based on review of published literature and specimens from historical and recent collections [3, 14, 15].

Depth Range: *Shallow, nearshore waters* [5, 22–24].



Benthic and reproductive distribution of Least Cisco (*Coregonus sardinella*).



Habitats and Life History

In Alaska, Least Cisco has three life history patterns: (1) amphidromous (feeding in brackish or marine systems during the summer), (2) exclusively freshwater, found in lakes, and (3) a resident dwarf form of freshwater variety. Amphidromous and freshwater forms can occur together [25]. Information in this account is about the amphidromous form. For information on freshwater residents, see [1, 5, 24, 26–28].

Eggs—Size: *0.9–2.0 mm for mature eggs* [29, 30]. Time to hatching: *Based on autumn spawning and late winter and spring hatching, about 6 months* [5, 31]. Habitat: *Shallow waters of rivers, in gravel and sand* [5, 31–33].

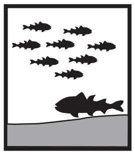
Larvae—Size at hatching: Unknown. Size at juvenile transformation: Unknown. Some fish as small as 25 mm migrate to sea [34]. Days to juvenile transformation: Unknown. Habitat: *Hatches in freshwater rivers* [5]. In Siberia, amphidromous fish move downstream to sea soon after hatching [35].

Juveniles—Age and size: 0 to at least 3 years and to at least 220 mm [24, 31, 36]. Habitat: *Fresh and nearshore brackish (rarely marine waters)* [5].

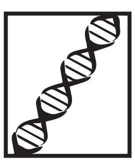
Adults—Age and size at first maturity: Highly variable, age ranges from *4 to 18 years* [24, 31]. *Most are mature by perhaps 6–10 years* [5, 16, 21, 25, 29, 30]; size *at least a few by about 220 mm and all by about 350 mm* [24, 36]. Maximum age: *28 years* [24]. Maximum size: 47 cm [3]. Habitat: *Fresh and nearshore brackish (rarely marine waters)* [5].

Substrate—Gravel to sand in freshwater for spawning [5, 37].

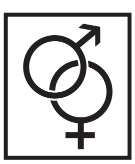
Physical/chemical—Temperature: *–1.7–16 °C* [25, 29]. Salinity: *0–32 parts per thousand* [25, 29], *primarily 20 parts per thousand or less* [5]. *Juveniles tend to remain in warmer and less saline waters, whereas older fishes are more tolerant of colder temperatures and increased salinity* [5, 8, 16, 22–24].



Behavior
Diel—Unknown.
Seasonal—*Fish enter U.S. Beaufort Sea following ice breakup in June and July, and begin to disperse and feed along the coast* [21, 29, 30, 34, 38]. *Young fish may remain in rivers for several years before entering the sea* [16]. *Due to higher temperature and lower salinity preferences, juveniles do not migrate as far as adults, who disperse farther along the coast* [5, 8, 16, 22–24]. *Most Least Cisco found along the North Slope originate from spawning and overwintering grounds in the Colville River* [8]. *Colville River fish migrate farther east in years of strong westerly winds.* Similarly, Mackenzie River fish move westward to a greater extent in years with strong easterly winds [8, 39, 40]. *Along the North Slope, larger fish can swim faster and reach distant feeding grounds before smaller individuals* [41]. *Given the short summer season, Least Cisco can travel substantial distances when conditions are favorable. For instance a fish tagged in Simpson Lagoon was recaptured off Barrow, 300 km to the west* [29]. *However, fish leaving the Colville River generally migrate eastward along the Arctic National Wildlife Refuge coast, because nearshore marine waters between Smith Bay and Cape Halkett may block westward movements* [20, 40]. *Return migrations to spawning and overwintering grounds begin between July and September* [8, 29, 41]. Both juveniles and adults overwinter in brackish waters of river deltas (for example, Colville River, Alaska, and Mackenzie River, Canada, are the largest overwintering areas along the Beaufort Sea), open coast (for example, Tuktoyaktuk Harbor), and freshwater lakes of the Tuktoyaktuk Peninsula, Canada [21, 41, 42]. *Except for the Sagavanirktok River (where some overwintering occurs in delta waters), Least Cisco do not seem to either spawn or overwinter in any waterway between the Colville and Mackenzie Rivers* [41].
Reproductive—*Spawning occurs under ice in the shallow waters of rivers over gravel and sand* [5, 31–33]. During spawning, males and females move toward the surface, perpendicular to the current, while the eggs are released and fertilized [43]. Sea-run fish spawn in lower reaches of rivers or, as in the Yukon-Koyukuk River system, may migrate at least as much as 1,600 km upstream [44]. *In U.S. Chukchi and Beaufort Sea drainages, spawning by the Least Cisco is known to occur in various rivers including the Kobuk River* [2], *Colville River* [45], and Mackenzie River and its tributaries [42]. Individuals have been variously reported to spawn annually [25], in alternate years, or perhaps for some fish, less often [5, 16, 24, 28]. After spawning, fish quickly migrate downstream to freshwater overwintering grounds [22].
Schooling—*In coastal waters, forms schools that can maintain their integrity for months* [29].
Feeding—*Generalists, feeding throughout the water column with planktonic organisms dominating* [28]. *Feeds both during winter and during spawning migrations, although feeding intensity in both instances may be low* [7, 29, 33, 42, 46].

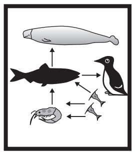


Populations or Stocks
Catch statistics from the Colville River and coastal monitoring in Prudhoe Bay provide useful life history information and indices of population abundance. Genetic research (phylogeography and population structure) is ongoing (University of Alaska, Fairbanks).



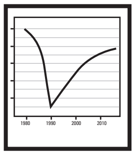
Reproduction
Mode—Gonochoristic, oviparous, and iteroparous with external fertilization [5].
Spawning season—*September–November* [2, 5].
Fecundity—10,505–100,939 eggs in North America [24, 47].

Food and Feeding
Food items—*Primarily crustaceans (for example, copepods, mysids, isopods, and amphipods) and insects, along with some polychaetes, clams, snails, fishes, fish eggs, fish larvae, and plant material* [5, 24, 28, 29, 48, 49].
Trophic level—3.24 (standard error 0.50) [50].



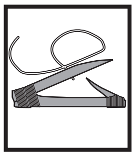
Biological Interactions

Predators—Dolly Varden and Arctic Smelt [34, 42], ice seals, and various seabirds such as the red throated loon.
Competitors—Other generalist feeders including various whitefish species and Dolly Varden, Arctic Flounder, and Fourhorn Sculpin. Lease Cisco is an important prey for loons and other predators in the coastal Chukchi Sea.



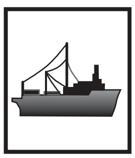
Resilience

Medium, minimum population doubling time 1.4–4.4 years (K=0.40; t_m=2–4; t_{max}=11; Fecundity=2,500) [50].



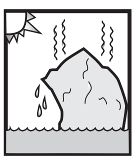
Traditional and Cultural Importance

Historically, Least Cisco have been of some importance in subsistence fisheries, particularly before the advent of snowmobiles, when local populations depended on dogs for transportation. At that time, this small species was widely caught and used for dog food. Currently, along many rivers, Least Cisco are only occasionally harvested for human and dog food [1, 25, 29, 51]. Subsistence fishermen in the Kotzebue Sound area often consume the eggs of freshly caught fish [2].



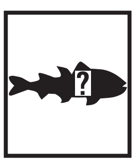
Commercial Fisheries

Currently, Least Cisco are not commercially harvested.



Potential Effects of Climate Change

Unknown. A general prediction is that, at least for anadromous fishes in subarctic rivers, shifts in biology will be effected by spring ice break-up and resultant peak flows and surrounding permafrost processes: both of which affect the supply of nutrients and (or) sediment to the watershed of climate change on spring break-up intensity [52].



Areas for Future Research [A]

Least Cisco populations are best studied in the western (for example, Dease Inlet) and central (Prudhoe Bay) regions of the southeastern Beaufort Sea. They are an important member of the coastal fish assemblage during ice-free months. Monitoring of key parameters relative to population growth, survival, and recruitment, relative abundance, and condition, should be continued at key reference locations.

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Pink Salmon (*Oncorhynchus gorbuscha*)

(Walbaum, 1792)

Family Salmonidae

Pink Salmon (*Oncorhynchus gorbuscha*), 211 mm, southeastern Chukchi Sea, 2007. Photograph by C.W. Mecklenburg, Point Stephens Research.

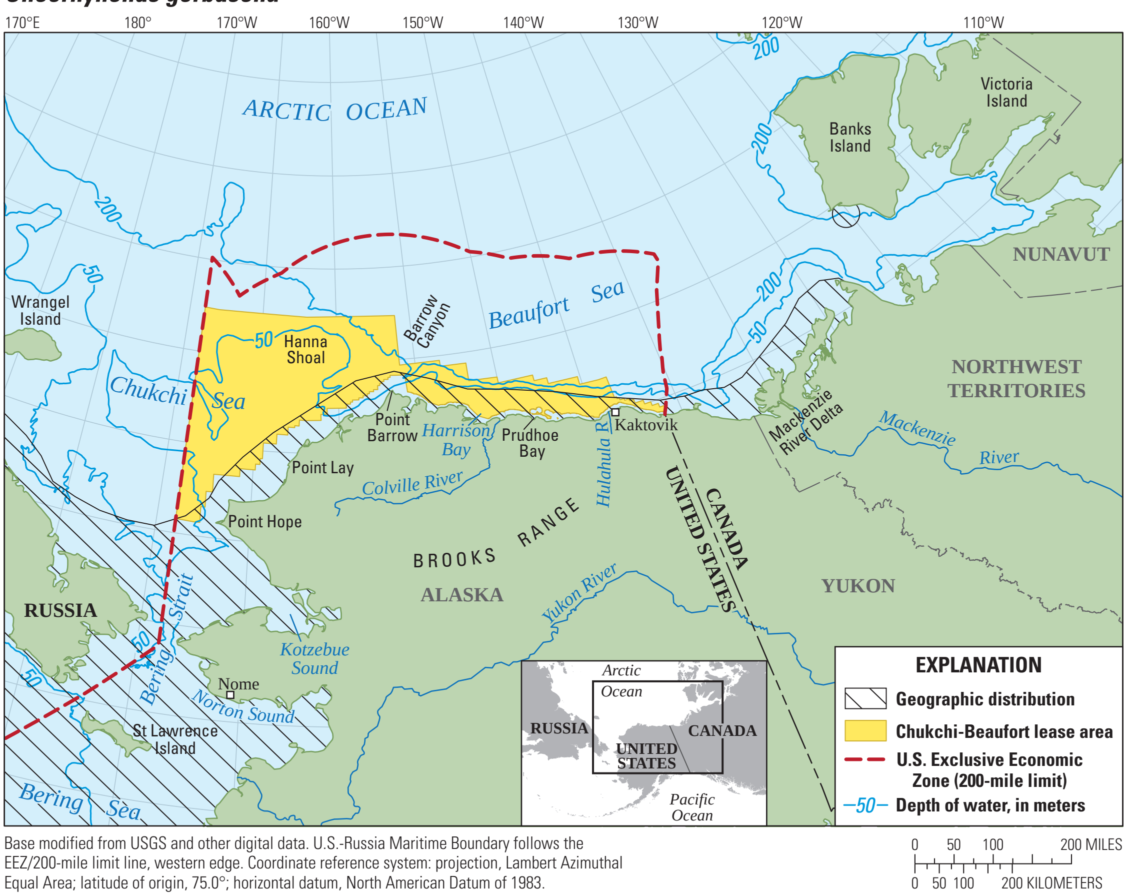
Colloquial Name: Iñupiat—*Amaqtuuq* [1].

Ecological Role: The seeming relatively recent increase in abundance of this species north and eastward to at least the Barrow area implies that this species is becoming of some ecological importance in coastal waters of the U.S. Chukchi Sea.

Physical Description/Attributes: At sea, metallic-blue to blue-green on back, silvery on sides, and white on belly with black, oval spots on the backs and upper sides and on both lobes of the caudal fins. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 205) [2]. Swim bladder: Present [3]. Antifreeze glycoproteins in blood serum: Unknown.

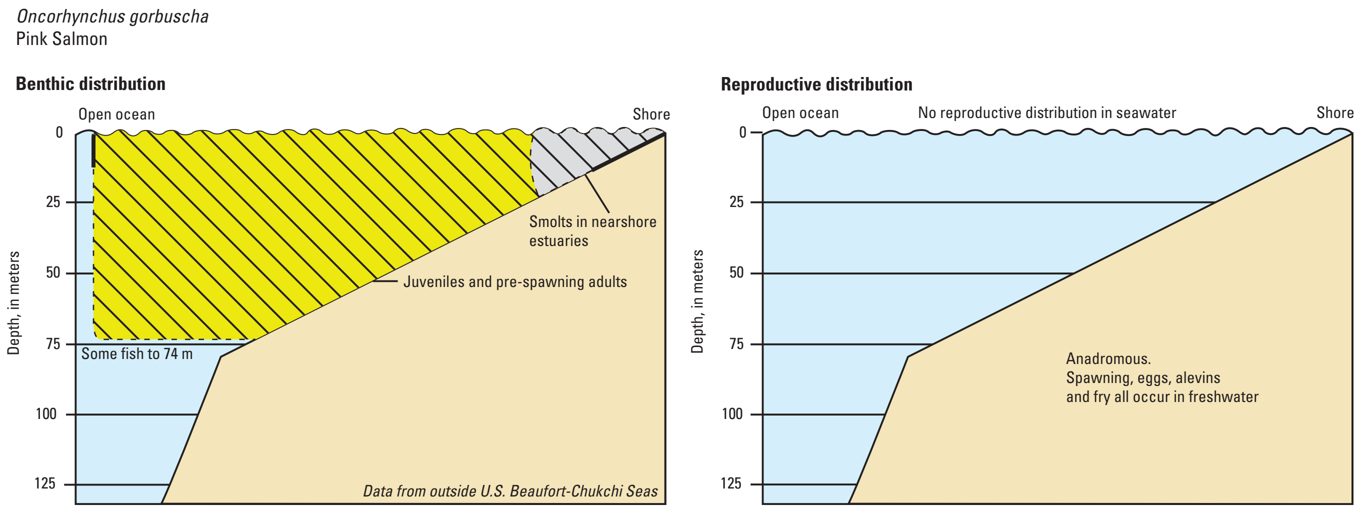
Range: *U.S. Chukchi and Beaufort Seas* [4, 5]. North Korea and Japan and northern Siberia to the Beaufort Sea coast of Alaska and western Canada, eastward to Sachs Harbor, Banks Island, [5] and south to La Jolla, California [6].

Relative Abundance: *Small runs occur in numerous rivers and streams running into the Chukchi Sea to about Barrow and perhaps in the Colville River* [4, 10]; common *in the Chukchi Sea (the most abundant of the salmon species) and, in the Beaufort Sea, at least as far east as Simpson Lagoon and in smaller numbers along the Alaska National Wildlife Refuge* [4, 11–14].

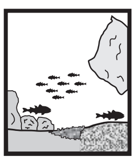


Geographic distribution of Pink Salmon (*Oncorhynchus gorbuscha*), at sea within Arctic Outer Continental Shelf Planning Areas [7] based on review of published literature and specimens from historical and recent collections [2, 8, 9].

Depth Range: Epipelagic, coastal and offshore, from surface to at least 74 m [15], usually from 0 to 10 m [16]. Young juveniles are neritic, occurring from nearshore waters as shallow as a few centimeters deep to the edge of the continental shelf as they mature [17].



Benthic and reproductive distribution of Pink Salmon (*Oncorhynchus gorbuscha*).



Habitats and Life History

Anadromous.

Eggs—Size: 4.0–7.9 mm [17]. Time to hatching: 5–8 months [17]. Length at hatching: About 19–24 mm [18]. Habitat: Benthic, buried under gravel in shallow, relatively fast-flowing waters of streams and rivers, often near the ocean [16, 17, 19, 20].

Alevins (larvae)—Size: 19–28 mm [16, 18]. Habitat: Under gravel for a few weeks to several months in shallow, relatively fast-flowing waters of streams and rivers, often near the ocean [16, 17, 19, 20].

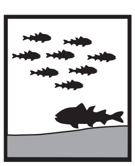
Fry—Size at emergence: About 28–34 mm [18]. Time as fry: Relatively short, as little as a few days [17]. Habitat: Benthopelagic in shallow waters of streams and rivers [16, 17].

Smolt and ocean phase—Age and size at smoltification: as young as a few days and 3.0–45.0 cm [16, 17]. Habitat: Epipelagic in ocean, over various habitats and often far from shore [16, 17, 20].

Adults— Age and size at first maturity: On average, 1.5 years and 45–55 cm [17]. Maximum age: 2 years [16]. Maximum size: 76 cm [2]. Habitat: Mature adults return to freshwater rivers and streams to spawn [17].

Substrate—Over various substrates while in ocean [16]. Gravel for spawning [17].

Physical/chemical—Temperature: In ocean, at least 3–15 °C, perhaps primarily at 4–11 °C [21]. Salinity: Tolerates fresh to marine waters, depending on life stage [17].



Behavior

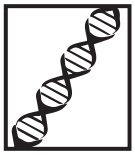
Diel—Migrations of fry to sea take place at night [17].

Seasonal—*Unknown in U.S. Chukchi and Beaufort Seas, although it is speculated that juveniles enter the northeastern Chukchi Sea during the late spring thaw (June to early July)* [11]. Vertical distribution at sea may change with season, with fish remaining in deep water during the night early in the year and then moving to shallow water later in the year [17].

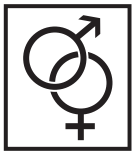
Reproductive—Spawning occurs in freshwater streams and rivers, often very close to the ocean. Females prepare a gravel nest and lay their eggs, which are fertilized by the males. All adults die after spawning [16].

Schooling—Newly emerged fry may or may not school; fry do school when they reach the lower reaches of rivers [17]. Juveniles school in nearshore waters during early phases of their seaward migration [17]. Schooling behavior during ocean phases of migration may be less structured and include intermingling with other stocks [17].

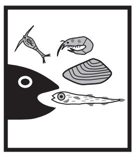
Feeding—At sea, may vertically migrate (ascending during the night) when following prey [17]. Juveniles feed primarily during the day with peak feeding at dusk [17].



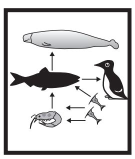
Populations or Stocks
There have been no studies in the U.S. Chukchi and Beaufort Seas.



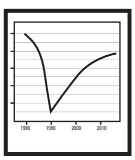
Reproduction
Mode—Gonochoristic, oviparous, and semelparous with external fertilization [22].
Spawning season—July–October and usually earlier in more northern waters [17, 23].
Fecundity—*854–1,549, Simpson Lagoon* [4].



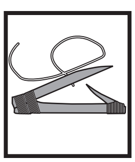
Food and Feeding
Food items—*In the U.S. Chukchi Sea, fishes, planktonic crustaceans (for example, mysids, calanoid copepods, and gammarid amphipods), fish eggs, and fish larvae* [11, 12].
Trophic level— 4.19 (standard error 0.71) [24].



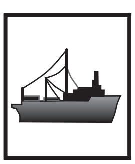
Biological Interactions
Predators—Dolly Varden, Arctic Smelt, Starry Flounder, Walleye Pollock, spotted seal, beluga whale, and orca [25–29].
Competitors—Likely other salmon species, as well as such gadids as Arctic Cod.



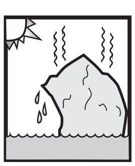
Resilience
Medium, minimum population doubling time 1.4–4.4 years (t_m=2; t_{max}=3; Fecundity=800) [24].



Traditional and Cultural Importance
Taken in subsistence fisheries in the U.S. Chukchi Sea [10, 30, 31] *and are caught in relatively small numbers in subsistence fisheries along the U.S. Beaufort Sea at least are far east as the Colville River* [32].



Commercial Fisheries
Pink Salmon are captured in small numbers in salmon fisheries for Chum Salmon in Kotzebue Sound.



Potential Effects of Climate Change
Warming temperatures likely will allow this species to become more abundant in the U.S. Chukchi and Beaufort Seas. Whether this species will be able to colonize additional freshwater habitats successfully on Alaska’s North Slope is hypothesized, but is not known.

Areas for Future Research [A]

Little is known about the ecology and life history of this species in the study area. Human use of this species in coastal villages seems to be increasing. Research needs include: preferred habitats (including depth ranges for juveniles and adults), spawning season, seasonal and ontogenetic movements, population studies, and predators. The success of colonization east of Point Hope will depend on the presence of suitable spawning habitats and thermal regimes for developing embryos. The timing of seaward migrations and quality of nearshore marine environments will be critical to population viability. The potential for colonization of perennial springs in the eastern Beaufort Sea and other prospective spawning areas in the Colville and Sagavanirktok Rivers should be examined in habitat-based monitoring. Salmon catches at Point Barrow and other villages should be monitored and biological investigations of salmon interactions with traditional fish foods, such as Arctic and Least cisco and Dolly Varden, should be undertaken.

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Chum Salmon (*Oncorhynchus keta*)
(Walbaum, 1792)

Family Salmonidae

Chum Salmon (*Oncorhynchus keta*), 209 mm, northeastern Chukchi Sea, 2007. Photograph by C.W. Mecklenburg, Point Stephens Research.

Colloquial Name: Iñupiat—*Iqalugruaq* [1].

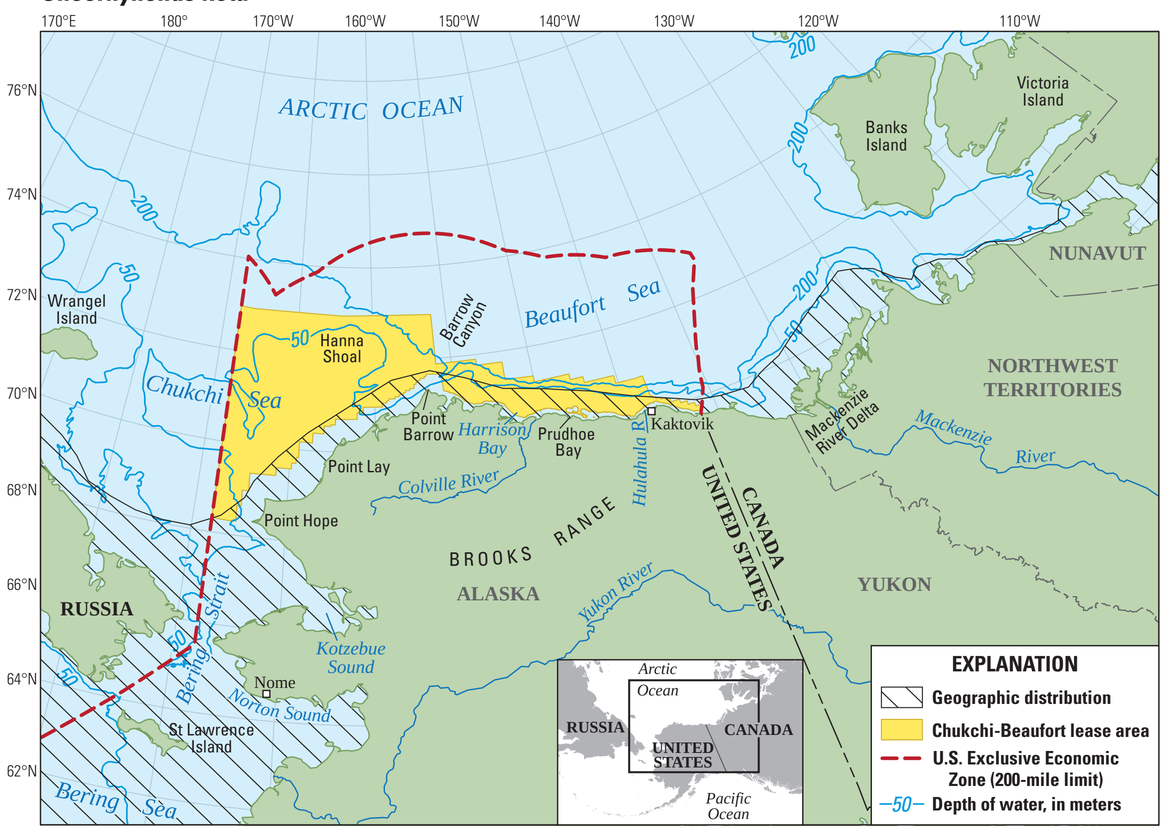
Ecological Role: The abundance of this species north and eastward to at least the Barrow area implies that this species is likely of some ecological importance. Especially important member of the nearshore marine in Kotzebue Sound.

Physical Description/Attributes: At sea, Chum Salmon have dark blue backs with silvery sides and bellies and no distinct black spots, fewer than 30 gill rakers, and gill rakers that are smooth, fairly short, stout, and widely spaced. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 208) [2]. Swim bladder: Present [3]. Antifreeze glycoproteins in blood serum: Unknown.

Range: *U.S. Chukchi and Beaufort Seas.* Arctic coasts of Siberia west to the Laptev Sea and east across Alaskan and Canadian Arctic to Kugluktuk, Nunavut; southward through Bering Sea to Korea and southern Japan, and to Del Mar, southern California near the United States–Mexico border [4, 5].

Relative Abundance: *The most common salmon species in the U.S. Chukchi and Beaufort Seas* [5]. *Spawning runs occur in a number of Chukchi Sea drainages and at least in a few Beaufort Sea drainages, such as the Mackenzie River, perhaps the Colville River, and others* [8, 9].

Chum Salmon
Oncorhynchus keta

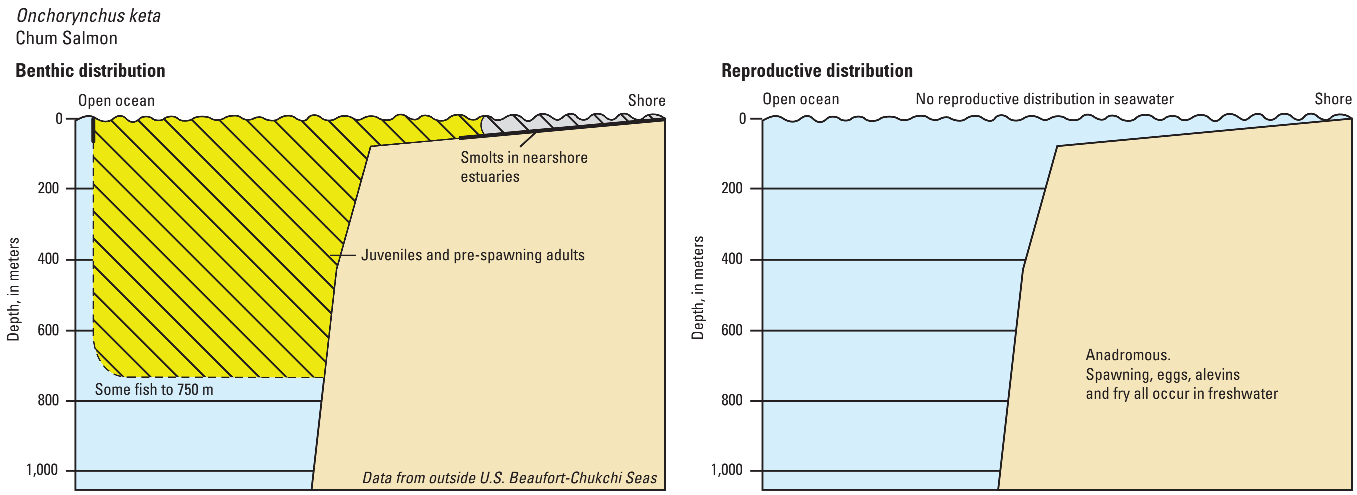


Base modified from USGS and other digital data. U.S.-Russia Maritime Boundary follows the EEZ/200-mile limit line, western edge. Coordinate reference system: projection, Lambert Azimuthal Equal Area; latitude of origin, 75.0°; horizontal datum, North American Datum of 1983.

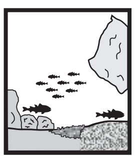
0 50 100 200 MILES
0 50 100 200 KILOMETERS

Geographic distribution of Chum Salmon (*Oncorhynchus keta*), at sea within Arctic Outer Continental Shelf Planning Areas [6] based on review of published literature and specimens from historical and recent collections [2, 7].

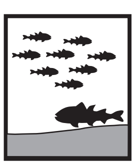
Depth Range: Epipelagic, coast and offshore, from surface to at least 750 m [10], primarily less than 40 m [10–12].



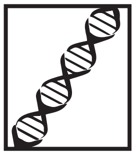
Benthic and reproductive distribution of Chum Salmon (*Oncorhynchus keta*).



Habitats and Life History
Anadromous.
Eggs—Size: At least 6.0–10.0 mm [13, 14]. Time to hatching: Highly variable, 52–182 days [14]. Size at hatching: 20–25.0 mm [13, 15]. Habitat: Benthic, buried under gravel of streams and rivers [13, 14].
Alevins (larvae)—Size range: 20–35.0 mm [13] Habitat: Under gravel of streams and rivers until yolk sac absorbed (30–50 days) [14, 16].
Fry—Size at emergence: About 30–39 mm [15]. Length of time as fry: 1 month or more. May remain in fresh water for several weeks or may immediately migrate downstream and enter marine or estuarine waters [14, 17]. Habitat: Demersal, in streams and rivers [13, 14].
Smolt (juveniles) and ocean phase—Size when entering ocean: Between 30–70.0 mm, depending on distance from spawning grounds [13]. Habitat: Juveniles spend their first few months to a year in nearshore, marine waters, often inhabiting eelgrass or algal beds [18], and then two to five winters offshore [19].
Adults: Age and size at first maturity: Highly variable, 2–6 years, primarily 3–5 years, and 60–80 cm [14]. Maximum age: 7 years [16]. Maximum size: 109 cm [14]. Habitat: Adults return to freshwater streams and rivers to spawn [13, 14].
Substrate—Gravel for spawning [14].
Physical/chemical—Temperature: At sea, -0.8–22.5 °C [20], most common between 2 and 11 °C [21]. Salinity: Fresh water to marine, depending on life stage [14]. Fry are euryhaline and can withstand daily fluctuations of 0–27 parts per thousand [14].

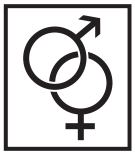


Behavior
Diel—Fry typically emerge from gravel and migrate downstream at night [14]. At sea, many individuals may ascend into surface waters at night and return to depth during the day [20].
Seasonal—Fry emerge from gravel beds in spring [17]. *At-sea behavior in U.S. Chukchi and Beaufort Seas is unknown.* It is speculated that fish entering the Beaufort Sea from various drainages may overwinter either in deeper waters of the Beaufort Sea or in the North Pacific [9].
Reproductive—Spawning occurs in freshwater in streams and rivers. Females prepare a gravel nest and lay their eggs, which are fertilized by a male [14]. All adults die after spawning [13].
Schooling—Fry do not strongly school [14]. Juveniles in estuaries and nearshore waters may form loose aggregations [14].
Feeding—Juveniles in estuaries feed most intensely at high tides when marsh is submerged [14].



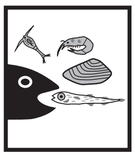
Populations or Stocks

The State of Alaska monitors catch and escapement of Chum Salmon in the major river drainages in Kotzebue Sound. Genetic analysis of samples of summer run Chum Salmon from six watersheds indicates a Kotzebue Sound complex that is related to but distinct from Norton Sound, Yukon, and Kuskokwim regions [22].



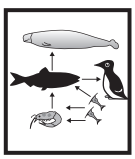
Reproduction

Mode—Gonochoristic, oviparous, and semelparous with external fertilization [23].
Spawning season—*Unknown in U.S. Chukchi and Beaufort Seas watersheds except for stocks from Kotzebue Sound.* In the Mackenzie River, Canada, spawning migrations are during July and August with spawning in autumn [24]. In other regions, spawning is in June–January [17].
Fecundity—At least 900–8,000 eggs [17].



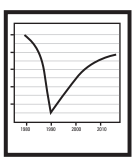
Food and Feeding

Food items—Zooplankton (for example, copepods, euphausiids, mysids, pteropods, and fish larvae) as well as insects and small amounts of fishes [25–27].
Trophic level—3.47 (standard error 0.48) [28].



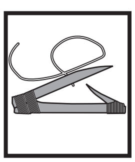
Biological Interactions

Predators—A wide variety of fishes, sea birds, and mammals. Examples include Pacific Halibut, Pacific Sleeper Shark, Walleye Pollock, rhinoceros auklet, pigeon guillemot, marbled murrelet, pelagic cormorant, northern fur seal, beluga whale, and orca [16, 29–31] [32–35].
Competitors—Likely other planktivores (for example, salmonids, Pacific Herring, and Polar and Saffron cods).



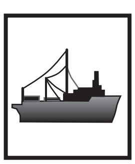
Resilience

Medium, minimum population doubling time 1.4–4.4 years (K=0.27–0.45; t_m=2–5; t_{max}=6) [28].



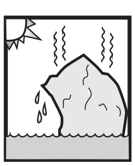
Traditional and Cultural Importance

Taken with some frequency in subsistence fisheries along the Chukchi Sea (that is, Kotzebue Sound) and near Barrow [36–40]. Chum Salmon also are taken in the Mackenzie River and its tributaries and in the Colville River [37, 41].



Commercial Fisheries

The Alaska Department of Fish and Game manages small Chum Salmon fisheries in Kotzebue Sound. Market conditions and availability of fish buyers have affected harvest levels in recent years. Estimated low salmon abundance in 2014 resulted in the termination of the fishery.



Potential Effects of Climate Change

An increase in the Arctic population with climate change has been hypothesized [42]. Availability of freshwater habitats and sufficient thermal conditions for incubation are potential limiting factors.

Areas for Future Research [A]

The potential colonization rivers and streams of Arctic Alaska is of research interest. Like other salmonids, limitations associated with potential source populations, incubation in freshwater habitats (temperature and oxygen), timing of seaward migration and related quality of nearshore marine habitats for juveniles, dispersal routes and migration corridors, and distance from natal habitats to oceanic rearing grounds will affect colonization success. Potential interactions and outcomes of Chum Salmon and other nearshore fishes is an expressed concern to residents. Regular surveys of prospective habitats for colonizing fish and evidence of successful reproduction should be established.

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Coho Salmon (*Oncorhynchus kisutch*)
(Walbaum, 1792)

Family Salmonidae

Note: *Exception for geographic range data, all information is from areas outside of the Chukchi and Beaufort Seas.*

Colloquial Name: Iñupiat—*Iqalugruaq* [1].

Ecological Role: Likely of minor subsistence importance in southeastern U.S. Chukchi Sea and occasional occurrence in coastal captures farther north.

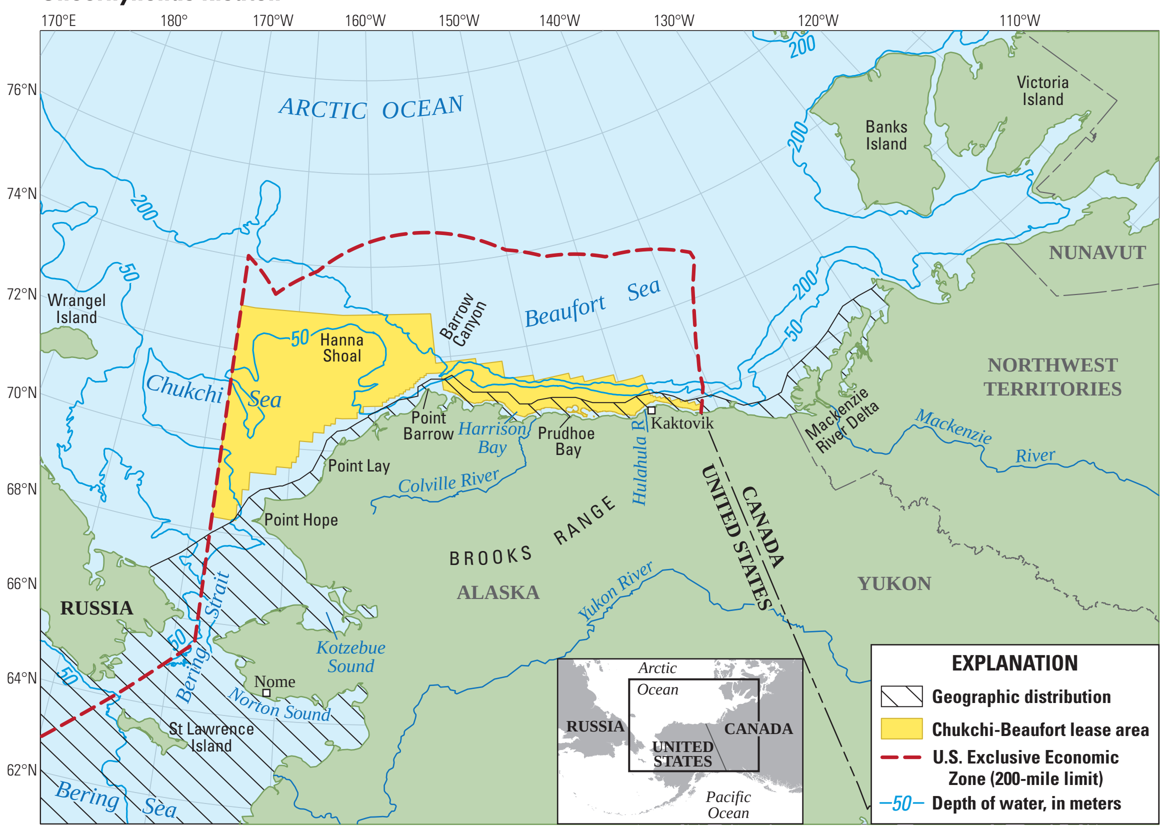
Coho salmon (*Oncorhynchus kisutch*), freshwater spawning stage. Photograph by Thomas Kline, http://www.salmonography.com.

Physical Description/Attributes: At sea, metallic-blue on back, silvery flanks, and white belly, small black spots on back and sides and on the upper lobe of the caudal fin, and white gums at the base of the teeth on the lower jaw. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 206) [2]. Swim bladder: Present [3]. Antifreeze glycoproteins in blood serum: Unknown.

Range: *U.S. Chukchi and Beaufort Seas* [2, 4, 5]. Worldwide, North Korea and Japan to the Mackenzie River, Canada, and to Bahia Camalu, northern Baja California, Mexico [2, 6].

Relative Abundance: *Uncommon in southeastern Chukchi Sea (where it returns to rivers to spawn) and rare in northeastern Chukchi and Beaufort Seas* east to Mackenzie River, Canada [4, 5, 10].

Coho Salmon
Oncorhynchus kisutch

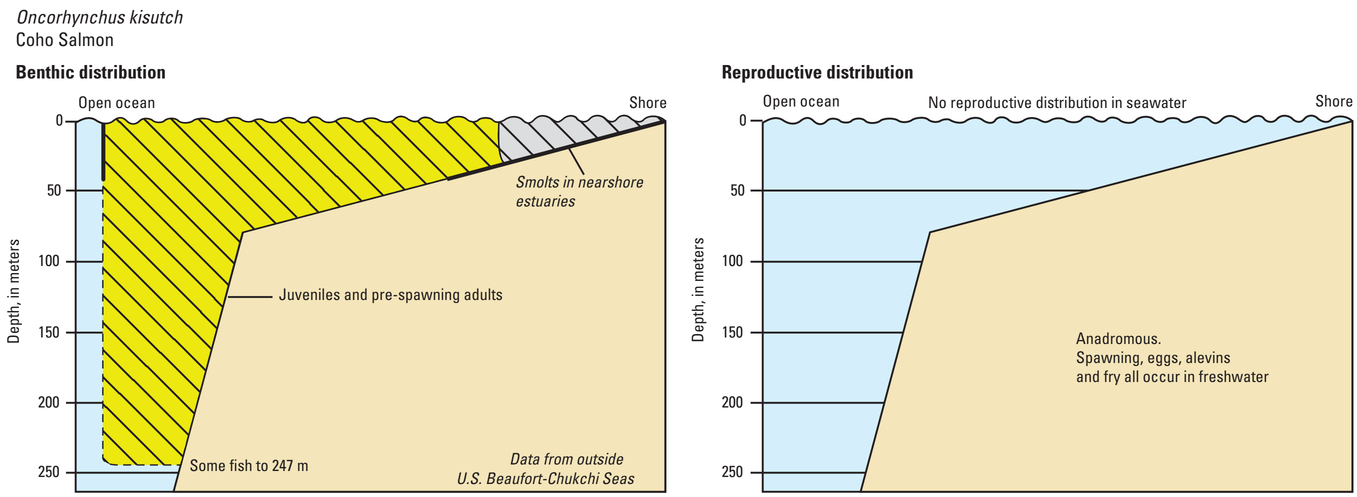


Base modified from USGS and other digital data. U.S.-Russia Maritime Boundary follows the EEZ/200-mile limit line, western edge. Coordinate reference system: projection, Lambert Azimuthal Equal Area; latitude of origin, 75.0°; horizontal datum, North American Datum of 1983.

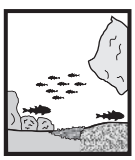
0 50 100 200 MILES
0 50 100 200 KILOMETERS

Geographic distribution of Coho Salmon (*Oncorhynchus kisutch*), at sea within Arctic Outer Continental Shelf Planning Areas [7] based on review of published literature and specimens from historical and recent collections [2, 8, 9].

Depth Range: Epipelagic, coastal and offshore, from surface to 247 m [11], primarily 40 m or less [12].



Benthic and reproductive distribution of Coho Salmon (*Oncorhynchus kisutch*).



Habitats and Life History

Anadromous.

Eggs—Size: 4.5–7.9 mm [13]. Time to hatching: 5–12 weeks. Length at hatching: About 19–24 mm [14]. Habitat: Benthic, buried under gravel of streams and rivers [15].

Alevins (larvae)—Size range: 19–30 mm [14, 15]. Habitat: Benthic, remain under gravel for 3–26 weeks until yolk sac is absorbed [11, 15].

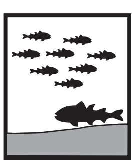
Fry—Size at emergence: About 27–30 mm [14, 15]. Length of time as fry: 1–4 years, typically 1 year [15]. Habitat: Benthic, in streams and rivers [15].

Smolt and ocean phase—Age and size at smoltification: 1–4 years and 8–17 cm [15]. Habitat: Epipelagic [13, 15]. Young fish newly entered into ocean waters often reside near shore, frequently in eelgrass beds, but also in kelp or over bare sea floor [16]. Generally, do not migrate far offshore. Some spend their entire marine lives in inshore waters [17].

Adults—Age and size at first maturity: A few males mature at 1 year, but most fish at 3–4 years and at about 60–70 cm [15]. Maximum age: About 4 years [15]. Maximum size: 108 cm [2]. Habitat: Mature adults return to rivers and streams to spawn [13, 15].

Substrate—Gravel for spawning [15].

Physical/chemical—Temperature: At sea, 5–16.2 °C, primarily 7 °C and greater [15, 18, 19]. Salinity: Fresh to marine waters depending on life stage [15].



Behavior

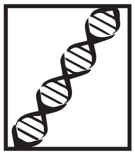
Diel—Fry and smolts migrate primarily at night [15]. At sea, many or most individuals may ascend into surface waters at night and return to depth during day [19].

Seasonal—Fry emerge from under gravel as much as 6 months after eggs were laid [15]. Young fish may spend as much as 4 years in fresh water before migrating to the sea, although a 1-year residency (including a winter) is more typical [15]. Most fish enter seawater in spring and many remain nearshore for at least a few months before moving somewhat offshore. At sea, fish entering from California to British Columbia tend to move northwards. Generally, Coho Salmon do not migrate far offshore and some spend their entire marine lives in inshore waters [17]. *Utilization of offshore waters as well as migrations in U.S. Chukchi and Beaufort Seas is unknown*. Coho Salmon spend 18 months or more at sea before entering freshwater to spawn [15].

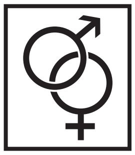
Reproductive—Spawning occurs in freshwater streams and rivers. Females prepare a gravel nest and lay their eggs, which are fertilized by a male [15]. All adults die after spawning [13].

Schooling—Smolts and marine individuals form schools [15].

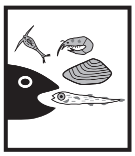
Feeding—Juveniles and adults are carnivorous, opportunistic feeders [13].



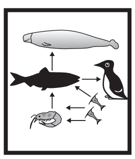
Populations or Stocks
There have been no studies in the U.S. Chukchi and Beaufort Seas.



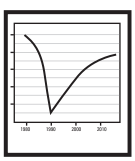
Reproduction
Mode—Gonochoristic, oviparous, and semelparous with external fertilization [20].
Spawning season—October–March, primarily November–January [15].
Fecundity—At least 1,724–7,600 eggs [15], varies between years, increasing to the north [21, 22].



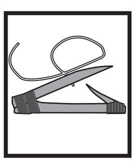
Food and Feeding
Food items—Various fishes and squids, and such small water column zooplankters as euphausiids, hyperiid amphipods, and crustacean larvae. Diets change seasonally and between years [23].
Trophic level—4.2 [24].



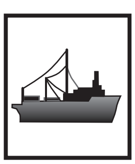
Biological Interactions
Predators—Fishes, sea birds, and marine mammals [11].
Competitors—Possibly gadids such as Arctic Cod and other salmonids.



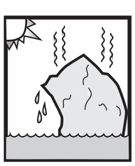
Resilience
Medium, minimum population doubling time 1.4–4.4 years (*K*=0.98; t_m=2–4; Fecundity=1,400) [24].



Traditional and Cultural Importance
Only rarely, but apparently increasing numbers harvested in subsistence fisheries in U.S. Chukchi and Beaufort Seas [10].



Commercial Fisheries
Currently, Coho Salmon are not commercially harvested.



Potential Effects of Climate Change
Warming temperatures likely will allow this species to colonize Arctic marine and freshwater ecosystems. It can be expected that Coho Salmon will eventually become more abundant, especially in the southeastern Chukchi Sea. Because of thermal requirements for incubation, it is unclear whether the viable populations will be able to establish in watersheds of the Chukchi and Beaufort Seas.

Areas for Future Research [B]
Coho Salmon are well studied in the State of Alaska. Specific information from the region is lacking with respect to (1) preferred habitat, including depth ranges for juveniles and adults; (2) spawning season; (3) seasonal and ontogenetic movements; (4) population studies; (5) prey; and (6) predators. Surveys of Chukchi and Beaufort Sea watersheds for suitable spawning and rearing habitats, evidence of spawning, or successful reproduction, should be considered.

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Sockeye Salmon (*Oncorhynchus nerka*)

(Walbaum, 1792)

Family Salmonidae

Note: *Except for geographic range data, all information is from areas outside the Chukchi and Beaufort Seas.*

Colloquial Name: *None in U.S. Chukchi and Beaufort Seas.*

Ecological Role: Of limited ecological importance in the U.S. Chukchi and Beaufort Seas. Harvested in small numbers in Kotzebue Sound; therefore, this fish may play a seasonal role in pelagic ecosystems in the southeastern Chukchi Sea.

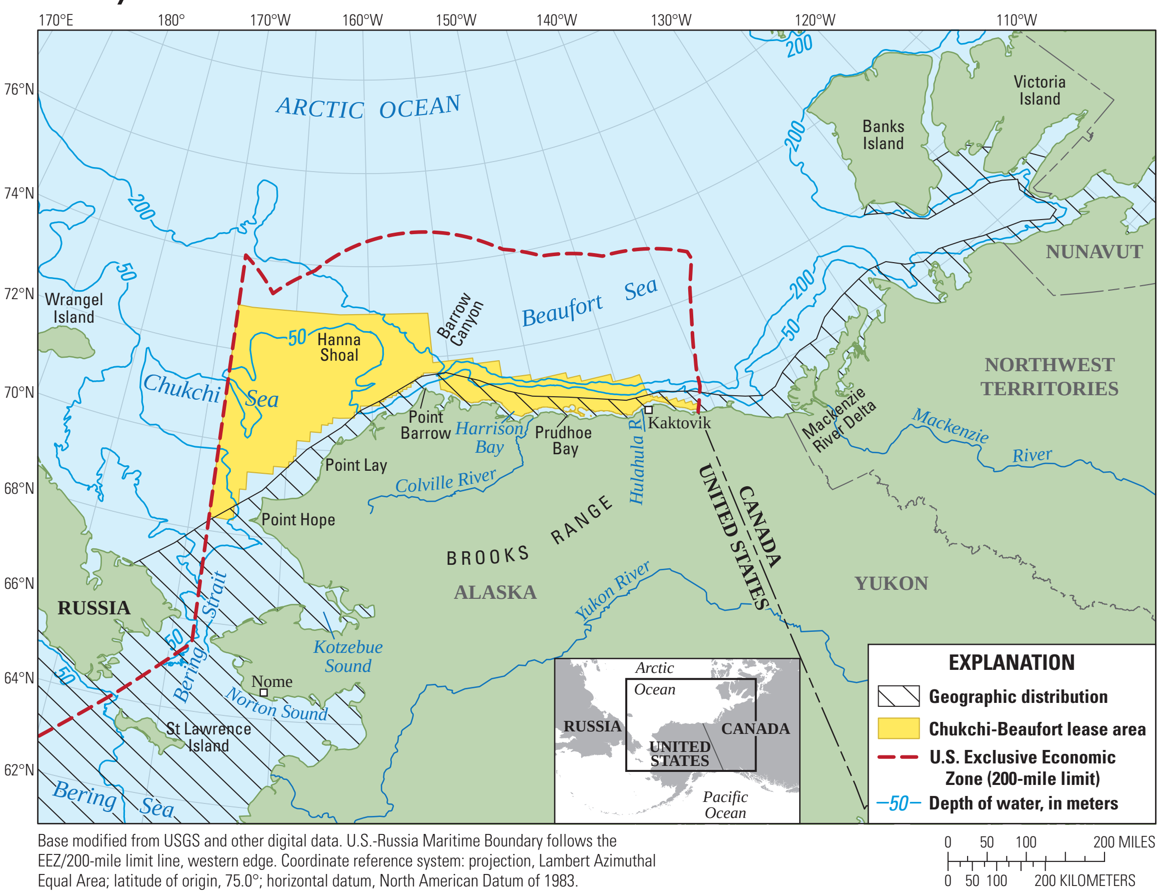
Sockeye Salmon (*Oncorhynchus nerka*), 237 mm, southwestern Gulf of Alaska, 2007. Photograph by C.W. Mecklenburg, Point Stephens Research.

Physical Description/Attributes: At sea, head blue to green-blue, rest of body silvery. Usually no black spots on back and fins, occasionally small spots on caudal or dorsal fin. For specific diagnostic characteristics and spawning coloration, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 209) [1]. Swim bladder: Present [2]. Antifreeze glycoproteins in blood serum: Unknown.

Range: *U.S. Chukchi and Beaufort Seas* [3]. Worldwide, northern Japan and the Sea of Okhotsk to the Klamath River, northern California, and Arctic Canada coasts to Bathurst Inlet, Nunavut and northward to the Sachs River estuary, Banks Island [3].

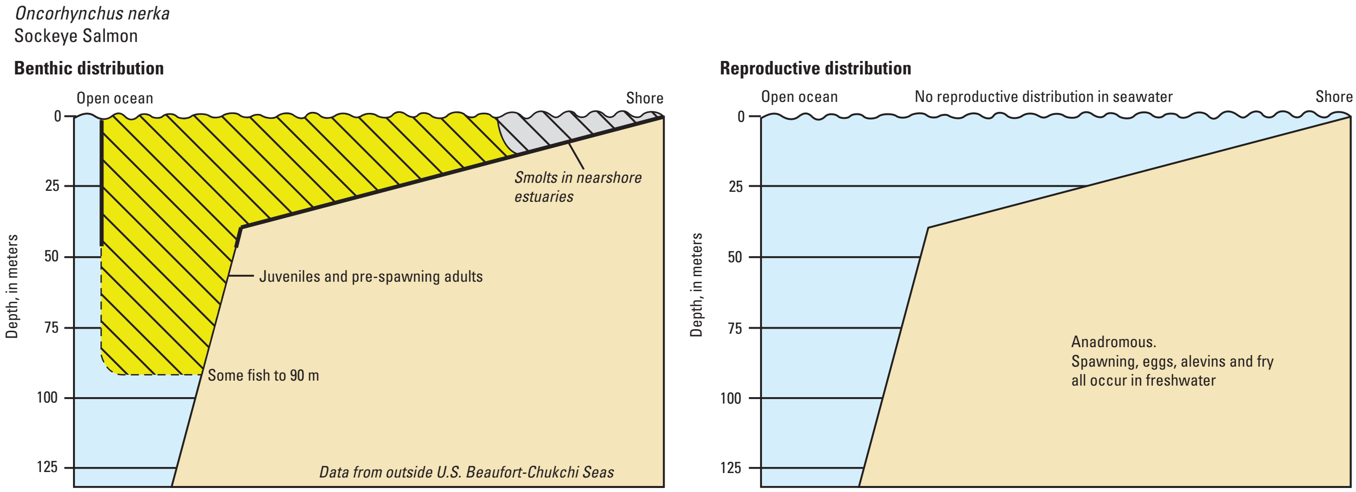
Relative Abundance: *Common in U.S. Chukchi Sea northward to about Kotzebue Sound area (where it spawns), occasionally farther north in U.S. Chukchi and Beaufort Seas* and to Sachs River, Canada [3, 7]. Generally, Sockeye Salmon are uncommon in the U.S. Chukchi and Beaufort Seas north of about Kotzebue Sound.

Sockeye Salmon
Oncorhynchus nerka

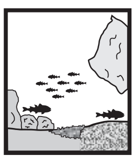


Geographic distribution of Sockeye Salmon (*Oncorhynchus nerka*), at sea within Arctic Outer Continental Shelf Planning Areas [4] based on review of published literature and specimens from historical and recent collections [1, 5, 6].

Depth Range: Epipelagic, coastal and offshore, from surface to 90 m, but mostly 40 m and less [8, 9].



Benthic and reproductive distribution of Sockeye Salmon (*Oncorhynchus nerka).*



Habitats and Life History

Anadromous.

Eggs—Size: 5.0–6.6 mm [10]. Size at hatching: Unknown, probably 20–25 mm TL [11]. Time to hatching: 57–171 days [10]. Habitat: Benthic, buried in gravel in waterways entering lakes or in shallow waters of lakes [10].

Alevins (larvae)—Size range: Become fry at about 25–30 mm [10, 11]. Habitat: Benthic, buried in the substrate of lakes and rivers [10].

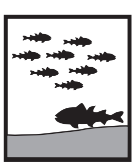
Fry—Size at emergence: 25–31 mm [10]. Length of time as fry: Several weeks to 3 years (although stream-reared juveniles and juveniles that migrate to sea within a few weeks are known) [10]. Habitat: Lakes and streams [10].

Smolt and ocean phase—Age and size at smoltification: Less than 1 year to 3 years and at a minimum of 60 mm [10]. Habitat: Following smoltification, epipelagic in ocean for 1–4 years (mostly 2–3 years), often far from shore [10]. In North American waters, may migrate almost as far west as Kamchatka Peninsula, Russia, and fish from Asia intermingle with those from North America [10, 12].

Adults—Age and size at spawning: On average 3–5 years and 50–60 cm [10]. Maximum age: At least 6 years [10], a non-native individual lived to 8 years in Connecticut [13]. Maximum size: 84 cm [1]. Habitat: At maturity, ascends natal rivers and lake systems to spawn [11].

Substrate—Coarse sand to large rubble for spawning [10].

Physical/chemical—Temperature: At least 2–8 °C in freshwater during spawning [10]. Less than 1–15 °C, mainly 2.5–9 °C at sea [14]. Salinity: Fresh to marine waters, depending on life stage [10].



Behavior

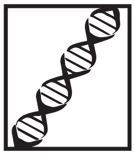
Diel—Fry emerge from substrate and make initial downstream migration at night. Smolt migrations to sea tend to be at night [10].

Seasonal—Smolts tend to migrate out of lakes when waters warm in spring and summer [11]. *Utilization of offshore waters as well as migrations in U.S. Chukchi and Beaufort Seas are unknown.*

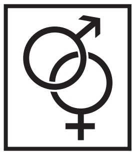
Reproductive—Spawning occurs in freshwater, most often in shallow water of lakes [10]. All adults die after spawning [11].

Schooling—Fry and freshwater smolts form schools, as do at least younger individuals at sea. The degree of schooling at sea, particularly of older individuals, is not well understood [10].

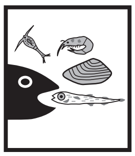
Feeding—Juveniles and adults are carnivorous planktivores. Spawning adults cease feeding [11].



Populations or Stocks
There have been no studies.

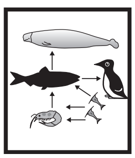


Reproduction
Mode—Gonochoristic, oviparous, and semelparous with external fertilization [15].
Spawning season—Late July through January, typically from midsummer through late autumn [10].
Fecundity—Highly variable, 2,000–5,000 eggs on average [10].

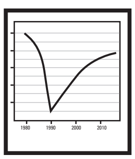


Food and Feeding

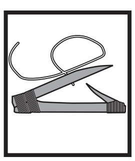
Food items—Primarily zooplankton (for example, euphausiids, hyperiid amphipods, copepods, pteropods, and crustacean larvae), as well as small fishes and squids. Diets vary with area and year [16, 17].
Trophic level—3.4 [18].



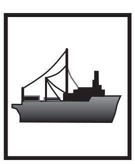
Biological Interactions
Predators—Fishes, sea birds, and marine mammals [10].
Competitors—Unknown, but likely to include Pacific Herring, Arctic Cod, Saffron Cod, and Dolly Varden.



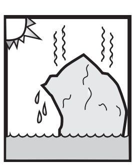
Resilience
Medium, minimum population doubling time 1.4–4.4 years (K=0.37–0.58; t_m=2–4; t_{max}=7; Fecundity=300) [18].



Traditional and Cultural Importance
Only rarely taken in subsistence fisheries in U.S. Chukchi Sea [19].



Commercial Fisheries
Currently, Sockeye Salmon are not commercially harvested in the U.S. Chukchi or Beaufort Seas.



Potential Effects of Climate Change
Warming temperatures will likely allow this species to become more abundant in the U.S. Chukchi and Beaufort Seas. Whether this species will be able to reproduce in the waters draining into these seas is unknown.

Areas for Future Research [B]

Sockeye Salmon are well studied in Alaska, but are not of great abundance in the American high Arctic. Specific information needs include: (1) preferred habitat, including depth ranges for juveniles and adults; (2) spawning season; (3) seasonal and ontogenetic movements; (4) population studies; (5) prey; and (6) predators. If range expansions occur, surveys for suitable spawning and rearing habitats and evidence of successful spawning should be undertaken.

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Chinook Salmon (*Oncorhynchus tshawytscha*)
(Walbaum, 1792)

Chinook Salmon (*Oncorhynchus tshawytscha*), southeastern Gulf of Alaska, 2003. Photograph by C.W. Mecklenburg, Point Stephens Research.

Family Salmonidae

Note: *Except for geographic range data, all information is from areas outside of the study area.*

Colloquial Name: Iñupiat—*Iqalugruaq* [1].

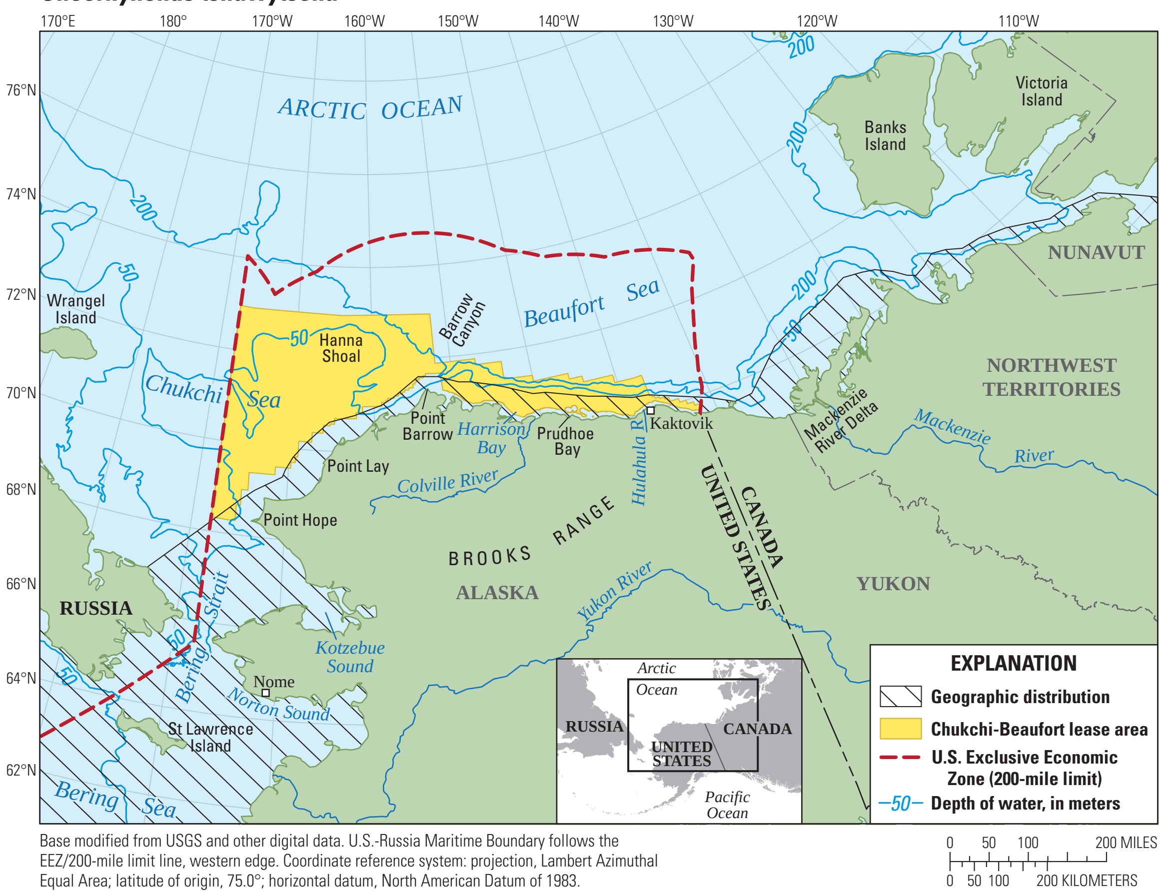
Ecological Role: With its apparent increase in abundance in the U.S. Chukchi and Beaufort Seas [1], this species is likely to be of increasing ecological importance. Chinook Salmon are occasionally captured in recreational fisheries at Point Barrow.

Physical Description/Attributes: At sea, metallic green to blue-black back, silver flanks, and white belly, small black spots on both lobes of the caudal fin and on back and the gums at the base of the teeth of the lower jaw are black. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 207) [2]. Swim bladder: Present [3]. Antifreeze glycoproteins in blood serum: Unknown.

Range: *U.S. Beaufort and Chukchi Seas* [4, 5]. Worldwide, from Northern Japan to Canadian Beaufort Sea at Coppermine River [2, 4] and to Bahia de Sebastian Vizcaino, central Baja California, Mexico [6].

Relative Abundance: *Common to at least the Barrow region* [1]. Rare eastward to the Coppermine River, Canada [2, 4]. Currently, the northernmost spawning stock known is in Kotzebue Sound, Alaska [10].

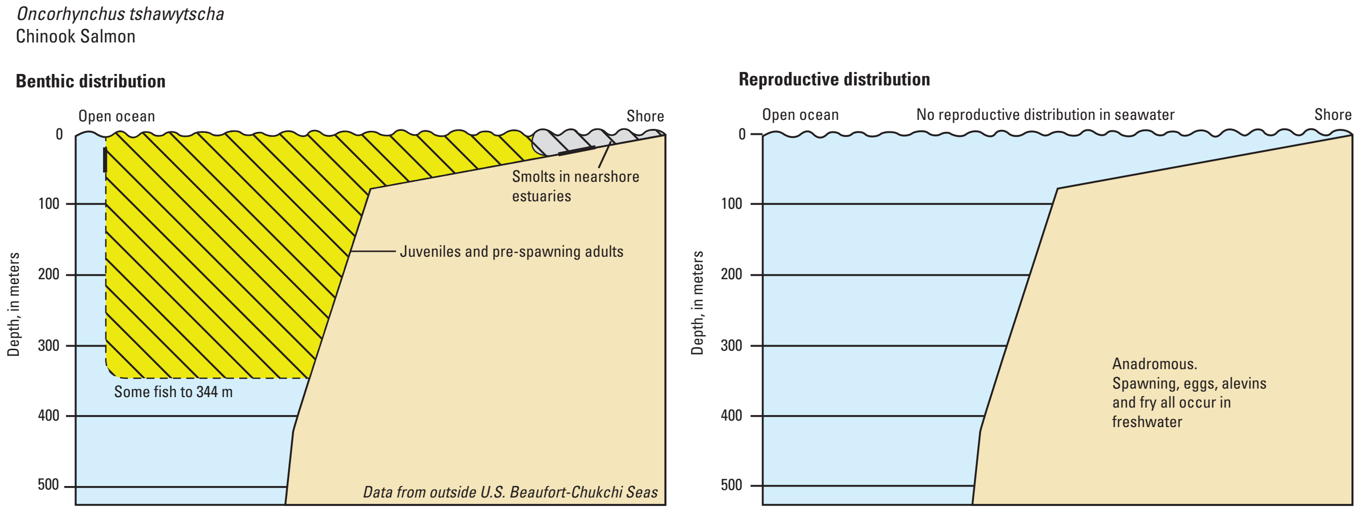
Chinook Salmon
Oncorhynchus tshawytscha



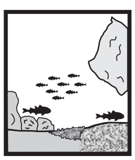
Base modified from USGS and other digital data. U.S.-Russia Maritime Boundary follows the EEZ/200-mile limit line, western edge. Coordinate reference system: projection, Lambert Azimuthal Equal Area; latitude of origin, 75.0°; horizontal datum, North American Datum of 1983.

Geographic distribution of Chinook Salmon (*Oncorhynchus tshawytscha*), at sea within Arctic Outer Continental Shelf Planning Areas [7] based on review of published literature and specimens from historical and recent collections [8, 9].

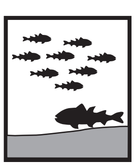
Depth Range: Epipelagic, coastal and offshore, from surface to 344 m [11]. Bering Sea fish tend to remain 30–50 m below the surface, making occasional forays into somewhat shallower waters during the day [12], although those farther south tend to remain in deeper waters [13].



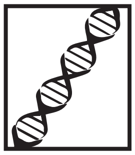
Benthic and reproductive distribution of Chinook Salmon (*Oncorhynchus tshawytscha*).



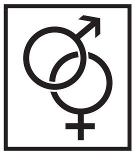
Habitats and Life History
Anadromous.
Eggs—Size: 6.0–8.5 mm [14]. Size at hatching: About 20–24 mm [14, 15]. Time to hatching: 30–160 days, warmer temperatures speed hatching time [16]. Habitat: Benthic, buried in gravel in streams and rivers [10].
Alevins (larvae)—Size range: 20–35 mm [14]. Habitat: Benthic, buried in gravel in streams and rivers [10]. Stay under gravel until yolk sac absorbed (4–6 weeks) [17].
Fry—Size at emergence: About 33–37 mm [15]. Length of time as fry: Several weeks to more than 1 year [10]. Habitat: Epipelagic in streams, rivers, and estuaries [10].
Smolt (juveniles) and ocean phase—Age and size at smoltification: Several weeks to at least 18 months and at least 35 mm to perhaps 160 mm [17]. Habitat: Epipelagic [10, 14, 18]. Smolts that quickly leave fresh water reside in estuaries for at least a few months, although length of residence varies annually and with location [10]. Two life history types: Ocean-type enters the ocean in their first year and migrates less. Stream-type spends first year in fresh water, enters the ocean in their second year, and tends to migrate farther [18]. Generally, ocean-type does not migrate out of nearshore waters when at sea, whereas stream-type disperses much broader and farther from shore [10].
Adults—Age at first maturity: Highly variable, depending on stock and ranges from 1 year for males to 7–8 years for females [10]. Mean ages per stock range from 3–6 years [10]. Maximum age: 8 years [10]. Maximum size: 160 cm [2]. Habitat: At maturity, ascends rivers and streams to spawn [10].
Substrate—Gravel for spawning [10]. Mud, sand, gravel, and over eelgrass for juveniles in estuaries [14].
Physical/chemical—Temperature: At sea, 2–16.9 °C [19, 20], may prefer 7–12 °C [13, 20]. Salinity: Fresh to marine waters, depending on life stage [10].



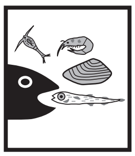
Behavior
Diel—Fry emerge from gravel and travel downstream primarily at night [10]. In at least some areas, fry settle to the bottom at dusk and move into shallow waters at night. Juveniles entering estuaries do so at night [17]. At sea, appears to move toward surface waters in evening and returns to depth in morning [21].
Seasonal—Depending on geographical location, Chinook Salmon may return to natal rivers during almost any month of the year [10]. *In the U.S. Chukchi and Beaufort Seas, utilization of ocean waters as well as migrations are unknown.*
Reproductive—Spawning occurs in freshwater streams and rivers. Females prepare a gravel nest and lay their eggs, which are fertilized by a male [10]. All adults die after spawning except for a few “jack” males [14].
Schooling—Fry form schools [22].
Feeding—Juveniles and adults are carnivorous, opportunistic feeders [10, 14].



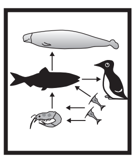
Populations or Stocks
There have been no studies in the U.S. Chukchi and Beaufort Seas.



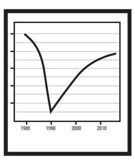
Reproduction
Mode—Gonochoristic, oviparous, and semelparous with external fertilization [23].
Spawning season—May–January, depending on run, fish in the more northerly parts of the range tend to spawn earlier in the season [10].
Fecundity—Highly variable, less than 2,000 to more than 17,000 eggs [10].



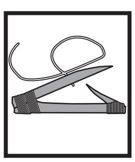
Food and Feeding
Food items—At sea, primarily fishes, although zooplankton (for example, euphausiids, amphipods, copepods, and pteropods) also is consumed [24].
Trophic level—4.4 (standard error 0.76) [25].



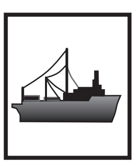
Biological Interactions
Predators—Fishes, sea birds, and marine mammals [26].
Competitors—Likely other Pacific Salmon, as well as gadid species.



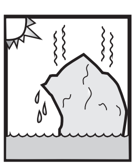
Resilience
Medium, minimum population doubling time 1.4–4.4 years (t_m=4; t_{max}=9; Fecundity=4,000) [25].



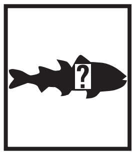
Traditional and Cultural Importance
Historically, Chinook Salmon were only rarely taken in the subsistence fisheries of the Chukchi and Beaufort Seas [27, 28]. *However, recent catches in the Point Barrow area suggest an increased abundance in recent years* [1].



Commercial Fisheries
Currently, Chinook Salmon are not commercially harvested in the U.S. Chukchi and Beaufort Seas.



Potential Effects of Climate Change
Warming temperatures likely will allow this species to become more abundant in the U.S. Chukchi and Beaufort Seas. Whether this species will be able to successfully reproduce due to thermal requirements for incubation, phenology of seaward migration, and quality of nearshore habitats, is unknown.



Areas for Future Research [B]

Chinook Salmon are well studied in areas where their populations are abundant in the State of Alaska. Little information is available about this species from the U.S. Chukchi and Beaufort Seas. Specific information needs include: (1) preferred habitat, including depth ranges for juveniles and adults; (2) spawning season; (3) seasonal and ontogenetic movements; (4) population studies; (5) prey; and (6) predators. Surveys to identify suitable habitats for spawning and rearing of young are needed. Coastal monitoring of freshwater drainages should include searches for evidence of Chinook Salmon spawning and successful reproduction.

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Dolly Varden (*Salvelinus malma*)
(Walbaum, 1792)

Family Salmonidae

Note: *Two subspecies are recognized by some taxonomists: Salvelinus malma malma, distributed from the Mackenzie River to the Alaska Peninsula, and* S. malma lordi*, living along and southward of the Alaska Peninsula* [1, 2].

Colloquial Name: Iñupiat—*Iqalukpik* [3].

Ecological Role: Likely of considerable ecological importance as fish predator in nearshore areas of the U.S. Chukchi and Beaufort Seas. Dolly Varden are widely distributed and common throughout the region.

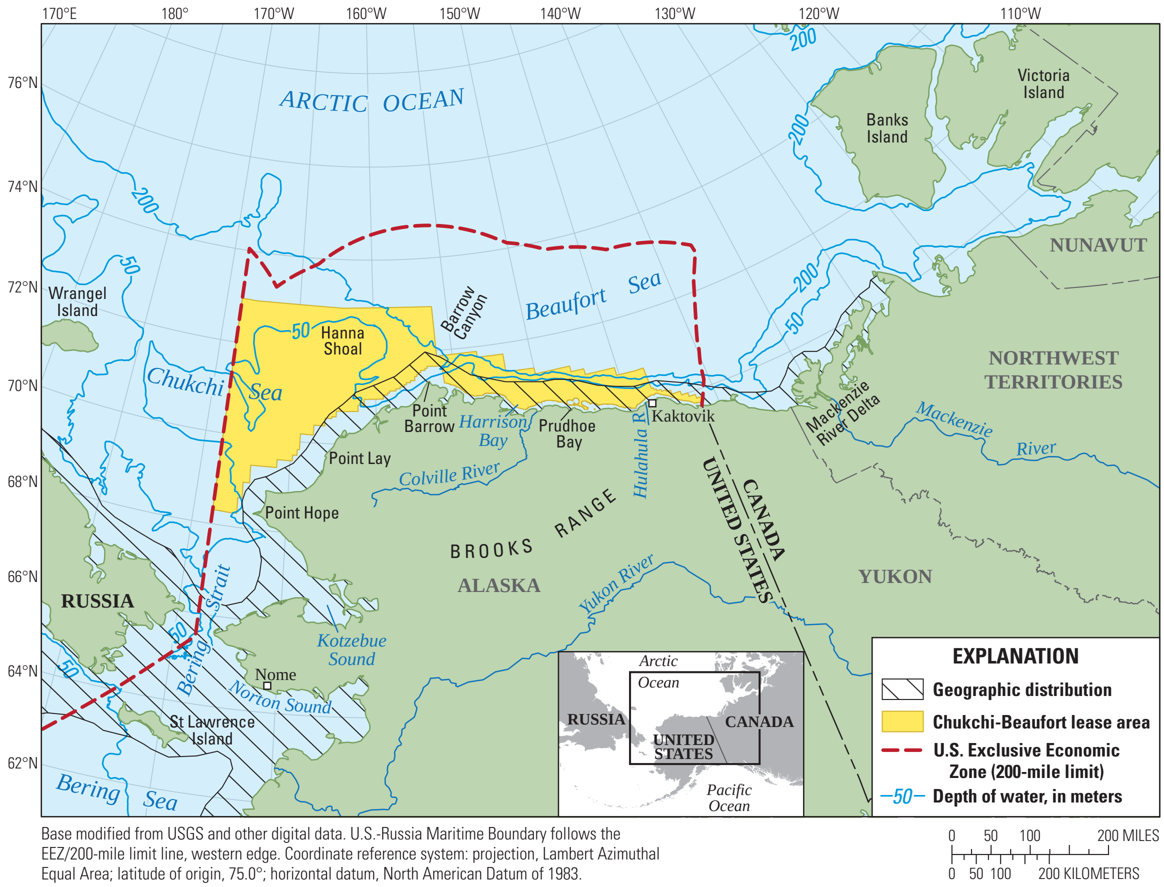
Dolly Varden (*Salvelinus malma)*. Photograph by Alfred L. DeCicco, Alaska Department of Fish and Game.

Physical Description/Attributes: Olive green to dark blue or brown on back and sides, with profuse yellow, orange, or red spots on side; largest spots usually smaller than pupil of eye; pectoral, pelvic, and anal fins with white leading edge and black or red line behind; spawning males orange to red, ventrally [4]. Coloration is highly variable and depends on race, age, and reproductive state. Extensive descriptions are given in *Fishes of Alaska* (Mecklenburg and others, 2002, p. 200) [4], McCart and others (1972) [5], and Armstrong and Morrow (1980) [1]. Swim bladder: Present [6]. Antifreeze glycoproteins in blood serum: Unknown.

Range: *U.S. Chukchi and Beaufort Seas.* Elsewhere in Alaska, found in all coastal waters in Bering Sea, south to Aleutian Islands and southern Gulf of Alaska. Worldwide, south to northern Washington and Korean Peninsula and Japan, northward to the Chukchi Peninsula, Russia, and east in Arctic to Mackenzie River, Canada, [4, 7].

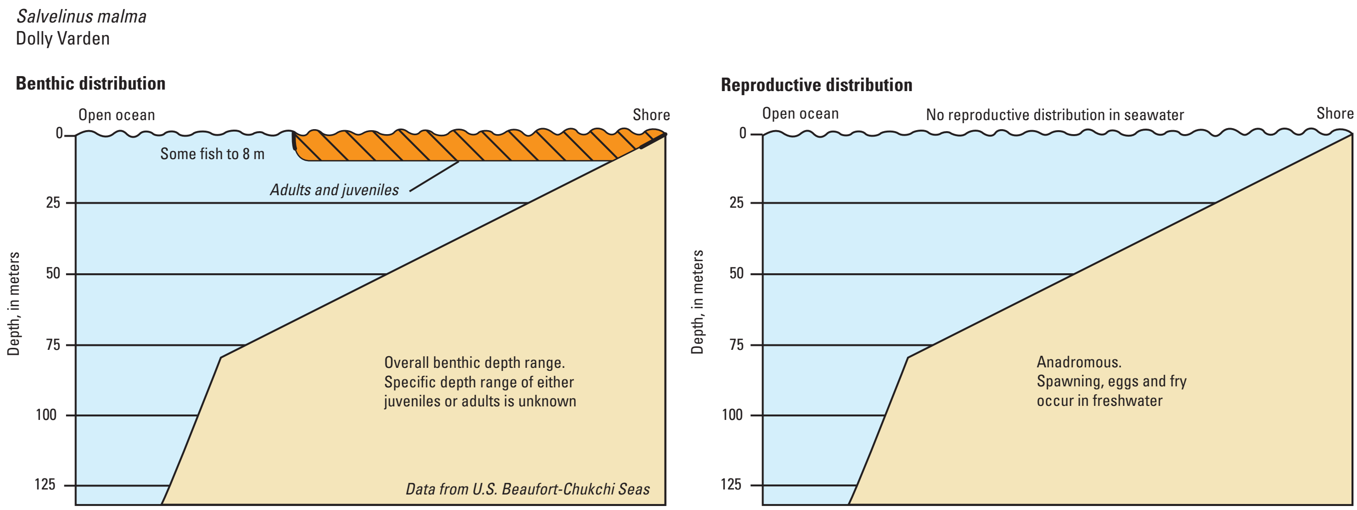
Relative Abundance: Common *near shore in U.S. Chukchi and Beaufort Seas during summer, except along northeastern Chukchi Sea coast (for example Point Lay)* [11, 12]. Elsewhere, common in Alaska throughout its range [13].

Dolly Varden
Salvelinus malma

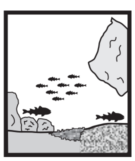


Geographic distribution of Dolly Varden (*Salvelinus malma*), at sea within Arctic Outer Continental Shelf Planning Areas [8] based on review of published literature and specimens from historical and recent collections [9, 10].

Depth Range: *Epipelagic, mostly nearshore but occasionally well offshore* [1]. *Primarily stays in top 3–4 m of water column, with occasional excursions down to 8 m* [14, 15].



Benthic and reproductive distribution of Dolly Varden (*Salvelinus malma*).



Habitats and Life History

Note: The systematics of Dolly Varden are complex and the species exhibits a wide range of behaviors including amphidromous stocks, stocks with freshwater resident males, but ocean-going females (termed "facultative anadromous" in literature, but referred to here as "amphidromous") [16], and various stocks where both sexes permanently reside in streams, springs, or lakes [1, 17]. Information in this account is on amphidromous *S. malma malma* living in U.S. Chukchi and Beaufort Sea drainages. Biological aspects of landlocked stocks and of more southerly subspecies are available in [1, 13, 18]. *In U.S. Chukchi and Beaufort Sea drainages, most individuals are amphidromous, although some males and dwarf residents never leave freshwater* [1]. In Beaufort Sea drainages, winter and spring are spent in those few areas of rivers kept ice-free by freshwater springs [1].

Eggs—Size: *3.2–6.0 mm* [1, 19, 20]. Time to hatching: *7–9 months* [1, 5]. Length at hatching: *8–12 mm* [5, 19, 21]. Habitat: Benthic, buried under gravel in freshwater streams and rivers [1].

Alevins (larvae)—Size: *From 8–27 mm* [5, 19]. Time to emergence: *60–70 days post-hatching* [22]. Habitat: *Benthic, in freshwater rivers and streams, under gravel until emergence (yolk-sac absorbed)* [22].

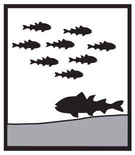
Fry and parr—Size at emergence: *20–27 mm* [5, 19]. Length of time as fry and parr: *1 to 5 years, mostly at 3–5 years* [1, 19, 20, 23]. Habitat: *Freshwater, in streams and rivers.*

Smolt and Adult—Age and size at smoltification: *1 to 5 years, mostly at 3–5 years* [1, 19, 20, 23], *and 16–39 cm* [1]. Habitat: *Nearshore waters during summer and early autumn and freshwater during winter and spring* [1].

Adults—Age and size at first maturity: *4–10 years, mostly at 6–8 years* [5, 19, 23, 24] *and 32–47 cm* [20, 24–26]. *Nonmigratory or "residual" males mature at 2 years* [5]. Maximum age: *At least 18 years* [16], *although fish over 10 years are relatively uncommon* [1, 20, 27–29]. *Anadromous fish may live slightly longer than resident individuals and grow larger* [5, 30]. Maximum size: *100 cm TL* [4]. Habitat: *Nearshore, shallow waters in ocean. In freshwater on spawning grounds, main channels of rivers, usually in strong currents or in the presence of springs* [1].

Substrate—*In marine conditions, mostly in mid-depths and surface waters. Spawning occurs in freshwater over gravel* [1].

Physical/chemical—Temperature: *-1–14 °C* [16, 31]. Salinity: *Freshwater to 32 parts per thousand* [16, 31].



Behavior

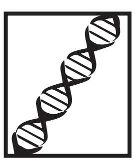
Diel—Unknown.

Seasonal—*On North Slope watersheds, before their first seaward migration, parr often overwinter in areas kept free of ice by perennial springs* [5]. *Some offspring of amphidromous Dolly Varden do not migrate to sea, but remain and mature in freshwaters. These diminutive "resident," "residual," or "accessory" fish are mostly males* [5, 16]. *Seaward migrations occur with ice break-up between May and July, with larger individuals leaving over-wintering grounds first. Fish enter marine waters in June and July* [19, 31, 32]. Most juveniles have a variable freshwater rearing period of 1–3 years before first migrating to sea. *Smaller fish entering marine waters form small schools* [23, 31] *and remain near mouths of natal rivers, whereas larger fish disperse widely along the coast, sometimes traveling as much as 300 km (Beaufort Sea)* [1, 16, 30, 33, 34]. *Some fish from Chukchi Sea drainages make even longer marine excursions. At the extreme, two fish tagged on overwintering grounds in the Wulik River (southeastern Chukchi Sea) were recovered well upstream in the Anadyr River of Siberia with one of the recoveries as much 1,690 km from the tagging site. It is likely that these recoveries were of Anadyr stock that had overwintered in the Wulik River* [32]. *Once in coastal waters many Dolly Varden inhabit shallow nearshore depths* [14, 31, 33], *although some move away from the coast, perhaps to feed under pack ice or when brackish waters extend off shore* [31, 33, 35]. *All Beaufort and Chukchi Sea Dolly Varden overwinter in freshwater and must return to rivers and streams during summer or early autumn* [23]. *In Beaufort Sea watersheds, both spawning and overwintering always take place in tributaries where perennial springs prevent freezing throughout the water column* [21, 36], *although in rivers flowing to the Chukchi Sea the lower parts of the waterways also may be partially ice free* [32]. *In Beaufort Sea, most fish overwinter in their natal drainages located in the mountain streams and rivers flowing from the Brooks Range* [37]. *In the southeastern Chukchi Sea, fish do not show overwintering fidelity to natal waterways and stocks from various rivers share ice-free zones* [1, 32, 37]. *During return migrations into fresh waters, the timing and behavior of Dolly Varden are quite complex and vary with location and with the state of maturity of individual fish* [32, 37].

Reproductive—*Spawning occurs in freshwater streams and rivers. Females prepare a gravel nest and lay their eggs, which are fertilized by a male* [1]. *Spawning periodicity is variable. Some individuals spawn annually, whereas many spawn every other year, and apparently there are a few that may reproduce only every third year* [16, 19, 20, 23, 32]. *In Beaufort Sea drainages, fish spawn in many of the "mountain" waterways located between the Colville and Mackenzie Rivers. In the southeastern Chukchi Sea, fish spawn in a number of rivers including the Kivalina, Noatak, and Wulik Rivers* [32]. *It is likely that spawning does not occur in Beaufort Sea coastal plain rivers that lie west of the Colville River because these waterways lack the perennial springs needed to keep waters from freezing solid* [36, 38]. *The vast majority of Dolly Varden seem to return to natal rivers and streams to spawn* [32, 36].

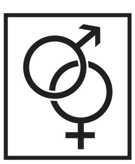
Schooling—*Juveniles form small schools upon entering marine waters* [23, 31].

Feeding—*Opportunistic feeders on various epibenthic and water column organisms including fishes* [28]. *Majority of annual growth is obtained while feeding at sea* [22]. *Fish migrating upstream in rivers during spawning runs feed only occasionally* [20, 39].



Populations or Stocks

Genetic studies have shown that there are multiple populations in drainages throughout their range, that these populations are centered around the various spawning and overwintering areas, and that there may be more than one population occupying tributaries of a single river system [2, 32, 40, 41]. Aerial surveys are used to monitor abundance in North Slope drainages. A combination of mark-recapture and genetic studies examined the feasibility of estimating population size and stock composition at overwintering grounds on the Ivishak River. DIDSON sonar has been used to study abundance patterns in the Hulahula River. The largest overwintering populations of Dolly Varden occur in Ivishak, Kongakut and Anaktuvuk Rivers. Other large overwintering populations occur in the Hulahula, Canning, and Sagavanirktok Rivers.

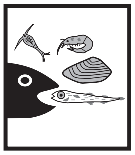


Reproduction

Mode—*Gonochoristic, oviparous, and iteroparous with external fertilization* [1].

Spawning season—*August–December, peaking in September and October* [5, 19, 20, 23, 27, 32].

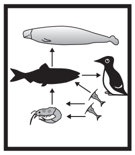
Fecundity—1,500–7,000 eggs [1].



Food and Feeding

Food items—*Epibenthic and water column organisms. Crustaceans (for example, amphipods, mysids, and isopods), fishes (for example, Dolly Varden, Fourhorn Sculpin, Arctic Cod, Least Cisco, Arctic Cisco, Arctic Lamprey, and snailfish), and insects tend to dominate the diet; fish eggs and polychaetes also are consumed. Smaller fish target insects and crustaceans, whereas larger individuals are more apt to feed on fishes* [19, 24, 31, 42].

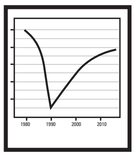
Trophic level—4.5 [43].



Biological Interactions

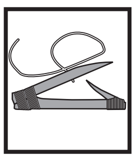
Predators—*Beluga whales, ringed seals, polar bears, and other Dolly Varden* [39, 44–46].

Competitors—Likely other nearshore fishes, including salmonids, whitefishes, sculpins, and Arctic Cod.



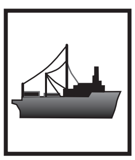
Resilience

Low, minimum population doubling time 4.5–14 years (t_m=3–5) [43].



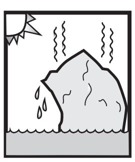
Traditional and Cultural Importance

A very important subsistence species along much of the Alaskan Beaufort and Chukchi Seas, although catches in the northeastern Chukchi Sea are small. Depending on location, large numbers are taken during the summer in coastal waters and at inland sites in autumn and winter [12, 24, 47–49]. *Also an important recreational species* [50].



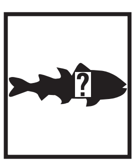
Commercial Fisheries

Currently, Dolly Varden are not commercially harvested.



Potential Effects of Climate Change

Unknown. Of particular relevance is the effect of climate change on the freshwater springs of rivers on the North Slope. If these springs dry up in the winter, the winter river refuges afforded Dolly Varden will not exist.



Areas for Future Research [A]

Future research should address the need for reliable estimates of population abundance from major overwintering habitats and genetic samples collected. Critical spawning and overwintering habitat should be identified and mapped. Subsistence harvests should be monitored, and the stock contribution in those harvests determined. Population parameters at key freshwater and coastal monitoring sites should be routinely monitored.

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