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Chapter 3a Alaska Arctic Marine Fish Species

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

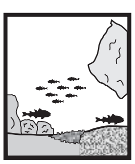
Relative abundance refers to the contribution a species makes to the total abundance of the fishery community. It is a measure that provides an index of the number of individuals present, but not the actual numbers. Relative abundance terms, such as "common," "uncommon," or "rare" often are used to express 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

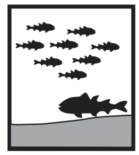
Benthic distribution refers to the spatial arrangement of a particular species at different depths over continental shelf and slope waters. The life cycle of fishes occurs in multiple dimensions in time and space and generally reflects genetically determined life history or behavior that has evolved 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.



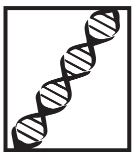
Behavior (see also Glossary [chapter 7]).—Behavior is the manner in which a fish operates or functions within its environment (that is, home range, territoriality, and many others) to procure food, orient to specific locations, or relate to other organisms. Knowing how individuals respond to the environment (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.

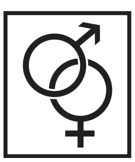
Schooling (that is, social structure of fish of the same species moving in more or less harmonious patterns in the sea) often is related to survival and reproduction. Schooling confers physical benefits to fish movement, safety against predators, search behaviors (for example, foods), population immunology,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

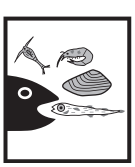
- Trophic level 1 (T1), plants and animals make their own food and are called primary producers;
- Trophic level 2 (T2), herbivores eat plants and are called primary consumers;
- Trophic level 3 (T3), carnivores eat herbivores and are called secondary consumers;
- Trophic level 4 (T4), carnivores eat 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.



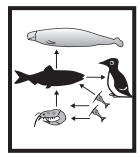
Populations or Stocks—A population often is defined as a group of organisms of the same species occupying a particular space at a particular time with the potential to breed with each other (Williams and others, 2002). Stocks are subpopulations of a particular species of fish that result from reproductive 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.



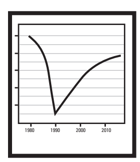
Reproduction Mode—Little information is available about the spawning times and locations, mating behaviors (breeders or nonbreeders), and genetic diversity of Arctic marine fishes. What is known is drawn largely from observations from populations studied outside the United States. For most Arctic marine 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.

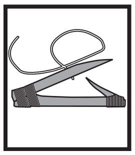


Resilience—In ecology, resilience traditionally refers to the ability of a population or biotic community to sustain or return to its former state after a disturbance. The rate of recovery is a measure of resilience determined by the population processes involved in restoring abundance to healthy, sustainable, 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.

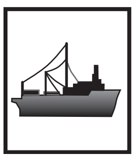
Traditional, Cultural, and Economic Values

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.



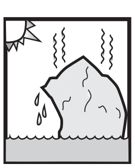
Traditional and Cultural Importance.—Several species of nearshore marine fishes are important in subsistence fisheries. The protection of traditional lifestyles and economies, including these subsistence fisheries, is a responsibility of the Federal government. Subsistence relates to resource use patterns (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

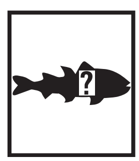
Alaska's climate is changing at more than twice the rate of the rest of the United States (Mellilo and others, 2014). Year-to-year and regional variability in air temperatures are evident and the warming trend currently is being moderated by large-scale cooling associated with the Pacific Decadal Oscillation. 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.

Pacific and Arctic Lampreys

Pacific Lamprey (*Entosphenus tridentatus*)
(Gairdner, 1836)

Family Petromyzontidae

Pacific Lamprey (*Entosphenus tridentatus*). Photograph by René Reyes, Bureau of Reclamation.

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

Colloquial Name: None within U.S. Chukchi and Beaufort Seas.

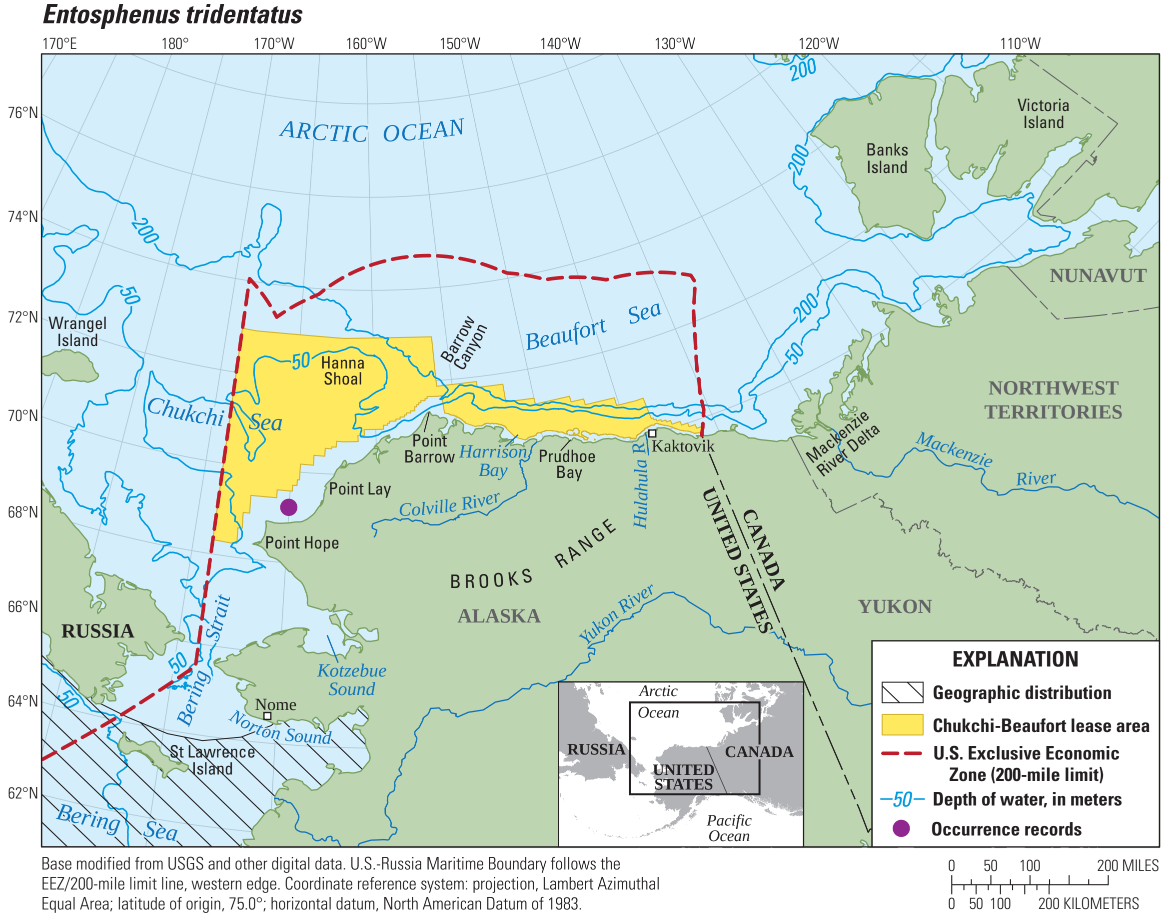
Ecological Role: Its rarity in the U.S. Chukchi Sea and absence from the U.S. Beaufort Sea implies an insignificant role in regional ecosystem dynamics.

Physical Description/Attributes: Elongate, eel-like body, blue-black to dark brown dorsally, pale or silver ventrally. For specific diagnostic characteristics, see *Fishes of Alaska*, (Mecklenburg and others, 2002, p. 61, as *Lampetra tridentata*) [1]. Swim bladder: Absent [2]. Antifreeze glycoproteins in blood serum: Unknown.

Range: *Eastern U.S. Chukchi Sea* [1, 3]. Elsewhere, from Bering Sea south to Punta Canoas, northern Baja California, Commander Islands, and Pacific coast of Kamchatka Peninsula, Russia, and Honshu, Japan [1].

Relative Abundance: *Rare in U.S. Chukchi Sea, with one record near Cape Lisburne, Alaska* [1, 3]. Common in southeastern Bering Sea [6]. Widespread at least as far southward as Honshu, Japan [7]. Rare to occasional in marine waters off Commander Islands and Pacific coasts of Kamchatka Peninsula, Russia, and Hokkaido, Japan [1].

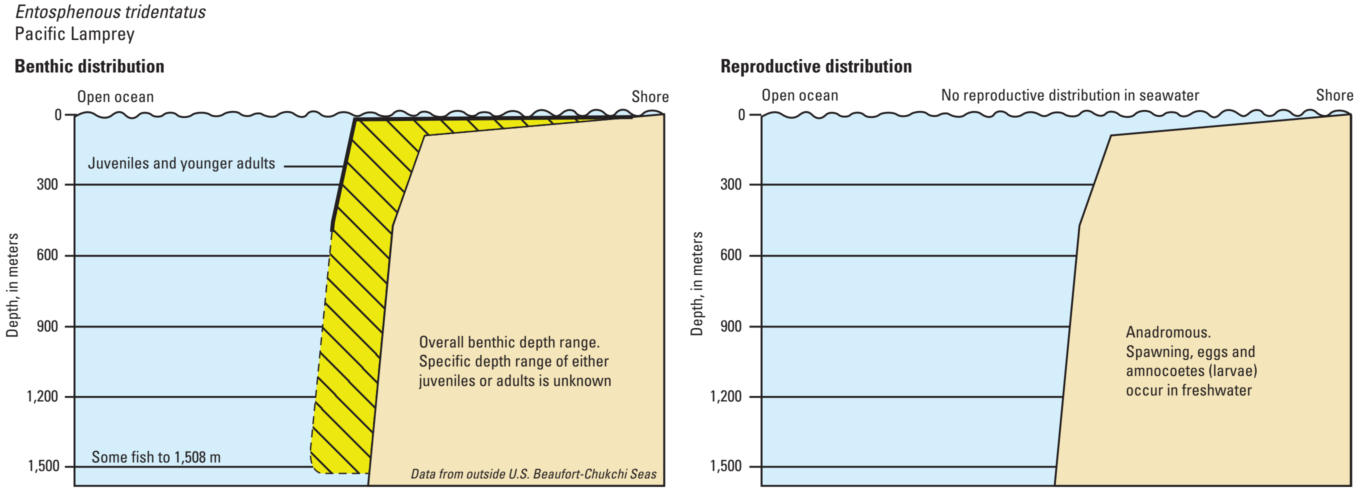
Pacific Lamprey
Entosphenus tridentatus



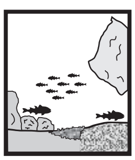
Base modified from USGS and other digital data. U.S.-Russia Maritime Boundary follows the EEZ/200-mile limit line, western edge. Coordinate reference system: projection, Lambert Azimuthal Equal Area; latitude of origin, 75.0°; horizontal datum, North American Datum of 1983.

Geographic distribution of Pacific Lamprey (*Entosphenus tridentatus*), within Arctic Outer Continental Shelf Planning Areas [4] based on review of published literature and specimens from historical and recent collections [3, 5].

Depth Range: Over continental shelf and slope, near surface to 1,508 m. Most abundant at depths less than 500 m and pelagically most abundant above 100 m [7].



Benthic and reproductive distribution of Pacific Lamprey (*Entosphenus tridentatus*).



Habitats and Life History

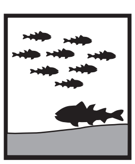
Eggs—Size: Small, 1.1–1.2 mm [8]. Time to hatching: 10–24 days, depending on temperature [9, 10]. Habitat: Freshwater, benthic [3]; attached to rocks among gravel nests near riffles in rivers [9, 11].

Larvae (ammocoetes)—Size at hatching: About 4–5 mm TL [12]. Size at juvenile transformation: From 4.7–17.0 cm [9, 13]. Days to juvenile transformation: 3–7 years [11]. Actual transformation process can take 85–126 days [14]. Habitat: Freshwater, benthic [3]; in gravel redds approximately 2–3 weeks after hatching, then drifts downstream and burrows into soft sediments of slow, shallow depositional areas along stream banks and in pools and eddies [15, 16].

Juveniles (macropthalmia)—Age and size: From 3 to 4.5–8 years [13, 15, 16]. Habitat: Pelagic and benthic in marine water [3]. Marine (parasitic) phase not well understood. Over continental shelf and slope sometimes far offshore [11]. Resides in ocean for 20 months up to 3.5 years, depending on area [7, 13, 17].

Adults—Age and size at first maturity: Unknown. Likely from 4.5–8 years [10–12]. Size at First Maturity: Size varies from 13–72 cm TL [13]. Maximum age: 9 years [18]. Maximum size: 85 cm TL and at least 0.5 kg [7, 11]. Habitat: Freshwater streams and rivers for a few months up to several years before spawning [3, 19]. Substrate: Unknown in ocean. Sandy gravel for spawning. Soft sediment for larval rearing [15, 16].

Physical/chemical—Temperature: Unknown at sea. Spawns between 13 and 18 °C [12]. Salinity: Fresh to marine waters [1].



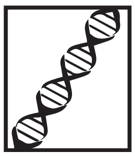
Behavior

Diel—In the ocean, makes daily vertical migrations into pelagic zone, higher at night perhaps to feed [7]. Ammocoete downstream migrations and adult upstream migrations are primarily at night [9, 19].

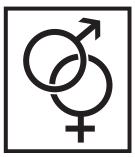
Seasonal—Ammocoete generally transform into juveniles during July through late November [15, 16]. Ammocoetes migrate downstream year-round but mainly from autumn through spring. Migration times differ among populations. In British Columbia, Canada, after leaving their mud-silt habitat they reside in gravel and boulder fields in moderate to strong current streams and then enter seawater from December–June (occasionally earlier than December or later than June) [13]. Adults generally return to freshwater rivers and streams in late spring and early summer (April–June in British Columbia) [13] and reside there from a few months to several years before spawning [19]. Generally, spawning begins the following spring and summer (about May–July) depending on river system [19].

Reproductive—Semelparous, most die within a month after spawning [16], though some seem to spawn at least twice [20]. Spawning occurs in low-gradient streams in sandy gravel usually at riffle heads and in pool tailouts [15, 19]. Males initiate nest building and then joined by females. Nests are constructed by fish attaching to rocks to lift them out of the nest and by digging down within the nest to line the bottom with loose sand for egg attachment [19]. Adults attach themselves side by side to a rock or to each other and release sperm and eggs.

Fertilized eggs drift into nests and attach to rocks. Some adults then cover eggs with rocks or debris [11].
Schooling—Unknown at sea. At times, tends to congregate in certain areas in freshwater rivers [9].
Feeding—Freshwater ammocoetes are burrowing filter feeders [9]. Macropthalmia begin parasitic feeding on fish during seaward migrations [19]. They are parasitic feeders, attaching themselves to fishes using their toothed tongues to penetrate scales and skin to suck out body fluid and blood. While feeding, anticoagulants are produced which prevents host's blood from coagulating [19, 21]. In general, host fish are not killed as various surveys show high incidences of fish with scars. For instance, off the Fraser River, British Columbia, Canada, 66 percent of Sockeye Salmon and 20 percent Coho Salmon had Pacific Lamprey wounds. Lampreys generally attack ventrally and anteriorly, leaving one to three holes, with younger fish creating more holes. They have been shown in the laboratory to hang on to a host for several days [13]. Feeding ceases during upstream migrations [22].

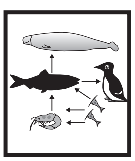


Populations or Stocks
There have been no studies within the study area. Elsewhere, recent studies show low levels of genetic differentiation between populations separated by large geographic distances [19].

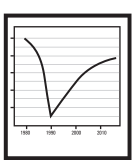


Reproduction
Mode—Oviparous, external fertilization [1].
Spawning season—Differs with regions, spawning earlier farther north. April–July in British Columbia [12]; in southern California occurs as early as January and may continue into at least May [23].
Fecundity—10,000–238,000 eggs [12, 16].

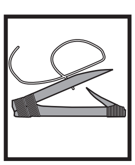
Food and Feeding
Food items–Ammocoetes: Detritus, diatoms and algae [19]. Parasitic macropthalmia and adults: Fishes and mammals including Greenland and Pacific Halibut, Arrowtooth and Kamchatka Flounders; Sablefish, Pacific Hake, Walleye Pollock, Pacific Cod, and Lingcod; Pink, Sockeye, Coho, and Chinook Salmon; Steelhead; Yellowmouth and Rougheye Rockfish; and cetaceans [13, 22]. Off Russia, Greenland Halibut were the most common prey [22].
Trophic level: 4.5 (standard error ±0.80) [18].



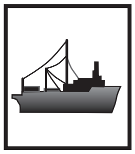
Biological Interactions
Predators—Fishes including Sablefish, rockfishes, various sharks, and White Sturgeon [11, 16, 24–26]. Ammocoetes are eaten by Coho Salmon [16]. Larger fish eaten by harbor seals, California sea lion, Steller sea lion, northern elephant seal, northern fur seal, sperm whales, Pacific White-sided Dolphin, minks, California Gulls, Ring-billed Gulls, Western Gulls, Foster's Terns, Great Blue Herons, and Common Murres [13, 16, 27–31, 32, 33].
Competitors: Pacific Lamprey in seawater [21].



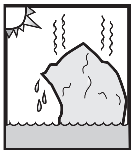
Resilience
Low, minimum population doubling time: 4.5–14 years (t_m 6–8; Fecundity=10,000–106,000) [18].



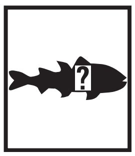
Traditional and Cultural Importance
None reported.



Commercial Fisheries
Currently, Pacific Lamprey are not commercially harvested.



Potential Effects of Climate Change
Unknown.



Areas for Future Research [B]
Little is known about the ecology and life history of this species in the U.S. Arctic. Research needs include: (1) locations of spawning areas, (2) spawning season, (3) size and age at maturity, (4) seasonal and ontogenetic movements, (5) population studies, (6) prey, and (7) predators.

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Arctic Lamprey (*Lethenteron camtschaticum*)

(Tilesius, 1811)

Family Petromyzontidae

Arctic Lamprey (*Lethenteron camtschaticum*), 176 mm TL, Norton Sound, northeastern Bering Sea, 2002. Photograph by C.W. Mecklenburg, Point Stephens Research.

Colloquial Name: Iñupiat: *Nimiqiaq* [24]

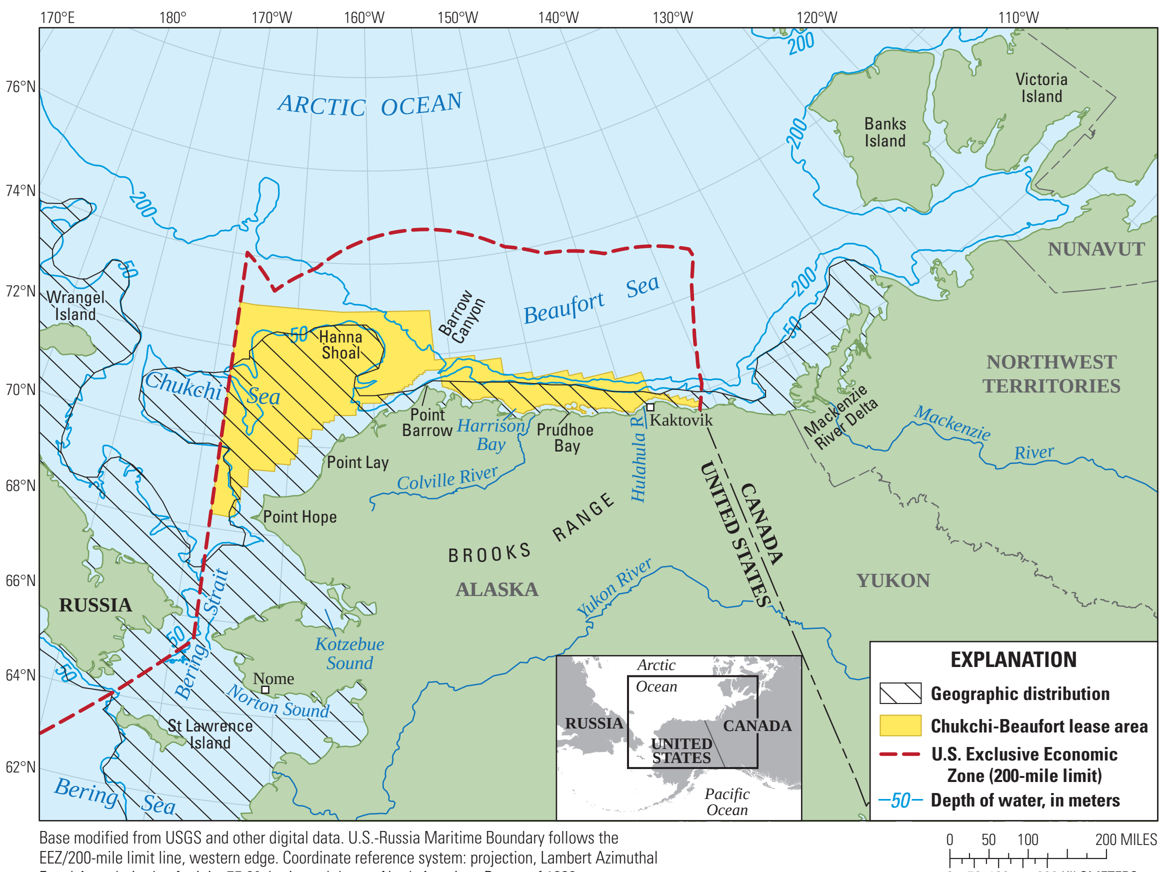
Ecological Role: The extent of this lamprey's parasitisms is *unknown in U.S. Chukchi and Beaufort Seas*.

Physical Description/Attributes: Elongate, eel-like body, blue-black to dark brown dorsally, silvery when fresh on sides and ventral surface, with blackish blotch on second dorsal fin and on tail. For specific diagnostic characteristics see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 62) [1]. Swim bladder: Absent [2]. Antifreeze glycoproteins in blood serum: Unknown.

Range: *U.S. Chukchi and Beaufort Seas* [3]. Elsewhere in Alaska, south through Bering Sea to Kenai Peninsula, Gulf of Alaska. Worldwide, White Sea and coasts of southern Barents Sea eastward off Siberia to Beaufort Sea off Anderson River, Canada; in western Pacific Ocean, south to Honshu, Japan, and Korean Peninsula, and East-Finnmark, Norway, in eastern Atlantic Ocean. Not in western Atlantic [3].

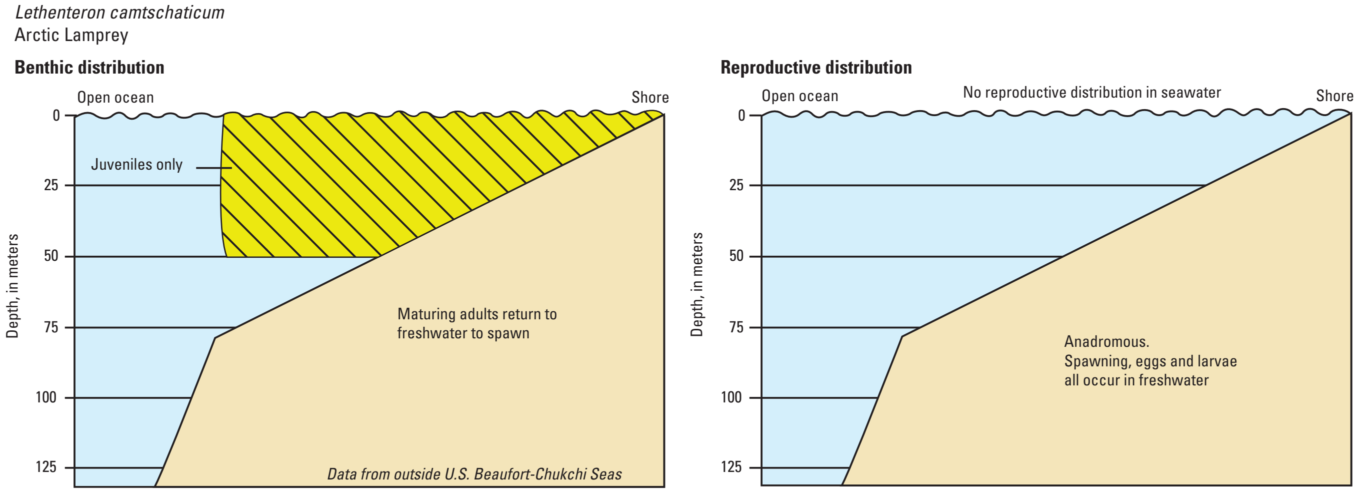
Relative Abundance: *Apparently common in some drainages of the U.S. Chukchi and Beaufort Seas. However, abundance in these drainages and in marine waters is poorly described. Presence at sea is typically indicated by wounds on pelagic fishes*. The most common lamprey in Alaska and, although abundance patterns are unknown, thought to occur in high numbers in localized areas [1, 6]. Common in Sea of Japan and around Sakhalin Island, Russia [7, 8].

Arctic Lamprey
Lethenteron camtschaticum

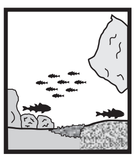


Geographic distribution of Arctic Lamprey (*Lethenteron camtschaticum*) within Arctic Outer Continental Shelf Planning Areas [4] based on review of published literature and specimens from historical and recent collections [3, 5].

Depth Range: Anadromous. Pelagic at sea over continental shelf to bottom depth of 50 m [1].



Benthic and reproductive distribution of Arctic Lamprey (*Lethenteron camtschaticum*).



Habitats and Life History

There are two life-history types, anadromous-parasitic and fluvial-nonparasitic. Eggs and ammocoete larvae of both types are demersal in freshwater lakes and streams. There are three juvenile/adult forms: typically anadromous, anadromous early maturing forma praecox (predominantly males), and resident freshwater. Both forms of anadromous fish are pelagic and migrate to sea. When mature they return to freshwater to spawn. The non-parasitic resident fish remain exclusively in fresh water until spawning [1, 9, 10].

Eggs—Size: As large as 1.25 mm, average of 0.8 mm [9]. Time to hatching: About 1 month after spawning [9]. Habitat: Pebble-sandy bottoms in rivers.

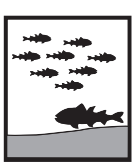
Ammocoetes (larvae)—Size at hatching: 6.8 mm long. Size at juvenile transformation: 13.1–16.8 cm [9]. Time to juvenile transformation: 4 years and longer [9]. Habitat: Sedentary burrowers in river and lake bottoms [11].

Juveniles/smolts (anadromous forms)—Age and size: 4–5 years. Transformation to smolt stage takes approximately 6 months and ends in downstream migration to the sea [10]. Size ranges from 13.0–16.8 to as long as 16.5–21.7 cm TL and from 2.8–4.4 to about 3.1–9.1 g. [10]. Habitat: Pelagic, in downstream migrations to the sea [10].

Adults—Age and size at first maturity: 7 years for anadromous form, 6 years for forma praecox and 5 years for freshwater residents. Typically, anadromous form is 25.0–35.0 cm TL and 30–88 g for males and 17.4–33.0 cm TL and 30–75 g for females [9, 10]. Anadromous forma praecox (predominantly males) is 14.5–22.0 cm TL and 3.2–15 g [9]. Freshwater residents are 11.3–13.9 cm and 1.6–5.0 g for males, and 110–141 cm TL and 2.1–4.5 g for females. Maximum age: Same as age at first maturity. Maximum size: 62.5 cm TL (anadromous form) [1]. Habitat: Anadromous form migrates downstream and becomes pelagic in shallow marine waters over continental shelf. Forma praecox remains in seawater from several months to 1 year, whereas typically anadromous lamprey remain as much as 1 year longer [9].

Substrate—In freshwater, gravel-sand for spawning and muddy sediments for ammocoete rearing [1].

Physical/chemical—Temperature: Spawning occurs between 12 and 15 °C in southwestern Alaska [12]. Salinity: Marine and fresh waters.



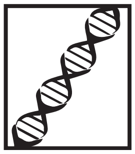
Behavior

Diel—Ammocoetes are primarily active at night and burrow into sediments during day [6].

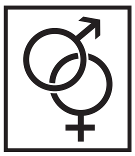
Seasonal—Metamorphosed ammocoetes migrate downstream to sea during August–November in Alaska [10] and May–July in Russia [9].

Reproductive—Adults migrate upstream to spawn in spring. Redds are constructed in riffles with pebbly-gravel bottom where sand prevails [10]. Redds are made by lampreys sucking on to rocks and swimming them away [13]. There is group spawning behavior in fast currents and paired behavior in slow, nearshore zones. In group

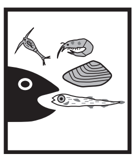
behavior, 6–44 individuals attach themselves by sucking on to each other and drifting downstream. Numerous males may attach to one female. Afterwards, individuals return to spawning redds. Females lay several batches of eggs in redd. One batch of eggs may be fertilized by several males. After spawning, fish stir up silt and small stones to cover the eggs [13]. Adults die after spawning [1].
Schooling—Migrating adults frequently congregate in large numbers, particularly around obstructions [14].
Feeding—Ammocoetes are filter feeders, whereas anadromous juveniles and adults are parasitic, feeding on other fish tissues and blood. Freshwater residents cease feeding upon sexual maturity [9, 10].



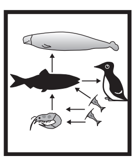
Populations or Stocks
There have been no studies.



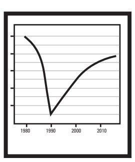
Reproduction
Mode—Separate sexes, oviparous [9, 13].
Spawning season—Spring in southwestern Alaska, generally late May to early July [12].
Fecundity: 12,272–34,586 eggs [9].



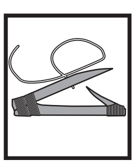
Food and Feeding
Food items—Ammocoetes filter-feed on small aquatic invertebrates, algae and fine organic debris [9]. Adults parasitize fish, including Pacific salmon, Starry Flounder, Saffron Cod, Least Cisco, Arctic Cisco, Broad Whitefish, Pacific Herring and smelt [11, 15–17].
Trophic level—4.5 (standard error ±0.81) [18].



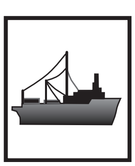
Biological Interactions
Predators—All life stages are preyed on by various fishes including Burbot, Northern Pike, Dolly Varden, and Inconnu; also taken by gulls, especially when lamprey are concentrated in shallow streams during migration [19].
Competitors—Pacific Lamprey in seawater [14]. In Alaska, often found co-occurring with Alaskan Brook Lamprey (*L. alaskensis*) [1].



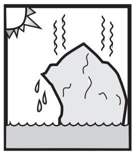
Resilience
Low, minimum population doubling time: 4.5–14 years (t_m 4–5) [18].



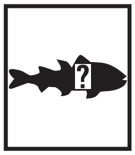
Traditional and Cultural Importance
None reported. Alaskan Natives on the Yukon and Kuskokwim Rivers have taken them in quantity for food using dip nets and sharped sticks [20, 21]. A small commercial fishery on the Yukon River was started in 2003 [6]. Commercially harvested in Sea of Okhotsk [22].



Commercial Fisheries
Currently, in Alaska, Arctic Lamprey are not commercially fished.



Potential Effects of Climate Change
Unknown.



Areas for Future Research [B]
Little is known about the ecology of this species from this region. Research needs include: (1) depth and location of pelagic larvae’ (2) depth, location, and timing of young-of-the-year benthic recruitment; (3) preferred depth ranges for juveniles and adults; (4) spawning season; (5) seasonal and ontogenetic movements; (6) population studies; (7) prey; and (8) predators.

Remarks

This is the most abundant and widely distributed lamprey in Alaska [23].

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Spotted Spiny Dogfish to Bering Cisco

Spotted Spiny Dogfish (*Squalus suckleyi*)
(Girard, 1855)

Family Squalidae

Spotted Spiny Dogfish (*Squalus suckleyi*). Photograph by NMFS-Alaska Fisheries Science Center, RACE Division.

Note on taxonomy: *Meristic, morphometric, and molecular data demonstrate that* Squalus suckleyi *is a distinct species from* S. acanthias (*Linnaeus, 1758*) *[1]. The latter species does not occur in the North Pacific, and previous reports of* S. acanthias *in the North Pacific are assumed to represent* S. suckleyi. *Information presented here is only from data or reports of Squalus in North Pacific waters.*

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

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

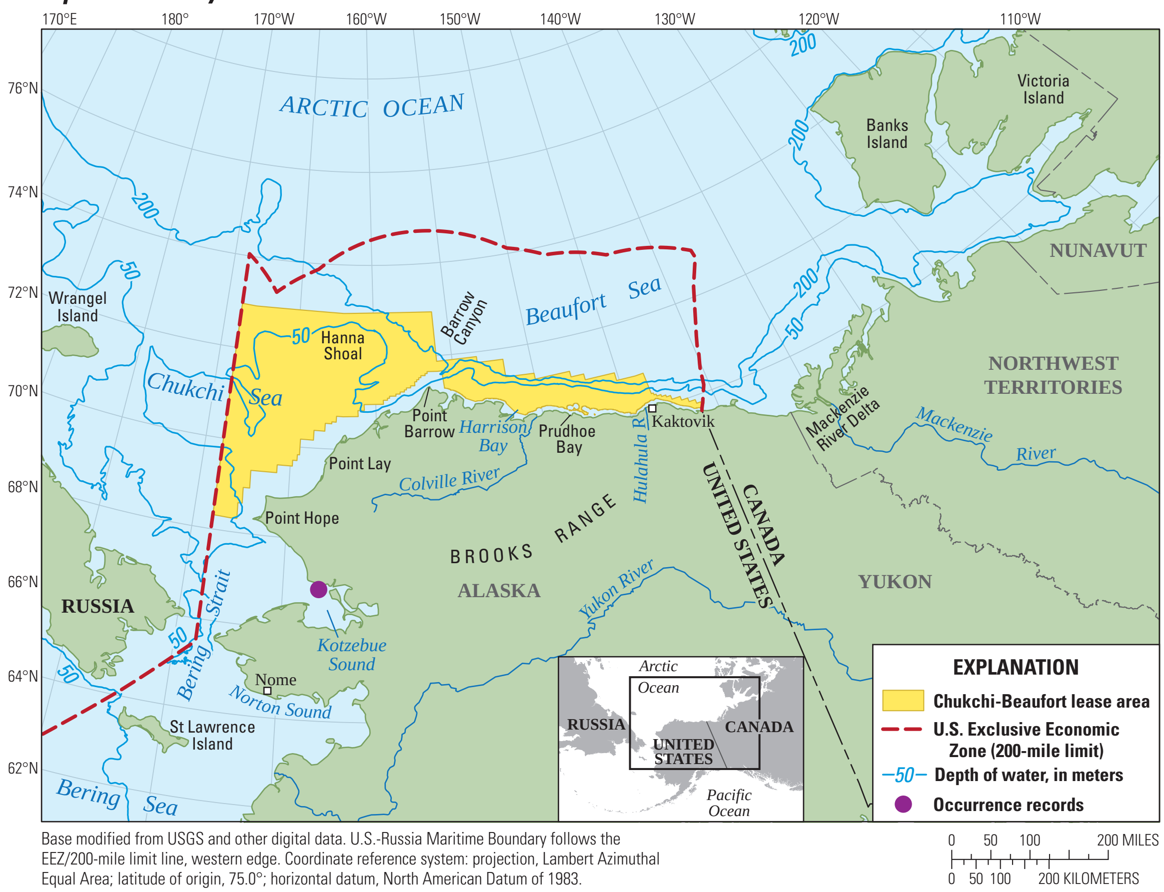
Ecological Role: A rare species in the U.S. Chukchi Sea and absent from the U.S. Beaufort Sea. The species has a very limited role and little significance in regional food webs.

Physical Description/Attributes: Gray or brown dorsally merging into lighter sides and belly with one or two rows of conspicuous white spots on sides. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 88) [1] and [2]. Swim bladder: Absent, as with other cartilaginous fishes [1]. Antifreeze glycoproteins in blood serum: Unknown. Dorsal spines are venomous [3].

Range: *U.S. Chukchi Sea at Kotzebue Sound* [1, 4]. Elsewhere in Alaska, from Bering Sea and Aleutian Islands, eastward in the Gulf of Alaska. Worldwide, from Koreas and Japan northwards to Bering Sea off Kamchatka Peninsula, Russia, Sea of Okhotsk and Sakhalin Island, and from British Columbia, Canada, and Washington south to southern Baja California [2, 5].

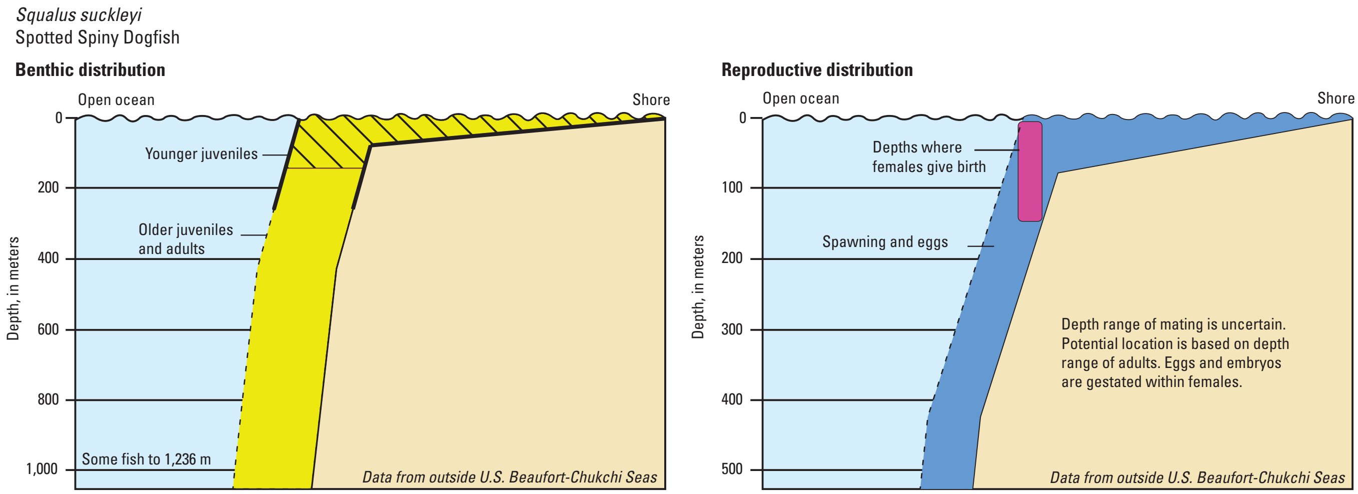
Relative Abundance: *Rare in U.S. Chukchi Sea, with one record of occurrence near Kotzebue* [1]. Common from Kodiak Island, Gulf of Alaska and southward into Baja California, and in Sea of Japan [7–9]. Very rare in northern Bering Sea [1, 10, 11]. Appears to be increasing in abundance in southern Bering Sea [10].

Spotted Spiny Dogfish
Squalus suckleyi

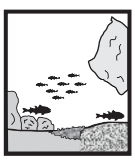


Geographic distribution of Spotted Spiny Dogfish (*Squalus suckleyi*) within Arctic Outer Continental Shelf Planning Areas based on review of published literature and specimens from historical and recent collections [4, 6].

Depth Range: Very shallow waters to at least 1,236 m [9], typically 250 m or less [5]. Juveniles are born in midwaters at depths of 10–140 m [12], and over bottom depths of 50–111 m [13].



Benthic and reproductive distribution of Spotted Spiny Dogfish (*Squalus suckleyi*).



Habitats and Life History

Eggs—Size: 3–4 cm [14]. Time to hatching: Fertilized eggs are contained within candles (a thin membrane containing multiple eggs) and incubated within the female's uterus. Candle membrane dissolves and embryos become free within the uterus within 4–6 months [5]. Habitat: In utero [5].

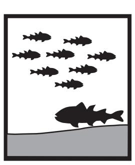
Embryos—Age and size: From about 4–6 months to 22 months (<10 to 22.5–30 cm TL) [5, 13]. Habitat: Embryos are completely dependent on their yolk-sacs and are gestated within the uterus [5, 13].

Juveniles—Size: 22.5–26.3 cm at birth to about 60 cm TL [5, 13]. Habitat: Pelagic, in water column, near surface and becoming benthic as they grow larger and near sexual maturity [5, 13].

Adults—Age and size at first maturity: Based on the most recent study (off British Columbia), a few females mature at about 80 cm TL (24 years), 50 percent matured at 93.9 cm (36 years), and almost all fish are mature at 110 cm (62 years) [15]. 100 percent of females matured at 119 cm [14]. A few males off British Columbia matured at 72 cm TL (15 years), 50 percent at 78 cm TL (19 years), and all at 94 cm [14]. In the North Pacific median size and age at maturity is 80–100 cm TL. (35.5 years) for females and 70–80 cm TL 18.5 for males [2]. Maximum age: 80 to possibly 100 years [5]. Maximum size: About 140 cm [10]. Habitat: Benthopelagic, in a wide depth range [5].

Substrate—Unknown. Have been taken over cobble [16].

Physical/chemical—Temperature: 0–15 °C [17]; prefers less than 7 °C, often migrating horizontally and vertically to follow temperature preference [9]. Salinity: Marine, but can tolerate freshwater for short periods [5].



Behavior

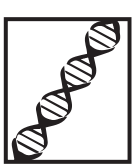
Diel—Migrates closer to surface at night [5, 10] and may be more active at night [16].

Seasonal—Makes seasonal feeding migrations, moving north and inshore as waters warm in spring [10]. Highly mobile in many areas, though movements are not completely predictable. In the North Pacific, many tagged fish were recaptured close to their release site, but some made extensive migrations (as far as 7,000 km) [16].

Reproductive—Males mate every year and females every other year. Smaller males mate earlier in the season [18]. Because of the female's long gestation period (22–24 months), she does not release young every year [9, 18, 19]. Females commonly give birth in shallow bays and estuaries or in mid-water at depths of 50–111 m [13].

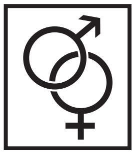
Schooling—Forms large schools [5]. Sexes tend to segregate into separate schools around time of parturition [13].

Feeding—Opportunistic feeders [5], congregating in schools where prey is abundant and sensed by smell [20].

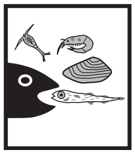


Populations or Stocks

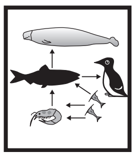
There have been no studies.



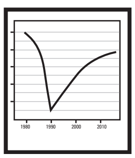
Reproduction
Mode—Aplacental viviparous. Internal fertilization [2].
Parturition season—September–January, probably peaks in late autumn [14, 18].
Fecundity—Litters as high as 20, averaging between 2–12 [9, 12, 14]. Number of pups increases as size of female increases [13].



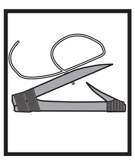
Food and Feeding
Food items—Fishes are a very important, particularly for larger individuals. However, squids, octopuses, medusae, ctenophores, crustaceans (for example, shrimps, euphausiids, and amphipods) and polychaetes also are often consumed [21–25].
Trophic level—4.3 (standard error 0.67) (based on trophic level of *S. acanthias)* [26].



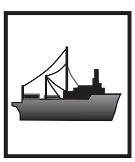
Biological Interactions
Predators—Various larger sharks (for example, Salmon Sharks, White Sharks, Pacific Sleeper Sharks), bald eagles, and marine mammals such as Steller sea lion, northern elephant seal, and sperm whale [21, 27–31].
Competitors—Likely various larger cods, flatfishes, and other macrocarnivores.



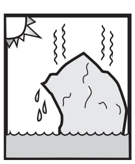
Resilience
Low, minimum population doubling time is more than 14 years (r_m=0.034; *K*=0.03–0.07; t_m=10–30; t_{max}=75; Fecundity=1) (based on resilience of *S. acanthias*) [26].



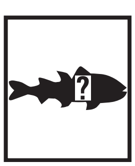
Traditional and Cultural Importance
None reported



Commercial Fisheries
Currently, Spiny Spotted Dogfish are not commercially fished.



Potential Effects of Climate Change
A wider distribution of this species in the Bering Sea occurred after 2000, possibly associated with recent climate change [10]. This species would be expected to move northwards into the Chukchi Sea as waters warm.



Areas for Future Research [B]
Little is known about the biology and ecology of this species from the region. If the species becomes more common, research needs include: (1) preferred depth ranges for juveniles and adults, (2) growth rates and size at maturation, (3) birthing season, (4) seasonal and ontogenetic movements, (5) population studies, (6) prey, and (7) predators.

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Arctic Skate (*Amblyraja hyperborea*)
(Collett, 1879)

Family Rajidae

Arctic Skate (*Amblyraja hyperborea*), continental slope off Barents Sea, 2011. Photograph by Arve Lynghammar, University of Tromsø, Norway.

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

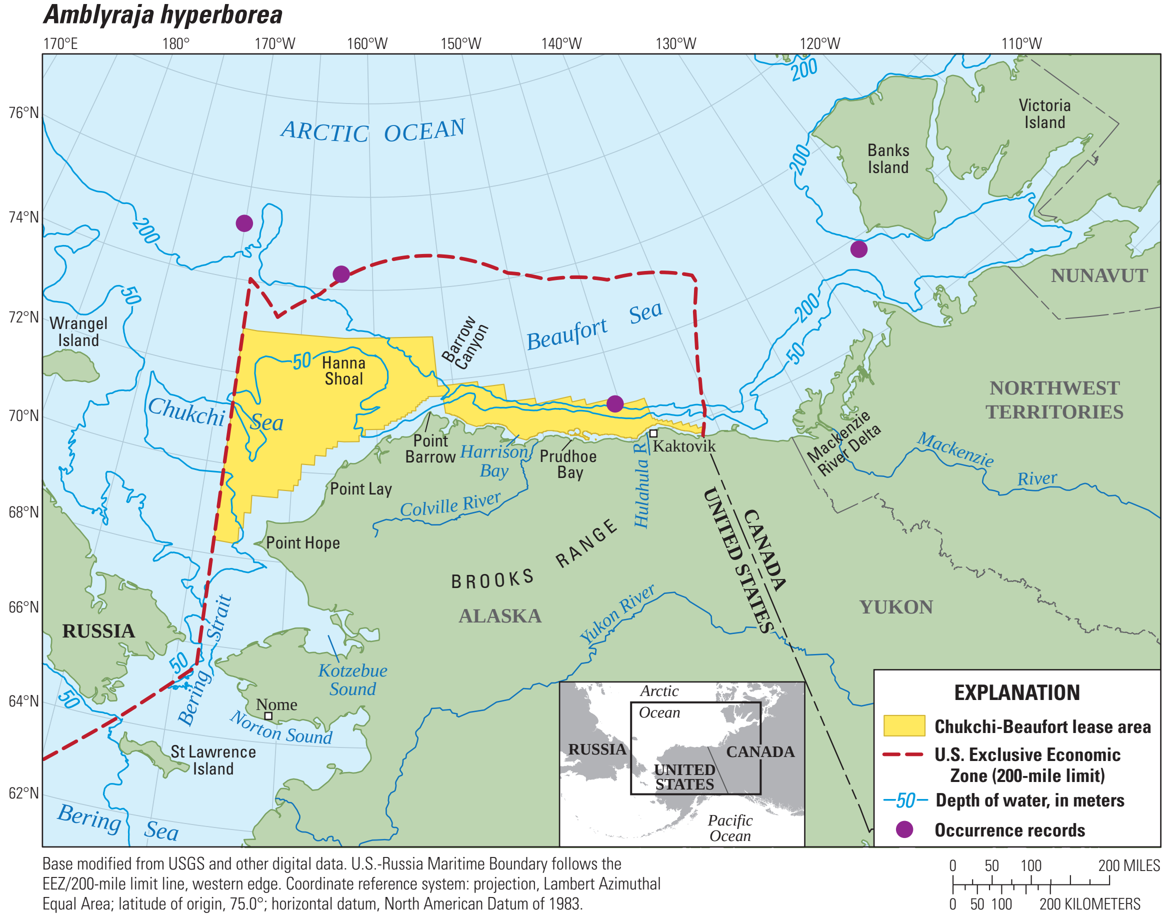
Colloquial Name: *None within U.S. Chukchi and Beaufort Seas.*

Ecological Role: Arctic Skate have only rarely been observed in deeper waters of the Alaska Beaufort Sea. Its role in benthic ecosystem dynamics, especially over shelf break and slope habitats is presently unknown.

Physical Description/Attributes: Brown or grayish brown, often with dark and light round spots. Body is flat, with wing-like pectoral fins, mouth on underside; has long rat-like tail with two small dorsal fins near the tip. For specific diagnostic characteristics, see Jensen (1948, p. 31–43) [1] and Stehmann and Bürkel (1984, p. 174) [2]. Swim bladder: Absent [3]. Antifreeze glycoproteins in blood serum: Unknown.

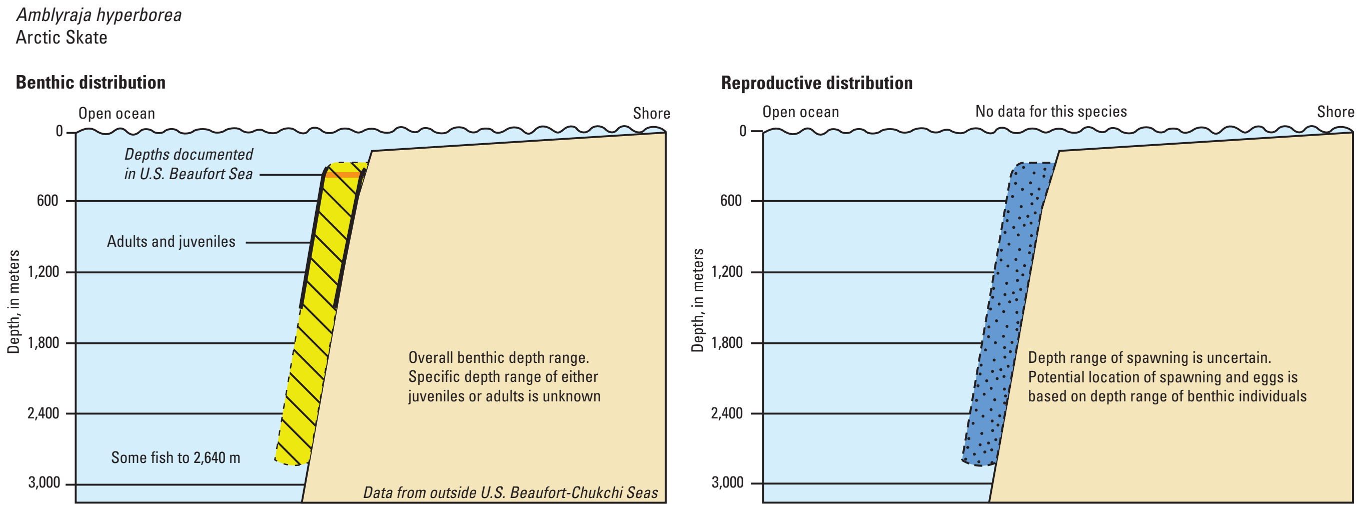
Range: *Continental slope off U.S. Beaufort Sea* [4]. Practically circumpolar; polar basins and south to western Canada, Davis Strait, Greenland, Iceland, Faroe-Shetland Ridge, Barents Sea and northern Norway [1, 4, 5].

Relative Abundance: *Absent from U.S. Beaufort Sea continental shelf, one record from the continental slope about 50 miles north-northeast of Brownlow Point at 70°51'N, 145°17'W; absent from Chukchi Sea* [4, 7]. Common off east and west Greenland, throughout the Norwegian Basin, and in Barents Sea [1, 5].

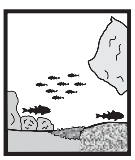


Geographic distribution of Arctic Skate (*Amblyraja hyperborea*) within Arctic Outer Continental Shelf Planning Areas [6] based on review of published literature and specimens from historical and recent collections [4, 7].

Depth Range: Typically between 300 and 1,500 m [2], with few records as shallow as 200 m [6] or as deep as 2,640 m [8]. *The one specimen from the slope off the U.S. Beaufort Sea was taken at a depth of 357 m* [7].

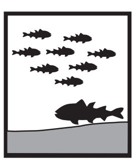


Benthic and reproductive distribution of Arctic Skate (*Amblyraja hyperborea*).



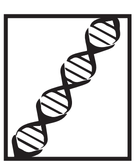
Habitats and Life History

Eggs—Female lays two egg cases, each with one egg [1]. Size: Egg cases measure 81–125 × 54–77 mm [2]. Time to hatching: Unknown. Habitat: Benthic [2].
Larvae—Eggs develop through larval stage to juvenile within the egg case [1]. Size at hatching: 15–16 cm [5]. Habitat: Benthic [2].
Juveniles—Age and size: Unknown. Habitat: Muddy bottoms [1].
Adults—Age and size at first maturity: Unknown. Maximum age: Unknown. Maximum size: 92 cm and 5.2 kg [5]. Habitat: Benthic, in deep water on the continental slopes and basins of the Arctic Ocean [1, 2, 4].
Substrate—Muddy bottoms [5].
Physical/chemical—Temperature: Mainly between -1.3 [1] and 1.5 °C [2], reported at 4 °C [7]. Salinity: Marine [3].



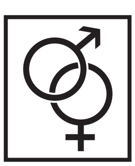
Behavior

Diel—Unknown.
Seasonal—Unknown.
Reproductive—Unknown.
Schooling: Unknown.
Feeding—Unknown.



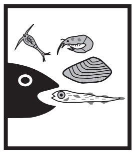
Populations or Stocks

There have been no studies.



Reproduction

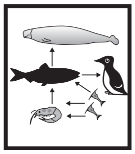
Mode—Oviparous [1, 2, 5, 9].
Spawning season—Unknown.
Fecundity—Less than 100 [10].



Food and Feeding

Food Items—Benthic and pelagic crustaceans such as shrimp, as well on fishes [1, 5].

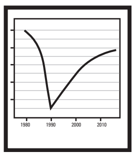
Trophic level—3.84 (standard error 0.58) [10]



Biological Interactions

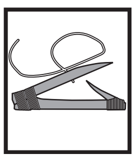
Predators—Unknown.

Competitors—Perhaps eelpouts and other benthic feeders.



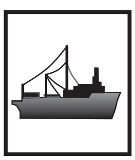
Resilience

Low, minimum population doubling time is 4.5–14 years (Fecundity assumed to be <100) [10].



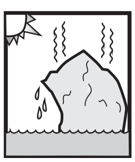
Traditional and Cultural Importance

None reported.



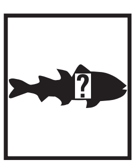
Commercial Fisheries

Currently, Arctic Skate are not commercially fished.



Potential Effects of Climate Change

Unknown.



Areas for Future Research [B]

Little is known about the ecology and life history of this species in the study area. In particular, research needs include: (1) preferred depth ranges for juveniles and adults, (2) growth rates and size at maturity, (3) spawning season, (4) seasonal and ontogenetic movements, (5) population studies, (6) prey, and (7) predators.

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Stehmann, M., and Bürkel, D.L., 1984, Rajidae, *in* Whitehead, P.J.P., and others, eds., Fishes of the North-eastern Atlantic and the Mediterranean: Paris, Unesco, p. 163–196. [2]

Wienerroither, R., Johannesen, E., Langøy, H., Børve Eriksen, K., de Lange Wenneck, T., Høines, Å., Bjelland, O., Aglen, A., Prokhorova, T., Murashko, P., Prozorkevich, D., Konstantin, Byrkjedal, I., Langhelle Drevetnyak, and G., Smirnov, O., 2011, Atlas of the Barents Sea fishes: IMR/PINRO Joint Report Series 1-2011, ISSN 1502-8828, 274 p. [5]

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Pacific Herring (*Clupea pallasii*)

Valenciennes, 1847

Family Clupeidae

Pacific Herring (*Clupea pallasii*) 217 mm TL, northeastern Chukchi Sea, 2007. Photograph by C.W. Mecklenburg, Point Stephens Research.

Colloquial Name: Iñupiat: *Uqsruqtuuq* [1].

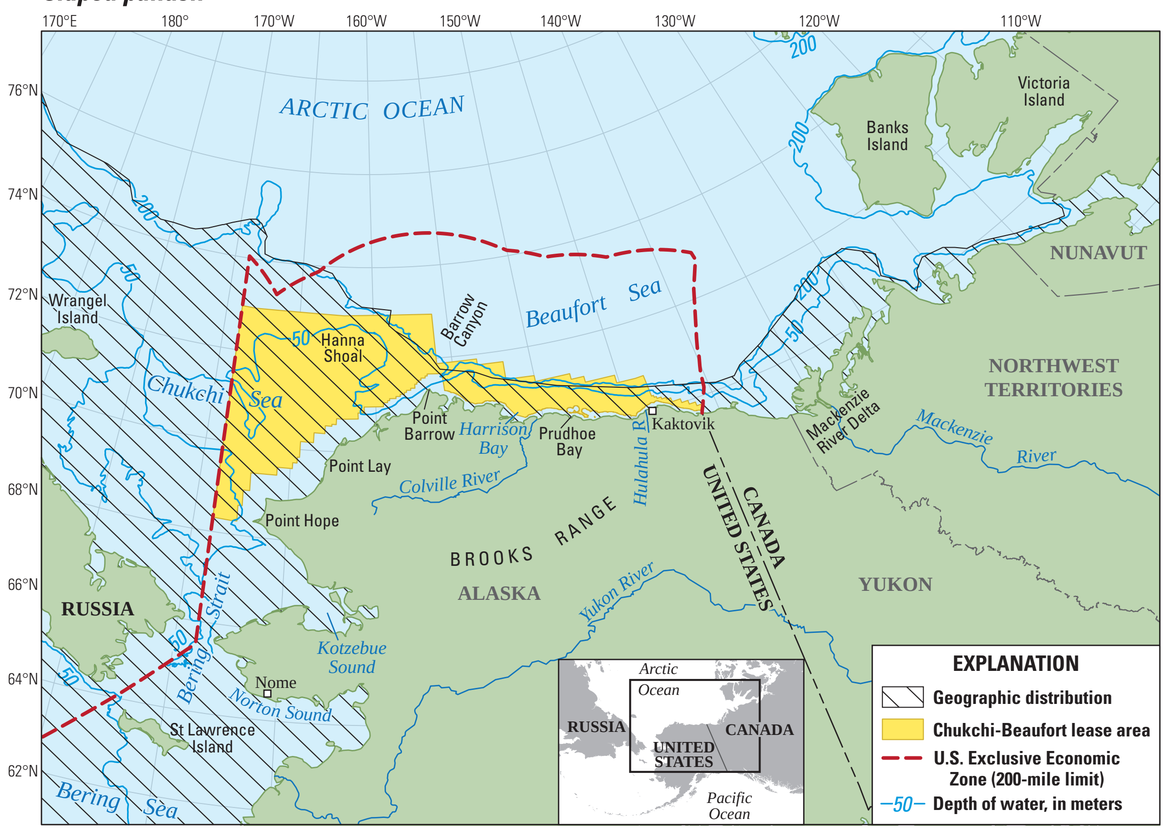
Ecological Role: Based on patterns of abundance, Pacific Herring likely are of considerable importance in the U.S. Chukchi Sea and of less importance in the U.S. Beaufort Sea.

Physical Description/Attributes: Moderately compressed body with metallic blue-green to olive back with silvery sides and belly. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 134) [2]. Swim bladder: Present [2]. Antifreeze glycoproteins in blood serum: Unknown.

Range: *U.S. Chukchi and Beaufort Seas* [3]. Elsewhere in Alaska, occurs in all marine waters. Worldwide, from Korea and Japan and the White Sea to Arctic Canada (as far north and east as Viscount Melville Sound and south and east to Bathurst Inlet [4]) and along the Pacific Coast south to northern Baja California [2].

Relative Abundance: *Common in southeastern and northeastern Chukchi Sea* [7, 8], *occasionally found along much of U.S. Beaufort Sea* [9–13]. Occasionally found in Canadian Beaufort Sea to Mackenzie River, common from Tuktoyaktuk Peninsula, Northwest Territories [14] to as far east as Darnley Bay in Amundsen Gulf [4].

Pacific Herring
Clupea pallasii

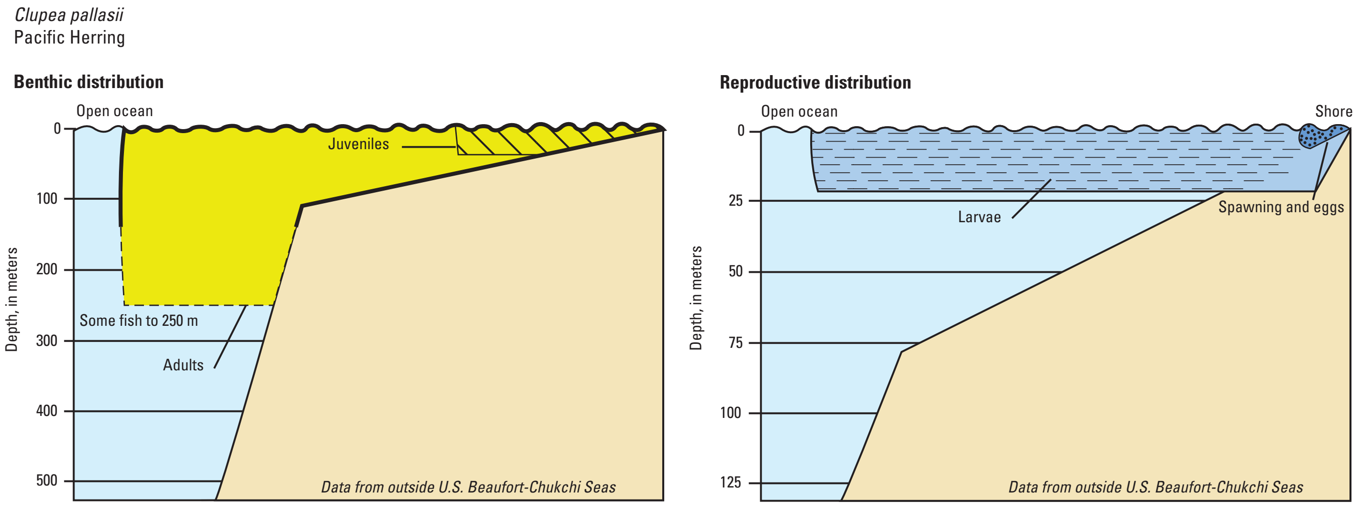


Base modified from USGS and other digital data. U.S.-Russia Maritime Boundary follows the EEZ/200-mile limit line, western edge. Coordinate reference system: projection, Lambert Azimuthal Equal Area; latitude of origin, 75.0°; horizontal datum, North American Datum of 1983.

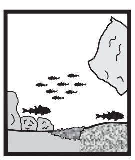
0 50 100 200 MILES
0 50 100 200 KILOMETERS

Geographic distribution within Arctic Outer Continental Shelf Planning Areas [5] of Pacific Herring (*Clupea pallasii*), based on review of published literature and specimens from historical and recent collections [3, 6].

Depth Range: Epipelagic, coastal and offshore, from surface to 250 m, typically 150 m or less. Juveniles usually remain in nearshore waters from barely subtidal to at least 30 m [15–17]. Spawning occurs intertidal to at least 10 m [18, 19]. Larvae in Canadian Beaufort Sea were most abundant at 20 m or less [20].



Benthic and reproductive distribution for Pacific Herring (*Clupea pallasii*).



Habitats and Life History

Eggs—Size: 1.2–1.8 mm when mature [21]. Time to hatching: 6–21 days [18, 22]. Habitat: Nearshore, on kelp, eelgrass, other plant material, and on rocks and other solid surfaces [23].

Larvae—Size at hatching: 5.6–7.5 mm SL [21]. Size at juvenile transformation: Metamorphosis starts at 26 mm TL and completes by 35 mm TL [24]. Days to juvenile transformation: About 2–3 months [24]. Habitat: Epipelagic, in ocean currents [24]. Most abundant near surface in estuarine-influenced waters [20, 25].

Juveniles—Age and size: 35–150 mm TL, depending on region [24]. Habitat: Epipelagic; often found among kelp and eelgrass, and over soft sea floors [15, 17].

Adults—Age and size at first maturity: With a few exceptions, depends on water temperatures. Fish mature earlier in warmer waters (and lower latitudes) [24, 26]; 2 years in California, 3–5 years in eastern Bering Sea [24, 27], and 6 years or older in Canadian Beaufort Sea [28]. Fish in California have shorter life spans and smaller maximum lengths than do those in the north [18]. 13–26 cm TL, depending on region [29]. Growth patterns are highly variable throughout the species' geographic range as groups of fish living even tens of kilometers apart can grow at significantly different rates [7, 22, 24]. Maximum age: As old as 19 years [14], but rarely more than 15 years [4, 30]. Maximum size: 46 cm TL [2]. Habitat: Epipelagic.

Substrate—Kelp, eelgrass, other plant material, rocks and other solid surfaces for spawning [23].

Physical/chemical—Temperature: -1.7 °C to at least 20 °C [31–33]. Salinity: Marine and brackish waters [24]. Occasionally enter rivers [28, 34]. Eggs can survive between 6.1–34.2 parts per thousand [35] and 8-hour exposures to air twice daily [36].

Behavior

Diel—At dawn and dusk, larvae, juveniles, and adults move toward the surface to feed [24].
Seasonal—Spawning, over-wintering, and migration patterns are highly variable. For example, within Tuktoyaktuk Harbor (Beaufort Sea) fish remain for most of the year, leaving the harbor only for a few months during the summer to feed. [28]. Of the 10 known wintering sites in the Tuktoyaktuk Peninsula region, 8 are in estuarine coastal habitats, 1 is in the lower Mackenzie River, and 1 in the marine waters of Tuktoyaktuk Harbour [37]. At the other extreme, in the eastern Bering Sea large schools of herring winter hundreds of kilometers offshore (at depths of 110–130 m) and move into nearshore waters in spring to prepare for summer spawning [27]. *Use of offshore waters as well as migrations within the U.S. Beaufort and Chukchi seas is unknown.* Elsewhere, there appears to be many migratory and non-migratory, as well as isolated and semi-isolated, populations throughout much of the species' range [24, 38, 39].
Reproductive—Spawning occurs nearshore in marine and brackish waters [18, 19]. During spawning, groups of males emit a pheromone-like substance that triggers egg laying [40]. Females lay adhesive eggs on kelp, eelgrass, and other plant material, as well as on rocks and other solid surfaces [23]. Eggs are usually deposited in layers of one or two eggs, but when spawning runs are heavy, egg deposits may reach 5 cm thick [18]. Off California, spawning occurs primarily at night, but has been observed during daylight hours and over all tidal stages [23]. Larger and older fish tend to spawn earliest and a female spawns all of her eggs in 1 or 2 days [24].
Schooling—Forms schools [24]. Depending on season and location, schools of adults may be found along the coast and out to 1,000 km or farther offshore [27]. Schools may remain quite cohesive for extended periods as individuals may associate with each other for more than 200 days while moving over 185 km (100 nautical miles) [41].
Feeding—Generally, feeding is less during winter [28, 42]. Larvae, juveniles, and adults are selective pelagic plankton feeders [24].

Populations or Stocks

Coastal sampling and aerial surveys have provided limited information about abundance. No detailed studies regarding populations or stocks have been conducted.

Reproduction

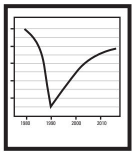
Mode—Gonochoristic, oviparous, and iteroparous with external fertilization [24].
Spawning season—June–September in the Canadian Beaufort Sea [14, 24, 25] where spawning begins in late spring and early summer around the time of ice break up when waters reach at least 2.5 °C [28, 31]. Spawning season is highly variable throughout its range, even among groups of fish in such relatively restricted areas such as Puget Sound [24]. Generally, spawning occurs earliest (often in the autumn) in the more southern part of the range.
Fecundity—Between 9,511 and 77,800 silver-gray eggs. Fecundity is highly variable and egg production at a particular body size is lower in high latitudes [26, 43].

Food and Feeding

Food items—*Primarily zooplankton, such as mysids, euphausiids, copepods, amphipods, cumaceans, polychaetes, crustacean larvae, fish larvae, plant material, foraminifera, small fishes (for example, Arctic Cod, Fourhorn Sculpin, and Pacific Sand Lance), and fish larvae* [8, 14, 30, 44–46].
Trophic level—3.5 [47].

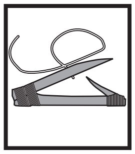
Biological Interactions

Predators—*Little is known. Beluga whales in spring near Barrow* [48, 49]. Elsewhere, all life stages, from eggs to adults, are heavily preyed upon by many species of fishes, seabirds, and marine mammals [16, 50].
Competitors—*Unknown, although likely to include various whitefishes, ciscoes, Capelin, Arctic Smelt, and Arctic Cod.*



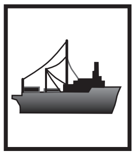
Resilience

Medium, minimum population doubling time: 1.4–4.4 years [51].



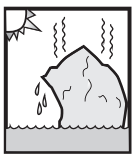
Traditional and Cultural Importance

Historically, Pacific Herring have been widely used as food as far north as the northeastern Bering Sea [52]. *Subsistence fisheries in most of the U.S. Chukchi and Beaufort Seas are modest, although some larger catches are made in the Chukchi Sea* [8, 45] and from the Mackenzie River eastward [4].



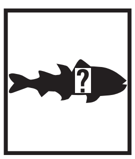
Commercial Fisheries

Currently, Pacific Herring are not commercially harvested. *The possibility of a fishery on the north side of the Seward Peninsula has been suggested*.



Potential Effects of Climate Change

Based on this species distributional pattern, increasing marine water temperatures will likely lead to increasing abundance in the U.S. Chukchi and Beaufort Seas. However, the introduction, transmission, and effects of novel pathogens and parasites associated with climate change elevates the risk of infection to Pacific Herring and its marine fish predators in the Chukchi Sea.



Areas for Future Research [A]

Pacific Herring are common in Port Clarence and Kotezebue Sound in the southeastern Chukchi Sea. Basic life history information and understanding of population dynamics are lacking. Improved knowledge about local patterns of abundance, timing and locations of reproduction, genetics, trophic linkages and energetic requirements, and movements and migrations are needed for stock assessments and information about their status and trends in time and space. Disease ecology research, including the periodic screening of Pacific Herring and its marine predators for the presence of infectious diseases, is recommended.

Remarks

Genetic analyses of Pacific and Atlantic Herrings imply that the ancestor of the Pacific Herring came across the Arctic from the Atlantic Ocean about 3 million years ago [53, 54].

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Pond Smelt (*Hypomesus olidus*)

(Pallas, 1814)

Family Osmeridae

Pond Smelt (*Hypomesus olidus*) 114 mm, northeastern Bering Sea, 2007. Photograph by C.W. Mecklenburg, Point Stephens Research.

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

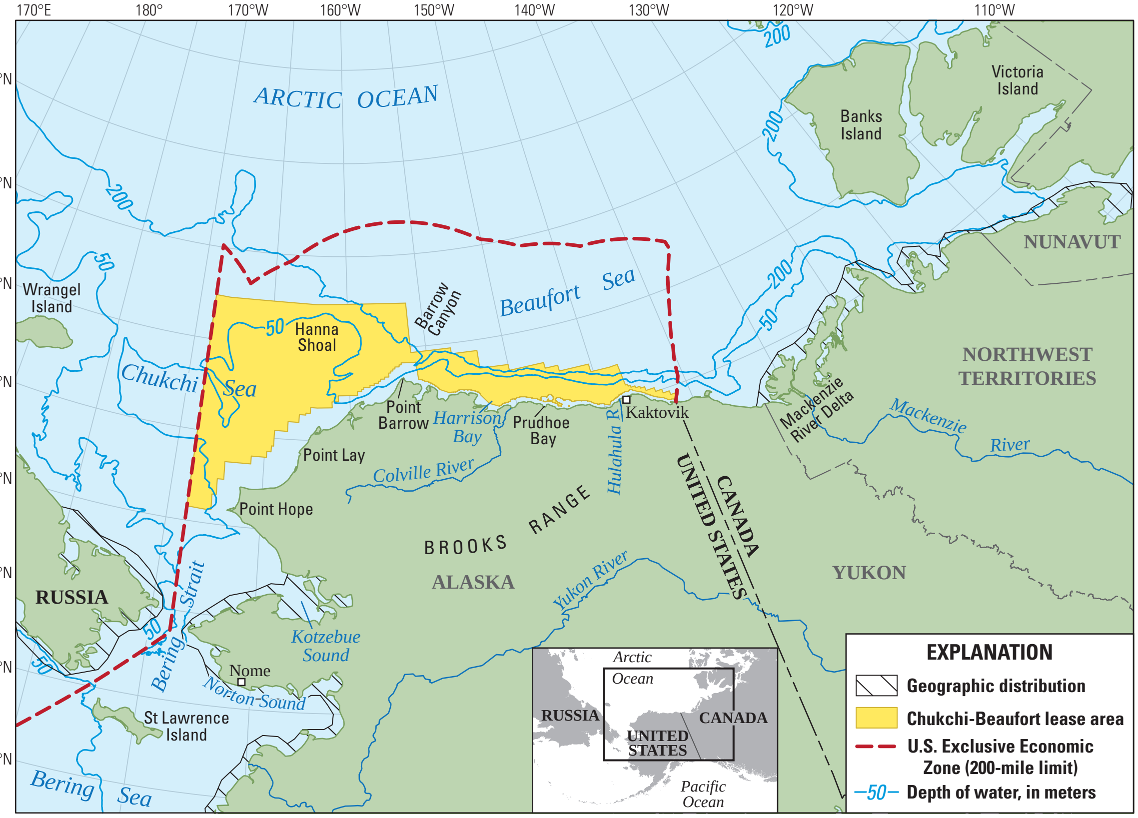
Colloquial Name: *None within U.S. Chukchi and Beaufort Seas.* Called “Cigarfish” around Nome and other areas of Norton Sound [1].

Ecological Role: The rare occurrence of Pond Smelt in brackish and marine waters of the U.S. Chukchi Sea implies a minor ecological role in other than freshwater habitats.

Physical Description/Attributes: Grey- or olive-green to yellow-brown dorsally becoming silvery white on belly. Snout and operculum are covered with black mottles or spots [2, 3]. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 172) [3]. Swim bladder: Present, physostomous [4]. Antifreeze glycoproteins in blood serum: Unknown.

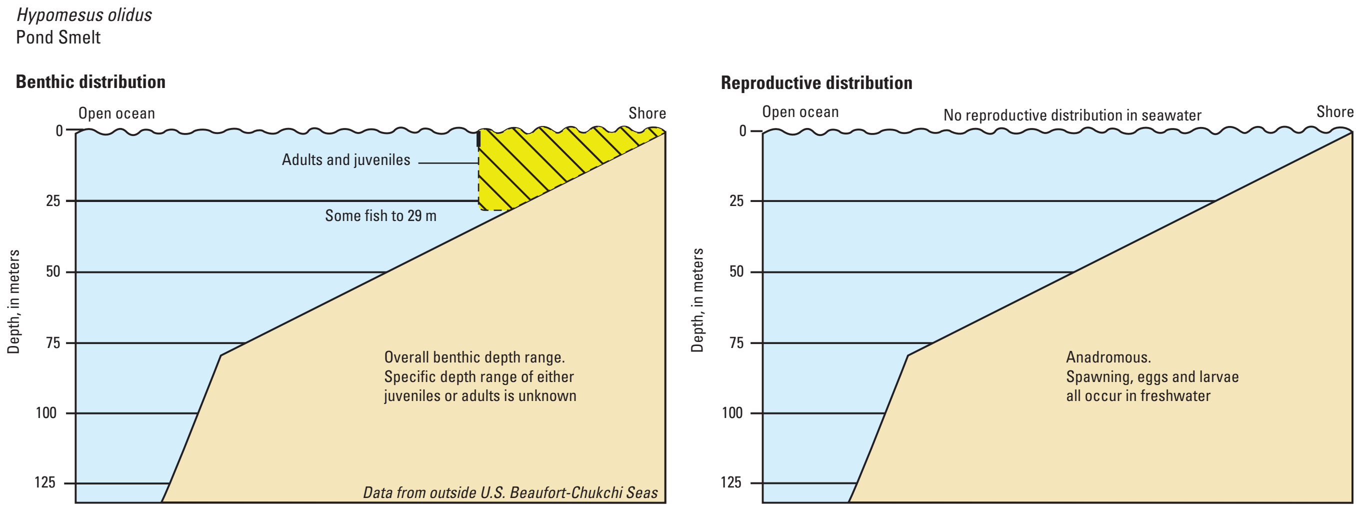
Range: *U.S. Chukchi Sea.* In Alaska, in drainages northwards from the Copper River, northeastern Gulf of Alaska, to the Kobuk River (draining into the Chukchi Sea). Worldwide, from North Korea and Japan to northern Siberia and east through drainages of Arctic Canada to Coronation Gulf, Northwest Territories, Canada [3].

Relative Abundance: *Absent or rare in coastal waters of the U.S. Chukchi and Beaufort Seas.* Elsewhere, common at least as far north as Port Clarence, northeastern Bering Sea [1], wherePond Smelt is occasionally found well offshore [6]. Common in fresh water and occasional in coastal, brackish conditions in Mackenzie Delta region [8–10].

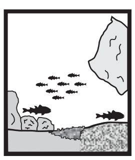


Geographic distribution of Pond Smelt (*Hypomesus olidus*) within Arctic Outer Continental Shelf Planning Areas [5] based on review of published literature and specimens from historical and recent collections [6, 7].

Depth Range: Nearshore, shallow waters, typically less than 5 m [1, 11]. Taken offshore of Cape Rodney and Sledge Island (northeastern Bering Sea) in 2007 by surface trawl fishing to depth of 29 m [6].

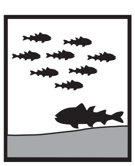


Benthic and reproductive distribution of Pond Smelt (*Hypomesus olidus*).



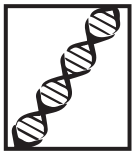
Habitats and Life History

Many populations are anadromous, although some stocks are landlocked [3].
Eggs—Size: 0.9 mm [12]. Time to hatching: 10–38 days at 5.0–15.0 °C [12, 13]. Habitat: Shallow depths of lakes and rivers, on submerged vegetation or rocks [12–14].
Larvae—Size at hatching: 4.6 mm long [12, 13]. Size at juvenile transformation: Unknown. Days to juvenile transformation: Unknown. Habitat: Pelagic, in freshwater rivers and lakes [12–15].
Juveniles—Age and size: As small as 24 mm FL [9, 12, 16]. Habitat: Pelagic in coastal marine and estuarine waters, and rivers and lakes [3]. Remain in their natal habitats 1 to 1 year before migrating to coastal waters [9, 12, 16].
Adults—Age and size at first maturity: 1–4 years for anadromous fish [2, 8, 12, 17–19]. In southwestern Bering Sea drainages, anadromous fish mature at age-3, whereas non-anadromous type matures at age-1 and age-2 [20]. Size is about 10.0 cm FL or more in Asia [2, 12–14]. In the Sea of Okhotsk, females are slightly larger at age than males [2]. Fish living in the Sea of Okhotsk grow faster than those in the Mackenzie Delta or a landlocked Yukon Lake population [2, 12–14]. Maximum age: About 6 years for anadromous fish in Asia, though few survive to that age [12, 20]. Maximum size: 20 cm TL [3]. Habitat: Pelagic, in coastal marine and estuarine waters, rivers and lakes [2, 3, 10, 12, 13, 17, 21].
Substrate—Taken over sand-gravel in Bristol Bay [22].
Physical/chemical—Temperature: As warm as 17 °C [20]. Salinity: Mainly freshwater, occasionally enters brackish river deltas and nearshore marine waters [3, 7].

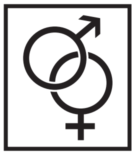


Behavior

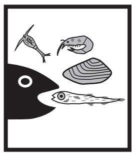
Diel—Unknown. Unidentified osmerid larvae in Auke Bay (southeastern Alaska) migrated to surface waters at midnight [23].
Seasonal—Large downstream migrations to Tuktoyaktuk Harbor occur August and September [9]. Migrations upstream may begin while the rivers are still under ice and be as long as 70 km (44 mi) [12].
Reproductive—Spawning occurs in rivers and lakes. Some populations in Asia ascend rivers from coastal waters in spring, just before spawning, whereas others migrate into fresh waters in autumn and overwinter prior to spawning [17]. Spawning takes place at dusk. Eggs are laid on submerged vegetation or rocks in shallow, swift-flowing, waters [12–14]. In many, but not all populations, fish die after spawning [10, 12, 17, 19]. Surviving fish migrate downstream shortly after spawning [12].
Schooling—Forms schools [13].
Feeding—Some populations do not feed during spawning season [20] although this is not a universal behavior [12].



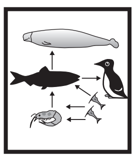
Populations or Stocks
There have been no studies.



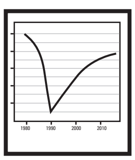
Reproduction
Mode—Oviparous [15].
Spawning season—Spawning in North America takes place at least during May–July [10, 19] and as early as April in Asia [13].
Fecundity—4,820–33,010 adhesive egg, spawned in a single batch (around Sakhalin Island, Russia) [12].



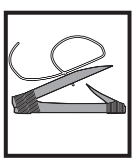
Food and Feeding
Food items—Primarily midwater crustaceans (for example, mysids, copepods, amphipods, and isopods), insects, snails, and small fishes [10, 18, 20, 24, 25].
Trophic level—3.21 (standard error 0.42) [11].



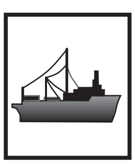
Biological Interactions
Predators—Beluga whales during May and June in Bristol Bay [26]. Inconnu and Northern Pike in North American Arctic fresh waters [10].
Competitors—Potentially midwater planktivores such as Arctic Cod, Pacific Herring, and Capelin, and other coastal fishes.



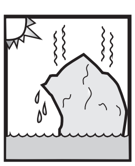
Resilience
Medium, minimum population doubling time: 1.4–4.4 years (t_m=2; t_{max}=5) [11].



Traditional and Cultural Importance
None reported.



Commercial Fisheries
Currently, Pond Smelt are not commercially harvested.



Potential Effects of Climate Change
Unclear. It is possible that warming Arctic waters will lead to increased abundance of this species as brackish habitats expand. However, it is unknown whether Arctic streams will become suitable spawning habitats for successful colonization.

Areas for Future Research [B]

Little is known about the ecology and life history of this species in the U.S. Chukchi and Beaufort Seas. Research needs include: (1) depth and location of pelagic larvae; (2) depth, location, and timing of young-of-the-year benthic recruitment; (3) preferred depth ranges for juveniles and adults; (4) spawning season; (5) seasonal and ontogenetic movements; (6) population studies; (7) prey; and (8) predators.

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Pacific Capelin (*Mallotus catervarius*)

(Pennant, 1784)

Family Osmeridae

Pacific Capelin (*Mallotus catervarius*) 84 mm TL, Semidi Islands, western Gulf of Alaska, 2001. Photograph by C.W. Mecklenburg, Point Stephens Research.

Note: *Until recently believed to be a junior synonym of* Mallotus villosus *(Müller, 1776). However, molecular genetic studies demonstrate a substantial genetic distance between this species and other Arctic mallotus spp. clades* [73].

Colloquial Name: Iñupiaq: *Panmagriq, Panmaksraq, Pagmaksraq* [1, 2].

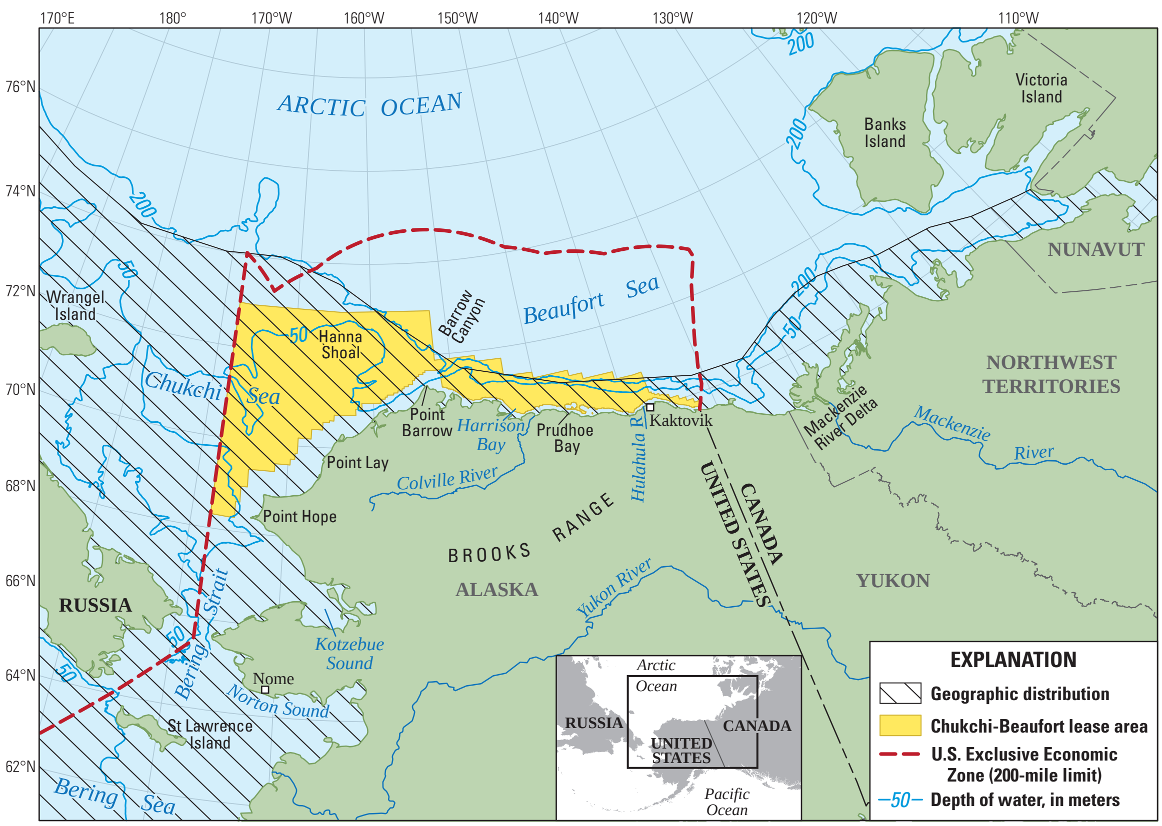
Ecological Role: The true abundance of Pacific Capelin is probably underestimated in existing survey data, but this species is hypothesized to be a major prey of many fish, birds, and marine mammals in the U.S. Chukchi and Beaufort Seas. Although its forage fish status is uncertain, its life history cycle suggests an important biological linkage between nearshore and offshore habitats especially in coastal waters influenced by large river deltas. It is a wide ranging, high lipid, cold-water fish that is an important part in Arctic and Subarctic food webs.

Physical Description: Elongate and narrow with a blueish, greenish, or yellowish back and silvery sides and belly. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 171) [3]. Swim bladder: Present [4]. Antifreeze glycoproteins in blood serum: Unknown, absent from *Mallotus villosus* in the Barents Sea [5].

Range: *U.S. Chukchi and Beaufort Seas* [3]. Elsewhere, Seas of Japan and Okhotsk, Commander and Aleutian Islands, Gulf of Alaska to Strait of Juan de Fuca eastwards to at least Davis Strait and southern end of Baffin Island, eastern Canada. Presence in Siberian Seas unclear [8].

Relative Abundance: *Common, patchily distributed, in U.S. Chukchi and Beaufort seas at least as far east as about Camden Bay* [9–14].

Pacific Capelin
Mallotus catervarius

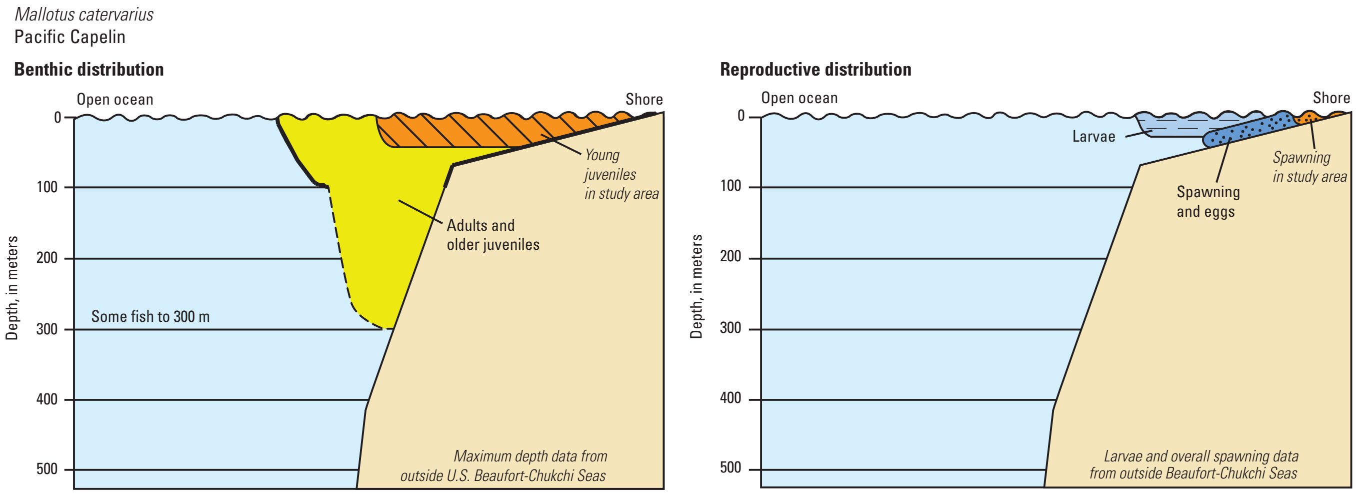


Base modified from USGS and other digital data. U.S.-Russia Maritime Boundary follows the EEZ/200-mile limit line, western edge. Coordinate reference system: projection, Lambert Azimuthal Equal Area; latitude of origin, 75.0°; horizontal datum, North American Datum of 1983.

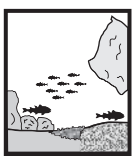
0 50 100 200 MILES
0 50 100 200 KILOMETERS

Geographic distribution of Pacific Capelin (*Mallotus catervarius*) within Arctic Outer Continental Shelf Planning Areas [7] based on review of published literature and specimens from historical and recent collections [3, 8].

Depth Distribution: Surface to 200 m [8]. *In western U.S. Beaufort Sea, common in intertidal and barely subtidal waters and to at least 8 m* [14]. In Prince William Sound and the Gulf of Alaska, most abundant in upper 100 m of water column [16]. Reports to 725 cm [17] are likely fish caught in trawls much nearer the surface. Larvae are found near the surface [18]. *Juveniles are reported in very shallow nearshore waters* [11, 14, 19]. Spawning occurs in very shallow waters barely subtidal waters [13, 20].



Benthic and reproductive distribution of Pacific Capelin (*Mallotus catervarius*).



Habitats and Life History

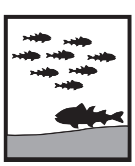
Eggs—Time to hatching: Unknown. Time to hatching: Unknown, but in *Mallotus villosus*, as much as 80 days at 2 °C, 30 days at 5 °C, and 15 days at 10 °C [22]. Size: Unknown. Once laid, eggs can survive as long as 6 hours at temperatures as low as -5 °C [25]. Habitat: *Spawning substrate has not been defined*. Demersal [26] or buried, usually in coarse sand and fine gravel [27, 28]. Occasionally in fine sand [26].

Larvae—Size at hatching: About 4 mm [31]. Size at juvenile transformation: 60 mm at start [31]. Larvae are found near the surface [18]. After hatching, some appear to remain in substrate for several days [33].

Juveniles—Age: Unknown. Size: 75.0–80.0 mm SL [31]. Habitat: *Poorly understood. Young-of-the-year live from very shallow nearshore waters out to at least 15 km from shore* [11, 14, 19].

Adults—Age and size at first maturity: *Little is known. At Point Lay, U.S. Chukchi Sea, almost all spawning fish were 2-year fish with a very small percentage of 3-year fish, and ranged in size from 110 to 155 mm FL* [9]. Bering Sea fish mature at 2 years [35]. Maximum age: In Canadian Beaufort Sea, at least 5 years [36]. Maximum size: *Fish in the U.S. Chukchi and Beaufort Seas do not appear to grow much larger than about 160 mm* [1, 9, 13, 36, 37]. Northern Pacific 21.8 cm [74]. Habitat: *Poorly understood. Older fish are taken in nearshore waters during the spawning season [11, 14, 19]. In a 3-year beach seine study conducted west of Barrow, Pacific Capelin were most abundant during the coldest-water year [14]. Their location in winter is unknown.* In Bering Sea, Pacific Capelin live as much as 560 km from shore, but only where the continental shelf is shallow and broad [35].

Physical/chemical—Temperature: Tolerate waters as cold as -2.0 to -1.8 °C and as warm as 14 °C for brief periods, but optimal temperatures are about -1.0–6.0 °C [16, 35, 38]. Salinity: Generally, marine and brackish waters, but may on occasion enter rivers [41].



Behavior

Capelin behavior is poorly understood in U.S. Chukchi and Beaufort Seas.

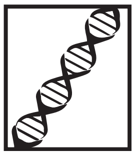
Diel—*Unknown.* Osmerid larvae in southeastern Alaska migrated to the surface at night [42].

Seasonal—*Unknown.* Some Capelin aggregations make extensive migrations to offshore feeding sites [35] where single sex schools are formed prior to migrating to spawning grounds [26].

Reproductive—*Poorly known.* Larger fish spawn earlier and males usually reach spawning grounds first [26]. Most spawning takes place in marine waters although some occurs in brackish conditions [26] and in very shallow, barely subtidal waters [13, 20]. However, there is some evidence that spawning in eastern Bering Sea and perhaps U.S. Chukchi and Beaufort Seas also may occur somewhat deeper [11, 46], although the maximum spawning depth is not known. In eastern Bering Sea and Gulf of Alaska, there is a tendency for spawning to occur or at least begin at night and around the highest tides. However, spawning can begin at any time of the day or night and has been known to continue over several days [26].

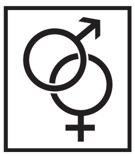
Schooling—*Capelin school in U.S. Chukchi and Beaufort Seas, but the extent of schools is unknown.* In the Gulf of Alaska, schools may be more than 1 km long and 20 m or more thick, and aggregations of schools may extend to 10 km [47].

Feeding—In the southeastern Bering Sea, Capelin feed most heavily in the afternoon and rarely at night [48]. Studies in the Chukchi and Barents Seas, North Atlantic Ocean, and off Kamchatka Peninsula, Russia, imply that fish feed heavily before and after the spawning season [9, 22, 49]. In the western Gulf of Alaska, fish to 126 mm were crepuscular feeders and fish in the Canadian Atlantic switch to diurnal feeding during winter [50].



Population or Stocks

Fish in U.S. Chukchi and Beaufort Seas may form a population that includes Bering Sea and western Pacific Ocean fish, but not fish from the Gulf of Alaska or Atlantic Ocean [51].

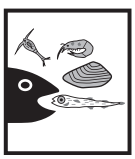


Reproduction

Mode—Separate sexes, oviparous. Fertilization is external.

Spawning season—*In the U.S. Chukchi and Beaufort Seas, spawning is primarily in July and August* [9, 19, 36, 52], *although some may take place in June* [53] *and early September* [54].

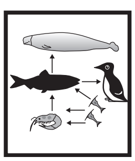
Fecundity—*Unknown.* Females release all of their eggs at one time and produce between 5,000 and 22,000 eggs [26]. Although not studied in the study area, in other locations most males die after the spawning season [26]. In some populations, substantial numbers of females may survive to spawn in the following year [56].



Food and Feeding

Food items—Food habits of larvae unknown. Capelin feed on midwater crustaceans, fish larvae, and other planktonic organisms. *Limited surveys in the Chukchi and Beaufort Seas have indicated that mysids are the most important prey, although calanoid and harpacticoid copepods, euphausiids, amphipods, crustacean larvae, and fish eggs and larvae also are consumed* [1, 9, 36].

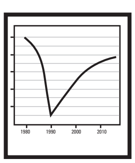
Trophic level—3.5 [60].



Biological Interactions

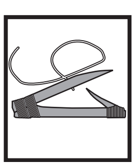
Predators—Besides the seabirds found at Capes Lisburne and Thompson, *Capelin are rarely reported in food habit studies in the U.S. Chukchi and Beaufort Seas. Ringed seals have eaten Capelin during the winter in the U.S. Chukchi Sea* [61]. In the Bering Sea, Gulf of Alaska, and eastern Canadian Arctic and northern Atlantic, this species is extremely important as food for a very wide range of marine mammals, seabirds, and fishes [63–67].

Competitors—Presumably a wide range of water-column, zooplankton feeders, including Arctic Cod and Walleye Pollock.



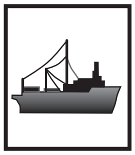
Resilience

Unknown for this species, but estimated for *Mallotus villosus* as medium, minimum population doubling time is 1.4–4.4 years (K=0.3–0.5; t_m=3; t_{max}=10; Fecundity=6,000) [68].



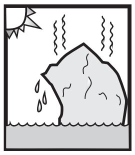
Traditional and Cultural Importance

Moderate importance in subsistence fisheries. Most fish are taken during spawning runs [2, 69–71].



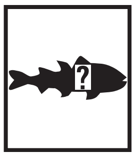
Commercial Fisheries

Currently, Pacific Capelin are not commercially harvested.



Potential Effects of Climate Change

Unclear for this species. However, *Mallotus villosus* have the capacity to respond quickly to climate change [for example, water temperature and food availability [72].



Areas for Future Research [A]

Although commonly sampled in coastal habitats, very little information exists on the life history of Pacific Capelin, particularly in U.S. Chukchi and Beaufort Seas. Because of this, many aspects of the biology of this species were inferred from other regions. It is a major forage species elsewhere in the Arctic and in other parts of Alaska. The phenology of the species in nearshore waters is brief and linked to reproduction and nursery. Early life history stages are likely swept offshore in wind-driven currents and thus the forage significance of the species in more poorly studied offshore habitats is not well documented. In particular, although it is clear that Pacific Capelin live and spawn (that is, beach versus ocean spawners) in this region, often in large numbers, there is a paucity of data on their basic biology, seasonality of their movements and behaviors, and locations of overwintering grounds. The basal metabolic and growth rates of Pacific Capelin living in the U.S. Chukchi and Beaufort Seas indicate adaptations to cold-water marine environments. The effects of warming temperatures on these physiological processes should be determined in laboratory experiments.

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Arctic Smelt (*Osmerus dentex*)

Steindachner & Kner, 1870

Family Osmeridae

Note on taxonomy: *Previously called* Osmerus mordax *in references by authors, as well as* O. eperlanus *and* O. mordax *dentex populations from the Pacific Arctic are now recognized from molecular genetics and morphological studies to be a distinct species*, O. dentex [1].

Arctic Smelt (*Osmerus dentex*), 273 mm, eastern Chukchi Sea, 2007. Photograph by C.W. Mecklenburg, Point Stephens Research.

Colloquial Name: Iñupiat: *Ithuagniq* [2]; *Ilhuagnig* [3, 4]. *Frequently called Rainbow Smelt and Boreal Smelt.*

Ecological Role: Likely of considerable importance as a prey species, at least in the Chukchi Sea.

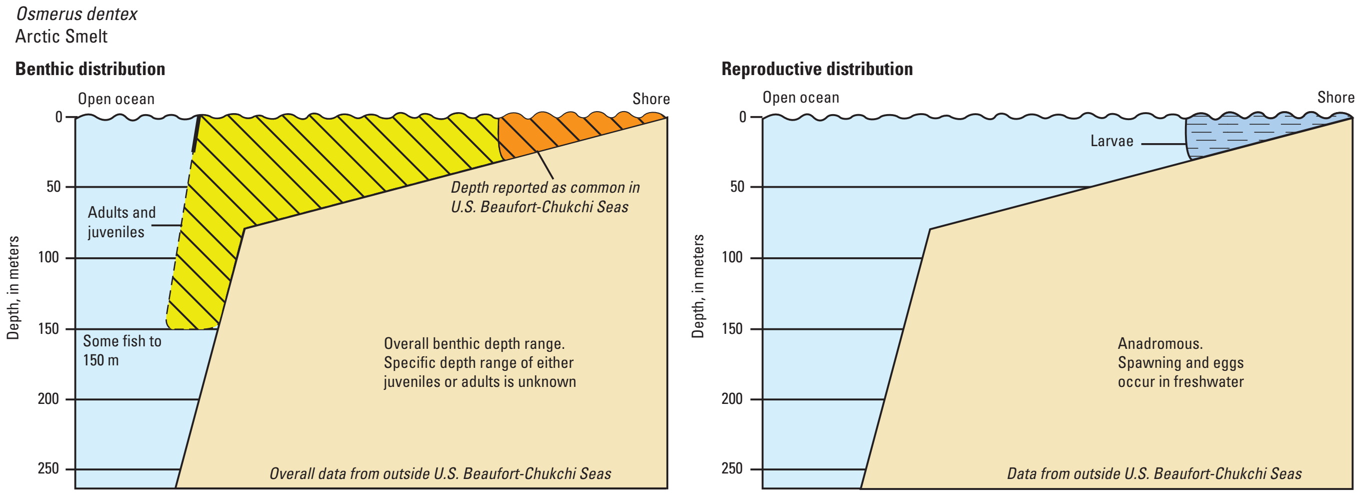
Physical Description/Attributes: Elongate, slender body with olive or pale green back, sometimes speckled with black, and a silvery belly. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 174, as *O. mordax*) [5]. Swim bladder: Present, physostomous [6]. Antifreeze glycoproteins in blood serum: Present [7].

Range: *U.S. Chukchi and Beaufort Seas.* Elsewhere, White and Barents Seas eastward to Bathurst Inlet, Nunavut, and southward to North Korea, Japan, Sea of Okhotsk, and Heceta Head, Oregon [1, 8].

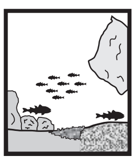
Relative Abundance: *Common along all coasts of U.S. Chukchi and Beaufort Seas* [11–14]. Common in Canadian Beaufort Sea as far east as Liverpool Bay [15–17].

Geographic distribution of Arctic Smelt (*Osmerus dentex*) within Arctic Outer Continental Shelf Planning Areas [9] based on review of published literature and specimens from historical and recent collections [1, 5, 10].

Depth Range: *Primarily in shallow, coastal waters of U.S. Chukchi and Beaufort Seas, common to a depth of about 25 m* [18]. In Bering Sea and northeastern Pacific Ocean, nearshore, surface to 150 m, occasionally deeper but deep records probably due to fish entering nets nearer the surface than at maximum depth of tow [19]. In late autumn, migrate to bottom depths of 90 m or more in southwestern Bering Sea [20].



Benthic and reproductive distribution of Arctic Smelt (*Osmerus dentex*).



Habitats and Life History

Anadromous [8].

Eggs—Size: *0.8–1.0 mm* [21, 22]. Time to hatching: *10–30 days depending on temperature* [23–26]. *Probably over 30 days on Alaskan North Slope in near-freezing waters* [2]. Habitat: Freshwater, on gravel, sand, or plants in shallow, swift flowing waters (to depths of a few meters). Adheres to substrate until hatching [20, 23, 25, 26].

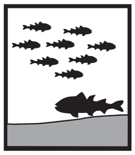
Larvae (fry)—Size at hatching: 5–8 mm SL [20, 27]. Size at juvenile transformation: Reported as post-larval at 14.7 mm TL [27]. Days to juvenile transformation: Unknown. Habitat: Pelagic in brackish to marine waters [5, 8]. Soon after hatching in freshwater, larvae are carried downriver and recruit to sheltered, shallow brackish and marine waters as small as 10–20 mm FL [15, 16, 28–30].

Juveniles—Age and size: A few months to 10 years [23–25, 31, 32]. Habitat: Pelagic in brackish to marine waters [5, 8]. *Nearshore estuaries, embayments and, at least in southeastern Chukchi Sea, coastal waters* [18].

Adults—Age and size at first maturity: Highly variable and ranges from 1 to 10 years or more [23–25, 31, 32]. *Averages between 5–7 years and perhaps 20.0–22.5 cm FL* [12, 26, 28, 33, 34]. *Growth rates vary between areas. Length-weight relationships also vary with location and perhaps with year. Larger males may be heavier at length than females* [16, 18]. Maximum age: At least 18 years in Arctic and subarctic waters [33], *however, rarely longer than 15 years* [22, 26, 30]. Fish in more temperate waters (specifically, southwestern Bering Sea and off Sakhalin Island, Russia) have much shorter life spans, rarely exceeding 6–9 years [20, 24, 25, 34]. Maximum size: 31.0 cm FL [8]. Habitat: Pelagic in brackish to marine waters [5, 8]. *Nearshore estuaries, embayments and, at least in southeastern Chukchi Sea, coastal waters* [18].

Substrate—Taken over sand-gravel in Bristol Bay [35].

Physical/chemical—Temperature: *2.0–13.5 °C. Tolerant of a very wide range* [22]. Salinity: *Tolerates brackish conditions, but typically 22 parts per thousand or greater and will avoid nearshore waters of lower salinities* [26]. Although most fish enter fresh water only to spawn, landlocked populations are known [36].



Behavior

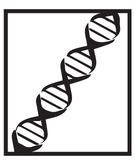
Diel—Enters rivers and spawns at night at least in Asia and eastern North America, [24, 25].

Seasonal—*Schools of juveniles and adults inhabit nearshore waters during summer* [20, 22, 29], *although significant numbers feed as far as 10 km (6 mi) offshore* [37]. Other than for spawning, fish in northeastern North America do not make extensive migrations [24], although those in southwestern Bering Sea do move offshore in early winter [20]. *In U.S. Beaufort and Chukchi Seas, juveniles and adults overwinter under ice in brackish river deltas and coastal waters*, whereas fish in southwestern Bering Sea retreat offshore to 90–100 m depths during early winter, returning to coastal waters in January and February [20]. *Many river mouths along U.S. Chukchi and Beaufort Seas harbor overwintering populations* [30, 32, 38–41]. Larvae and perhaps fertilized eggs are carried into marine waters during spring and early summer [23, 28, 30]

Reproductive—*Fish gather near spawning grounds as winter progresses* [34]. Spawning takes place in spring, just prior to ice break-up [28, 30, 32]. *Spawning takes place in many rivers entering U.S. Chukchi and Beaufort Seas* [33, 34, 42] and in at least one lake (Lake Tasiqpaatchiaq, Alaska) [37]. *Most spawning seems to occur in lowermost but still freshwater parts of rivers, often very near the mouth* [23, 26]. However, fish in some Russian waters (for example, Yenisei River, Siberia) may travel upstream more than 1,000 km (621 mi) to spawning grounds [43] and some have been taken well upstream on the Mackenzie River in the Arctic Red River area, though it is not clear that spawning had occurred there [44]. Occasionally spawns in estuaries and possibly coastal marine waters [17, 27, 43]. Sticky and stalked eggs are shed over gravel, sand, or plants in shallow, swift flowing waters (to depths of a few meters) and adhere to the substrate until hatching [20, 23, 25, 26]. In Asia, adults often leave fresh waters within a few hours of spawning, although some remain in spawning area for several weeks [20]. *At least some spawn more than once in their lifetimes* [26].

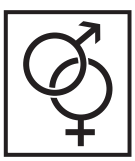
Schooling—*Schooling, water column fish* [18].

Feeding—*Midwater and, to a certain extent, benthic feeders. Feeding is most intense in summer, declines as winter progresses, and almost ceases during spring spawning* [20, 22, 26, 33, 34].



Populations or Stocks

There have been no studies. Some life history parameters for Arctic Smelt in Simpson Lagoon, Alaska, were estimated [34].



Reproduction

Mode—Oviparous [8].

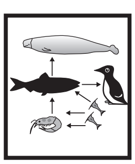
Spawning season—*March–July, peaking in May–June in the U.S. Chukchi and Beaufort Sea drainages* [12, 22, 29, 34, 45]. May–July in Bering Sea and Asia [20, 25, 46].

Fecundity—1,700–207,900 eggs. Females lay eggs in small batches [24, 25].

Food and Feeding

Food items—*Small fishes (for example, Arctic Cod, Fourhorn Sculpin, Arctic Cisco, Arctic Smelt, and eelpouts) and small crustaceans (for example, mysids, amphipods, isopods, and copepods) but occasionally snails, plant material, oligochaetes, penaeid shrimps, fish larvae, and insects* [12, 16, 29, 34, 42]. Very young fish eat zooplankton and insects [33].

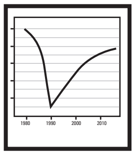
Trophic level—4.2 (standard error 0.73) [47].



Biological Interactions

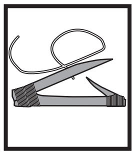
Predators—Dolly Varden and other Arctic Smelt in Canadian Beaufort Sea [16, 30]. *May be a major food for Beluga Whales between May and July in U.S. Chukchi Sea, at least in Wainwright area*, and in eastern Bering Sea [48]. *Extensively preyed upon by spotted seals in summer near Point Lay* [26] *and in April in eastern Chukchi Sea by ringed seals* [49]. In eastern Bering Sea, other predators include harbor seals, Fin and Sei Whales [50, 51].

Competitors—Other water column piscivores and zooplanktivores such as Arctic Cod and Dolly Varden.



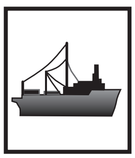
Resilience

Medium, minimum population doubling time: 1.4–4.4 years (t_m=2–3; t_{max}=7; Fecundity=1,700) [47].



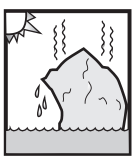
Traditional and Cultural Importance

For many years, Arctic Smelt have been of great importance to the subsistence fisheries in the Wainwright, Alaska, area [52], *where during winter and spring fishermen catch large numbers by jigging through the ice as these highly valued fish aggregate in the lower Kak River* [2, 53]. *Arctic Smelt are believed to be one of the few resources in the Wainwright area that were regularly sold* [53]. *During the autumn and winter of 1937, hunting was particularly poor around Wainwright and Arctic Smelt saved the local peoples from starvation* [26]. *Fish caught in November are perceived to taste saltier and are less valued than those taken later in the winter* [26]. *Elsewhere in U.S. Chukchi and Beaufort Seas, occasionally taken as bycatch in other subsistence fisheries* [53–55]. Also taken in some numbers in eastern Bering Sea [11] and off Russia [23].



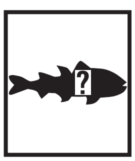
Commercial Fisheries

Currently, Arctic Smelt are not commercially harvested.



Potential Effects of Climate Change

Arctic Smelt reproduce in both Arctic and Boreal waters [1], which makes it difficult to predict how their distribution might be affected by climate warming. Like other Arctic marine fish species, they are adapted to life in cold waters and changes in temperature could affect physiological functions such as growth and metabolism.



Areas for Future Research [A]

Little offshore research has been conducted in the Arctic and their abundance in offshore waters is unknown [26, 32], although likely to be negligible since Arctic Smelt are primarily a shallow-water coastal species. Basic life history information is limited and little is known about the larval and juvenile ecology of this species. Overwintering areas have not been described and no population studies have been conducted. Bioenergetic relationships, including consumption rates by high trophic level organisms need to be described as this species is believed to be of major forage importance in certain locales, such as coastally in the southeastern Chukchi Sea and near the Colville River Delta.

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