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Chapter 3d 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

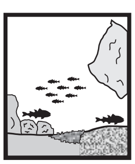
Relative abundance refers to the contribution a species makes to the total abundance of the fishery community. It is a measure that provides an index of the number of individuals present, but not the actual numbers. Relative abundance terms, such as “common,” “uncommon,” or “rare” often are used to express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

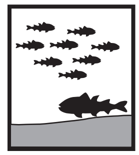
Benthic distribution refers to the spatial arrangement of a particular species at different depths over continental shelf and slope waters. The life cycle of fishes occurs in multiple dimensions in time and space and generally reflects genetically determined life history or behavior that has evolved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



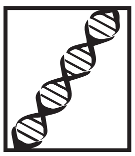
Behavior (see also Glossary [chapter 7]).—Behavior is the manner in which a fish operates or functions within its environment (that is, home range, territoriality, and many others) to procure food, orient to specific locations, or relate to other organisms. Knowing how individuals respond to the environment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

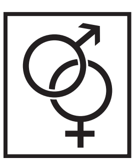
Schooling (that is, social structure of fish of the same species moving in more or less harmonious patterns in the sea) often is related to survival and reproduction. Schooling confers physical benefits to fish movement, safety against predators, search behaviors (for example, foods), population immunology,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

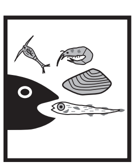
- Trophic level 1 (T1), plants and animals make their own food and are called primary producers;
- Trophic level 2 (T2), herbivores eat plants and are called primary consumers;
- Trophic level 3 (T3), carnivores eat herbivores and are called secondary consumers;
- Trophic level 4 (T4), carnivores eat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



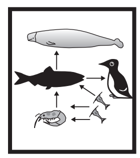
Populations or Stocks—A population often is defined as a group of organisms of the same species occupying a particular space at a particular time with the potential to breed with each other (Williams and others, 2002). Stocks are subpopulations of a particular species of fish that result from reproductive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



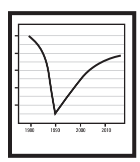
Reproduction Mode—Little information is available about the spawning times and locations, mating behaviors (breeders or nonbreeders), and genetic diversity of Arctic marine fishes. What is known is drawn largely from observations from populations studied outside the United States. For most Arctic marine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

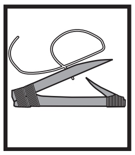


Resilience—In ecology, resilience traditionally refers to the ability of a population or biotic community to sustain or return to its former state after a disturbance. The rate of recovery is a measure of resilience determined by the population processes involved in restoring abundance to healthy, sustainable,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

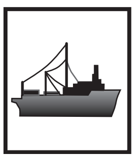
Traditional, Cultural, and Economic Values

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.



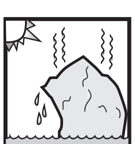
Traditional and Cultural Importance.—Several species of nearshore marine fishes are important in subsistence fisheries. The protection of traditional lifestyles and economies, including these subsistence fisheries, is a responsibility of the Federal government. Subsistence relates to resource use patterns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

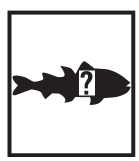
Alaska's climate is changing at more than twice the rate of the rest of the United States (Mellilo and others, 2014). Year-to-year and regional variability in air temperatures are evident and the warming trend currently is being moderated by large-scale cooling associated with the Pacific Decadal Oscillation.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

Whitespotted Greenling (*Hexagrammos stelleri*)

Tilesius, 1810

Family Hexagrammidae

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

Ecological Role: Likely of limited abundance and little ecological importance in the U.S. Chukchi and Beaufort Seas.

Physical Description/Attributes: Brown to green tinged with orange and yellow. Body and head usually have small white spots and anal fin is yellow often with brown bars. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 392) [1]. Swim bladder: Absent [1]. Antifreeze glycoproteins in blood serum: Unknown.

Whitespotted Greenling (*Hexagrammos stelleri*) 32 cm TL, southern Kuril Islands, 2003. Photograph by B.A. Sheiko, Russian Academy of Sciences.

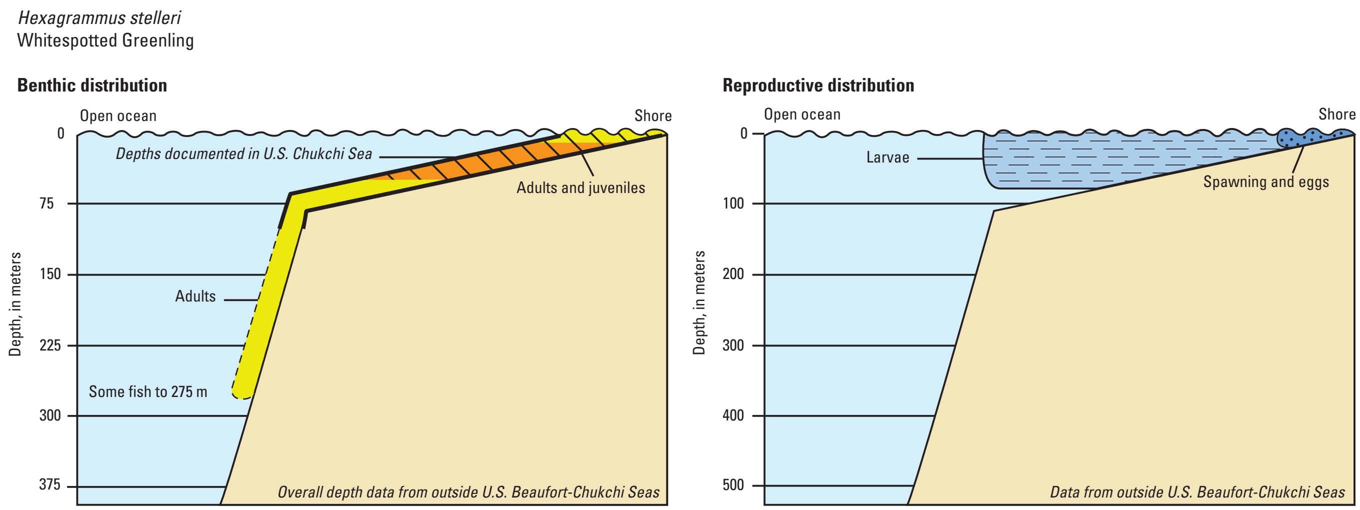
Range: *U.S. Chukchi Sea and Beaufort Seas, reported eastward to Simpson Cove (about 70°N, 145°W)* [1–4]. Northern Sea of Japan, Hokkaido Island to Commander-Aleutian chain and northeast to Simpson Cove, Beaufort Sea, and Bering Sea to Puget Sound, Washington [4].

Relative Abundance: *Uncommon in U.S. Chukchi Sea and western Beaufort Sea* [1–4, 6, 7]. Abundant from Sea of Japan [8] to eastern Bering Sea [9] and the Gulf of Alaska [10, 11].

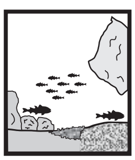
Whitespotted Greenling
Hexagrammos stelleri

Geographic distribution of Whitespotted Greenling (*Hexagrammos stelleri*), within Arctic Outer Continental Shelf Planning Areas [5] based on review of published literature and specimens from historical and recent collections [2, 4].

Depth Range: In northern waters, intertidal to 175 m, usually less than 100 m [1]; down to 275 m in Sea of Japan [2]. Juveniles, very shallow waters to 50 m [12–14]. *Documented from 14–50 m in U.S. Chukchi Sea* [3, 6]. Spawning occurs in shallow waters to at least 8 m [15]. In Gulf of Alaska, larvae are abundant in surface waters [16].



Benthic and reproductive distribution of Whitespotted Greenling (*Hexagrammos stelleri*).



Habitats and Life History

Eggs—Size: 1.6–1.9 mm [17]; colored green, blue, violet, or grey [15]. Time to hatching: 30 days [14, 18]. Habitat: Demersal, nearshore [15].

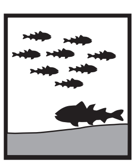
Larvae—Size at hatching: 7.0–9.0 mm SL [11, 19]. Size at juvenile transformation: 30–40 mm FL [14, 19]. Days to juvenile transformation: About 1 year [14]. Habitat: Pelagic, near surface [16, 20].

Juveniles—Age and size: 3–15 cm FL [9, 19]. Habitat: Demersal, nearshore, among rocks, often in heavy algae and eelgrass cover [1, 14, 20–22].

Adults—Age and size at first maturity: A few mature at age–1 (15.0 cm FL) and most at age–2 (17.0–20.0 cm FL) [9, 12, 17]. Maximum age: At least 6 years, probably more [17]. Maximum size: About 48 cm TL [1], and 1.6 kg [23]. Habitat: Demersal, on continental shelf among complex substrates and, occasionally, soft bottoms, often in heavy algae and eelgrass cover [1, 14, 20–22, 24, 25].

Substrate—Sand, silt, gravel, cobble, shell hash [3, 26, 27].

Physical/chemical—Temperature: –1.5–11.7 °C in southeastern Bering Sea, (mainly 4–7.2 °C) [28]. Salinity: Marine and estuarine [14, 24].



Behavior

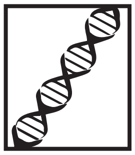
Diel—Substrate-oriented; remains within 1.5 m of sea floor, occasionally rising to 5–6 m in midwaters [29]. Strictly diurnal (Sea of Okhotsk) [29] and active, moving into shallow waters to feed at night (eastern Bering Sea) [9]. More agonistic toward each other than toward other species [29].

Seasonal—From late spring to autumn, pelagic larvae transform to juveniles and recruit to sea floor [12–14]. Mature fish winter in deeper waters of continental shelf and return to nearshore in the summer, whereas juveniles remain nearshore year-round [12, 14].

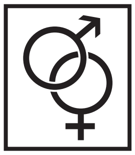
Reproductive—Spawning occurs in shallow waters [15]. Females lay adhesive eggs on algae and highly territorial males guard them until they hatch. Males may guard as many as 7 egg masses (1,200–5,200 eggs each) from multiples females [14, 15].

Schooling—Usually solitary though small schools of as much as 1 dozen individuals have been observed [29].

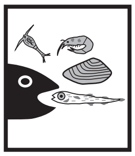
Feeding—Both juveniles and adults move into shallow, often intertidal waters, to feed [9]. Often roots around in substrate for prey [29].



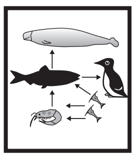
Populations or Stocks
There have been no studies.



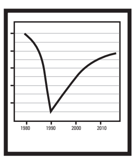
Reproduction
Mode—Partial (heterochronal) spawners.
Spawning season—Spawning occurs from autumn through spring in Puget Sound [15, 30] and from June to October in the Gulf of Alaska, Bering Sea, and off Asia [17, 31–33].
Fecundity—1,070–12,397, in batches [15, 17, 19].



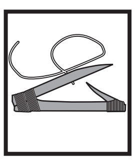
Food and Feeding
Food items—A very diverse array of benthic and midwater prey in Bering Sea and Gulf of Alaska. Pelagic larvae: Such zooplankters as copepods, amphipods, ostracods, crab larvae, and euphausiids. Benthic juveniles and adults: Crustaceans (for example, gammarid and caprillid amphipods, calanoid and harpacticoid copepods, shrimps, crabs, and barnacles), snails, bivalves and bivalve siphons, polychaetes, fish eggs, and fishes [20, 26, 34–36].
Trophic level—3.33 (standard error 0.41) [37].



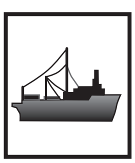
Biological Interactions
Predators—Arctic Terns, horned and tufted puffins, and river and sea otters in Gulf of Alaska and eastern Bering Sea [38–41]. Predation by seals is likely in the Chukchi Sea.
Competitors—Likely other benthic feeders such as flounders, sculpins, and eelpouts.



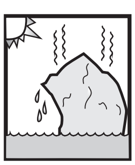
Resilience
Medium, minimum population doubling time 1.4–4.4 years (Fecundity=6,679–38,408) [37].



Traditional and Cultural Importance
None reported. Elsewhere, Whitespotted Greenling was an important food fish for Alaska Natives living in the Gulf of Alaska, Aleutian Islands, and eastern Bering Sea [42, 43].



Commercial Fisheries
Currently, Whitespotted Greenlings are not commercially harvested. There is a commercial fishery for this species in the northern Sea of Okhotsk [44].



Potential Effects of Climate Change
As with other predominantly boreal Pacific fish species, Whitespotted Greenling are expected to expand their range in Arctic waters as the climate warms.

Areas for Future Research [B]

Little is known about the ecology and life history of this species. Research needs for this species in the study area 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. The vulnerability of Whitespotted Greenling to climate change should be assessed. It is a suitable indicator of changes in the nearshore marine and, if incorporated into a regional monitoring design, key population parameters should be studied.

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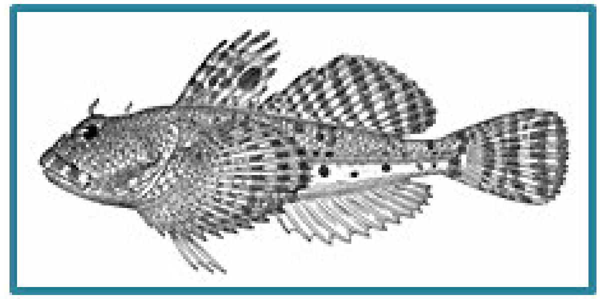
Okhotsk Hookear Sculpin (*Artediellus ochotensis*)

Gilbert & Burke, 1912

Family Cottidae



Okhotsk Hookear Sculpin (*Artediellus ochotensis*). From Mecklenburg and others (2002, p. 494) citing others; drawing of fish from off western Kamchatka Peninsula, Russia.

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

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

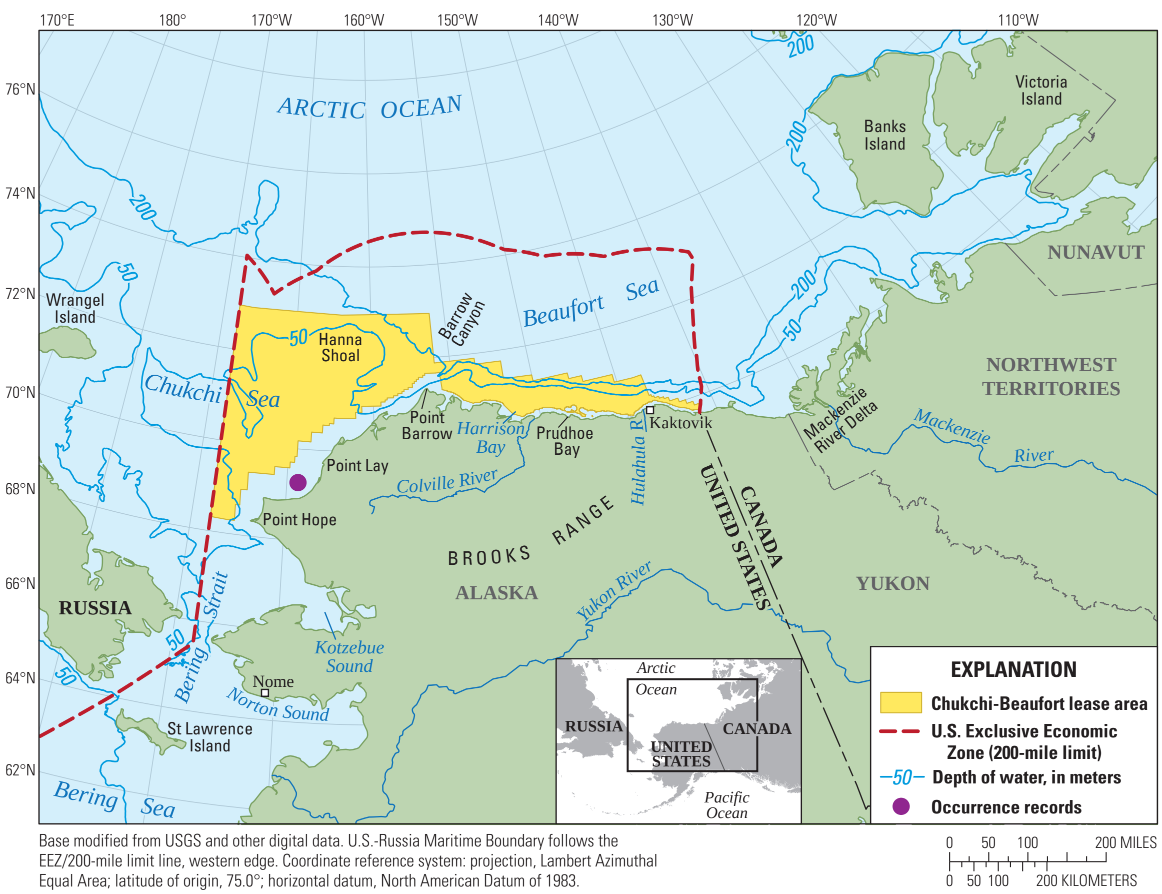
Ecological Role: Largely unknown. However, Okhotsk Hookear Sculpin are unlikely to represent a significant prey resource to higher-level organisms.

Physical Description/Attributes: Head and upper body light reddish brown, light reddish spots on body and small reddish brown blotches on first dorsal fin. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 494) [1]. Swim bladder: Absent [1]. Antifreeze glycoproteins in blood serum: Unknown.

Range: *U.S. Chukchi Sea north of Lisburne Peninsula (one record only)* [2]. Worldwide, Japan Sea at Peter the Great Bay to Okhotsk Sea, Kuril Islands, and Commander Islands, to Gulf of Anadyr, Russia, western Bering Sea [2].

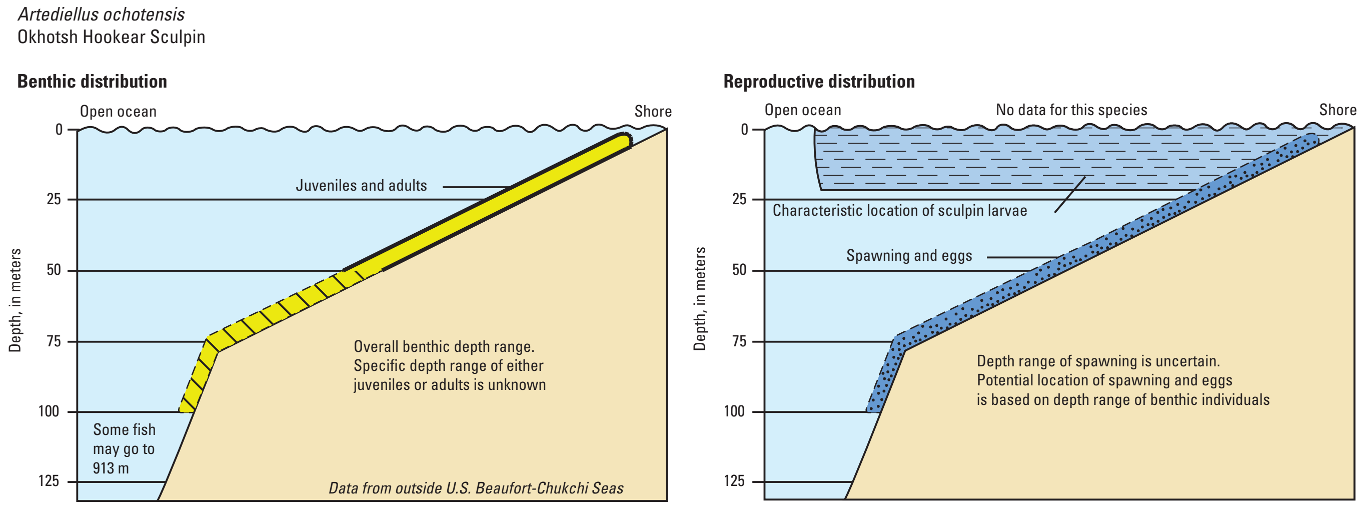
Relative Abundance: *Rare in U.S. Chukchi Sea* [2]. Elsewhere, occasional in Sea of Okhotsk. [5] and rare in Sea of Japan [6].

Okhotsk Hookear Sculpin
Artediellus ochotensis

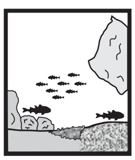


Geographic distribution of Okhotsk Hookear Sculpin (*Artediellus ochotensis*), within Arctic Outer Continental Shelf Planning Areas [3] based on review of published literature and specimens from historical and recent collections [2, 4].

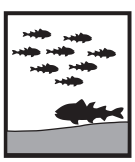
Depth Range: Benthic, at least 4–100 m [1] and perhaps to 913 m [5]. Typically less than 50 m [1].



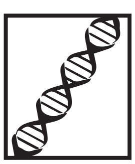
Benthic distribution and reproductive distribution of Okhotsh Hookear Sculpin (*Artediellus ochotensis*).



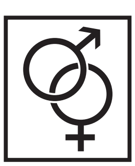
Habitats and Life History
Eggs—Size: Unknown. Time to hatching: Unknown. Habitat: Likely benthic [1].
Larvae—Size at hatching: Unknown. Size at juvenile transformation: Unknown. Days to juvenile transformation: Unknown. Habitat: Pelagic [1].
Juveniles—Age and size: Unknown. Habitat: Benthic [1].
Adults—Age and size at first maturity: Unknown. Maximum age: Unknown. Maximum size: 10.2 cm TL [1]. Habitat: Unknown.
Substrate—Unknown.
Physical/chemical—Temperature: Unknown. Salinity: Marine [1].



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

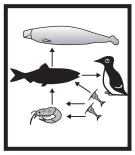


Populations or Stocks
There have been no studies.

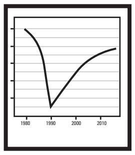


Reproduction
Mode—Separate sexes; oviparous [7].
Spawning season—Unknown.
Fecundity—Unknown.

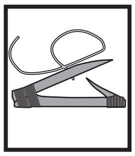
Food and Feeding
Food items—Unknown.
Trophic level—3.33 (standard error 0.40) [8].



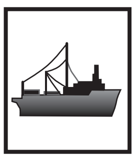
Biological Interactions
Predators—*In the mid-eastern U.S. Chukchi Sea, Artediellus sp. are occasionally eaten by ringed seals* [9].
Competitors—Presumably a wide range of other zoobenthos feeders such as Arctic Cod, Walleye Pollock, other sculpins, poachers, and eelpouts.



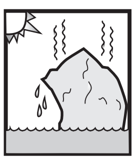
Resilience
High, minimum population doubling time less than 15 months (Preliminary *K* or Fecundity) [8].



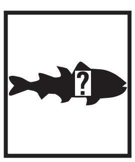
Traditional and Cultural Importance
None reported.



Commercial Fisheries
Currently, Okhotsk Hookear Sculpin are not commercially harvested.



Potential Effects of Climate Change
As with other boreal Pacific species, climate warming would be expected to increase its abundance in the U.S. Chukchi Sea and possibly expand its range into the U.S. Beaufort Sea.



Areas for Future Research [B]
Little is known about the ecology and life history of this species. Research needs in the study area 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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Mecklenburg, C.W., Mecklenburg, T.A., and Thorsteinson, L.K., 2002, Fishes of Alaska: Bethesda, Maryland, American Fisheries Society, 1,116 p. [1]

Mecklenburg, C.W., Møller, P.R., and Steinke, D., 2011, Biodiversity of Arctic marine fishes—Taxonomy and zoogeography: Marine Biodiversity, v. 41, no. 1, p. 109–140, Online Resource 1. [2]

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Hamecon (*Artediellus scaber*)

Knipowitsch, 1907

Family Cottidae

Hamecon (*Artediellus scaber*), 83 mm TL, western Chukchi Sea, 2004. Photograph by C.W. Mecklenburg, Point Stephens Research.

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

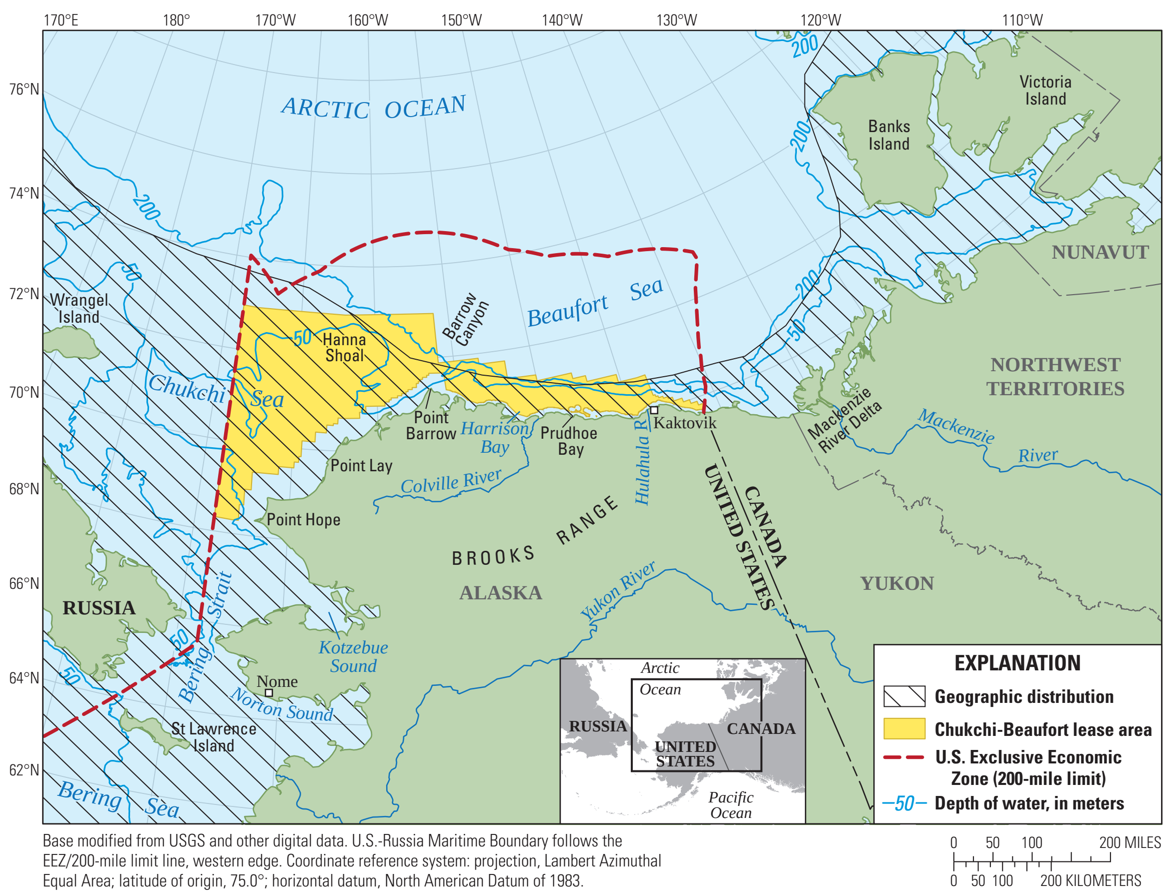
Ecological Role: Largely unknown. However, the Hamecon is unlikely to represent a significant prey resource to higher-level organisms, but it is an important subsistence resource in some Alaskan communities.

Physical Description/Attributes: Grayish brown with large blotches and bars; fins have orange bars. Males have a dark blotch on posterior part of first dorsal fin. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 491) [1]. Swim bladder: Absent [1]. Antifreeze glycoproteins in blood serum: Unknown.

Range: *U.S. Chukchi and Beaufort Seas.* Elsewhere in Alaska, in eastern Bering Sea to south of St. Lawrence Island. Worldwide, in western Bering Sea south to Cape Navarin, Russia; through Arctic Ocean eastward to Somerset Island, Canada, and westward to Barents and Kara Seas [1, 2].

Relative Abundance: Common, *although patchily distributed in U.S. Chukchi Sea at least as far north as 71°N*. [5–8]. Common *in westernmost Beaufort Sea, although abundance in rest of Alaskan Beaufort Sea is unknown as few have been taken in nearshore areas* [5–7, 9, 10]. Elsewhere, common in Canadian Beaufort Sea at Herschel Island, Yukon Territory [11] and in Russian Chukchi Sea [7].

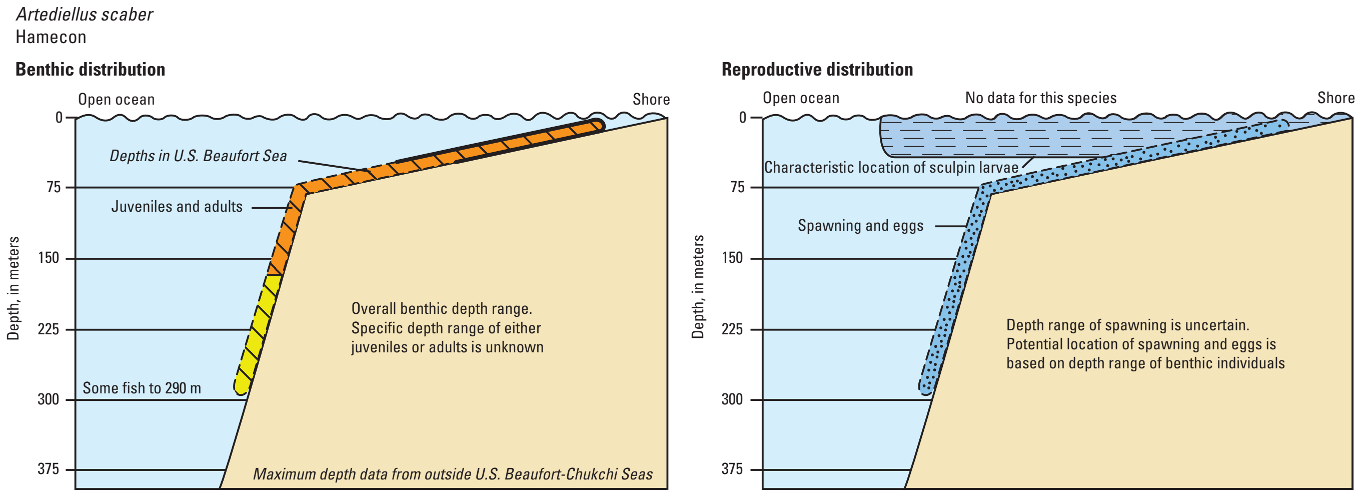
Hamecon
Artediellus scaber



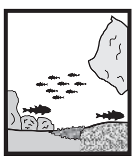
Base modified from USGS and other digital data. U.S.-Russia Maritime Boundary follows the EEZ/200-mile limit line, western edge. Coordinate reference system: projection, Lambert Azimuthal Equal Area; latitude of origin, 75.0°; horizontal datum, North American Datum of 1983.

Geographic distribution of Hamecon (*Artediellus scaber*), within Arctic Outer Continental Shelf Planning Areas [3] based on review of published literature and specimens from historical and recent collections [2, 4].

Depth Range: *At depths of 4–159 m, mostly shallower than 55 m* [2]. Elsewhere, overall depth range given for benthic individuals is 7 m [9] to 290 m [12], although depths greater than 159 m are likely in error [2].

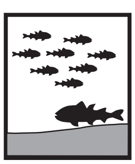


Benthic and reproductive distribution of Hamecon (*Artediellus scaber*).



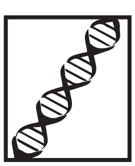
Habitats and Life History

Eggs—Size: Unknown. Time to hatching: Unknown. Habitat: Benthic [13].
Larvae—Size at hatching: Unknown. Size at juvenile transformation: *Young-of-the-year may recruit to nearshore waters at lengths of 2.0 cm TL* [9]. Days to juvenile transformation: Unknown. Habitat: Pelagic [1].
Juveniles—Age and size: Unknown and *2.0–5.6 cm TL* [9, 14]. Habitat: Benthic [1].
Adults—Age and size at first maturity: *Females larger than 5.6 cm TL are mature (about 3 or 4 years)* [14]. Maximum age: *At least seven years* [13, 14]. Maximum size: 11.4 cm TL [15]. Habitat: Benthic, in coastal waters [13].
Substrate—Over sand, mud, and around rocks [7, 13]. *Larger individuals may be found in deeper parts of species' depth range* [9].
Physical/chemical—Temperature: -1.8–9.8 °C or more [4]. Salinity: Brackish and marine, primarily brackish [16]. *In U.S. Chukchi Sea, documented as much as 32.41 parts per thousand* [7]. Off Russia and in western Chukchi Sea, documented between 10 and 32.87 parts per thousand [7, 13],



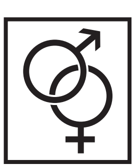
Behavior

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



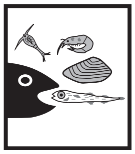
Populations or Stocks

There have been no studies.



Reproduction

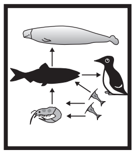
Mode—Separate sexes; oviparous [17].
Spawning season—Reproduction appears to take place at least in the autumn [13].
Fecundity—*Females produce between 50 and 100 eggs* [14].



Food and Feeding

Food items—*Benthic individuals eat a variety of benthic and epibenthic prey, most importantly polychaetes and gammarid amphipods, as well as mysids, cumaceans, euphausiids, hyperiid amphipods, and isopods* [14]. Food habits of larvae unknown.

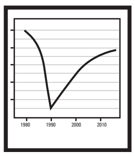
Trophic level—3.5 (standard error 0.38) [18].



Biological Interactions

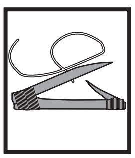
Predators—*In the mid-eastern U.S. Chukchi Sea Artediellus sp. are occasionally eaten by ringed seals* [19].

Competitors—Presumably a wide range of other zoobenthos feeders such as Arctic Cod, Walleye Pollock, other sculpins, poachers, and eelpouts.



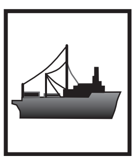
Resilience

High, minimum population doubling time less than 15 months (Preliminary *K* or Fecundity) [18].



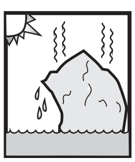
Traditional and Cultural Importance

None reported



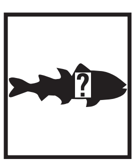
Commercial Fisheries

Currently, Hamecon are not commercially harvested.



Potential Effects of Climate Change

An essentially Arctic species, climate warming would be expected to contract this species' range northward from the Bering Sea.



Areas for Future Research [B]

Little is known about the ecology and life history of this species in the study area. Research needs include: (1) depth 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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Antlered Sculpin (*Enophrys diceraus*)

(Pallas, 1787)

Family Cottidae

Antlered Sculpin (*Enophrys diceraus*), 101 mm TL, Chukchi Sea, 2007. Photograph by C.W. Mecklenburg, Point Stephens Research.

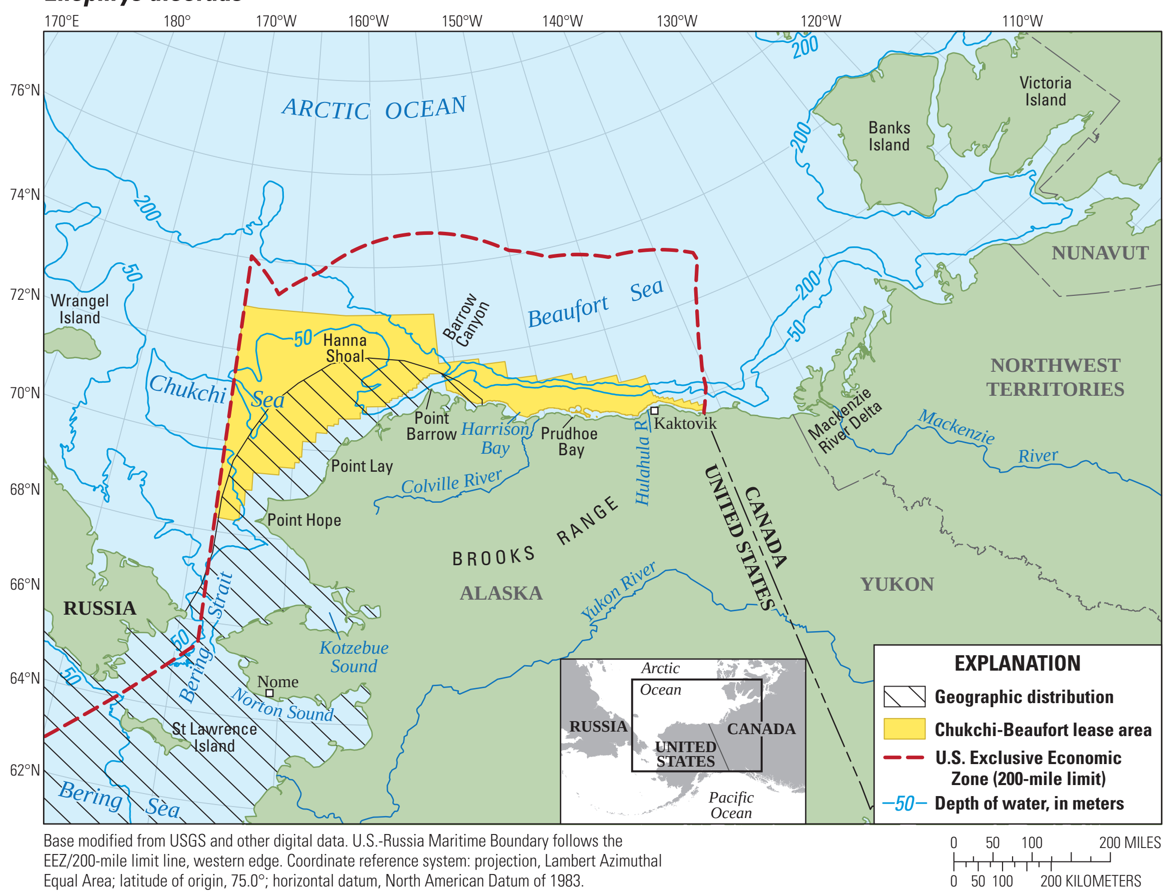
Colloquial Name: *None in U.S. Chukchi and Beaufort Seas.*

Ecological Role: Antlered Sculpin are common in the U.S. Chukchi Sea and uncommon in the U.S. Beaufort Sea. Their respective roles in marine ecosystem dynamics, although unknown, probably are more significant than many other species, and correspond to this abundance pattern.

Physical Description/Attributes: Greenish and reddish brown mottling on back and sides on cream or pale yellow background. Often with three or four vague dark bands and some marbling and spotting and fins are barred [1]. Spawning males have dark dorsal, pectoral, and caudal fins [2]. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 472) [1]. Swim bladder: Absent [1]. Antifreeze glycoproteins in blood serum: Unknown.

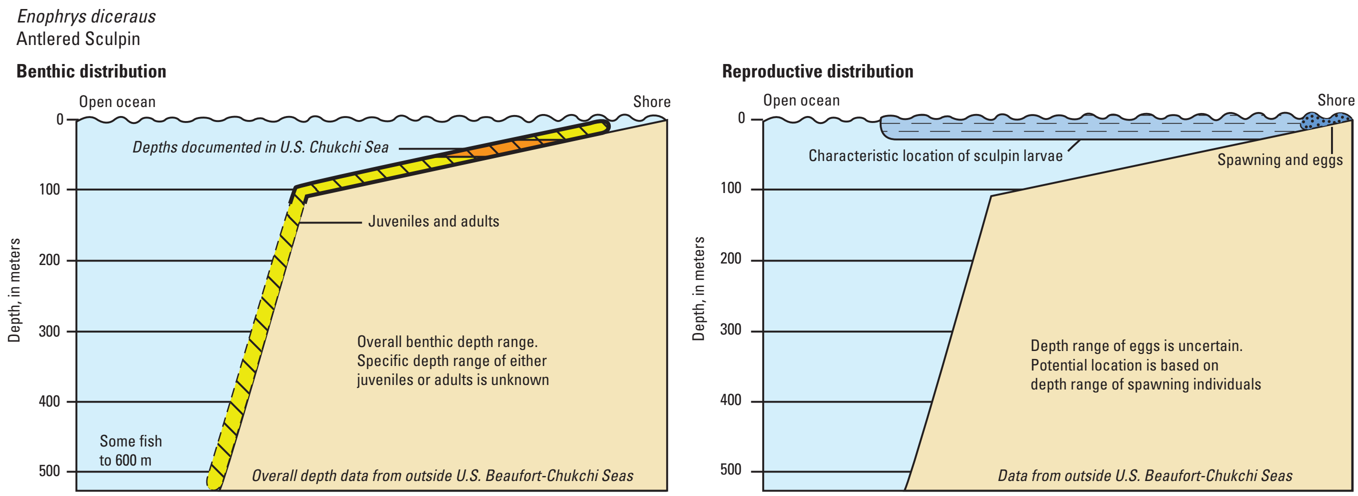
Range: *In U.S. Chukchi Sea* [1, 3] *and western U.S. Beaufort Sea* [4]. Elsewhere in Alaska, in Bering Sea and Commander (Russia)–Aleutian islands chain, southeastwards to Fort Tongass, Alaska. Worldwide, in Sea of Japan to Sea of Okhotsk [1].

Relative Abundance: *Fairly common in the northeastern U.S. Chukchi Sea* [7, 8]. Elsewhere, common from the Sea of Japan [9] and Sea of Okhotsk [10] to Bering Sea [11].

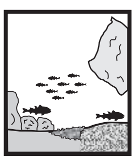


Geographic distribution of Antlered Sculpin (*Enophrys diceraus*), within Arctic Outer Continental Shelf Planning Areas [5] based on review of published literature and specimens from historical and recent collections [3, 6].

Depth Range: *Documented at 26–50 m in U.S. Chukchi Sea* [7, 12]. In other areas, primarily between 2–120 m deep [3, 13], but has been reported to 600 m in Peter the Great Bay, Sea of Japan [13]. Depth range of larvae and juveniles is unknown. Spawning occurs in nearshore waters as shallow as 2–15 m [2, 13].

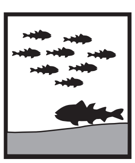


Benthic and reproductive distribution of Antlered Sculpin (*Enophrys diceraus*).



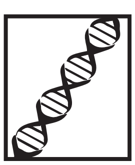
Habitats and Life History

Eggs—Size: 1.7–2.2 mm in diameter [2, 13]. Time to hatching: Unknown. Habitat: Nearshore, on rocks [2, 13].
Larvae—Size at hatching: 6.5–6.9 mm. Larvae hatch in spring [2, 13]. Size at juvenile transformation: 1.3–2.2 cm TL in Sea of Japan [2]. Days to juvenile transformation: Unknown. Habitat: Pelagic [2].
Juveniles—Age and size: Age unknown and 1.3–2.2 cm TL to 18–21 cm TL [2, 13]. Habitat: Benthic [2].
Adults—Age and size at first maturity: Most mature at 18–21 cm TL and males grow larger than females [2, 13]. Maximum age: Unknown. Maximum size: 38 cm (15.2 in) TL [13]. Habitat: Benthic. In Prince William Sound, mainly found along protected beachlines and in shallow embayments dominated by seaweed and seagrasses [14]. Large aggregations have also been found over soft sea floors in Sea of Japan [13].
Substrate—*Shell hash, rocks, mixed gravel, sand, and mud* [12, 13].
Physical/chemical—Temperature: Between -1.5 and 10 °C, but may prefer temperatures greater than 0 °C [2, 12, 13, 15]. Salinity: Marine [2].



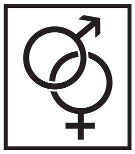
Behavior

Diel—Unknown.
Seasonal—In Sea of Okhotsk it moves into deeper waters in winter [13].
Reproductive—In Sea of Japan, spawning occurs nearshore on rocks. In autumn, large mature males migrate into spawning areas first, followed by smaller mature males and, lastly, females. Juvenile fish do not inhabit the spawning grounds. Females lay eggs on rocks and these are guarded by adult fish, most likely males. Multiple females may lay their eggs in one nest and egg masses can be as large as 30 × 20 cm [2, 13]. Following spawning migrations occur offshore into deeper waters [13, 16].
Schooling—Unknown.
Feeding—Unknown.

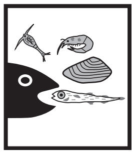


Populations or Stocks

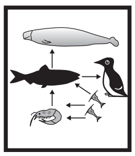
There have been no studies.



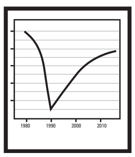
Reproduction
Mode—Separate sexes; oviparous [17].
Spawning season—*Unknown in U.S. Chukchi and Beaufort Seas.* Elsewhere, spawning is from November to February [2, 13] and in April and May in the more northerly waters of Sea of Japan [18]. Fecundity: Females produce between 9,523 and 17,160 crimson, orange, or purple eggs [2].



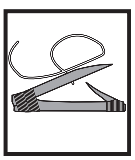
Food and Feeding
Food items—Food habits of larvae unknown. Benthic individuals eat a wide range of benthic prey. Important food items are crustaceans (for example, gammarid amphipods, brachyuran, and hermit crabs), limpets, sea urchins, and brittle stars [14, 16, 18].
Trophic level—3.26 (standard error 0.43) [19].



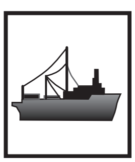
Biological Interactions
Predation—Off Kamchatka Peninsula, Russia, both great and plain sculpins eat this species [20]. At Tee Harbor, southeastern Alaska, commonly eaten by river otters [21].
Competitors—Presumably a wide range of other zoobenthic feeders such as Arctic Cod, Walleye Pollock, other sculpins, poachers, and eelpouts.



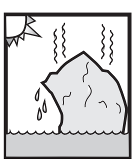
Resilience
Low, minimum population doubling time 4.5–14 years (Preliminary *K* or Fecundity) [19].



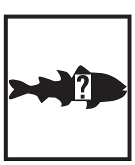
Traditional and Cultural Importance
None reported.



Commercial Fisheries
Currently, Antlered Sculpin are not commercially harvested.



Potential Effects of Climate Change
A boreal Pacific species that appears to be common in the Gulf of Alaska, and Bering Sea, and common in the northeastern Chukchi Sea, Antlered Sculpin would be expected to increase in abundance in abundance of shelf areas of both seas.



Areas for Future Research [B]
Little is known about the ecology and life history of this species in Arctic Alaska. Research needs for this species 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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Arctic Staghorn Sculpin to Ribbed Sculpin

Arctic Staghorn Sculpin (*Gymnocanthus tricuspis*)
(Reinhardt, 1830)

Family Cottidae

Colloquial Name: *No colloquial name within U.S. Chukchi and Beaufort Seas*.

Ecological Role: Largely unknown. Current information about the precise occurrence in the U.S. Chukchi and Beaufort Seas is limited, although it appears to be one of the more common benthic fish species in the Arctic Ocean [1, 2]. Information regarding most of the biology and ecology of this species within the U.S. Chukchi and Beaufort Seas is not available. However, as one of the most common species in the Chukchi Sea, the Arctic Staghorn Sculpin is likely to represent a significant prey resource to higher level organisms.

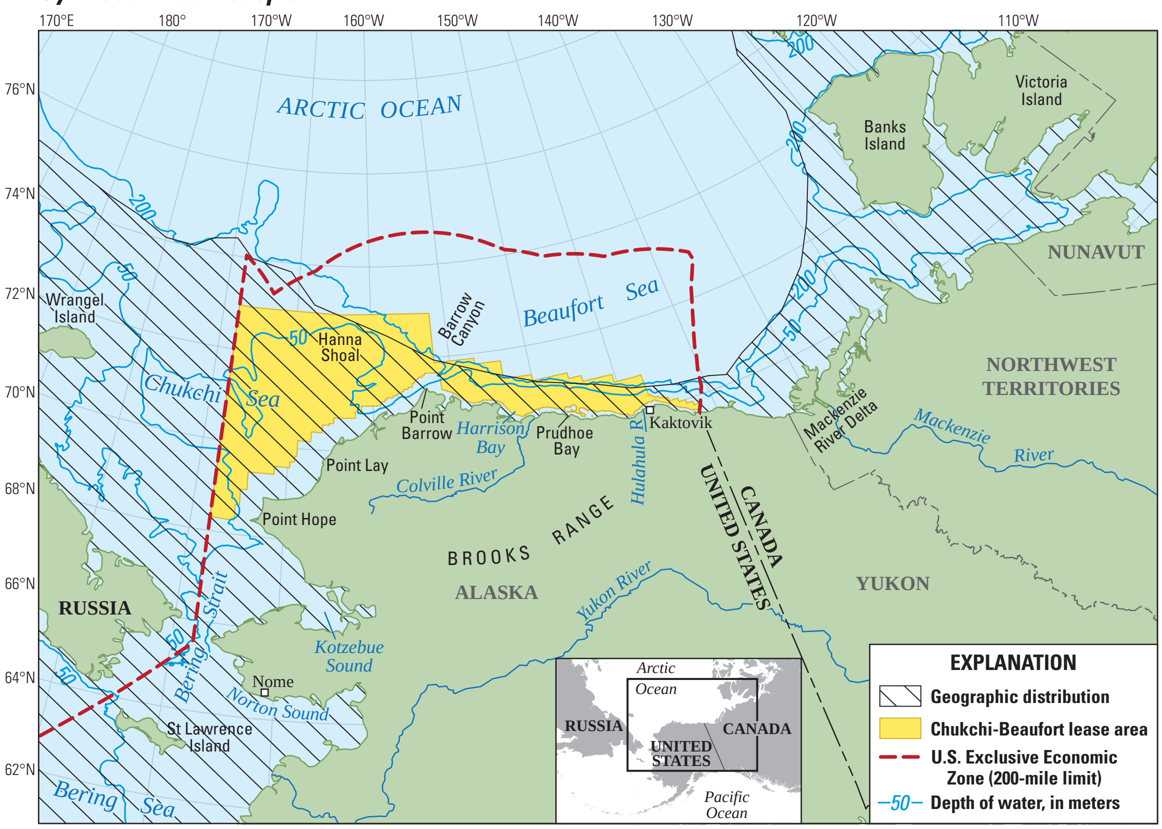
Arctic Staghorn Sculpin (*Gymnocanthus tricuspis*) female, 146 mm TL, Chukchi Sea, 2007. Photograph by B. Sheiko, Russian Academy of Sciences and C.W. Mecklenburg, Point Stephens Research.

Physical Description/Attributes: Dark brown backs with dark blotches extending below lateral line and yellowish lower sides. Dark bars on dorsal and pectoral fins. First dorsal fin of males is blackish with scattered white spots. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 464) [3]. Swim bladder: Absent [3]. Antifreeze glycoproteins in blood serum: Unknown.

Range: *Throughout U.S. Chukchi and Beaufort Seas*. Elsewhere in Alaska, in eastern Bering Sea southwards to Saint Matthew Island (61°03'N, 173°40'W) [2]. Worldwide, circumpolar in distribution [3], in the Atlantic Ocean southward to Gulf of Maine (Eastport, Maine) and northern Norway [1].

Relative Abundance: *Common throughout U.S. Chukchi Sea at least as far north as 72°19'N, 175°57'W* [2, 6, 7], *and in the U.S. Beaufort Sea to at least Herschel Island, Yukon Territory* [8, 9]. In the northern Bering Sea, common to just south of Bering Strait [10].

Arctic Staghorn Sculpin
Gymnocanthus tricuspis

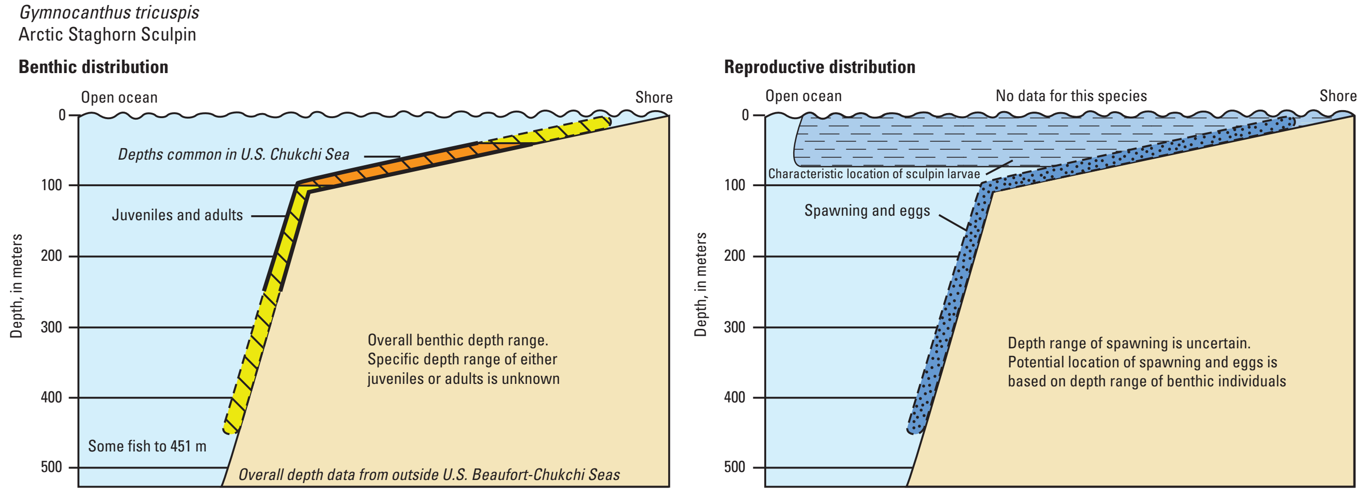


Base modified from USGS and other digital data. U.S.-Russia Maritime Boundary follows the EEZ/200-mile limit line, western edge. Coordinate reference system: projection, Lambert Azimuthal Equal Area; latitude of origin, 75.0°; horizontal datum, North American Datum of 1983.

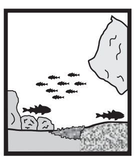
0 50 100 200 MILES
0 50 100 200 KILOMETERS

Geographic distribution of Arctic Staghorn Sculpin (*Gymnocanthus tricuspis*) within Arctic Outer Continental Shelf Planning Areas [4] based on review of published literature and specimens from historical and recent collections [1, 5].

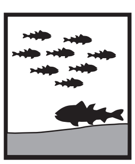
Depth Range: *In northern U.S. Chukchi Sea common from 40–100 m. One juvenile taken in midwaters at 37 m to surface and one at 81 m to surface. A few juveniles and larvae documented from midwaters with maximum tow depths varying from 51 to 29 m* [11]. Elsewhere, 2–451 m, but uncommon less than 10–20 m [12–15].



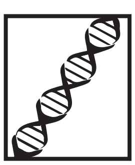
Benthic and reproductive distribution of Arctic Staghorn Sculpin (*Gymnocanthus tricuspis*).



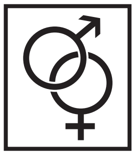
Habitats and Life History
Eggs—Size: 1–2 mm [16, 17]. Time to hatching: Unknown. Habitat: Benthic [3, 17].
Larvae—Size at hatching: Unknown. Size at juvenile transformation: 18–30 mm [16, 17]. Days to juvenile transformation: Unknown. Habitat: Pelagic [17].
Juveniles—Age: Unknown. Size: 1.8–9.0 cm SL [16]. Habitat: Benthic.
Adults—Age and size at first maturity: Males mature at 6.0–7.0 cm SL (2–3 years) and females at about 9.0 cm SL (3–4 years). Females grow faster than males, reach a larger size, and are heavier at length [16]. Maximum age: *In northeastern Chukchi Sea, females live to at least 9 years and males to 8 years* [18]. Maximum size: 29.9 cm TL [3]. Habitat: Benthic [17]; soft or low relief sea floors, sometimes in association with algal beds [1, 16, 19].
Substrate—*Documented on mud to gravel and rock in U.S. Chukchi Sea* [2]. Elsewhere, sand, sand–mud, and gravel [1, 16, 20].
Physical/chemical—Temperature: -1.9–12.5 °C. Tolerant of a fairly broad range of temperatures but mainly about 0 °C or less [16, 21]. Salinity: Marine and brackish water as low as 8.1 ppt [16, 21].



Behavior
Diel—Partly buries itself in bottom substrates [17].
Seasonal—Unknown.
Reproductive—Unknown.
Schooling—Unknown.
Feeding—Unknown.

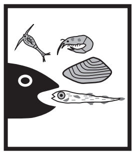


Populations or Stocks
There have been no studies.



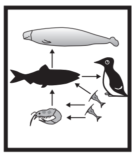
Reproduction

Mode—Separate sexes; oviparous [22]. Internal fertilization likely [16].
Spawning season—Autumn and early winter in Atlantic Ocean and White and Kara Seas [13, 16, 23].
Fecundity—*In U.S. Chukchi Sea, 3,030–5,414 eggs* [18]; Elsewhere, 2,060–3,512 eggs in an unidentified Arctic location [16].



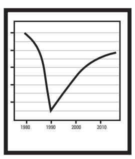
Food and Feeding

Food items—*In U.S. Chukchi Sea, prey varies with site, but crustaceans (for example, amphipods, cumaceans, and hermit crabs), polychaetes, clam siphons, echiurioids, gastropods, bivalves, and larvaceans are all important* [24]. In general, benthic and water column invertebrates [24, 25].
Trophic level—3.46 standard error 0.49 [26].



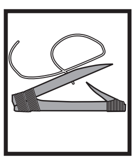
Biological Interactions

Predators—*In U.S. Chukchi Sea off Point Barrow, Alaska, predators include Polar Cod, Bering Flounder, and Estuarine Eelpout* [18]. In Canadian Arctic, Black Guillemots, Thick-billed Murres, and bearded seals [27, 28].
Competitors—Presumably a wide range of other zoobenthic feeders such as Arctic Cod, Walleye Pollock, poachers, eelpouts, and other sculpins.



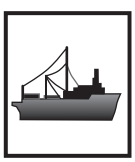
Resilience

Medium, minimum population doubling time: 1.4–4.4 years (t_m=2–4; t_{max}=9; Fecundity=3,030) [26].



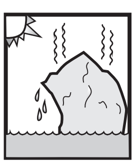
Traditional and Cultural Importance

None reported.



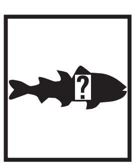
Commercial Fisheries

Currently, Arctic Staghorn Sculpin are not commercially harvested.



Potential Effects of Climate Change

As a predominantly Arctic species with a low temperature preference [16] a northward shift this species distribution is possible.



Areas for Future Research [A]

Life history information is limited; however, distribution and abundance data suggest its potential as an indicator of changing conditions. 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. Arctic Staghorn Sculpin should be considered in vulnerability assessments of Arctic marine fish to climate change.

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Butterfly Sculpin (*Hemilepidotus papilio*)

(Bean, 1880)

Family Cottidae

Butterfly Sculpin (*Hemilepidotus papilio*) 167 mm, Chukchi Sea, 2004. Photograph by C.W. Mecklenburg, Point Stephens Research.

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

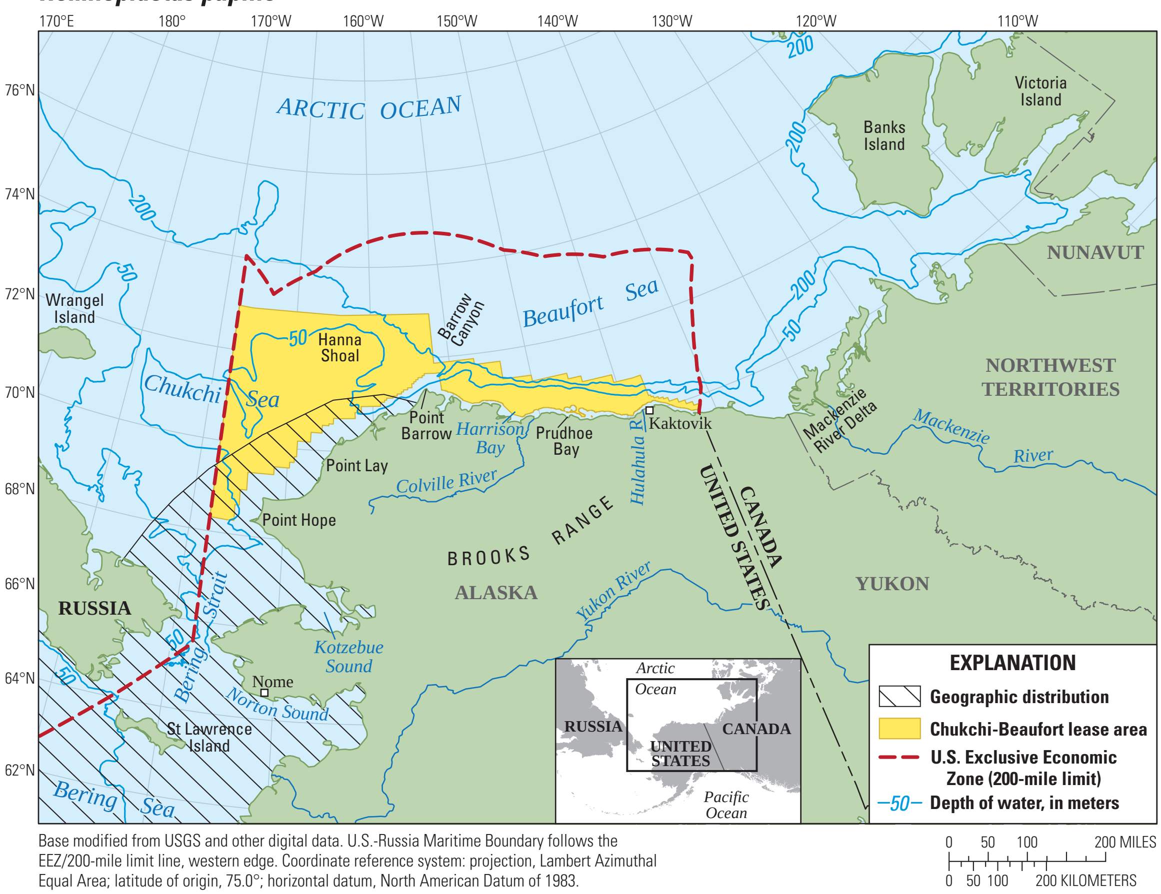
Colloquial Name: *None within U.S. Chukchi and Beaufort Seas.*

Ecological Role: Largely unknown. Current information about the occurrence of this fish is limited to the Chukchi Sea. The Butterfly Sculpin is unlikely to represent a significant prey resource to higher level organisms but may be an important consumer of benthic invertebrates.

Physical Description/Attributes: Reddish brown, yellow, and white, with metallic gold sheen and four more or less distinct blackish bars on upper sides and back extending onto dorsal fin [1]. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 431) [2]. Swim bladder: Absent [2]. Antifreeze glycoproteins in blood serum: Unknown.

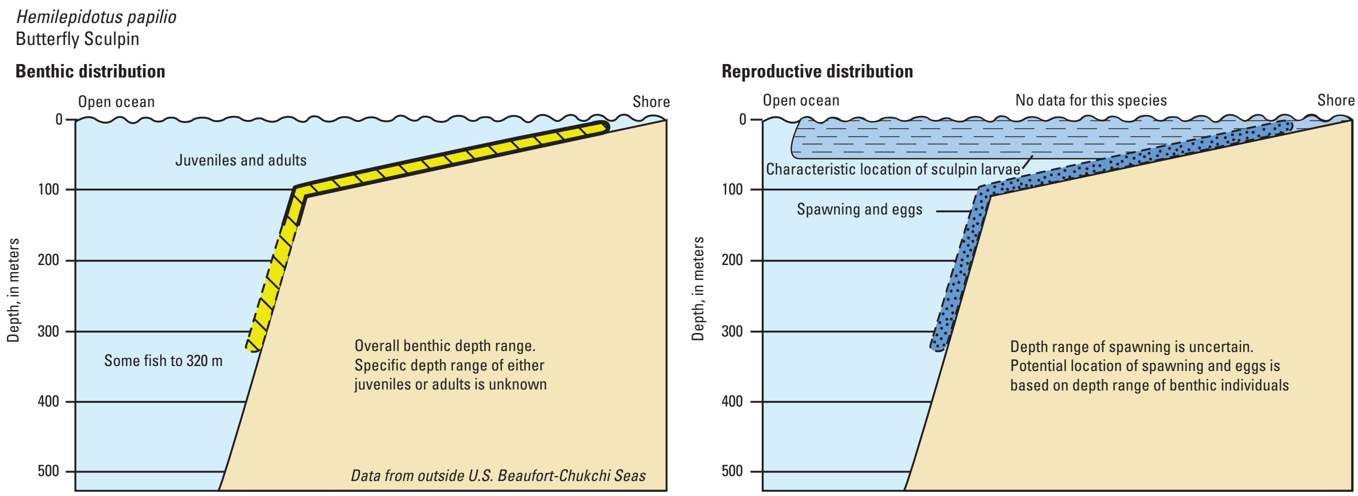
Range: *U.S. Chukchi Sea as far north as 69°55'N, 168°00'W* [3]. Elsewhere in Alaska, eastern Bering Sea and along Aleutian Islands west to Buldir Island. Worldwide, from western Bering Sea to Sea of Okhotsk and Sea of Japan off Hokkaido, Japan [3].

Relative Abundance: *Fairly common but not abundant in U.S. Chukchi Sea* [6, 7]. Common in the Bering Sea [8], most common south of St. Matthew Island [6] and from Kamchatka Peninsula [9] to Sea of Okhotsk off eastern Sakhalin Island, Russia [10].

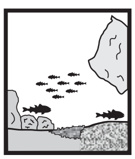


Geographic distribution of Butterfly Sculpin (*Hemilepidotus papilio*) within Arctic Outer Continental Shelf Planning Areas [4] based on review of published literature and specimens from historical and recent collections [5, 6].

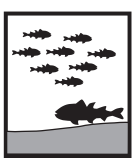
Depth Range: From intertidal zone to 320 m [2], and typically less than 150 m [11]. Larvae are found over continental shelf, slope, and in oceanic waters [12].



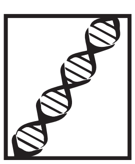
Benthic and reproductive distribution of Butterfly Sculpin (*Hemilepidotus papilio*).



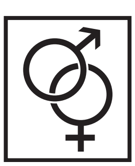
Habitats and Life History
Eggs—Size: Unknown. Time to hatching: Unknown. Habitat: Benthic [2].
Larvae—Size at hatching: Unknown. Size at juvenile transformation: Unknown. Days to juvenile transformation: Unknown. Habitat: Likely pelagic. Larvae of the related *Hemilepidotus hemilepidotus* are found over continental shelf, slope, and in oceanic waters [12].
Juveniles—Age and size: Unknown. Habitat: Benthic, primarily on low relief sea floors [13]. Frequently in tide pools [2].
Adults—Age and size at first maturity: Unknown. Maximum age: Unknown. Maximum size: About 42 cm TL [21]. Habitat: Benthic, primarily on low relief sea floors [13]. Frequently in tide pools [2].
Substrate—Mainly on stony-gravel bottoms [13].
Physical/chemical—Temperature: -1.8–11.8 °C [3, 5, 13, 14]; prefers 2.0 °C or less [9]. Salinity: Marine [13].



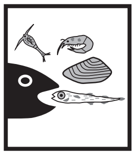
Behavior
Diel—Unknown.
Seasonal—Unknown.
Reproductive—Unknown.
Schooling—Unknown.



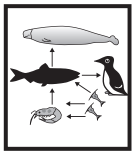
Populations or Stocks
There have been no studies.



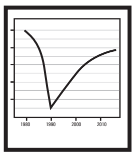
Reproduction
Mode—Separate sexes; oviparous [15].
Spawning season—July in Bering Sea [16].
Fecundity—Unknown.



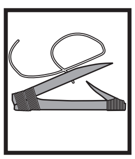
Food and Feeding
Food items—In eastern Bering Sea, primarily benthic and epibenthic prey such as Tanner crabs, gammarid amphipods, young Walleye Pollock, and ostracods [17].
Feeding—Unknown.
Trophic level—4.0 [18].



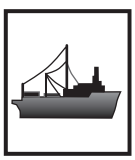
Biological Interactions
Predators—Unknown.
Competitors—Presumably a wide range of other zoobenthic feeders such as Arctic Cod, Walleye Pollock, other sculpins, poachers, and eelpouts.



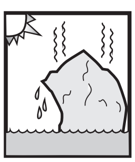
Resilience
Low, minimum population doubling time: 4.5–14 years (Preliminary *K* or Fecundity) [19].



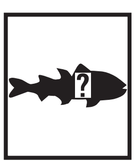
Traditional and Cultural Importance
None reported. Occasionally used as food by Alaska Natives on the Pribilof Islands. [20].



Commercial Fisheries
Currently, Butterfly Sculpin are not commercially harvested.



Potential Effects of Climate Change
As a predominantly Boreal species, Butterfly Sculpin would be expected to increase in abundance in the U.S. Chukchi Sea and to expand its range into the Beaufort Sea.



Areas for Future Research [B]
Little is known about the ecology and life history of this species in the U.S. Arctic marine environment. 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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Twohorn Sculpin (*Icelus bicornis*)

(Reinhardt, 1840)

Family Cottidae

Twohorn Sculpin (*Icelus bicornis*) 88 mm, Beaufort Sea, 2011. Photograph by C.W. Mecklenburg, Point Stephens Research.

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

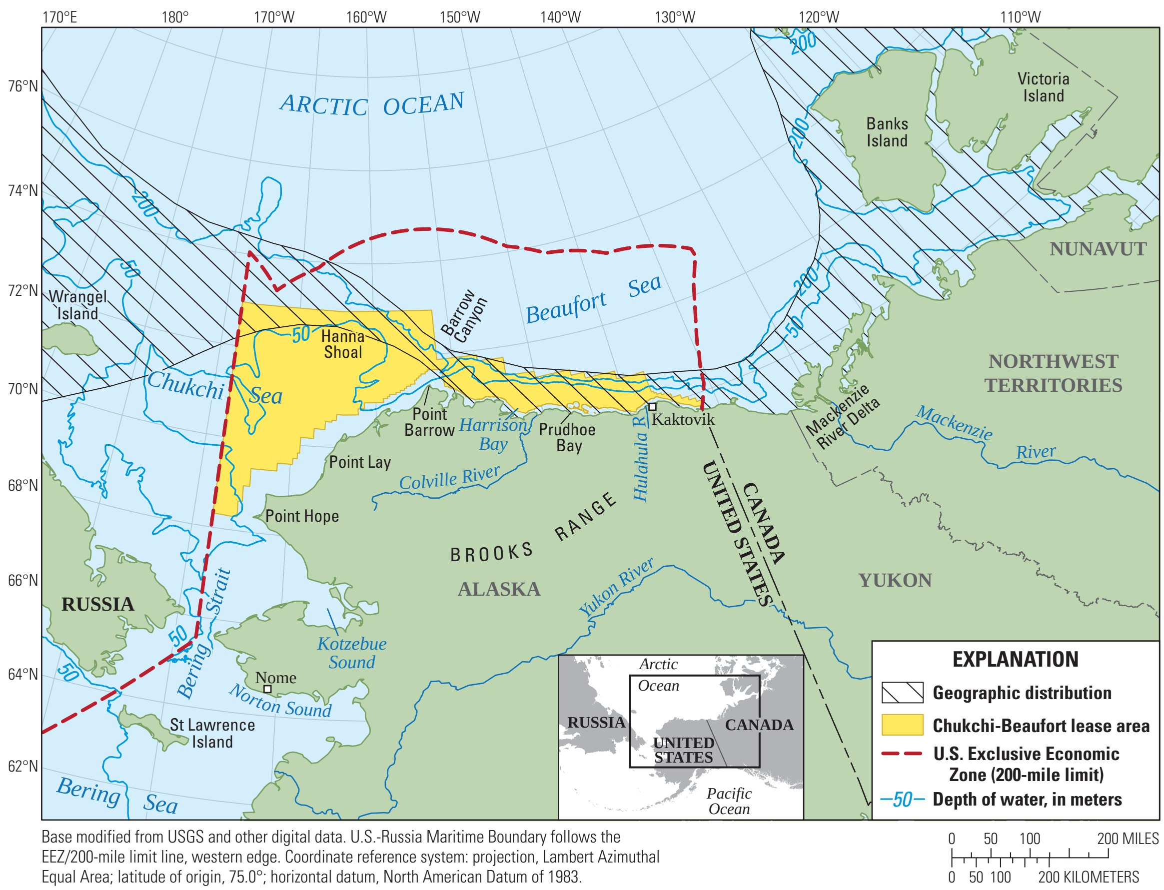
Ecological Role: Twohorn Sculpin are uncommon in the U.S. Chukchi and Beaufort Seas. Their ecological role in benthic ecosystems, though not fully known, is thought to be minor with respect to predation and energy flows.

Physical Description/Attributes: Yellowish brown with brown spots. Nasal tubes and cirri are pale. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 456) [1]. Swim bladder: Absent [1]. Antifreeze glycoproteins in blood serum: Unknown.

Ranges: *U.S. Beaufort Sea; presence in U.S. Chukchi Sea assumed from confirmed presence in adjacent waters of the East Siberian Sea, the slope north of the U.S. Chukchi Sea, and reported presence in western Chukchi Sea* [2]. Worldwide: Predominantly Arctic; circumpolar [2].

Relative Abundance: *Uncommon on outer continental shelf of U.S. Beaufort Sea* [2].

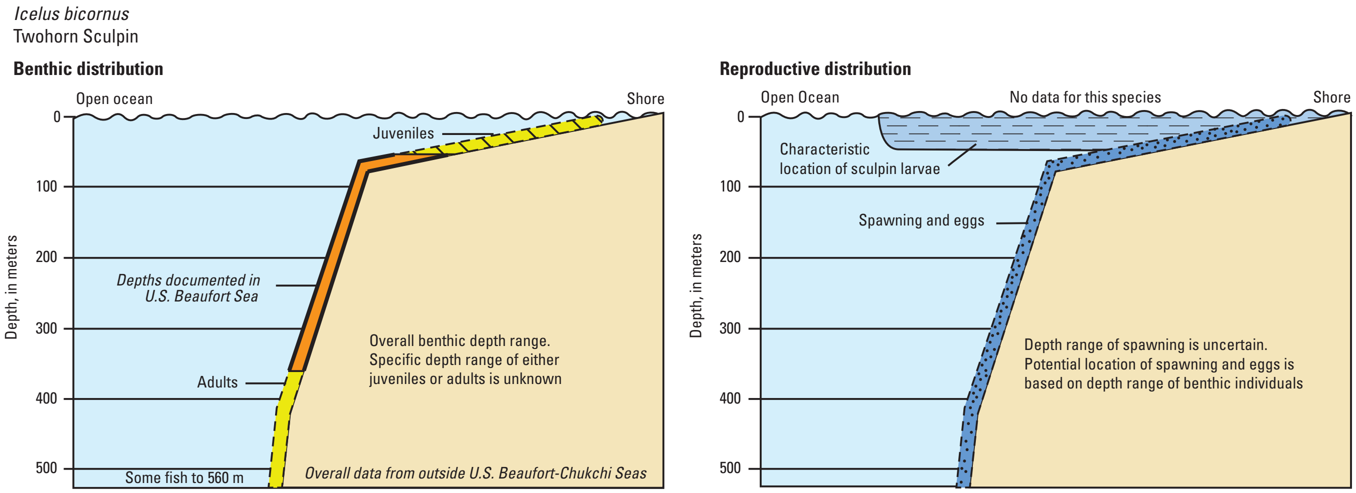
Twohorn Sculpin
Icelus bicornis



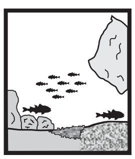
Base modified from USGS and other digital data. U.S.-Russia Maritime Boundary follows the EEZ/200-mile limit line, western edge. Coordinate reference system: projection, Lambert Azimuthal Equal Area; latitude of origin, 75.0°; horizontal datum, North American Datum of 1983.

Geographic distribution of Twohorn Sculpin (*Icelus bicornis*) within Arctic Outer Continental Shelf Planning Areas [3] based on review of published literature and specimens from historical and recent collections [1, 2, 4].

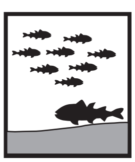
Depth Range: *Documented in U.S. Beaufort Sea at depths of 41–360 m* [4]. At depths of 14–560 m, but mostly at 50–180 m on outer shelf [2, 4, 5]. Larvae of *Icelus* sp. are abundant in surface waters [6]. Juvenile fish live in shallow waters [5].



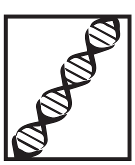
Benthic and reproductive distribution of Twohorn Sculpin (*Icelus bicornis*).



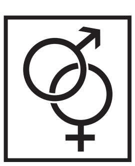
Habitats and Life History
Eggs—Size: Almost ripe eggs are 3.1 mm [5]. Time to hatching: Unknown. Habitat: Likely benthic based on life history patterns of many other members of this family [1].
Larvae—Size at hatching: Unknown. Size at juvenile transformation: Unknown. Days to juvenile transformation: Unknown. Habitat: Likely pelagic based on life history patterns of many other members of this family [1].
Juveniles—Age and size: Unknown. Habitat: Benthic, frequently in algal beds [5].
Adults—Age and size at first maturity: *In U.S. Beaufort Sea, females grew larger than males and matured at about 4 years and 6 cm TL* [7]. Maximum age: *At least 5 years, based on a small sample from the Beaufort Sea* [7]. Maximum size: 17 cm TL [4]. *8.8 cm TL in the U.S. Beaufort Sea* [4]. Habitat: Benthic [1].
Substrate—Mud, shell hash, or cobble sea floors [5].
Physical/chemical—Temperature: -1.8–8.8 °C, preferably around 0 °C [5]. Salinity: Marine and brackish-water at salinities as low as 25.4 ppt [5].



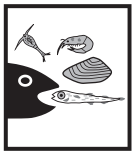
Behavior
Diel—Unknown.
Seasonal—Unknown.
Reproductive—Unknown.
Schooling—Unknown.
Feeding—Unknown.



Populations or Stocks
There have been no studies.



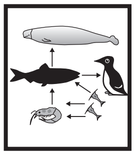
Reproduction
Mode—Separate sexes; oviparous [9].
Spawning season—August –October [5].
Fecundity—79–1,300 eggs [7, 8].



Food and Feeding

Food items—Food habits of larvae unknown. Major prey includes gammarid amphipods: polychaetes, euphausiids, hyperiid amphipods, isopods, shrimps, cumaceans, and sipunculids also are consumed [5, 7].

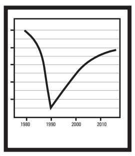
Trophic level—3.13 standard error 0.35 [10].



Biological Interactions

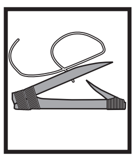
Predators—Unknown.

Competitors—Presumably a wide range of other zoobenthic feeders such as Arctic Cod, Walleye Pollock, poachers, eelpouts, and other sculpins.



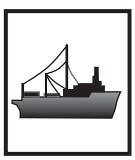
Resilience

Medium, minimum population doubling time: 1.4–4.4 years (Preliminary *K* or Fecundity) [10].



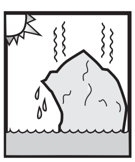
Traditional and Cultural Importance

None reported.



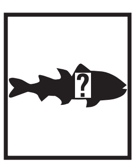
Commercial Fisheries

Currently, Twohorn Sculpin are not commercially harvested.



Potential Effects of Climate Change

The Twohorn Sculpin is a predominantly Arctic species. The potential effects of climate change could be expected to shift the species distribution farther northwards.



Areas for Future Research [B]

Little is known about the ecology and life history 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.

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Spatulate Sculpin (*Icelus spatula*)

Gilbert & Burke, 1912

Family Cottidae

Spatulate Sculpin (*Icelus spatula*) 79 mm, western Chukchi Sea, 2004. Photograph by C.W. Mecklenburg, Point Stephens Research.

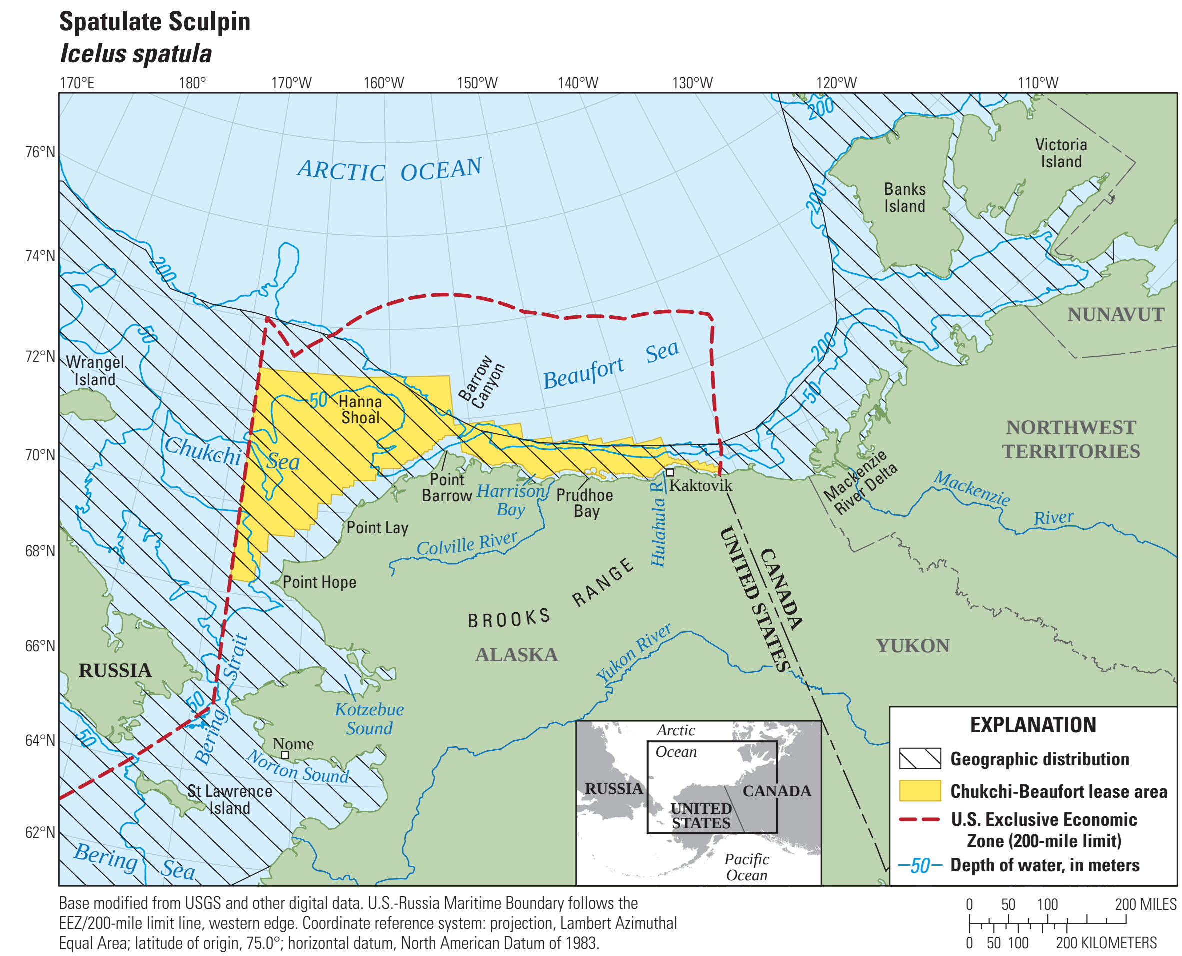
Colloquial Name: *None within U.S. Chukchi and Beaufort Seas*.

Ecological Role: Largely unknown. Specific information regarding biology and ecology is sparse. This species is not a dominant species in the U.S. Chukchi and Beaufort Seas and is unlikely to be ecologically significant in regional food webs.

Physical Description/Attributes: Light brown backs with four or five indistinct dark saddles and white underside. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, p. 455) [1]. Swim bladder: Absent [1]. Antifreeze glycoproteins in blood serum: Unknown.

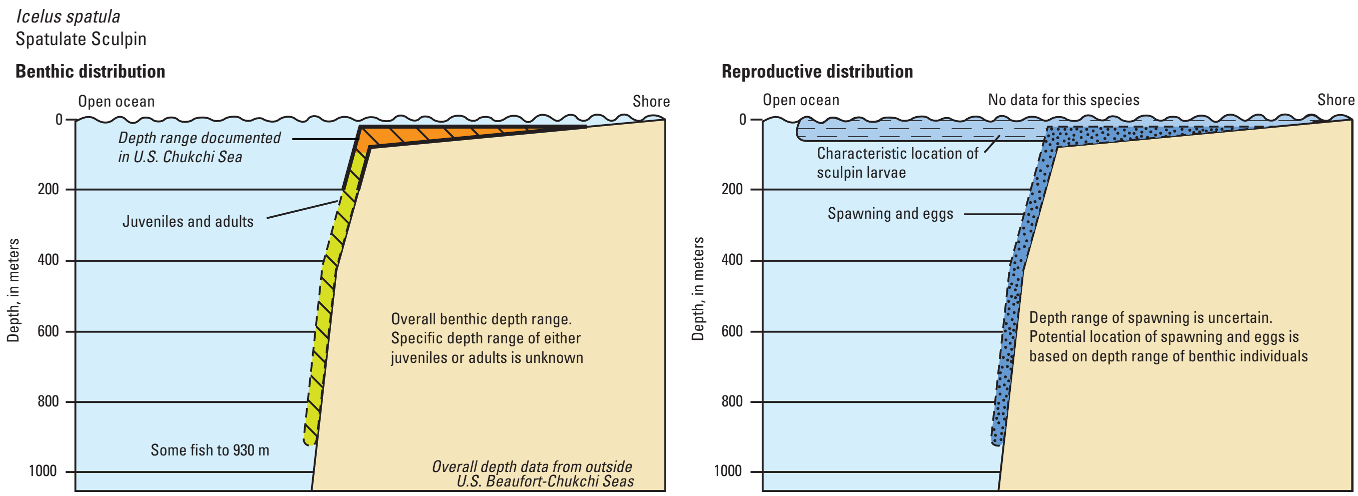
Ranges: *U.S. Chukchi and Beaufort Seas* [1–4]. Elsewhere in Alaska, in Bering Sea and Aleutian Islands west to Atka Island, and eastern Gulf of Alaska at Glacier Bay [1]. Worldwide, in Sea of Okhotsk, around Kuril Islands, Russia, and in western North Pacific off Kamchatka Peninsula to Arctic seas off Russia, and Canada to western Greenland and Labrador [1]. In Arctic Ocean, documented to 77°26′N [3] north of Siberia and to about 81°N in the Canadian High Arctic archipelago [5].

Relative Abundance: *Common in U.S. Chukchi and Beaufort Seas* [1–4, 7]. Elsewhere, common in Sea of Okhotsk, along Kuril Islands and Kamchatka Peninsula, Russia, and in Bering Sea [1, 3, 8, 9].

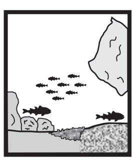


Geographic distribution of Spatulate Sculpin (*Icelus spatula*) within Arctic Outer Continental Shelf Planning Areas [6] based on review of published literature and specimens from historical and recent collections [1, 7].

Depth Range: *In U.S. Chukchi Sea, documented in 100 m or less* [3]. Elsewhere, 12–930 m [10], mainly shallower than 200 m [11]. Larvae of *Icelus* sp. are abundant in surface waters in Gulf of Alaska [12]. *In U.S. Chukchi Sea, one Icelus sp. juvenile was found in midwaters between 37 m and the surface* [4].

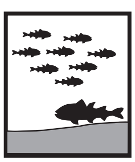


Benthic and reproductive distribution of Spatulate Sculpin (*Icelus spatula*).



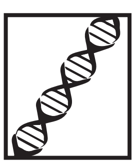
Habitats and Life History

Eggs—Size: 1.4 mm. Pale yellow in color [11]. Time to hatching: Unknown. Habitat: Benthic [11].
Larvae—Size at hatching: Unknown. Size at juvenile transformation: Unknown. Days to juvenile transformation: Unknown. Habitat: Pelagic [12].
Juveniles—Age and size: Unknown. Habitat: Benthic [11].
Adults—Age and size at first maturity: Unknown. Maximum age: 10 years [11]. Maximum size: About 21 cm TL. Females grow larger than males [11]. Habitat: Benthic [11].
Substrate—Complex substrates (for example, rocks and sponges) and soft sea floor [3, 11, 13].
Physical/chemical—Temperature: -1.8–10.5 °C [3, 7]. Salinity: Primarily marine, documented as low as 24.7 ppt [13].



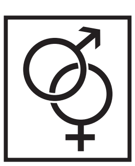
Behavior

Diel—Unknown.
Seasonal—In autumn, fish along the northern Kuril Islands migrate from the mid-continental shelf to the shelf-slope break [11].
Reproductive—Unknown.
Schooling—Unknown.
Feeding—Have been observed feeding in water column to 1 m above the bottom [14].



Populations or Stocks

There have been no studies.



Reproduction

Mode—Separate sexes; oviparous [15].
Spawning season—August –December [11, 16].
Fecundity—110–9,100 eggs, in a single batch [11, 16].

Food and Feeding

Food items—*In U.S. Chukchi and Beaufort Seas, epibenthic and benthic prey, such as mysids, gammarid amphipods, shrimps, and polychaetes* [16]. In Russia, similar prey, as well as fishes and mollusks [11, 13].
Trophic level—3.92 standard error 0.67 [17].

Biological Interactions

Predators—Bearded seals and Thick-billed Murres in Canadian Arctic [18, 19], river otters in southeastern Alaska [20], and Great Sculpin off Kamchatka Peninsula [21].
Competitors—Presumably a wide range of other zoobenthos feeders such as Arctic Cod, Walleye Pollock, poachers, eelpouts, flatfish, and other sculpins.

Resilience

Medium, minimum population doubling time: 1.4–4.4 years (Preliminary *K* or Fecundity) [17].

Traditional and Cultural Importance

None reported.

Commercial Fisheries

Currently, Spatulate Sculpin are not commercially harvested.

Potential Effects of Climate Change

The Spatulate Sculpin is an Arctic Boreal species [10]. Although climate warming may not greatly affect the species current distribution, abundance patterns are likely to change and probably increase.

Areas for Future Research [B]

Little is known about the ecology and life history 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.

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