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Alaska Arctic Marine Fish Ecology Catalog

Scientific Investigations Report 2016–5038

U.S. Department of the Interior
U.S. Geological Survey

Cover: Photographs of various fish studied for this report. Background photograph shows Arctic icebergs and ice floes. Photograph from iStock™, dated March 23, 2011.

Alaska Arctic Marine Fish Ecology Catalog

By Lyman K. Thorsteinson and Milton S. Love, editors

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U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
SALLY JEWELL, Secretary

U.S. Geological Survey
Suzette M. Kimball, Director

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Contents

Acknowledgments iii
Chapter 1. **Alaska Arctic Marine Fish Ecology Catalog—Chukchi and Beaufort Seas**
By Lyman K. Thorsteinson 1
Chapter 2. **Alaska Arctic Marine Fish Inventory**
By Lyman K. Thorsteinson 23
Chapter 3. **Alaska Arctic Marine Fish Species Accounts**
By Milton S. Love, Nancy Elder, Catherine W. Mecklenburg,
Lyman K. Thorsteinson, and T. Anthony Mecklenburg 41
Pacific and Arctic Lampreys 49
Pacific Lamprey (*Entosphenus tridentatus*) 49
Arctic Lamprey (*Lethenteron camtschaticum*) 55
Spotted Spiny Dogfish to Bering Cisco 60
Spotted Spiny Dogfish (*Squalus suckleyi*) 60
Arctic Skate (*Amblyraja hyperborea*) 66
Pacific Herring (*Clupea pallasii*) 70
Pond Smelt (*Hypomesus olidus*) 78
Pacific Capelin (*Mallotus catervarius*) 83
Arctic Smelt (*Osmerus dentex*) 91
Arctic Cisco (*Coregonus autumnalis*) 98
Bering Cisco (*Coregonus laurettae*) 107
Broad Whitefish to Dolly Varden 112
Broad Whitefish (*Coregonus nasus*) 112
Humpback Whitefish (*Coregonus pidschian*) 121
Least Cisco (*Coregonus sardinella*) 128
Pink Salmon (*Oncorhynchus gorbuscha*) 136
Chum Salmon (*Oncorhynchus keta*) 142
Coho Salmon (*Oncorhynchus kisutch*) 148
Sockeye Salmon (*Oncorhynchus nerka*) 153
Chinook Salmon (*Oncorhynchus tshawytscha*) 158
Dolly Varden (*Salvelinus malma*) 163
Inconnu and Glacier Lanternfish 172
Inconnu (*Stenodus leucichthys*) 172
Glacier Lanternfish (*Benthosema glaciale*) 179
Ice Cod to Pacific Cod 183
Ice Cod (*Arctogadus glacialis*) 183
Arctic Cod (*Boreogadus saida*) 189
Saffron Cod (*Eleginus gracilis*) 201
Walleye Pollock (*Gadus chalcogrammus*) 209
Pacific Cod (*Gadus macrocephalus*) 218
Threespine Stickleback to Antlered Sculpin 226
Threespine Stickleback (*Gasterosteus aculeatus*) 226
Ninespine Stickleback (*Pungitius pungitius*) 233
Whitespotted Greenling (*Hexagrammos stelleri*) 239
Okhotsk Hookear Sculpin (*Artediellus ochotensis*) 245

Contents—Continued

Chapter 3. **Alaska Arctic Marine Fish Species Accounts—Continued**
Threespine Stickleback to Antlered Sculpin—Continued
Hamecon (*Artediellus scaber*) 249
Antlered Sculpin (*Enophrys diceraus*) 254
Arctic Staghorn Sculpin to Ribbed Sculpin 259
Arctic Staghorn Sculpin (*Gymnocanthus tricuspis*) 259
Butterfly Sculpin (*Hemilepidotus papilio*) 265
Twohorn Sculpin (*Icelus bicornis*) 270
Spatulate Sculpin (*Icelus spatula*) 274
Belligerent Sculpin (*Megalocottus platycephalus*) 279
Brightbelly Sculpin (*Microcottus sellaris*) 283
Plain Sculpin (*Myoxocephalus jaok*) 287
Great Sculpin (*Myoxocephalus polyacanthocephalus*) 292
Fourhorn Sculpin (*Myoxocephalus quadricornis*) 298
Arctic Sculpin (*Myoxocephalus scorpioides*) 305
Shorthorn Sculpin (*Myoxocephalus scorpius*) 310
Hairhead Sculpin (*Trichocottus brashnikovi*) 316
Bigeye Sculpin (*Triglops nybelini*) 320
Ribbed Sculpin (*Triglops pingelii*) 324
Crested Sculpin to Leatherfin Lumpsucker 330
Crested Sculpin (*Blepsias bilobus*) 330
Eyeshade Sculpin (*Nautichthys pribilovius*) 335
Polar Sculpin (*Cottunculus microps*) 339
Smoothcheek Sculpin (*Eurymen gyrinus*) 343
Alligatorfish (*Aspidophoroides monopterygius*) 347
Arctic Alligatorfish (*Aspidophoroides olrikii*) 353
Fourhorn Poacher (*Hypsagonus quadricornis*) 358
Atlantic Poacher (*Leptagonus decagonus*) 363
Bering Poacher (*Occella dodecaedron*) 368
Tubenose Poacher (*Pallasina barbata*) 373
Veteran Poacher (*Podothecus veternus*) 378
Pimpled Lumpsucker (*Eumicrotremus andriashevi*) 383
Leatherfin Lumpsucker (*Eumicrotremus derjugini*) 387
Sea Tadpole to Polar Eelpout 391
Sea Tadpole (*Careproctus reinhardti*) 391
Nebulous Snailfish (*Liparis bathyarcticus*) 396
Gelatinous Seasnail (*Liparis fabricii*) 400
Variegated Snailfish (*Liparis gibbus*) 405
Kelp Snailfish (*Liparis tunicatus*) 410
Black Seasnail (*Paraliparis bathybius*) 415
Halfbarred Pout (*Gymnelus hemifasciatus*) 420
Fish Doctor (*Gymnelus viridis*) 424
Adolf's Eelpout (*Lycodes adolfi*) 429

Contents—Continued

Chapter 3. **Alaska Arctic Marine Fish Species Accounts—Continued**
Sea Tadpole to Polar Eelpout—Continued
Doubleline Eelpout (*Lycodes eudipleurostictus*) 433
Glacial Eelpout (*Lycodes frigidus*) 437
Shulupaoluk (*Lycodes jugoricus*) 441
White Sea Eelpout (*Lycodes marisalbi*) 445
Saddled Eelpout (*Lycodes mucosus*) 449
Wattled Eelpout (*Lycodes palearis*) 453
Polar Eelpout (*Lycodes polaris*) 458
Marbled Eelpout to Banded Gunnel 463
Marbled Eelpout (*Lycodes raridens*) 463
Arctic Eelpout (*Lycodes reticulatus*) 467
Threespot Eelpout (*Lycodes rossi*) 471
Archer Eelpout (*Lycodes sagittarius*) 475
Longear Eelpout (*Lycodes seminudus*) 479
Scalebelly Eelpout (*Lycodes squamiventer*) 483
Estuarine Eelpout (*Lycodes turneri*) 487
Blackline Prickleback (*Acantholumpenus mackayi*) 491
Stout Eelblenny (*Anisarchus medius*) 497
Bearded Warbonnet (*Chirolophis snyderi*) 502
Fourline Snakeblenny (*Eumesogrammus praecisus*) 506
Daubed Shanny (*Leptoclinus maculatus*) 510
Slender Eelblenny (*Lumpenus fabricii*) 515
Snake Prickleback (*Lumpenus sagitta*) 520
Arctic Shanny (*Stichaeus punctatus*) 525
Banded Gunnel (*Pholis fasciata*) 530
Northern Wolffish to Greenland Halibut 534
Northern Wolffish (*Anarhichas denticulatus*) 534
Bering Wolffish (*Anarhichas orientalis*) 538
Prowfish (*Zaprora silenus*) 543
Arctic Sand Lance (*Ammodytes hexapterus*) 548
Bering Flounder (*Hippoglossoides robustus*) 556
Pacific Halibut (*Hippoglossus stenolepis*) 561
Yellowfin Sole (*Limanda aspera*) 569
Longhead Dab (*Limanda proboscidea*) 577
Sakhalin Sole (*Limanda sakhalinensis*) 582
Arctic Flounder (*Liopsetta glacialis*) 586
Starry Flounder (*Platichthys stellatus*) 592
Alaska Plaice (*Pleuronectes quadrituberculatus*) 600
Greenland Halibut (*Reinhardtius hippoglossoides*) 607
Chapter 4. **Synthesis of Arctic Alaska Marine Fish Ecology**
By Lyman K. Thorsteinson and Milton S. Love 617

Contents—Continued

Chapter 5. **Arctic Climate Change—A Tale of Two Cods**
By Deborah A. Reusser, Melanie L. Frazier, Rebecca A. Loiselle, Henry Lee II, and Lyman K. Thorsteinson....659

Chapter 6. **Conservation of Arctic Alaska's Marine Fish Resources**
By Lyman K. Thorsteinson....679

Chapter 7. **Glossary of Ecological Terms**....691

Chapter 8. **References Cited**....699

Appendixes....739

Appendix A. Ongoing and Recently Completed Fishery Studies Funded by Bureau of Ocean Energy Management in Arctic Outer Continental Shelf Lease Areas....739

Appendix B. Age-At-Size and Length-Weight Relationships for Arctic Marine Fishes....741

Appendix C. Models Evaluated for Simulating Effects of Climate Change on the Distributions and Abundances of Arctic Cod and Saffron Cod in the Eastern Bering Sea....763

Conversion Factors

[Inch/Pound to International System of Units]

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)

[International Systems of Units to Inch/Pound]

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Area	
square meter (m^2)	0.0002471	acre
square kilometer (km^2)	247.1	acre
hectare (ha)	0.003861	square mile (mi^2)
square kilometer (km^2)	0.3861	square mile (mi^2)
	Flow rate	
cubic kilometer per year (km^3/yr)	0.000811	acre-foot per year (acre-ft/yr)
kilometer per day (km/d)	0.6214	mile per day (mi/d)
	Mass	
gram (g)	0.03527	ounce, avoirdupois (oz)
kilogram (kg)	2.205	pound avoirdupois (lb)
	Density	
kilogram per hectare (kg/ha)	0.06242	pound per cubic foot (lb/ft^3)
gram carbon per square meter (g C/m^3)	62.4220	pound per cubic foot (lb/ft^3)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F = (1.8 \times °C) + 32.$$

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C = (°F - 32) / 1.8.$$

Datum

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Abbreviations

ACW	Alaska Coastal Water
ADFG	Alaska Department of Fish and Game
AFGP	antifreeze blycoprotein
AFP	antifreeze protein
AFS	American Fisheries Society
AFS-ASIH	American Fisheries Society-American Society of Ichthyologists and Herpetologists
AFSC	Alaska Fisheries Science Center
AI	Aleutian Islands
AIC	Akaike information criterion
AMAP	Arctic Monitoring and Assessment Programme
AO	Arctic Oscillation
AW	Anadyr Water
AOOS	Alaska Ocean Observing System
ArcOD	Arctic Ocean Diversity
BSW	Bering Sea Water
BOEM	Bureau of Ocean Energy Management
C	carbon
Cl^-	chloride
CO_2	carbon dioxide
CoML	Census of Marine Life
CPUE	catch-per-unit-effort
DBO	Distributed Biological Observatory DIDSON. Dual Frequency Identification Sonar
DOI	U.S. Department of the Interior
EBSA	Ecological and Biologically Sensitive Area
eDNA	environmental DNA
EIS	Environmental Impact Statement
EEZ	U.S. Exclusive Economic Zone
EBS	Eastern Bering Sea
EPA	U.S. Environmental Protection Agency
FL	fork length
GAM	Generalized Additive Model
GI	ganodosomal index
GOA	Gulf of Alaska
IARPC	Interagency Arctic Research Policy Commission
IDW	Inverse Distance Weighted interpolation
ITIS	Integrated Taxonomic Information System
LME	large marine ecosystem
M	natural mortality
Ma	million years
MCA	Metabolic Cold Adaptation

Abbreviations—Continued

MMS	Minerals Management Service
Na^+	sodium
NEPA	National Environmental Policy Act
NOAA	National Oceanic and Atmospheric Administration
NPFMC	North Pacific Fisheries Management Council
NPRB	North Pacific Research Board
NSF	National Science Foundation
OA	ocean acidification
OBIS	Ocean Biogeographic Information System
OCS	Outer Continental Shelf
OR1	Online Resource 1
psu	practical salinity unit
RACE	Research Assessment and Conservation Engineering
rm	intrinsic rate of increase
RUSALCA	Russian-American Long-term Census of the Arctic
SDM	species distribution model
SL	standard length
SST	sea surface temperature
T	Trophic Index
TL	total length
tm	age at first maturity
UAF	University of Alaska, Fairbanks
USCGC	U.S. Coast Guard Cutter
USGS	U.S. Geological Survey
VBGM	von Bertalanffy growth model
WFRC	USGS Western Fisheries Research Center
YOY	young-of-the-year

Chapter 1. Alaska Arctic Marine Fish Ecology Catalog—Chukchi and Beaufort Seas

By Lyman K. Thorsteinson[1]

Abstract

The marine fishes in waters of the United States north of the Bering Strait have received new and increased scientific attention over the past decade (2005–15) in conjunction with frontier qualities of the region and societal concerns about the effects of Arctic climate change. Commercial fisheries are negligible in the Chukchi and Beaufort Seas, but many marine species have important traditional and cultural values to Alaska Native residents. Although baseline conditions are rapidly changing, effective decisions about research and monitoring investments must be based on reliable information and plausible future scenarios. For the first time, this synthesis presents a comprehensive evaluation of the marine fish fauna from both seas in a single reference. Although many unknowns and uncertainties remain in the scientific understanding, information presented here is foundational with respect to understanding marine ecosystems and addressing dual missions of the U.S. Department of the Interior for energy development and resource conservation. This chapter describes the Department's information need with respect to planned offshore oil and gas development, provides an overview of the *Alaska Arctic Marine Fish Ecology Catalog*, and presents regional background information, synthesis methodologies, and definitions for commonly used terms and concepts throughout the report.

Introduction

Accurate natural resource inventories and knowledge of baseline conditions for Arctic resources and ecosystems are essential for estimating effects of the U.S. Department of the Interior (DOI) offshore oil and gas-leasing program. The exploration and development of these offshore resources is managed by the DOI Bureau of Ocean Energy Management (BOEM). This document, *Alaska Arctic Marine Fish Ecology Catalog*, addresses a specific need of BOEM to inform its decision making with respect to the fisheries ecosystems in Arctic Outer Continental Shelf (OCS) Planning Areas. This report is a compilation of species accounts of the marine fishes known from United States sectors of the Chukchi and Beaufort Seas. Certain diadromous (for example, Pacific salmon, char, and whitefishes) species are treated as marine fishes (McDowall, 1987) because much of their life cycle is in marine and brackish environments. This synthesis of information is meant to provide current information and understanding of this fauna and its relative vulnerability to changing Arctic conditions.

The National Environmental Policy Act (NEPA) requires the BOEM to prepare an Environmental Impact Statement (EIS) for each offshore oil and gas lease sale area offered through the DOI leasing program. The EISs provide an assessment of the potential environmental effects associated with major development proposals and communicate this information to decision-makers and the broader public (Wood, 2008). In complying with the NEPA, the BOEM relies on the best available science to evaluate potential effects on regional ecosystems and living resources. Our objectives were to review and synthesize current fish biology, ecology, and fisheries information to assist BOEM's NEPA analysts in assessing environmental effects from planned future offshore oil and gas development on the Arctic OCS.

BOEM's NEPA analysts require detailed information about the biodiversity, life history, and population ecology of regional biota to assess adversity of impact in the EIS process. For Arctic marine fishes, impact is evaluated in terms of potential declines in abundance or changes in geographic distribution and recovery of populations to pre-impact status (thresholds of significance analysis, see Miner and Rivasplata, 1994, and Musick, 1999). To illustrate, adverse effects would require three of more generations for a population to recover (Bureau of Ocean Energy Management Regulation and Enforcement, 2011). The population understanding required for a robust EIS analysis is similar to what is required to assess Essential Fish Habitat under provisions of the Magnuson-Stevens Fishery Conservation and Management Act.

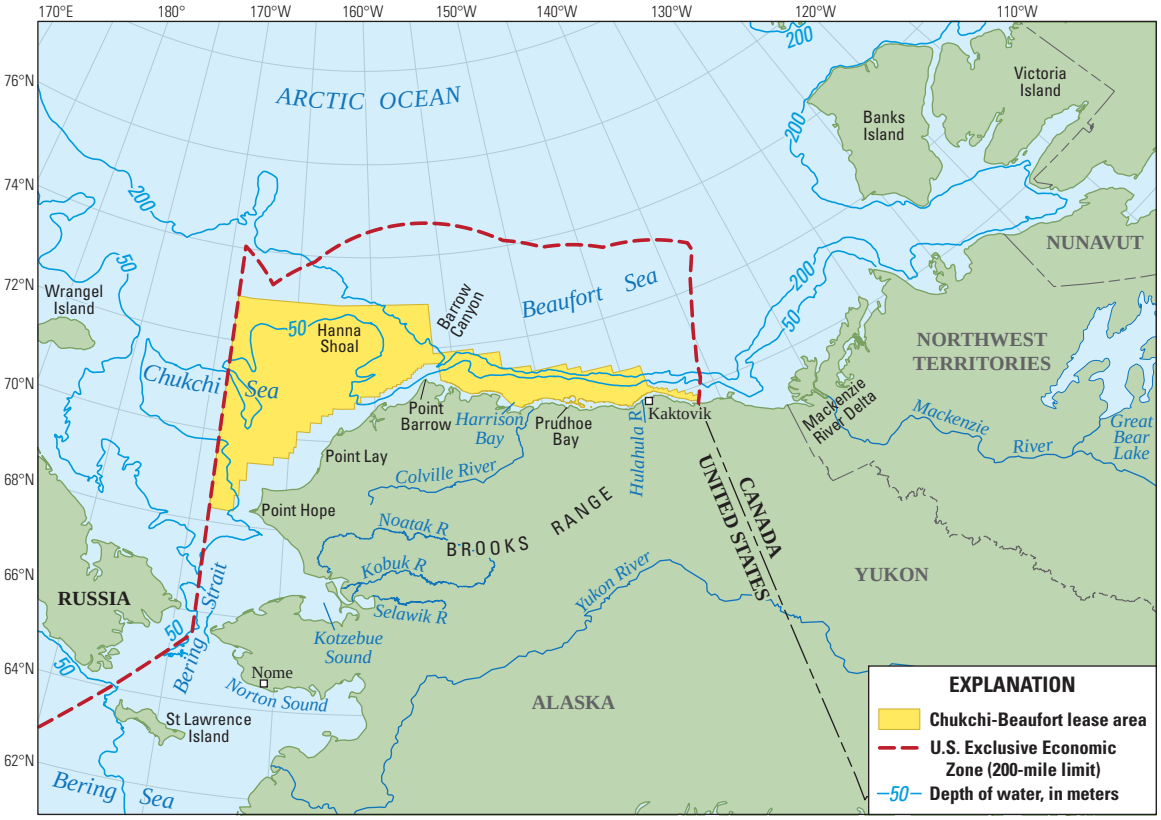
[1]U.S. Geological Survey.

The compilation of species information provides BOEM's NEPA analysts and others with a single, authoritative scientific reference about the biology and ecology of marine fishes in the United States Chukchi and Beaufort Seas. Biodiversity is broadly assessed with respect to current understanding of (1) classification and taxonomy, (2) abundance and geographic distribution, and (3) life history and population ecology. A focus of this study has been on new information and discoveries about this fauna since the publication of *Fishes of Alaska* (Mecklenburg and others, 2002). As such, the species checklist, geographic distribution maps, and depth profiles represent new biodiversity products to science. This synthesis is unique because it is based on confirmed species occurrences in United States sectors of the Chukchi and Beaufort Seas. Confirmation is an important process because it assures the reliability of resource information in management areas of direct concern to decision makers. For most species, the link between occurrence and abundance remains tenuous given the nature of sampling conducted to date. As such, quantitative aspects of the dynamics of fish populations and their interactions with the Arctic marine environment are hindered by inadequacies of existing data and relative lack of Alaskan records. The emphasis on population dynamics and ecologic relationships in the species accounts provides an important basis for assessment of outstanding needs.

Although knowledge about the marine fish fauna in the Alaska Arctic is among the poorest in the state, it has been slowly improving over time. However, much life history information presented in this report was acquired from scientific observations outside Alaska. As such, basic taxonomic science and population understanding is needed to support modern assessments and potential fisheries in the Arctic high seas. The goals of this report are to present the most current information about what is known about the marine fishes in the Arctic area of the United States with a special focus on geographic distributions, vertical structure, abundance, and life history parameters of key populations. The section, "Outline of Species Accounts" in chapter 3 serves as a users' guide to information presented in the individual species descriptions.

Study Area

The primary geographical boundaries encompass Arctic OCS Planning Areas (Bureau of Ocean Energy Management (2012) in the U.S. Chukchi and Beaufort Seas (hereafter Chukchi and Beaufort Seas, fig. 1.1) and the U.S. Exclusive Economic Zone (EEZ) including the Arctic Management Area. The eastern boundary of the Beaufort Sea EEZ extends to the north and offshore of the Alaska-Canada Border. The Chukchi Sea extends from Point Barrow in Alaska and the Beaufort Sea in the east to the United States–Russia Maritime Boundary in the west. The Bering Strait forms the southern boundary of the Chukchi Sea. Some chapters, especially those addressing species descriptions (chapter 3) and discussing species diversity and possible geographic origins (chapter 4), include comparative information from adjacent seas and broader basin and ocean considerations, respectively.



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.

Figure 1.1. Bureau of Ocean Energy Management administrative boundaries for Outer Continental Shelf oil and gas leasing in the Chukchi and Beaufort Seas, Alaska.

Environmental Setting

Physical and biological components of the Arctic marine environment as they relate to marine regional descriptions of fish habitats and their use by fish and other biota were described by DeGange and Thorsteinson (2011)[2]. The descriptions of physical oceanography, substrates, and biological productivity supporting marine fish habitats and populations are primarily based on this review. Information about the distribution of Arctic marine birds and mammals, potential competitors and predators of marine fishes, is not reported here but is available in DeGange and Thorsteinson (2011).

Regional Oceanography

Large-scale features of the Chukchi and Beaufort Seas oceanography were reviewed by Weingartner and others (2008). Surface circulation in the Beaufort Sea is dominated by the southern edge of the perpetual clockwise Beaufort Gyre of the Canadian Basin (fig. 1.2). The subsurface Beaufort Undercurrent Atlantic water masses and flows in the opposite direction, to the east, over the shelf (fig. 1.2). Bering Sea waters generally follow topography, moving north across the Chukchi Sea shelf and to the east over the shelf edge and slope (fig. 1.2). Currents in the shallower waters of the inner Beaufort Sea Shelf (fig. 1.2) primarily are wind driven and, thus, can flow either east or west. Because the predominant wind direction during the summer ice-free season is from the east, near-shore flow generally is from east to west.

Oceanographers have observed regional, seasonal, and interannual variability in water mass properties in the Chukchi and Beaufort Seas. Generally, the temperature and salinity characteristics of the major water masses are:

- Alaska Coastal Water—warm (2–13 °C), low salinity (to 32.2 practical salinity units [psu]);
- Bering Sea Water—warm (>0.0 °C); well-mixed and moderate salinity (about 32.5 psu;
- Anadyr Water—cold (<0.0 °C), marine salinities (32.8–33.2 psu);
- Siberian coastal waters—cold (<0.0 °C), low salinity (24 psu);
- Atlantic Water (at depths > 220 m)—warm (>0 °C), highly salinity (>34 psu); and
- Beaufort Gyre—cold (<0.0 °C), moderate to high salinity (31–34 psu).

In the Chukchi Sea, the summer water masses are cold in the east and warm in the west. Similarly, warm brackish waters (5–10 °C, <15 psu) occur adjacent to Alaska's north coast during summer (to about 10 km off the coast) and cold marine waters (<1 °C, 28 psu) farther offshore.

Under persistent east winds, bottom marine water can move onshore, where it is forced to the surface. This upwelling of marine water can cause some otherwise brackish and warm areas along the coast to become colder and more saline. This replacement of brackish with marine waters results in the transport of warmer, less saline waters offshore.

The Chukchi Sea receives water that flows northward through the Bering Strait, driven by the 0.5 m drop in sea level between the Aleutian Basin of the Bering Sea and the Arctic Ocean (fig. 1.2). Coachman and others (1975) provide a good overview of the northward movement of Bering Sea waters into the Chukchi Sea. Three distinct water masses, each of different origin, move northward through the Bering Strait. Anadyr Water, cold, high salinity, nutrient-laden oceanic water that originates along the slope of the Bering Sea Shelf, flows northward through Anadyr Strait, west of St. Lawrence Island and into the central Chukchi Sea (fig. 1.2). As much as 72 percent of the water transported through the Bering Strait in the summer may come through Anadyr Strait. Alaska Coastal Water originates in the Gulf of Alaska. This low salinity, seasonally warm water hugs the Alaska coast as it transits the Bering Sea into the Chukchi Sea. Alaska Coastal Water is influenced by freshwater run-off from major rivers in western Alaska. Bering Shelf Water is the resident water mass of the central shelf region south of St. Lawrence Island. This water mass is intermediate with respect to its hydrographic properties when compared to Anadyr Water and Alaska Coastal Water, is advected northward on both sides of St. Lawrence Island, and then flows through the Bering Strait where it mixes with the other water masses. These waters are an important source of plankton and carbon in the Chukchi and Beaufort Seas, and influence the seasonal distribution and abundance of marine biota and migration behaviors of many species (Piatt and Springer, 2003; Hopcroft and others, 2008; Weingartner and others, 2008; Crawford and others, 2012). The deep waters offshore in the northern Chukchi Sea also are a potentially important source of nutrient-rich waters.

[2]This review of large-scale physical oceanography was guided by DeGange and Thorsteinson (2011) who presented information previously reported in Minerals Management Service (2008) and Weingartner and others (2008). The summaries of primary and secondary levels of ecosystem production are from Bluhm and others (2008), Hopcroft and others (2008), Stockwell and others (2008), and Yager and others (2008). Other key references included Carmack and Wassmann (2006); Grebmeier and Maslowski, 2014; Moore and Stabeno, 2015; and Grebmeier and others (2015).

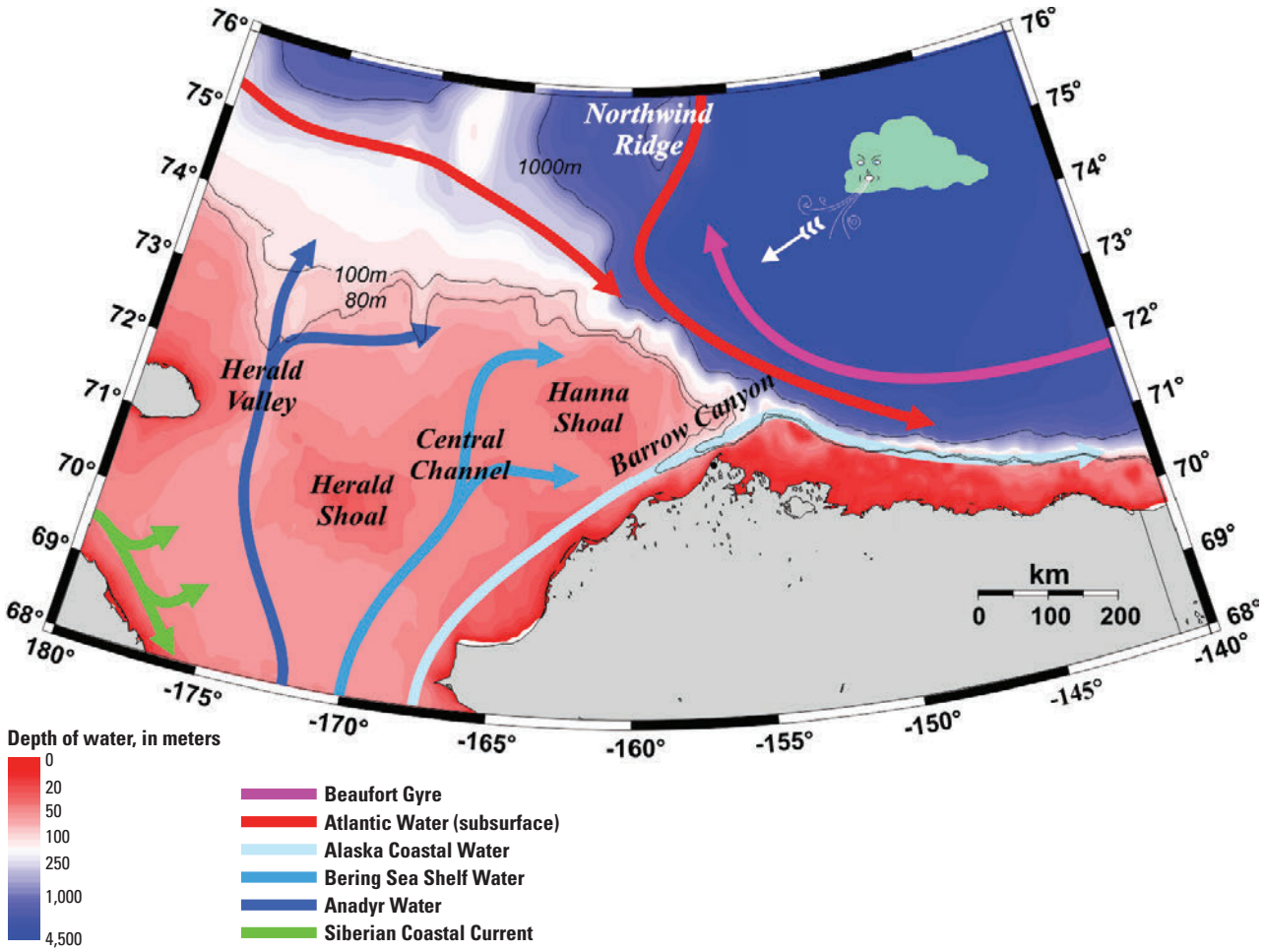


Figure 1.2. Schematic circulation map of the northern Chukchi Sea and western Beaufort Sea. From Weingartner and others (2008).

Bering Sea Cold Pool

Mecklenburg and others (2011) described the boundaries of an "*arctic region*" to include the Arctic Ocean and its seas and adjacent waters of the North Atlantic and North Pacific southward to an ichthyofaunal boundary (Arctic–Boreal species in chapter 2). Mecklenburg and others (2011, p. 110) reported that, "*...position of the boundary is reflected in major differences in species composition associated with seafloor topography, such as sills and canyons, and water characteristics, such as temperature and salinity, that form barriers against fish movements.*" In the northern Bering Sea, the location of the 2 °C isotherm during summer months, generally south of St. Lawrence Island, demarks this zoogeographic boundary and the northern edge, or ecotone, of marine waters associated with the Bering Sea cold pool (bottom temperatures ≤ 2 °C) that relates to the seasonal presence of sea ice (see chapters 4 and 5).

Sea Ice Dynamics

The presence of ice in the Arctic is one of the most important physical conditions to deal with for developing offshore OCS oil and gas resources. The seasonal sea ice cycle is a pervasive force in the Arctic, influences human activities and many aspects of the region's natural history, and demonstrates great seasonal and inter-annual variability off the coast of Alaska. Generally, there are two forms of sea ice: fast ice that is anchored along the shore and free-floating pack ice that moves with winds and currents. Shore fast and pack ice interact to cause an extensive, somewhat predictable, system of flaw leads (swathes of open water in between ice) and polynyas off the coasts of the Chukchi and Beaufort Seas eastward to the Canadian Archipelago. These flaw leads and polynyas become more prevalent in spring and are biologically significant features with respect to the timing and location of seasonal movements and northward migrations of wildlife species, such as bowhead whales and marine birds.

Maximum sea-ice cover occurs in March or early April, lagging minimum insolation in late December by 3 months because of the heat capacity of the ocean and the cold atmosphere. During these months, essentially all of the Beaufort and Chukchi Seas are ice-covered (fig. 1.3). Winter ice extent in the Arctic has decreased since the late 1970s (fig. 1.3) along the southern margins of sea-ice extent, but not severely (fig. 1.4). Maximum retreat of the sea ice occurs in September, again lagging maximum insolation by about 3 months. The extent of sea-ice loss in Septembers since the satellite record began has been remarkable (fig. 1.5). By September, in normal years, the ice pulls away from the Arctic coasts of Canada, Alaska, and Siberia, leaving a nearly continuous, relatively ice-free corridor that varies in width around the permanent ice pack. In recent years (2010–15), the ice-free corridor has expanded to hundreds of kilometers in the East Siberian Sea and offshore of the northern Alaska coast. The contrasts between 1980, a representative year with extensive ice cover, and 1987, when sea-ice extent in the Arctic was at a record minimum, and the long-term median ice edge are evident (fig. 1.5).

In addition to decreases in sea-ice extent during late summer and autumn, the amount of multi-year compared with summer sea ice in the Arctic also is changing; conditions are moving toward an abundance of younger and thinner sea ice (figs. 1.3–1.6). The longer sea ice remains in the Arctic Ocean the thicker it becomes because of additional freezing and deformation. The thinning of Arctic Ocean sea ice has occurred largely because of the export of older, thicker sea ice out of the Arctic through Fram Strait, east of Greenland. This is important because young, thin ice is more vulnerable to the melting that results from warm air and water temperatures, perpetuating a feedback cycle because the open ocean absorbs solar insolation.

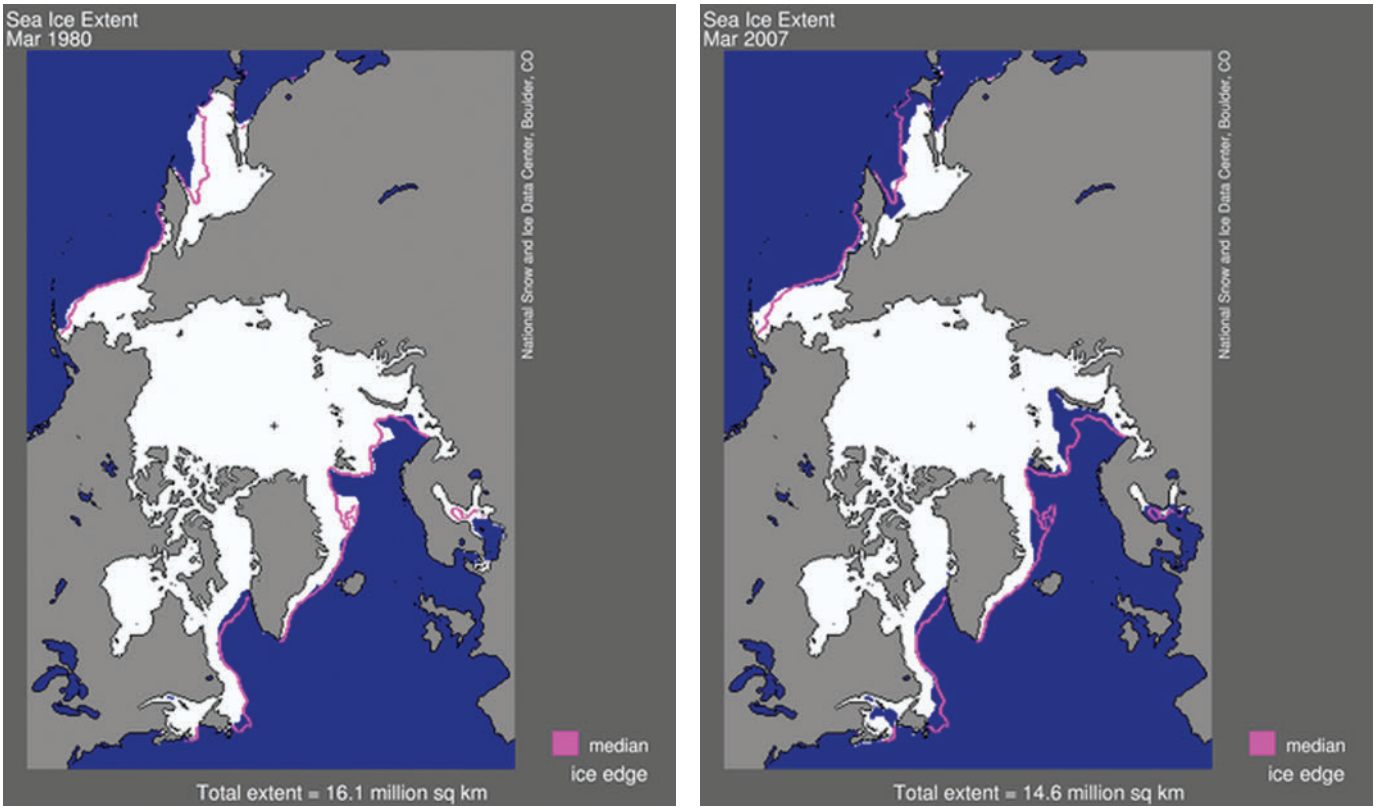


Figure 1.3. Extent of sea ice for single months and single years, using 1980 as an example of an extensive ice cover year, and 2007 as the record minimum year—maximum winter extent. The border plots the long-term median ice edge based on data from 1979 to 2000. From National Snow and Ice Data Center, 2011a, monthly sea ice extent for 1980 and 2007: National Snow and Ice Data Center database, accessed April 15, 2011, at http://nsidc.org/.

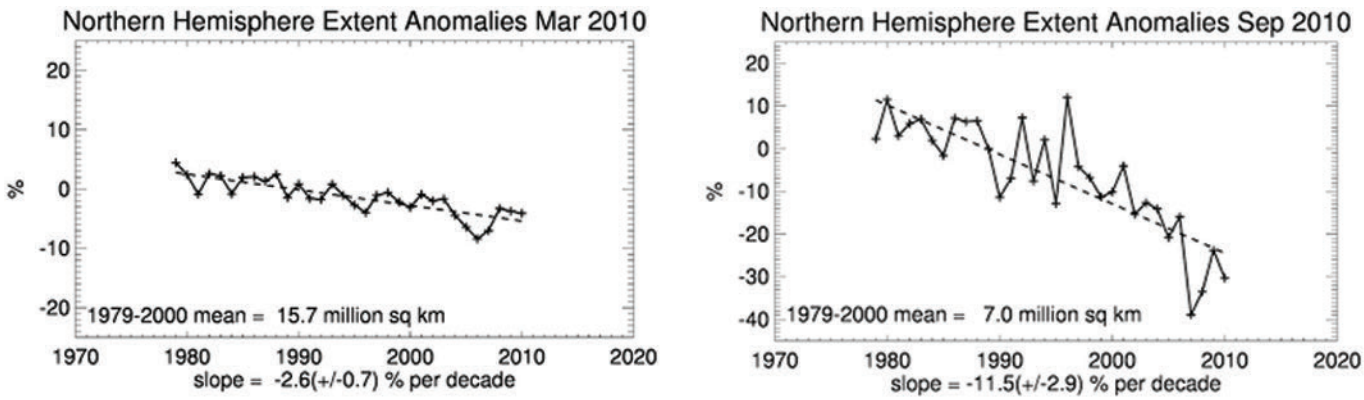


Figure 1.4. Sea-ice extent anomalies for March (maximum sea-ice extent) and September (minimal sea-ice extent) expressed as percentage-departure from average (that is, anomalies as compared to the 1979–2000 mean). From National Snow and Ice Data Center (2011b).

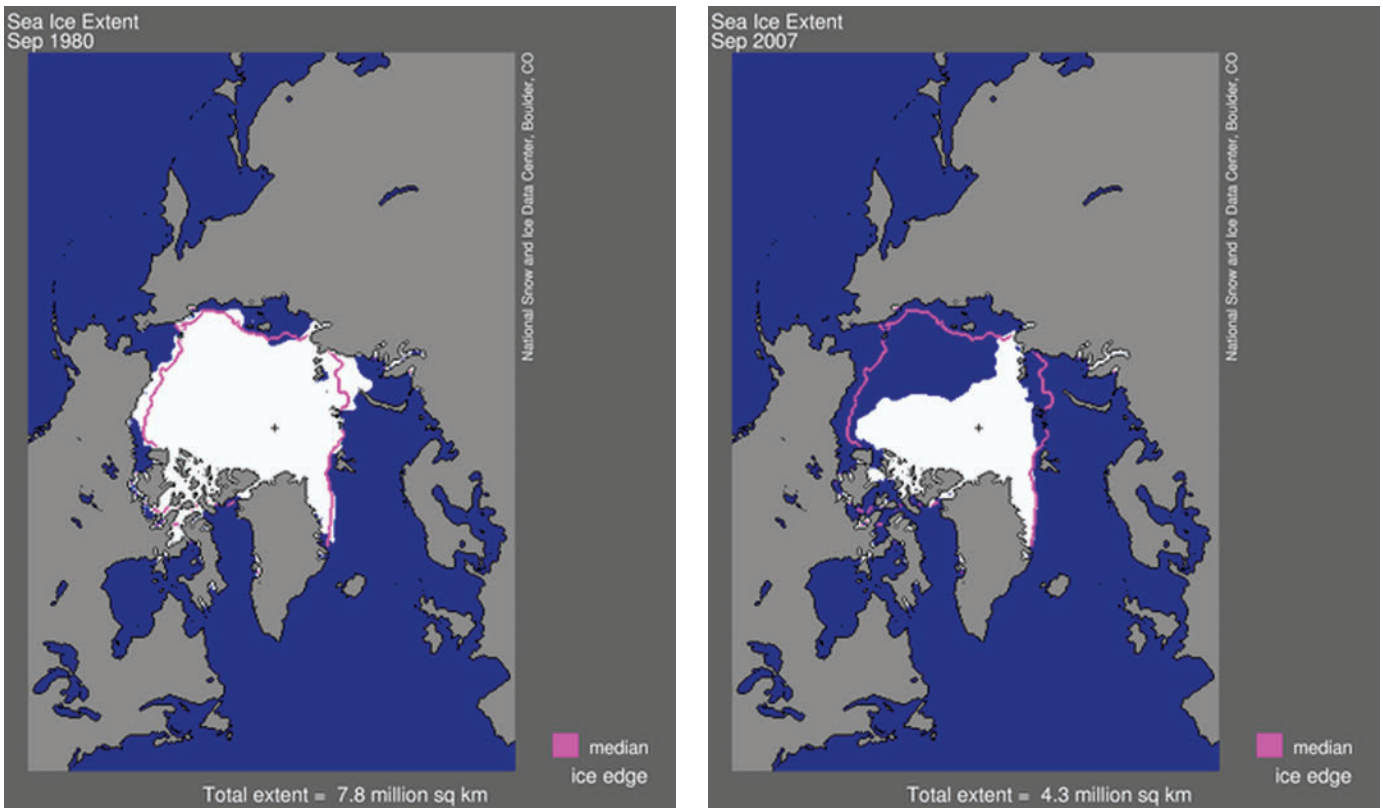


Figure 1.5. Extent of sea ice for single months and single years, using 1980 as an example of an extensive ice cover year, and 2007 as the record minimum year. The border plots the long-term median ice edge based on data from 1979 to 2000. Source: National Snow and Ice Data Center (2011a).

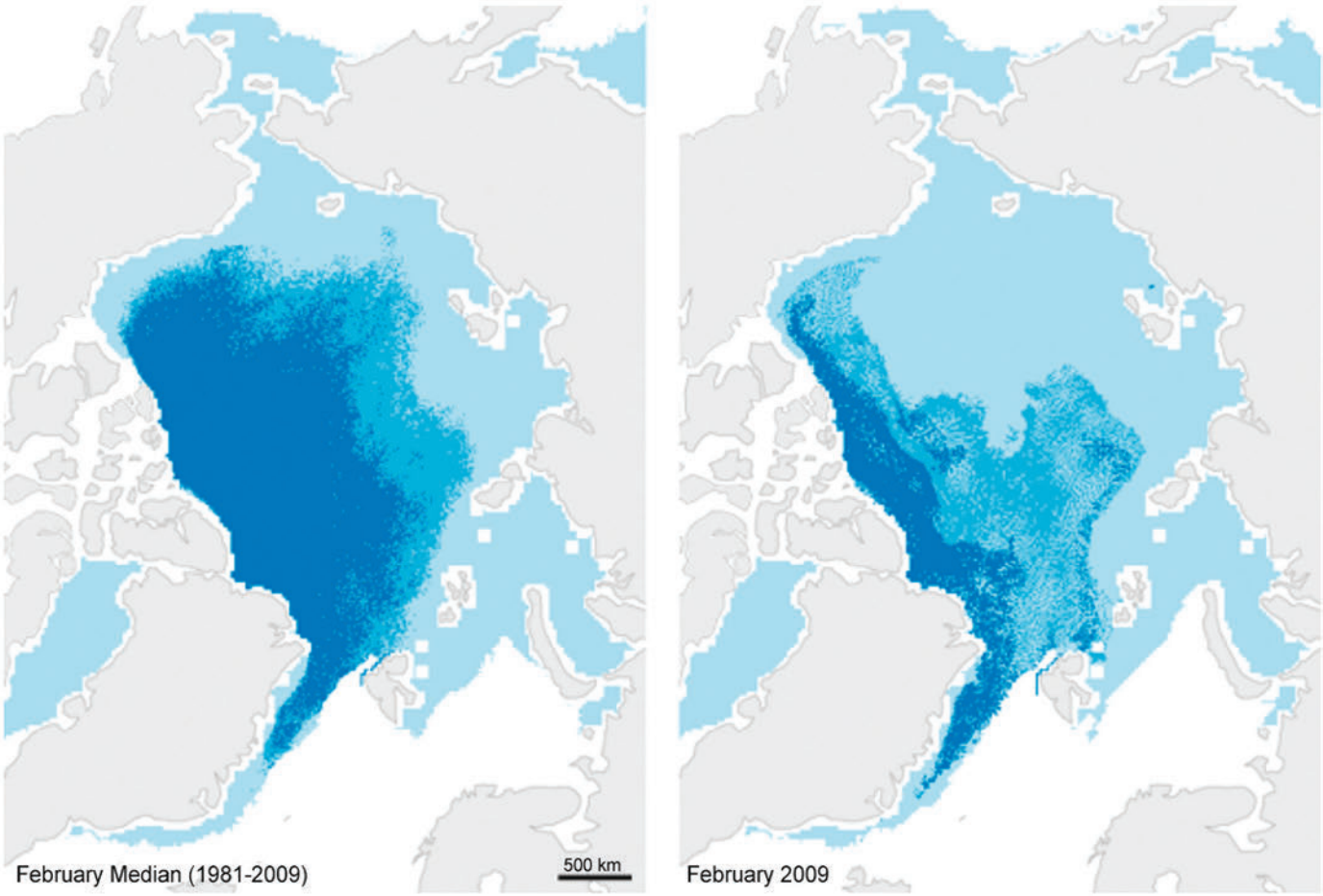


Figure 1.6. Old and new ice in the Arctic for February. These maps show the median age of February sea ice from (*A*) 1981 to 2009 and (*B*) February 2009. As of February 2009, ice older than 2 years accounted for less than 10 percent of the ice cover. Dark blue indicates ice greater than 2 years old; medium blue indicates 2-year-old ice; pale blue indicates annual ice. From National Snow and Ice Data Center (2011c), accessed April 15, 2011, at http://nsidc.org/sotc/sea_ice.html.

Seafloor Substrates

Soft sediments dominate the sea floors of the continental shelves of the Beaufort and Chukchi Seas. These are largely combinations of muds, sands, and gravels (fig. 1.7). These soft-sediment bottoms support high densities and biomass of benthic invertebrates, particularly in the extensive shallow shelf areas of the Chukchi Sea where productivity is high (for example, Hanna Shoal and Barrow Canyon [fig. 1.1]). Only two areas with hard substrates have been identified in the entire region (Smith, 2010) (fig. 1.7)—one in Peard Bay, southwest of Barrow, and the other in Steffanson Sound near Prudhoe Bay that is known as the "boulder patch" (Dunton and others, 1982). The boulder patch is characterized as sediment with greater than 10 percent boulder cover. It provides attachment habitat for the endemic kelp *Laminaria solidungula* and other macroalgae, which are the primary carbon source for consumers living there.

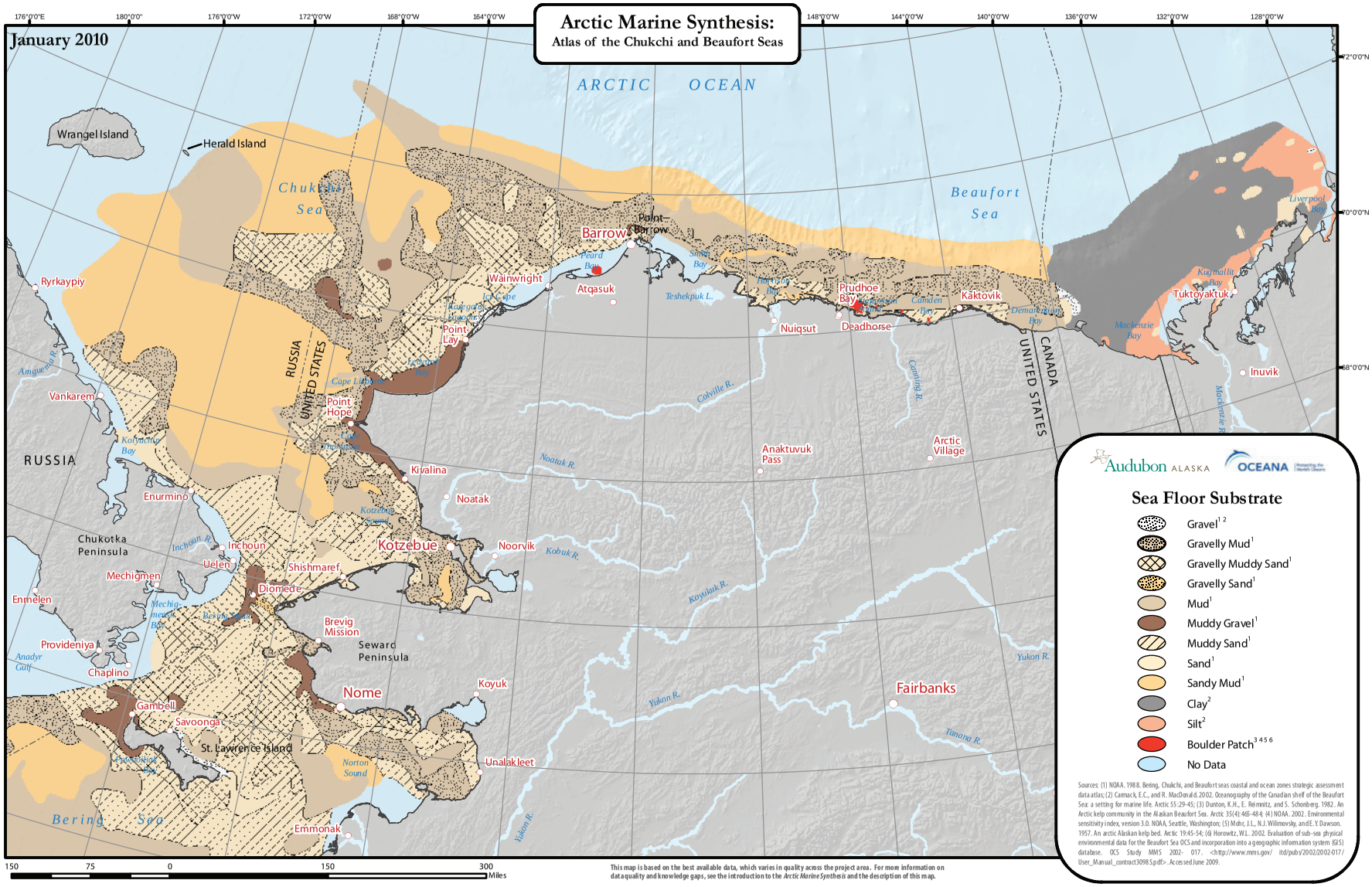


Figure 1.7. Seafloor substrates of the Alaska Beaufort and Chukchi Seas. From Smith (2010).

Benthos

Benthic food supply originates in surface waters and is highly seasonal in the Arctic. Densities of sediment particles and their nutritional values range vastly from the nutrient rich waters of the northern Bering and Chukchi Seas to the oligotrophic deep waters of the Arctic Basins. Less is known about the benthos from the Beaufort Sea although preliminary data from ongoing BOEM surveys suggest there is much less biomass and diversity, and that different ecological processes occur (appendix A). Generally, however, comparisons of energy fluxes show that the benthic systems receive more energy in the Arctic than from temperate and tropical systems.

Much of the broad, shallow shelf of the Chukchi Sea is strongly influenced by northward flowing nutrient-rich Pacific Ocean water through the Bering Strait, resulting in high benthic biomass, which is among the highest worldwide in soft-sediment macrofaunal communities (for example, Grebmeier and Maslowski, 2014; fig. 1.8). Specifically, the south-central Chukchi Sea has the highest algal and faunal biomass on the combined Bering Sea and Chukchi Sea shelf because of the high settlement rates of organic production that is not grazed by microbes and zooplankton. These rich benthic communities, tied to high pelagic production and advection, serve as prey for various diving sea birds and marine mammals, a key feature of the productive Chukchi Sea. About 1,200 species are known from the Chukchi Sea fauna to date with amphipods, clams, and polychaetes dominating infaunal community. Important macrofauna prey species for higher trophics include bivalves taken by walrus, in particular *Macoma* spp. and *Mya truncata*, and benthic amphipods used by gray whales and bearded seals. Within the epifauna, ophiuroids dominate abundance and biomass in much of the surveyed Chukchi Sea, and other patchily distributed echinoderms (especially asteroids), gastropods, ascidians, sponges, cnidarians, and bryozoans are locally abundant.

The comparatively narrow Beaufort Sea Shelf is influenced by large freshwater inflow from numerous small rivers and streams, the larger Colville and Mackenzie Rivers (fig. 1.1), and permafrost resulting in estuarine conditions in the nearshore. Because of this freshwater flow, non-marine sources of carbon may play an increasingly important role for the benthic food web in parts of the nearshore Beaufort Sea. The Beaufort Sea floor is dominated by soft sediments (fig. 1.7), but high ice cover and associated scouring, along with glacial erratics, have left coarser sediments (gravel and boulders) in various areas of the Beaufort Sea. The Alaskan part of the Beaufort Sea coast is fringed by sandy barrier islands forming numerous shallow lagoons with average depths less than 5 m and ecological traits different from those in the open water. Compared to the Chukchi Sea, productivity and benthic biomass in the Alaskan Beaufort Sea are dramatically lower. Consequently, benthic-pelagic coupling is not as pronounced as in the Chukchi Sea and food chains are shorter. Much less is known about the slopes of the Chukchi Sea and especially the Beaufort Sea, and the adjacent basins (Bluhm and others, 2008). The existing investigations of the slopes and abyssal infaunal benthos in the western Arctic revealed low abundances and biomass values relative to the shelves, especially with increasing water depth and distance from the shelves. At taxonomic levels of phylum and orders, the soft-bottom deep Arctic macrofauna appear to be similar to the shelf communities: polychaetes, bivalves, and crustaceans are dominant, but on a family, genus, and species level, inventories differ from the shelves.

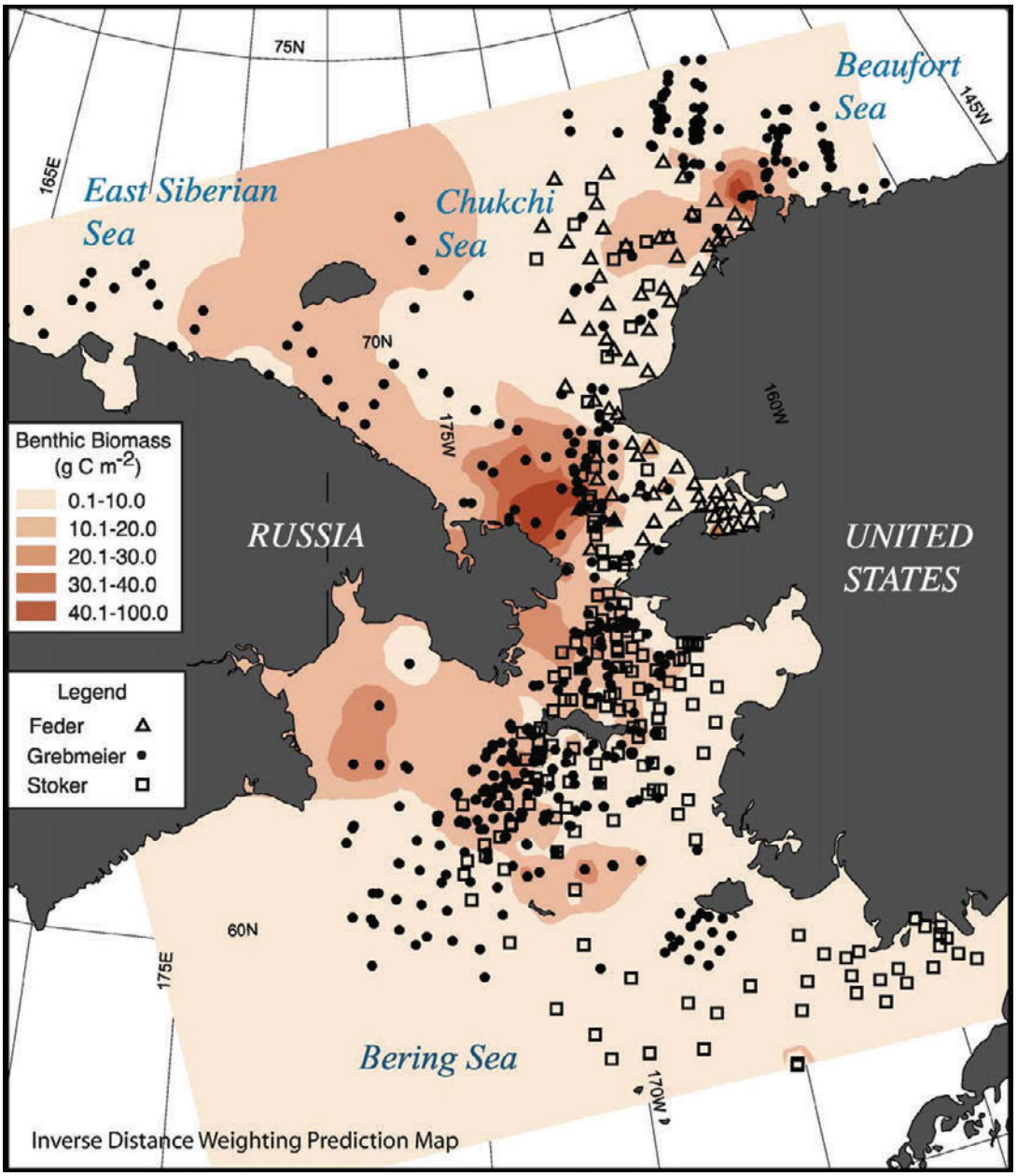


Figure 1.8. Benthic biomass distribution in the Chukchi and northern Bering Seas. From Grebmeier and others, 2006a. Feder and Stoker station locations reference historical sampling stations by University of Alaska-Fairbanks researchers in the Bering and Chukchi Seas as part of NOAA's Outer Continental Shelf Environmental Assessment Program. (g C m^{-2}, grams of carbon per square meter.)

Primary and Secondary Production

In the Arctic, the combination of cold temperature, the occurrence of sea ice, and the extreme seasonal variations in light regimes controls phytoplankton growth and governs its spatial and temporal growth patterns. The stabilizing effect of sea ice allows production to occur near the surface under low light intensities. A large number of planktonic algae thrive in Arctic waters, but there seem to be relatively few truly Arctic species. Estimates of phytoplankton biomass vary widely depending on the region, with the highest amounts in the Chukchi Sea. Algal production and biomass in the Arctic primarily are controlled by light, stratification, and nutrient fields. On the shelves, advection and turbulent mixing of nutrients through the Bering Strait and local nutrient remineralization sustain extremely high primary production values on the Chukchi Sea Shelf (fig. 1.9). Much of the production is not grazed, falls to the sea floor, and fuels benthic communities. In addition to phytoplankton, ice algae contribute to the total primary production of the Arctic Ocean with higher production values in first-year ice compared to multi-year ice. The contributions of ice algae to total primary production range from less than 1 percent in coastal regions to as much as 60 percent in the central Arctic Ocean.

Secondary producers include the microbes, protists, and zooplankton that consume phytoplankton and algae. Compared to phytoplankton and mesozooplankton, much less is known about the composition, distribution, and rates of activity of microbes and protists in the Arctic Ocean, and this confounds the ability to estimate the effect of climate change or other disturbances on food webs and basic biogeochemical processes. Biomass of heterotrophic microbes in Arctic surface waters shows a strong response to seasonal changes in phytoplankton stocks. In the Chukchi Sea, concentrations of bacteria are low in spring, increase over the course of the bloom, and are highest in late summer. Heterotrophic protists include nanoflagellates, ciliates, and dinoflagella.

Recent work in the Gulf of Alaska, the Bering Sea, and shelf and slope regions of the western Arctic Ocean has confirmed the role of these organisms, known as microzooplankton, as consumers of phytoplankton in sub-Arctic and Arctic food webs. Although it is likely that phytoplankton and sea ice algae still represent a crucial food source for the larger zooplankton, use of microzooplankton as food is recognized as being of similar import, particularly during periods when phytoplankton standing stock is low or of poor quality. Because strong local pulses of primary production are a frequent characteristic of high-latitude oceans, including the Chukchi and Beaufort Seas, the response of microbes (including both bacteria and protists) to these pulses determines the rate of remineralization and the fraction of total production exported to the benthos. Weak microbial activity in the Arctic contributes to the high degree of bentho-pelagic coupling in many shelf regions of the Arctic and the consequent strength of demersal ecosystems.

Zooplanktons are the major grazers of the primary production in the Arctic and determine the resources available to many higher trophic levels, such as fishes, seabirds, and marine mammals. In the Chukchi Sea, large quantities of Pacific zooplankton enter the region through the Bering Strait, in a complicated mixture of water masses. The influx of the rich Pacific water determines the reproductive success of both the imported and resident zooplankton communities. Both inter-annual and long-term variation in climate will affect the relative transport of these various water masses and hence the composition, distribution, standing stock, and production of zooplankton and their predators in the Chukchi Sea. Zooplankton abundance and community structure also affect the amount and quality of carbon exported to the benthic communities in this region. In contrast, the Beaufort Sea primarily is Arctic in character, with cross-shelf exchange mechanisms more important in determining the relative contribution of “oceanic,” “shelf,” and “estuarine” species. In the Eastern Beaufort Sea, the outflow of the McKenzie River has significant effect on both the composition of the zooplankton and its productivity. Thus, the Beaufort Sea is responding to a fundamentally different set of factors than the Chukchi Sea, even if they are both driven by similar climate-related variations and trends.

Although copepods typically predominate throughout the Arctic, there is a broad assemblage of other planktonic groups. Euphausiids are less abundant and diverse in Arctic waters than elsewhere, but can be important prey for higher trophic levels such as bowhead whales, birds, and fishes. Larvaceans (Appendicularians) have been shown to be abundant in Arctic polynyas, and are transported in high numbers through the Bering Strait into the Chukchi Sea. Similarly, important and common predatory groups, such as the chaetognaths, amphipods, ctenophores, and cnidarians have been reported on in detail by only a few surveys. Hyperiid amphipods also can be common in Arctic waters and, like chaetognaths, have a potential to graze a large proportion of the *Calanus* population. Relatively little is known of the abundance, composition, or ecology of the delicate gelatinous zooplankton, such as jellyfish. There are indications that climate change has resulted in increased numbers of jellyfish in the Bering Sea in recent years. Scientists have recorded jellyfish piled up several feet deep along shorelines near Barrow, Alaska. The ecological effect of these predators is substantial and underestimated in polar waters.

The ongoing reduction of the sea-ice cover will have major effects on the ecosystems and biogeochemical fluxes on the extensive continental shelves of the Arctic Ocean. Many processes involved in the regulation of the vertical and trophic fluxes of particulate organic carbon, and the production of dissolved organic carbon, are controlled by the zooplankton. Knowledge of zooplankton community ecology, especially the temporal and spatial distribution patterns of the different classes of zooplankton, is needed to understand the role of sea-ice variability in dictating fluxes of biogenic carbon on and off the shelves.

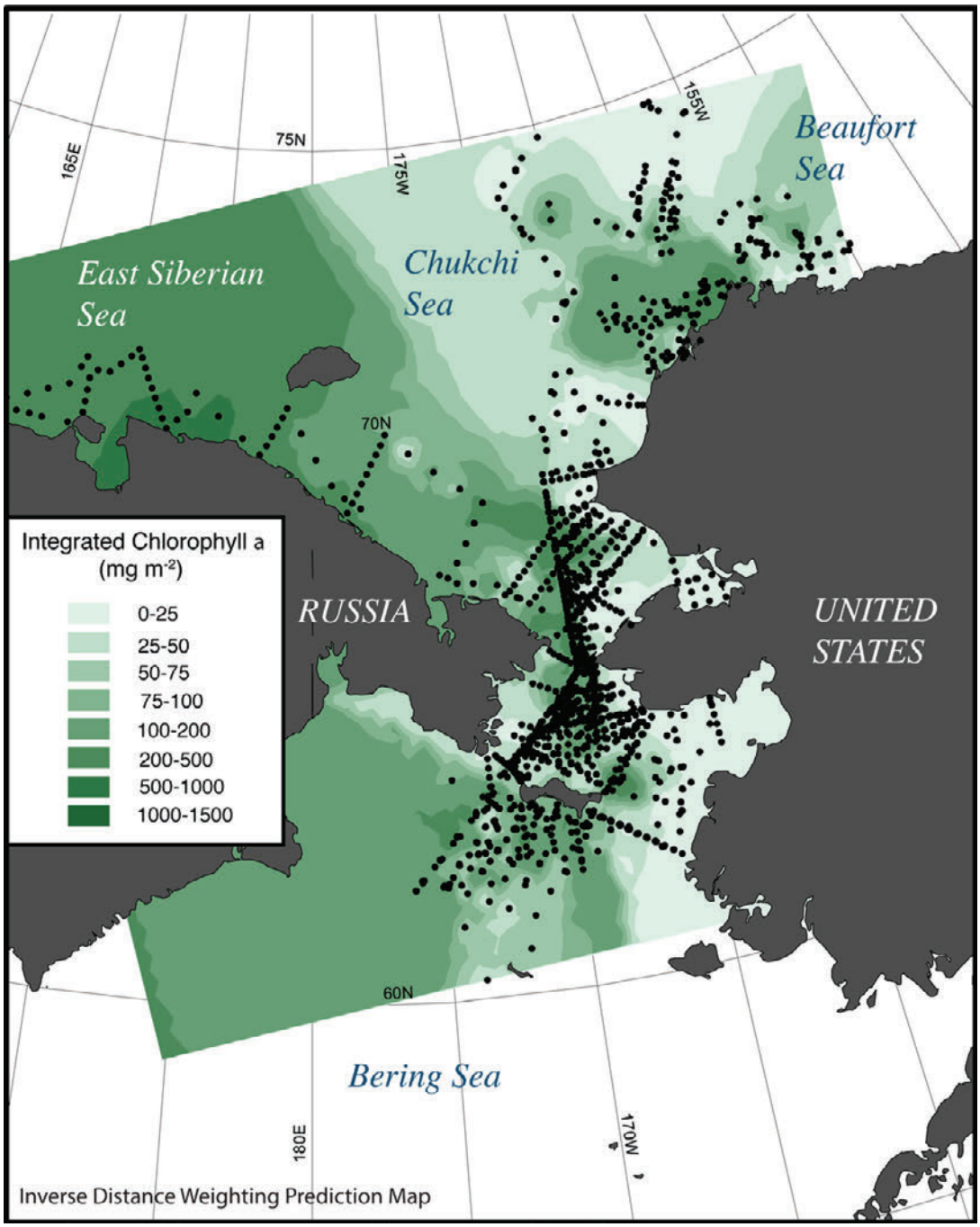


Figure 1.9. Contours of integrated chlorophyll *a* concentrations, in milligrams per square meter [mg m^{-2}]) based on discrete measurements at sampling locations in the northern Bering Sea, east Siberian Sea, and Chukchi and Beaufort Seas, April–September 1976–2004 (Grebmeier and others, 2006a).

Environmental Context Within the Pacific Arctic Region

The information summarized in the section, "Environmental Setting" focused on the United States Chukchi and Beaufort Seas, and included relevant physical and biological information from the Pacific Arctic Region. The description of the Pacific Arctic Region includes the northern Bering Sea, Chukchi and Beaufort Seas, East Siberian Sea, and western sectors of the Canadian Arctic Archipelago (for example, Grebmeier and others, 2015). Regional information, from data collections outside the United States, was included because large scale understanding of physical and biological processes (for example, the delineation of boundaries for the Arctic Large Marine Ecosystem [Protection of the Arctic Marine Environment, 2013] evaluates interactions and connections at scales of the northeast Pacific and Arctic Ocean) is needed to address historical and ecological biogeography objectives of this study (chapter 4). Additional focus and synthesis on the environmental features of the Pacific Arctic Region address scale issues by drawing special attention to the importance of shelf geography and advection on regional ecology (this chapter) as it pertains to marine fish distributional patterns described in chapters 3 and 4.

Geographic relations between advection, sea ice, and stratification properties were reviewed by Carmack and Wassmann (2006) to classify shelf typologies and compare regional connections between physical habitats and biota in Arctic seas. Inflow, interior, and outflow shelves were described for the Pacific Arctic Region and collectively these shelf types were estimated to cover 2,145 × 10^3 km^2 or approximately 35 percent of the entire shelf area of the Arctic Ocean (6,048 × 10^3 km^2). Continental shelf area is greatest in the East Siberian Sea (16 percent of total Arctic Ocean shelf area) followed by the Chukchi Sea (10 percent), Beaufort Sea (3 percent), and Canadian Arctic Archipelago (about 2 percent). The total volume of seawater over Arctic shelves is 829 × 10^3 km^3 of which 7 percent is associated with the East Siberian Sea, 6 percent the Chukchi Sea, about 4–5 percent in the Canadian Arctic Archipelago, and 3 percent the Beaufort Sea.

The northern Bering/Chukchi Sea is a shallow inflow shelf (mean depth = 58 m) as the transport of Pacific water through the Bering Strait connects Pacific and Arctic Oceans (S ~ 32 psu, V_T ~ 1 Sv) (fig. 1.2; salinity and annual mean volume as reported by Woodgate and others, 2015). As these waters flow across the Chukchi shelf they are responsive to atmospheric forcing and are strongly modified by geophysical and physical processes before their subduction along the break and upper slope. Freshwater transport from rivers, ice (primarily first year ice), and stratified waters of the Bering Sea is significant and supports strong seasonal stratification and high primary productivity in the Chukchi Sea. The Bering Sea inflows, especially from upwelled deep waters, are rich in nutrients and biogenic materials such as phytoplankton, zooplankton, and meroplankton. Large herbivores are not abundant in the zooplankton community overlying shelf waters and the grazing efficiency is low. The advection of freshwater and suspended organic matter combined with high primary production and inefficient cropping over shallow depths results in tight pelagic-benthic coupling and high standing stocks of benthic communities (Renaud and others, 2008). As a consequence of the large vertical flux of locally and advected carbon, the Chukchi shelf (and southwestern Beaufort Sea) are also the site of substantial denitrification and high benthic biomass in offshore areas compared to the more river-influenced central and eastern Beaufort Sea. Benthic ecosystems and short food chains are adaptations to the fluxes and cycling of carbon as evidenced in the composition and life history traits of the benthos and seasonal migrations of large numbers of benthic feeding animals in the Bering Strait and Chukchi Sea each year.

The East Siberian Sea (mean depth = 48 m) and Beaufort Sea are interior shelves (mean depth = 80 m). According to Carmark and Wassman (2006), interior shelves are shallow and characterized by strong effect of major Arctic rivers (for example, Kolyma and Mackenzie Rivers). Interior shelves exhibit a positive estuarine flow (plume spreading) in summer and a negative estuarine circulation (brine release) in winter. During summer, sediments and organic matter are transported to the nearshore in a highly variable mix of riverine, estuarine, and marine waters. The horizontal exchange of water masses is thus considerable and variation in salinity is significant. Carmack and others (2015) defined the brackish water mass that forms near the coast (≤30 m) as the River Coastal Domain. In deeper waters beyond the shelf break, boundary currents flow to the east and contain Arctic water derived from Atlantic and Pacific origins. Interior shelf waters are turbid (large terrigenous loads) and seafloors featureless except in large river areas where small valleys continue across the bed. The interior shelves are characterized by a predominance of landfast ice that melts during summer and flaw polynyas in winter. Primary production and the general biological activity are low over offshore areas of the interior shelves due to high turbidity, export of surface waters below the ice cover, and nutrient limitation due to stratification. Suspended biomass of planktonic organisms is thus low, but that of benthic organisms is relatively high. This relates to benthic foods from marine advection and local production and significant imports from littoral and riverine sources. Shoreline erosion delivers large amounts of peat to coastal waters and represents a major source of carbon in lagoonal food webs (Dunton and others, 2005; 2006; 2012). During winter, the lagoons freeze to depths about 2–5 m, often to the bottom, a disruption so great that the epibenthic community at the base of their food webs must re-colonize them annually.

The Beaufort Sea is a narrow interior shelf. The primary production in some of the coastal lagoon ecosystems of the United States Beaufort Shelf is less than 10 grams of carbon per meter (g C m^2/yr) as light penetration in spreading and meandering river plumes is extremely limited. Land fast ice cover is persistently strong and severely limits primary

production. Primary production on the adjacent Canadian Beaufort Shelf with its mixture of land fast and multi-year ice, flow polynyas, stamukhi, and higher light penetration outside the river plumes, is high, in the range of 30 to 70 g C m^2/yr. High freshwater inputs from numerous rivers and streams produce an environment that is decidedly estuarine in character, especially during the late spring and the summer months. Coastal erosion and river discharge are largely responsible for introducing high concentrations of suspended sediment from upland regions into the nearshore zone and often trapped in nearshore lagoons. Shelf energetics are characterized by a relatively low autochthonous production and a rich terrestrial, allochthonous carbon supply, especially in more productive regions. Benthic biomass is relatively rich in terrestrial carbon. Zooplankton populations, however, are poorly developed in the inner coastal region and the brackish waters that form along the coast each summer allows access to more marine foraging areas outside of the lagoons by several species of amphidromous fishes of importance in traditional economies.

In contrast the East Siberian Sea is a wide interior shelf. The wide interior shelves may extend far offshore (about 800 km) before reaching the shelf break. Most of the trophic dynamics in this sea remain to be resolved. This sea is heavily covered by land fast ice, is shallow (<50 m), and is exposed to most of the discharge of freshwater to the Arctic Ocean when the Lena River is considered. As a consequence, total primary production is low and the contribution from ice algae is probably significant. Stratification is strong during the productive season and the biota is dominated by benthos. High chlorophyll *a* concentrations in the sediments indicate a tight coupling between sympagic and pelagic primary production and nutrient supply to the benthos throughout the entire Laptev Sea. However, pronounced regional differences exist in the magnitude of primary production. The shallow nature of the ecosystem implies that the effect of zooplankton on carbon flux is limited and may increase toward the shelf break. Preliminary carbon budgets indicate that a high proportion of primary production is channeled through the benthic food web. As in the case of the narrow interior shelves input of allochthonous organic carbon seems to be required to balance the overall carbon demand. Despite its refractory nature, the supply of riverine dissolved organic carbon and particulate matter of terrestrial origin, mediated by microbial food webs, may be significant for this shelf.

The Canadian Arctic Archipelago is a network outflow shelf (mean depth = 124 m). Outflow shelves allow Arctic Water to drain back into the North Atlantic. The Canadian Arctic Archipelago is a complicated network of channels, straits, and sounds, and water mass transit times are long enough for thermohaline and biogeochemical changes to occur en route. There are no large rivers in this system, but moderately sized rivers enter from the Canadian mainland; there is other, local freshwater run-off. Stratification derives primarily from ice melt. Land fast ice in the region is regular, but strongly variable with regard to depth, time of melt, and snow-cover. The archipelago is ice-covered during most of the year with extensive, but variable ice melt and stratification observed during summer and early autumn. Primary production on outflow shelves is spatially variable. Over the southern parts of outflow shelves the primary production can be significant and is highly seasonal, quickly nutrient limited, and highly variable between years. The comparatively great depth implies that much of the carbon flux is channeled through plankton, with additional supplies from sympagic biota. Existing measurements of total primary production in the entire Archipelago suggest that it may support as much as 32 percent of the total primary production of pan-Arctic shelves. The zooplankton dynamics are even more variable, probably because of irregular advection episodes through the Archipelago. Ice fauna and flora are rich in the Archipelago and close pelagic–benthic coupling results in rich benthic communities in the shallow sections. However, primary production is generally low and the transport of organic matter (mostly of terrestrial origin) and ice biota by multi-year ice and the Transpolar Drift is significant along longitudinal outflow shelves. Interannual comparisons of ice algae production in Barrow Strait (to the east of M'Clure Strait, Canada) reveal strong year-to-year variability, ranging from 2 to 23 g C m^2 y^1 (Smith and others,1988). Thus, this outflow shelf probably experiences similar significant variability in its planktonic/sympagic primary production.

A conceptual model for the Pacific Arctic Region relates observed patterns in ecosystem structure and function to advection and related functional attributes (fig. 1.10; Grebmeier and others, 2015). The patterns are consistent with shelf processes described by Carmack and Wassman, (2006) denoting significance to areas of convergence in the Chukchi and Beaufort Seas and along the shelf break, large freshwater influences from the Mackenzie River and through the Bering Strait, and within different water masses of the Chukchi Sea. The conceptual model also is consistent with information about the physical environment and the marine resources in this chapter and portrays the role of advection more clearly with respect to seasonality and patterns in species distribution and abundance and further description of biological connections between Chukchi and Beaufort Sea shelves and other Pacific Arctic environments (for example, northern Bering Shelf and nearshore waters).

Two other conceptual models also inform current understanding of the present state: (1) a food web model linking physical factors to biological distribution and abundance and food web relationships (Wiese and others, 2013); and (2) a marine-pulsed model focusing on the seasonality of production cycles and biological activity as they relate to connections between riverine exports, benthic-pelagic coupling and remineralization, advection, winds and episodic upwelling events, and sea ice coverage (Moore and Stabeno, 2015). The advection, food web, and marine-pulsed models are complementary, building on the unifying constructs of the contiguous domain, and depict current understanding and suggest how energy pathways and efficiencies in benthic

and pelagic communities could be affected by the changes in meteorology (temperature, winds and cloudiness), sea ice (timing and extent of open water) hydrology (freshwater discharge), hydrography (stratification and halocline), and plankton dynamics (timing, intensity, magnitude, and production) and related ecological efficiencies (energy transfers between trophic levels).

Advection is a key forcing function for the Arctic marine environment in general and the Pacific Arctic Region in particular (Grebmeier and others, 2015). In this conceptual model, advection of water, ice, and biological constituents through the Bering Strait creates the energetic pathways and connections that affect much of the region and influence regional productivity and abundance of biota. Sea ice is a primary forcing factor in the region and is inherently connected to advection. Because of a steep decadal decline in seasonal sea ice coverage in the Chukchi Sea, it is thought to be among the most vulnerable Arctic continental seas for ecosystem change (Wiese and others, 2013; Grebmeier and others, 2015).

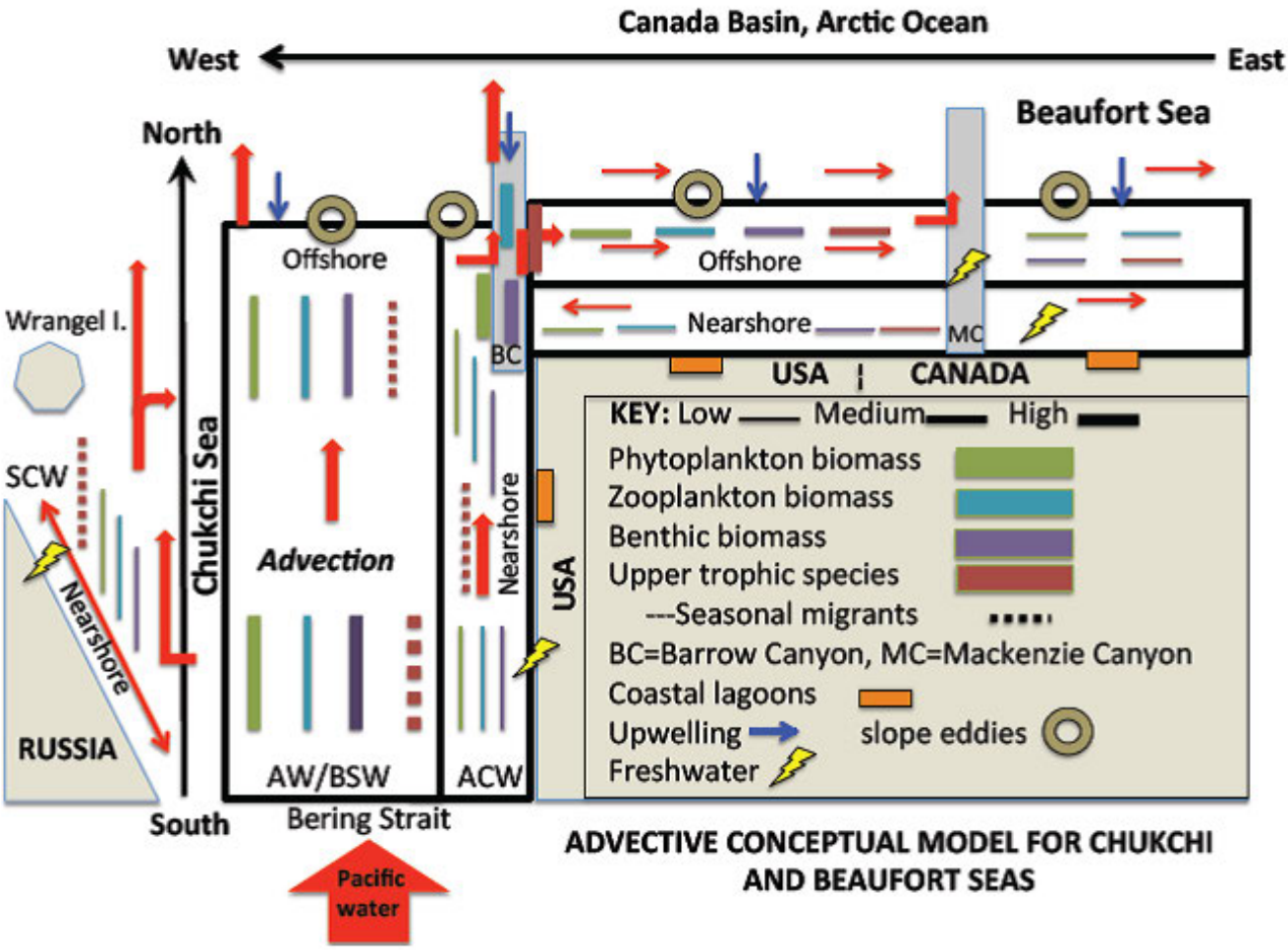


Figure 1.10. Advective conceptual model for Pacific Arctic Region (emphasis on Chukchi and Beaufort Seas, Alaska. (From Grebmeier and others, 2015). A 30-meter contour separates nearshore and offshore regions. The inflow of Pacific water masses (Anadyr Water [AW], Bering Shelf Water [BSW], and Alaska Coastal Water [ACW]) is critical to ecosystem dynamics, for example benthic ecosystem functioning, and transport processes in this conceptual framework. The East Siberian Coastal Current, not shown, while important, may be of less significant to the United States Chukchi and Beaufort Sea marine ecosystem dynamics.

Methods, Sources, and Terminology

Standard methods of literature review for published and unpublished data sources were followed. The search process for data and information included reviews of: current and historical studies; peer-reviewed journal and monographs; regional guides; museum specimens; technical reports and survey databases; searchable Web-based databases; oral communications; limited new data collection; and use of defensible unpublished scientific data.

Unless otherwise noted we conformed with conventions of scientific and common nomenclature used by Nelson and others (2004), Nelson and Bouchard (2013), Love and others (2005), Mecklenburg and others (2011), Maslenikov and others (2013), and Mecklenburg and Steinke (2015). This publication includes a key list of Arctic species referred to as the Online Resource 1 (OR1). The American Fisheries Society-American Society of Ichthyologists and Herpetologists (AFS-ASIH) recently completed an update to its list of common and scientific names (Page and others, 2013). In this report, *Boreogadus saidi* refers to Arctic Cod instead of Polar Cod (Page and others, 2013). *Arctogadus glacialis* is called Ice Cod. Other changes in nomenclature as they pertain to differences in taxonomy since the *Fishes of Alaska* (Mecklenburg and others, 2002) was published are noted. The *Fishes of Alaska* is a critical companion document to this report for the physical description of species including the key diagnostic features of anatomy for proper identifications.

Synthesis Methods

The preparation of species accounts involved several interrelated tasks including (1) documenting marine fish biodiversity; (2) defining terminology relative to the fauna and environment; (3) developing a standard template for information delivery (outline of species accounts); (4) acquiring and reviewing biological, ecological, and economic data and information; (5) producing species accounts; (6) synthesizing environmental (physical, biological, and ecological) information; and (7) managing the scientific review. The second and third tasks were most challenging because of limitations in existing data and the related need for consistent, reliable information in each species account. Pilot efforts involved the development of prototype species accounts and their review and improvement in an iterative process that introduced an evolutionary quality to product formation and information portrayal. The pilots highlighted the need for clarity in usage of standard terminologies being applied to Arctic baselines.

The fifth synthesis task involved an in-depth analysis of the collective body of the biological and ecological information presented in the species accounts to give it proper context to the biogeography of the fauna. Synthesis efforts were framed using historical and ecological components of biogeography (Nelson, 2006) to describe patterns of species occurrence, habitat and population relationships, and the ecosystem processes that affect the distribution and abundance of marine fishes in the Chukchi and Beaufort Seas. These environmental influences reflect physical, biological, and ecological attributes and interactions in the region and include human uses, such as fisheries, that can affect the population dynamics, community dynamics, and species presence in an area. In addition to providing information about environmental constraints (limiting factors) to marine fish populations, the BOEM requested more generalized information about the region's physical setting, adaptation and acclimation, life history strategies, marine fish assemblages, foraging and feeding behaviors, seasonality, growth and reproduction, predation and disease, population abundance and production, and human uses. We were asked to consider potential effects of climate change and, in light of all of the above, provide our impressions of information needs and research directions. Our opinions on potential effects of climate change should be viewed as hypotheses and, our thoughts on information needs are directed at the Arctic scientific community, in general, and no single organization, in particular. In many instances, these opinions were directed at deficiencies in understanding of species biology and ecology and basic information needs for any assessment or management action.

Biodiversity Assessment

The assessment of regional biodiversity included: (1) developing and updating an Arctic marine fish checklist; (2) reviewing recent (since *Fishes of Alaska* was published) ichthyologic sampling and management documents; (3) searching online databases; (4) systematic investigations that include documenting current taxonomic understanding with genetic information, historical museum collections, and voucher specimens; (5) acquiring digital images (photographic and line drawings); (6) creating visualization products that include distribution maps and vertical species profiles; and (7) conducting peer reviews.

Arctic Marine Fish Checklist

A provisional working list of marine fishes inhabiting the Chukchi and Beaufort Seas was initially prepared. This important first list incorporated new discoveries and taxonomic resolutions from ichthyologic sampling, genetic analysis, and museum studies conducted since the regional monograph *Fishes of Alaska* (Mecklenburg and others, 2002) and checklist of fishes (Love and others, 2005) were published. The list included only marine fish species confirmed from the region and greatly benefited from recently completed and ongoing field, laboratory, and museum research establishing new baselines for marine fish in the Pacific Arctic Region (Mecklenburg and Steinke, 2015). It was evident to BOEM and the U.S. Geological Survey (USGS) that much

new information on species distribution and occurrence had been collected in the decade following publication of the *Fishes of Alaska* and, as noted by Mecklenburg and Steinke (2015), this reference is no longer complete for the region. An important objective of this study was to illustrate the relationship of the final checklist to Mecklenburg and others (2002), which remains an important companion document and primary source for taxonomic information and identification guides for Alaskan fishes.

In addition to Mecklenburg and others (2002), other key references included reviews and syntheses on the taxonomy and zoogeography of Arctic marine fishes by Mecklenburg and others (2007), Mecklenburg and others (2011, 2013, 2014), Mecklenburg and Steinke (2015), and Maslenikov and others (2013). A new atlas and identification guide for the marine fishes of the Pacific Arctic Region is an important source of information about the diversity, taxonomy, and geographic distribution of marine fishes in the Chukchi and Beaufort Seas (Mecklenburg and others, 2016).

Scientific Reviews

Recent publications, technical reports, and unpublished data were reviewed for new species occurrences and expansions in range. Survey results from fish sampling in the Chukchi Sea (Mecklenburg and others, 2007, 2011; Norcross and others, 2009, 2013a) and Chukchi Borderlands (for example, Mecklenburg and others, 2013; Longshan and others, 2014) and industry research (Gallaway and Norcross, 2011; Norcross and others, 2013b) were reviewed. Surveys from the southwestern Beaufort Sea (Johnson and others, 2010; Parker-Stetter and others, 2011; Rand and Logerwell, 2011; and Johnson and others, 2012) were reviewed for new information from nearshore and shelf waters. Additionally, National Oceanic and Atmospheric Administration (NOAA), University of Alaska-Fairbanks (UAF), and RUSALCA scientists are involved in ongoing fishery investigations for BOEM's Alaska OCS Region in the Chukchi and Beaufort Seas. Taxonomic support provided to these studies and other research (for example, Mecklenburg and Steinke, 2015) and analysis of previously unprocessed samples from WEBSEC-71 (1971) (Hufford, 1974) was a source of new records from the Beaufort Sea.

Relevant environmental analyses and Arctic resource management plans done by the BOEM (Minerals Management Service [MMS], 2008) and North Pacific Fishery Management Council (NPFMC, 2009), respectively, were reviewed in this assessment of biodiversity, human uses, and environmental relationships. The DOI synthesis of priority science needs for continued oil and gas development in the Arctic was consulted for information about the region's environmental setting, living resource information, and USGS-identified research needs (Holland-Bartels and Pierce, 2011). A supplemental draft EIS addressing possible offshore oil and gas development in the U.S. Chukchi and Beaufort Seas was reviewed for species and community assemblage information (National Oceanic and Atmospheric Administration, 2013). A significant study of subsistence use and traditional ecological knowledge of whitefish in the southeastern Chukchi Sea (Georgette and Shiedt, 2005) provided an important source of information about Iñupiat taxonomy and seasonal use of whitefishes in the Noatak, Kobuk, and Selawik Rivers of Kotzebue Sound (fig. 1.7).

Searchable Databases

The exploration of the Arctic is at the forefront of ecological research to document and understand marine ecosystems and population ecologies with respect to climate change, possible commercial fisheries, and other stressor effects. In recent years, active research in conjunction with RUSALCA, Census of Marine Life (CoML) programs [that is, Pan-Arctic Inventory/Arctic Ocean Diversity (ArcOD) and Marine Barcode of Life] has emphasized fishery objectives for resource inventory. In this capacity, data for this report were from the Global Marine Life Database, Census of Marine Life Community Database, and CoML bibliographic database (for example, Mecklenburg and others, 2007 and Mecklenburg and Mecklenburg, 2009). Other searchable Web-based databases used included: FishBase; BOEM Arctic Fisheries Database; United Nations Ocean Biogeographic Information System (OBIS Database); Encyclopedia of Life; World Register of Marine Species; Catalogue of Life Species; and Integrated Taxonomic Information System (ITIS). NOAA's on-line database services provide access to life history and distributional information for nearshore atlases; offshore fishery resources were accessed at the National Oceanic and Atmospheric Administration Web site (http://alaskafisheries.noaa.gov). The automated database at the University of Washington School of Fisheries and Ocean Sciences provided key access to type specimens and mapping tools.

The BOEM database, "Alaska Scientific and Technical Publications" (http://www.boem.gov/Alaska-Scientific-Publications/), was a significant resource for marine fishery, subsistence, and socioeconomic data. A summary of ongoing and recently completed BOEM fishery studies is provided in appendix A. A major synthesis by Braund and Kruse (2009) provided an authoritative review of subsistence harvest patterns for fish and wildlife patterns over the past 30 years (from the mid-1980s). During this period, the OCS subsistence studies and this synthesis focused on coastal harvest patterns in the Alaska North Slope villages of Wainwright, Barrow, Nuiqsut, and Kaktovik. An early study by Craig (1987) provided important baseline documentation of subsistence patterns and Iñupiat taxonomy from the Chukchi and Beaufort Seas.

Systematic Investigations

Recent information about the taxonomy and biogeography of Alaskan Arctic fishes has come from numerous analyses using field and museum studies, DNA sequencing, and exhaustive literature review, as well as efforts to synthesize the accumulated results for the Pacific Arctic region; particularly the works of Mecklenburg and others (2006, 2007, 2011, 2013, 2014, 2016), Mecklenburg and Mecklenburg (2009), and Mecklenburg and Steinke (2015). Voucher specimens provide a crucial link to historical data sets, allowing determination of existing baselines and accurate identification of new field collections. Museum collections housing the specimens are globally located and managed by many institutions. The following collections are some of those studied for the works just cited: California Academy of Sciences, San Francisco; Canadian Museum of Nature, Gatineau, Quebec; Hokkaido University Museum of Zoology, Hakodate, Japan; U.S. National Museum of Natural History, Washington, D.C.; NOAA, Alaska Fisheries Science Center, Auke Bay Laboratory, Juneau, Alaska; University of Alaska Museum, Fairbanks, Alaska; University of British Columbia, Vancouver, Canada; University of Washington, Seattle; and Zoological Institute, St. Petersburg, Russia. Detailed data on voucher specimens examined, including the authors' verified or redetermined identifications, have been published (for example, Mecklenburg and others, 2006; Mecklenburg and Mecklenburg, 2009; and Mecklenburg and others, 2011, Online Resources 1 and 2) and the most recent results are available from the museums' online search databases. In many instances, the museum studies have revealed previously misidentified or unreported specimens and have led to extensions or contractions in known patterns of distribution; these results are reported here in abbreviated form from the authors' more detailed works. The origins, classification, diversity, human uses, and vulnerabilities of circumpolar freshwater and marine Arctic fishes were reviewed as part of the most recent Arctic Biodiversity Assessment (Christiansen and others, 2013).

Genetic Analyses

Mecklenburg and others (2011, 2014, 2016) and Mecklenburg and Steinke (2015) described the DNA analyses (barcoding) performed on Arctic fish specimens as part of the CoML, RUSALCA, and other fisheries investigations. This analytical tool has provided critical information to ichthyologists to help resolve taxonomic problems, assist difficult identifications, and, in many instances, generate hypotheses about potential population structuring. Many of the Arctic fishes that have been barcoded were collected in the Chukchi and Beaufort Seas and in other parts of Alaska. Online Resources 3 and 4 of Mecklenburg and others (2011) provide museum catalog numbers and collection data for barcoded specimens. That collection has been increased, and data on additional specimens may be found on the Barcode of Life Data System (BOLD) Web site from links supplied by Mecklenburg and Steinke (2015).

Other sources of genetic identification information were found in the literature review. Research on Pacific salmon has been extensive in Alaska including north through Kotzebue Sound. BOEM and other organizations including the North Pacific Research Board (NPRB) are funding new research on the genetic diversity and population structure of Arctic Gadidae (for example, Arctic, Saffron, and Ice cod) and the new results and ongoing studies are, or will, assist in addressing existing taxonomic complexities (for example, see appendix A and Nelson and Bouchard, 2013).

Digital Images

Many recent high-quality images of marine fishes were obtained from active Arctic researchers who photographed freshly sampled specimens in the field. For example, most of the images in this report are products of research of Mecklenburg and others (2016). Each photograph is properly attributed with names of providers and date and location of sample collection.

Distribution Maps and Vertical Species Profiles

ArcGIS geographic range maps were developed for each confirmed species from the Chukchi and Beaufort Seas. Vertical distribution profiles were created in Adobe software to portray specific information in a generalized life cycle schemata depicting water column distributions of life stages over continental shelf and slope habitats. The maps and profiles depicting geographic distributions and vertical distribution information are composite products from multiple sources of data collection and observation. A BOEM study with objectives of compiling existing fishery data sets for the Chukchi and Beaufort Seas into an electronic format was not completed in time for use herein. Although the data were acquired through traditional sources, easier access to, and manipulation of these data, in concert with the results of ongoing fishery research, would improve the efficiency and number of Alaskan records in future updates.

Peer Review

USGS standards for science quality (USGS Fundamental Science Practices) were followed (http://www.usgs.gov/fsp/) for this study and report. The USGS process includes technical and policy reviews for technical reports and journal publications. For this report, we relied on external subject matter experts due to the diversity of species and ecological topics addressed. The USGS reviews were supported by BOEM technical reviews that included additional internal and external scientists having appropriate ichthyologic expertise.

Operational Definitions

In some cases, especially in the species accounts and synthesis discussions, highly technical information relative to various aspects of marine biogeography is presented. In several disciplinary areas, especially those dealing with quantitative population ecology, special attention to defining the scientific terminology used was needed. To facilitate consistency and understanding, a glossary of key terms was developed as an aide for users. The glossary (chapter 7) defines many of the more complex terms and quantitative relationships used in the species accounts. Each definition is appropriately cited so that, if they are not clear, additional sources can be quickly accessed and referenced. Other terms commonly used to describe spatial relationships in biogeography, involve ecological scaling considerations of importance to conservation and are described in the section, "Geospatial Terminology." The terms described in this chapter are used widely throughout the report and, for that reason, are introduced here. Abundance terminology represented a special case where the derivation of a unique classification scheme for the Arctic region was necessary and developed in chapter 2 with application to other chapters as well.

Geospatial Terminology

This study focuses on the biological geography of marine fishes in Alaska's Arctic Ocean and describes their distribution and abundance using various spatial terms. Some have zoogeographic meaning (for example, realm and province) and others refer to common descriptions of a species occurrence by scale (for example, region, area, and local). The mapping classifications for biogeographic realms and faunal provinces used herein are as described by Lourie and Vincent (2004) and Spalding and others (2007), respectively. The Arctic region, as described by Briggs and Bowan (2012), adds additional clarity to the boundaries of marine provinces by considering the zoogeography of fishes of fishes. For Alaska, Sigler and others (2011) described three provinces that relate to conventional management areas in the United States segments of the northern Bering Sea and the Chukchi and Beaufort Seas.

In each case, the biogeographic concepts relate to ecological patterns and processes, and thus to conservation. Lourie and Vincent (2004, p. 1,005) noted that, "…*biodiversity exists on multiple scales biologically, spatially and temporally, and these scales are, to some extent, independent of one another*." They related spatial scales of conservation planning to physical, temporal, and biological patterns and processes, to mapping scale as follows (Lourie and Vincent (2004, p. 1,007):

> *(1) global approximate map scale 1:100 million – ocean basin divisions, major currents, global climate, historical biogeography, highly migratory species, large marine ecosystems (LMEs); (2) regional, 1:10 million – regional currents, historical biogeography, genetic connectivity, widespread species, individual LMEs or ecoregion; (3) provincial, 1.1 million – small scale currents, upwelling, genetic connectivity, major habitats with LME or ecoregion restricted-range species, bioregion; (4) local, 1:500,000 – local gyres and eddies, watershed runoff, coastal geomorphology, ecological connectivity, planning unit; (5) site, 1:10,000 – tides, watershed runoff, ecological connections, habitat specialists, habitats within planning unit, zoning for marine protected areas.*

The scales are germane because they give additional texture to how (unless otherwise specified) the concepts of realm and province should be understood and, generally, the geographic distinctions between "region" and "area" as used in this report. Typically, "region" is used to refer to large-scale patterns and process (for example, scale 3 in Lourie and Vincent [2004]) and "area" refers to local or site specific ecological conditions (for example, scales 4 and 5).

The use of other geographical or habitat terms, including inshore, coastal, nearshore, and offshore in this report are somewhat more ambiguous with respect to meaning or area involved. For example, in some instances "coastal" may have a legal meaning with respect to a state's territorial waters, or meteorological and oceanographic meaning with respect to wave influence. Similarly, "nearshore" also may have multiple oceanographic meanings including reference to littoral zone components, photic zones, or waters extending to the shelf break. There can be considerable overlap in area with respect to how these terms are applied with respect to the notion of "close to shore." In an attempt to reduce such ambiguity, some practical distinctions are made for these terms based on scientific knowledge of Arctic fish habitat characteristics (depth, temperature and salinity influences, and distance from shore) and realities of their sampling by proven fisheries techniques:

- Inshore reflects the area from shoreline to depths of 2 m. This reflects the shallow water areas where much of the historical fish baseline data were collected in the Chukchi and Beaufort Seas surveys with fyke net and gill net sampling techniques. Freshwater influences typically are important seasonally, especially in the Beaufort Sea.

- Coastal habitats can include lower reaches of rivers and streams, deltas, inshore, and deep waters adjacent to the coast. Lagoons and shallow waters adjacent to outer coasts of barrier islands are included in the category. Freshwater influences are seasonally important in coastal habitats.

- Nearshore, *or* nearshore marine, as used herein, generally refers to those waters located inside the 10-m isobath. This depth is often where large (class 1) oceanographic vessels cease to operate for safety reasons. Additionally, the presence of brackish water

can be a factor in describing the distance that nearshore waters occur from the coast. For example, during summer, brackish waters can extend more than 10 km offshore and often overlay cold more saline water masses deep in the water column. The nearshore includes inshore and coastal habitats, but tend to extend farther offshore.

- Offshore as used here describes shelf, slope, and deep-water habitats located beyond the nearshore.
- Nearshore-Marine refers to a descriptive adaptive model in this report as evidenced by those species having distribution patterns that are widespread over nearshore, shelf, and slope environments. An example would be the distribution of Arctic Cod in the United States Chukchi and Beaufort Seas.

A fish species can be distributed in one or more habitats in time and space. This report provides a comprehensive examination of how fish in Arctic environments have adapted, which depending on life strategy adaptations, represents a continuum of habitats on a gradient from freshwater to marine. For each species, patterns of habitat use are multi-dimensional with respect to areas and volumes occupied, space and time, and life cycle requirements for reproduction, growth and survival, dispersal, and other life functions. The distribution and abundance of life stages for each species throughout the water column are presented in chapter 3 to capture these relationships in the context of life zones (Allen and Smith, 1988) that portray key aspects of reproductive ecology by depth and location. Depictions in this report are unique for this region because the shelf break is depicted at 75 m on the basis of the bathymetry of the Chukchi and western Beaufort Seas.

Organization of the Catalog

The BOEM requested that the USGS conduct a synthesis of available environmental information addressing Arctic marine fish biology and ecology in the following areas: environmental and biological constraints; oceanographic overview; adaptation and acclimation; life history strategies; fish assemblages; foraging and feeding behavior; bioenergetics; use of time and space; growth and reproduction; migration; predation, parasitism, competition, and mutualism; dynamics of population abundance and production; conservation; subsistence; climate change; and information needs. The resultant *Arctic Marine Fish Ecology Catalog* is organized in eight chapters, a glossary, and three appendixes.

Chapters 1–3 provide detailed characterizations of the United States Arctic region's environmental setting and marine fish biodiversity and establish much of the physical and biological background information supporting ecological synthesis and management objectives of this project. Chapter 1 provides a broad overview of the Arctic marine environment and scientific goals and methods of this synthesis as it pertains to BOEM information needs as well as other users. Additional purposes are to describe the meaning of commonly used oceanographic and zoogeographic terminologies to avoid possible ambiguity associated with their use herein. Chapter 2 presents an inventory of the marine fish known from the United States Chukchi and Beaufort Seas including an analysis of changes resulting from new data and information acquired from the region since the early 2000s. Chapter 3 includes more than 100 species accounts and describes current knowledge about the biology and ecology for each marine fish known from the United States Arctic region using information from studies in Alaska and elsewhere within the species ranges. The species accounts are quick references to some topics (for example, climate change) and are described in more detail in chapters 5–6.

Chapter 4 provides a synthesis of information that, in its entirety, addresses the ecological objectives requested by BOEM. The USGS approach to this synthesis was to evaluate data and information about the descriptive and interpretive components of biogeography as described by Nelson (2006). By necessity, much information is incorporated by reference in this description of historical and environmental influences on marine fish presence and patterns of distribution and abundance in the United States Arctic marine environment.

Chapter 5 focuses on the modeling of climate change effects on the distribution of Arctic and Saffron cod in the Bering Sea. The Bering Sea was selected because of the extensive fishery data that are available from this region. Arctic and Saffron cod were selected because they are notably important in Arctic food webs and subsistence fisheries north of the Bering Strait. Our emphasis on modeling approach and distributional effects represent an important potential application to the Chukchi and Beaufort Seas as Arctic fishery data become more widely accessible in electronic formats. The results of modeling in the Bering Sea are considered in light of potential warming effects in the Chukchi and Beaufort Seas.

Chapter 6 focuses on how scientific information about the Arctic marine fish can inform policy and the conservation and management of Arctic species. Information needs relate to environmental assessment for OCS oil and gas development, fisheries management, and understanding potential effects of climate change. A traits-based approach can be used to assist resource management until population-level information and dynamics are better known. The information needs for high-priority species identified in chapter 3 also are evaluated with respect to future research and ecosystem-based management.

This report includes many descriptive and quantitative terms and complex concepts common in scientific literature. A "Glossary of Ecological Terms" is provided in chapter 7 to reduce confusion about these terms and concepts as used in this report. Chapter 8 provides a list of scientific references cited in narrative sections of the report. Each species account presented in chapter 3 includes a listing of the scientific reports and articles used.

Appendix A describes age, weight, and size relationships for marine fish species where data are available. The information supports life history and population dynamic sections of the report in chapters 4 and 6. Appendix B provides additional information about the availability of recent fishery investigations supported by BOEM as well ongoing studies, and topics where new information is anticipated. Appendix C provides summaries of the models developed to examine temperature effects on Arctic and Saffron cods in chapter 5.

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Summary

The need for reliable fishery information for National Environmental Policy Act analysis related to offshore oil and gas development in Chukchi and Beaufort Sea Planning Areas is described. The conduct of systematic surveys in these areas has been hampered by environmental and budgetary constraints and thus, in many respects, the existing data remain scattered and fragmented and are difficult to access. Lack of access to quantitative catch and observational data from ongoing research precluded our full use of modern geospatial technologies. Despite, this limitation, new information and visualization products were developed for each species of confirmed presence in the study area. The biological and ecological information presented in this report is regional in scale and, unless otherwise noted, local variations in seasonal fish habitat and abundance can be found in the literature cited. Given the spatial resolution of existing data, background descriptions of the physical and biological environments of the Chukchi and Beaufort Seas are presented at the landscape scale. All methods, terminologies, and operational definitions for this study are described. The organization of the report and linkages between chapters are described as they relate to the Bureau of Ocean Energy Management's information need for this synthesis.

Chapter 2. Alaska Arctic Marine Fish Inventory

By Lyman K. Thorsteinson[1]

Abstract

Several other marine fishery investigations, including efforts for Arctic data recovery and regional analyses of range extensions, were ongoing concurrent to this study. These included Bureau of Ocean Energy Management-sponsored research in the Chukchi Sea and nearshore and transboundary surveys in the Beaufort Sea. New collections in the Chukchi Sea and Chukchi Borderland also were being obtained through National Oceanic and Atmospheric Administration's multidisciplinary Russian-American Long-term Census of the Arctic (RUSALCA) program. These were major exploratory efforts and represented potential sources of new marine species information. Building on the "*Fishes of Alaska,*" an updated checklist was constructed of known and probable marine fishes with catch data obtained in these studies. There are 109 known species from 24 families of marine fish from the United States High Arctic, with 97 species reported from the Chukchi Sea and 83 from the Beaufort Sea. As this synthesis was being done, changes in the confirmation process, based on morphological and genetic analysis, were captured as information became available in scientific publications. The known species are reviewed with respect to taxonomic, geographic, and large-scale abundance considerations. Each species' zoogeographic pattern with respect to our understanding of broadly defined evolutionary origins is noted. Changes in species nomenclature are described as they relate to newly described standards.

[1]U.S. Geological Survey.

Introduction

A large number of Arctic fisheries studies were started following the publication of the *Fishes of Alaska* (Mecklenburg and others, 2002). Although the results of many of these efforts are not yet available, those involving field sampling are important new sources of biodiversity information including voucher specimens and genetic confirmation of a species existence and phylogenetic relationships. The addition of new morphological data and genetic analyses is important because despite many efforts, systematic sampling in the Chukchi and Beaufort Seas has been logistically difficult due to ice, storms, and platform limitations. Further variations in research missions and sampling methods have hampered regional assessments of diversity, relative abundance, and habitat importance because the resulting database is sparse and fragmented in time and space. Quantitative evaluations of abundance based on catch data are difficult, although local variability and persistent hot spots are known to exist. This chapter builds on the species inventory established by the *Fishes of Alaska* by incorporating new species information obtained primarily in Bureau of Ocean Energy Management (BOEM)-sponsored (appendix A) and National Oceanic and Atmospheric Administration (NOAA) Russian-American Long-term Census of the Arctic (RUSALCA) surveys (Mecklenburg and Steinke, 2015). This information is complemented with a uniformly applied assessment of relative abundance and qualitative analysis of population viability based on present day understanding of endemism.

Checklist of Marine Fish

The updated checklist of confirmed occurrences is significant because it incorporates the new knowledge gained since the publication of the *Fishes of Alaska* (Mecklenburg and others, 2002). It includes the most recent information from the Pacific Arctic Region including the Chukchi and Beaufort Seas from Mecklenburg and Steinke (2015). Unlike Mecklenburg and Steinke (2015), this checklist includes diadromous species from the family Salmonidae as these species spend significant portions of their lives in the marine environment and have great importance in subsistence lifestyles. Even though this list represents a significant advance, many uncertainties remain about the true composition of the marine fish assemblage. For this reason, information about probable occurrences of marine fishes is included in this chapter. The uncertainties result in part because the taxonomy of Arctic fishes was still in its infancy at the turn of the 21st century, with many species misidentified in historical literature and others not recognized from the region due to sampling inadequacies (Mecklenburg and others, 2011). The scientific improvements in knowledge about the Arctic region's biodiversity reflect new data collection and, importantly, advances in taxonomic and zoogeographic understanding that have resulted from genetic resolution of issues that morphological studies failed to notice or resolve (for example, Mecklenburg and others, 2011; Lynghammar and others, 2012; Mecklenburg and Steinke, 2015). The Arctic marine fish inventory, presented in table 2.1, is a major biodiversity achievement, which documents known (verified) marine fish species from the Chukchi and Beaufort Seas.

Although advances have been significant in recent years, the taxonomy, including naming of Arctic marine fishes remains a source of inconsistency and confusion between leading authorities such as the American Fisheries Society (AFS), California Academy of Sciences *Catalog of Fishes*, Integrated Taxonomic Information Systems, and World Register of Marine Fishes, for members of several families. This is especially true for common names associated with different languages (Mecklenburg and others, 2013). Changes in nomenclature are not uncommon in the classification process, especially for lesser-studied species, and can affect the regional use of scientific and common names in literature (Eschmeyer and others, 2010). Thus, in creating checklists, it is important to cite the authority used and rationale for inclusion or naming of a particular species where disagreement occurs. In this report, the marine fish inventory presented in table 2.1 reflects the editors' understanding of the classification and nomenclature of marine Arctic fishes. In most instances, the scientific and common names are those listed by Page and others (2013) and Eschmeyer and others (2015). However, in several instances where differences exist, we relied on the work of contemporary Arctic specialists and note areas of transitional change with respect to common names for species.

The nomenclature of a small number of fish species from four families (Squalidae, Gadidae, Liparidae, and Zoarcidae) are in transition and reflect areas where we disagree with the AFS nomenclature (Page and others, 2013). For purposes of this report, we decided to agree with the AFS nomenclature for *Boreogadus saida* due to the species' significance to the region's marine ecology. Although, we acknowledge that Polar Cod is emerging as the widely accepted common name for *B. saida*, we decided to use Arctic Cod (as recommended by Page and others [2013]) to avoid any confusion with new and historical Alaska literature. In contrast, we decided to use Ice Cod, not Polar Cod, as the common name for *Arctogadus glacialis*. This decision was made to avoid any potential ambiguity and confusion with *B. saida*. The use of Ice Cod is emerging nomenclature in scientific literature (for example, Arctic Council's Conservation of Arctic Flora and Fauna) and clarification of the vernacular name is supported by genetic analysis (Nelson and Bouchard, 2013). Regarding other families and species, we recognize (1) Spotted Spiny Dogfish instead of Pacific Spiny Dogfish as the common name for *Squalus suckleyi* (Squalidae, see Lynghammar and others [2012]); (2) Estuarine Eelpout, not Polar Eelpout as the common name for *L. turneri* (Mecklenburg and others, 2002); and (3) Arctic Sand Lance for *Ammodytes hexapterus* following Orr and others (2015) and Mecklenburg and others (2016). Other more recent changes (for example, Mecklenburg and others, 2016) include changes in the scientific names for Capelin (now *Mallotus catervarius*) and Arctic Flounder (now *Liopsetta glacialis*). In every case, the scientific name of a fish is conclusive for the species being described.

One hundred nine (109) species from 24 families are confirmed with 97 verified occurrences from the Chukchi Sea and 83 from the Beaufort Sea (table 2.1). Mecklenburg and others (2002) suggested other species (<20) also might be present and it remains likely that the total number will change with additional field sampling, examination of existing voucher specimens, and with shifts in range due to climate warming. Mecklenburg and others (2007, 2011, 2014, 2016)

and Mecklenburg and Steinke (2015) have recently confirmed the presence of at least 18 species in the Alaskan Chukchi and Beaufort Seas that were not previously verified to be present: *Somniosus pacificus*, *Amblyraja hyperborea*, *Bathyraja parmifera*, *Myoxocephalus polyacanthocephalus*, *Triglops nybelini*, *Hypsagonus quadricornis*, *Careproctus reinhardti*, *Liparis bathyarcticus*, *Paraliparis bathybius*, *Lycenchelys kolthoffi*, *Lycodes adolfi*, *L. frigidus*, *L. jugoricus*, *L. marisalbi*, *L. pallidus*, *L. reticulatus*, *Anarhichas denticulatus*, and *Zaprora silenus*. The status of three of these species was previously described as being of "probable" occurrence in the provisional checklist developed for this study:

- **Pacific Sleeper Shark** (*Somniosus pacificus*): Benz and others (2004) reported a new occurrence of the species from an animal found washed onshore at Point Hope, Alaska. The animal remains were highly decomposed; this occurrence was reviewed by Lynghammar and others (2012), who determined that the physical condition of the shark suggested its death from outside the Chukchi Sea. In 2014, a Pacific Sleeper Shark was taken alive by a seal hunter in a southeastern Chukchi Sea lagoon. Parts and photographs were archived in the University of Alaska Museum. This is a mesobenthopelagic shark species recorded as deep as 2,205 m. It is abundant in the southern Bering Sea and the Gulf of Alaska, and reaches 4.4 m TL or more (Mecklenburg and others (2016).
- **Alaska Skate** (*Bathyraja parmifera*): Mecklenburg and others (2011 Online Resource 1) reported that two specimens were found washed ashore in the Chukchi Sea. Examination of one of the specimens indicated advanced deterioration and possible death elsewhere in the northern Bering Sea. Later, Mecklenburg and others (2016) reported that in 2012 an adult specimen was taken alive in the southern Chukchi Sea. Mecklenburg and others (2016) also reported the collection locations of other beachcast specimens and spent egg cases from the Chukchi and Beaufort Sea. The authors noted the species can reach a size of 135 cm TL. They also reported that the occurrences of the Alaska Skate in the Chukchi Sea could indicate a northerly shift in its distribution.
- **Pale Eelpout** (*Lycodes pallidus*): Mecklenburg and others (2016) identified this species in a collection made in 1971 in the Beaufort Sea and confirmed presence in the Beaufort Sea again in voucher collections from 2012 and 2013. Common at least in the Greenland, Barents, and Kara Seas, otherwise found nearly circumpolar. It is epi-meso-bathybenthic and lives on muddy substrate at depths of 11–1,750 m and temperatures of -1.8–3.7 °C. Maximum size is 28.9 cm SL or more (Mecklenburg and others, 2016).

The updated checklist was examined with respect to new species occurrences and differences in the geographic distributions reported in the *Fishes of Alaska* (Mecklenburg and others, 2002) for the Chukchi and Beaufort Seas (table 2.2). Our decision to include two species, *Artediellus ochotensis* and *Lumpenus sagitta*, on the checklist was made recognizing that uncertainty exists about their occurrence in the Chukchi Sea (Mecklenburg and others, 2016). As an example, Mecklenburg and others (2016) state "Many of the specimens that had been previously identified as "*A. ochotensis*" on further investigation have been found to be *A. scaber*." However, not all of the identifications were refuted. In the case of *L. sagitta*, Mecklenburg and others (2011) described a range extension for this species into the Chukchi Sea based on a single specimen. Presently, Mecklenburg and others (2016) raise doubts "The provenance of a specimen reported to be a possible record of *L. sagitta* from the Chukchi Sea...is uncertain." The uncertainty stems from conflicting issues in the 1960s field collection data and location of sampling (possibly not Chukchi Sea), and not with species identification. Until these issues can be resolved with species confirmations with new specimens, we chose to retain them on the checklist. As a final note, we recognize *Icelus spiniger* as a valid species from the Chukchi Sea noting that genetic similarities with *I. spatul*a specimens from the region raise questions about relationships. Other technical and unresolved issues for the marine fishes in the Chukchi and Beaufort Seas are described in Mecklenburg and Steinke (2015) and Mecklenburg and others (2016).

Table 2.1. Inventory of confirmed species of Arctic marine fish in the United States Chukchi and Beaufort Seas, Alaska.

[Blank cells indicate that the species occurrence has not been confirmed in that sea. Marine waters out to the U.S. Exclusive Economic Zone (200-mile limit) are included]

Family	Scientific name	Common name	Confirmed occurrence	
			Chukchi Sea	Beaufort Sea
Petromyzontidae	*Entosphenus tridentatus*	Pacific Lamprey	X	
Petromyzontidae	*Lethenteron camtschaticum*	Arctic Lamprey	X	X
Squalidae	*Squalus suckleyi*	Spotted Spiny Dogfish	X	
Somniosidae	*Somniosus pacificus*	Pacific Sleeper Shark	X	
Rajidae	*Amblyraja hyperborea*	Arctic Skate		X
Rajidae	*Bathyraja parmifera*	Alaska Skate	X	
Clupeidae	*Clupea pallasii*	Pacific Herring	X	X
Osmeridae	*Hypomesus olidus*	Pond Smelt	X	
Osmeridae	*Mallotus catervarius*	Pacific Capelin	X	X
Osmeridae	*Osmerus dentex*	Arctic Smelt	X	X
Salmonidae	*Coregonus autumnalis*	Arctic Cisco	X	X
Salmonidae	*Coregonus laurettae*	Bering Cisco	X	X
Salmonidae	*Coregonus nasus*	Broad Whitefish	X	X
Salmonidae	*Coregonus pidschian*	Humpback Whitefish	X	X
Salmonidae	*Coregonus sardinella*	Least Cisco	X	X
Salmonidae	*Oncorhynchus gorbuscha*	Pink Salmon	X	X
Salmonidae	*Oncorhynchus keta*	Chum Salmon	X	X
Salmonidae	*Oncorhynchus kisutch*	Coho Salmon	X	X
Salmonidae	*Oncorhynchus nerka*	Sockeye Salmon	X	X
Salmonidae	*Oncorhynchus tshawytscha*	Chinook Salmon	X	X
Salmonidae	*Salvelinus malma*	Dolly Varden	X	X
Salmonidae	*Stenodus leucichthys*	Inconnu	X	
Myctophidae	*Benthosema glaciale*	Glacier Lanternfish	X	
Gadidae	*Arctogadus glacialis*	Ice Cod	X	X
Gadidae	*Boreogadus saida*	Arctic Cod	X	X
Gadidae	*Eleginus gracilis*	Saffron Cod	X	X
Gadidae	*Gadus chalcogrammus*	Walleye Pollock	X	X
Gadidae	*Gadus macrocephalus*	Pacific Cod	X	X
Gasterosteidae	*Gasterosteus aculeatus*	Threespine Stickleback	X	X
Gasterosteidae	*Pungitius pungitius*	Ninespine Stickleback	X	X
Hexagrammidae	*Hexagrammos stelleri*	Whitespotted Greenling	X	X
Cottidae	*Artediellus ochotensis*	Okhotsk Hookear Sculpin	X	
Cottidae	*Artediellus scaber*	Hamecon	X	X
Cottidae	*Enophrys diceraus*	Antlered Sculpin	X	X
Cottidae	*Gymnocanthus tricuspis*	Arctic Staghorn Sculpin	X	X
Cottidae	*Hemilepidotus papilio*	Butterfly Sculpin	X	
Cottidae	*Icelus bicornis*	Twohorn Sculpin	X	X
Cottidae	*Icelus spatula*	Spatulate Sculpin	X	X
Cottidae	*Icelus spiniger*	Thorny Sculpin	X	
Cottidae	*Megalocottus platycephalus*	Belligerent Sculpin	X	X
Cottidae	*Microcottus sellaris*	Brightbelly Sculpin	X	
Cottidae	*Myoxocephalus jaok*	Plain Sculpin	X	X
Cottidae	*Myoxocephalus polyacanthocephalus*	Great Sculpin	X	
Cottidae	*Myoxocephalus quadricornis*	Fourhorn Sculpin	X	X
Cottidae	*Myoxocephalus scorpioides*	Arctic Sculpin	X	X
Cottidae	*Myoxocephalus scorpius*	Shorthorn Sculpin	X	X
Cottidae	*Trichocottus brashnikovi*	Hairhead Sculpin	X	X
Cottidae	*Triglops nybelini*	Bigeye Sculpin	X	X
Cottidae	*Triglops pingelii*	Ribbed Sculpin	X	X
Hemitripteridae	*Blepsias bilobus*	Crested Sculpin	X	
Hemitripteridae	*Nautichthys pribilovius*	Eyeshade Sculpin	X	X
Psychrolutidae	*Cottunculus microps*	Polar Sculpin		X
Psychrolutidae	*Eurymen gyrinus*	Smoothcheek Sculpin	X	
Agonidae	*Aspidophoroides monopterygius*	Alligatorfish	X	X
Agonidae	*Aspidophoroides olrikii*	Arctic Alligatorfish	X	X

Table 2.1. Inventory of confirmed species of Arctic marine fish in the United States Chukchi and Beaufort Seas, Alaska.—Continued

Family	Scientific name	Common name	Confirmed occurrence	
			Chukchi Sea	Beaufort Sea
Agonidae	*Hypsagonus quadricornis*	Fourhorn Poacher	X	
Agonidae	*Leptagonus decagonus*	Atlantic Poacher	X	X
Agonidae	*Occella dodecaedron*	Bering Poacher	X	
Agonidae	*Pallasina barbata*	Tubenose Poacher	X	
Agonidae	*Podothecus veternus*	Veteran Poacher	X	X
Cyclopteridae	*Eumicrotremus andriashevi*	Pimpled Lumpsucker	X	
Cyclopteridae	*Eumicrotremus derjugini*	Leatherfin Lumpsucker	X	X
Liparidae	*Careproctus reinhardti*	Sea Tadpole	X	X
Liparidae	*Liparis bathyarcticus*	Nebulous Snailfish	X	X
Liparidae	*Liparis fabricii*	Gelatinous Seasnail	X	X
Liparidae	*Liparis gibbus*	Variegated Snailfish	X	X
Liparidae	*Liparis tunicatus*	Kelp Snailfish	X	X
Liparidae	*Paraliparis bathybius*	Black Seasnail	X	X
Zoarcidae	*Gymnelus hemifasciatus*	Halfbarred Pout	X	X
Zoarcidae	*Gymnelus viridis*	Fish Doctor	X	X
Zoarcidae	*Lycenchelys kolthoffi*	Checkered Wolf Eel		X
Zoarcidae	*Lycodes adolfi*	Adolf's Eelpout		X
Zoarcidae	*Lycodes eudipleurostictus*	Doubleline Eelpout		X
Zoarcidae	*Lycodes frigidus*	Glacial Eelpout	X	X
Zoarcidae	*Lycodes jugoricus*	Shulupaoluk		X
Zoarcidae	*Lycodes marisalbi*	White Sea Eelpout		X
Zoarcidae	*Lycodes mucosus*	Saddled Eelpout	X	X
Zoarcidae	*Lycodes palearis*	Wattled Eelpout	X	X
Zoarcidae	*Lycodes pallidus*	Pale Eelpout		X
Zoarcidae	*Lycodes polaris*	Polar Eelpout	X	X
Zoarcidae	*Lycodes raridens*	Marbled Eelpout	X	X
Zoarcidae	*Lycodes reticulatus*	Arctic Eelpout		X
Zoarcidae	*Lycodes rossi*	Threespot Eelpout		X
Zoarcidae	*Lycodes sagittarius*	Archer Eelpout		X
Zoarcidae	*Lycodes seminudus*	Longear Eelpout	X	X
Zoarcidae	*Lycodes squamiventer*	Scalebelly Eelpout		X
Zoarcidae	*Lycodes turneri*	Estuarine Eelpout	X	X
Stichaeidae	*Acantholumpenus mackayi*	Blackline Prickleback	X	
Stichaeidae	*Anisarchus medius*	Stout Eelblenny	X	X
Stichaeidae	*Chirolophis snyderi*	Bearded Warbonnet	X	
Stichaeidae	*Eumesogrammus praecisus*	Fourline Snakeblenny	X	X
Stichaeidae	*Leptoclinus maculatus*	Daubed Shanny	X	X
Stichaeidae	*Lumpenus fabricii*	Slender Eelblenny	X	X
Stichaeidae	*Lumpenus sagitta*	Snake Prickleback	X	
Stichaeidae	*Stichaeus punctatus*	Arctic Shanny	X	X
Pholidae	*Pholis fasciata*	Banded Gunnel	X	
Anarhichadidae	*Anarhichas denticulatus*	Northern Wolffish	X	X
Anarhichadidae	*Anarhichas orientalis*	Bering Wolffish	X	X
Zaproridae	*Zaprora silenus*	Prowfish	X	
Ammodytidae	*Ammodytes hexapterus*	Arctic Sand Lance	X	X
Pleuronectidae	*Hippoglossoides robustus*	Bering Flounder	X	X
Pleuronectidae	*Hippoglossus stenolepis*	Pacific Halibut	X	
Pleuronectidae	*Limanda aspera*	Yellowfin Sole	X	X
Pleuronectidae	*Limanda proboscidea*	Longhead Dab	X	X
Pleuronectidae	*Limanda sakhalinensis*	Sakhalin Sole	X	
Pleuronectidae	*Liopsetta glacialis*	Arctic Flounder	X	X
Pleuronectidae	*Platichthys stellatus*	Starry Flounder	X	X
Pleuronectidae	*Pleuronectes quadrituberculatus*	Alaska Plaice	X	
Pleuronectidae	*Reinhardtius hippoglossoides*	Greenland Halibut	X	X
	Totals:	109	97	83

Table 2.2. Changes in occurrence and geographic distribution of Arctic marine fishes in the Chukchi and Beaufort Seas since 2002.

[Changes were made since publication of Mecklenburg and others (2002)]

Scientific name	Common name	New occurrence	Geographic distribution	
			Range change	No change
Entosphenus tridentatus	Pacific Lamprey			X
Lethenteron camtschaticum	Arctic Lamprey			X
Squalus suckleyi	Spotted Spiny Dogfish		X	
Somniosus pacificus	Pacific Sleeper Shark	X	X	
Amblyraja hyperborea	Arctic Skate	X	X	
Bathyraja parmifera	Alaska Skate	X	X	
Clupea pallasii	Pacific Herring			X
Hypomesus olidus	Pond Smelt		X	
Mallotus catervarius	Pacific Capelin			X
Osmerus dentex	Arctic Smelt			X
Coregonus autumnalis	Arctic Cisco		X	
Coregonus laurettae	Bering Cisco			X
Coregonus nasus	Broad Whitefish			X
Coregonus pidschian	Humpback Whitefish			X
Coregonus sardinella	Least Cisco			X
Oncorhynchus gorbuscha	Pink Salmon			X
Oncorhynchus keta	Chum Salmon			X
Oncorhynchus kisutch	Coho Salmon		X	
Oncorhynchus nerka	Sockeye Salmon		X	
Oncorhynchus tshawytscha	Chinook Salmon			X
Salvelinus malma	Dolly Varden			X
Stenodus leucichthys	Inconnu		X	
Benthosema glaciale	Glacier Lanternfish			X
Arctogadus glacialis	Ice Cod		X	
Boreogadus saida	Arctic Cod			X
Eleginus gracilis	Saffron Cod			X
Gadus chalcogrammus	Walleye Pollock		X	
Gadus macrocephalus	Pacific Cod		X	
Gasterosteus aculeatus	Threespine Stickleback			X
Pungitius pungitius	Ninespine Stickleback			X
Hexagrammos stelleri	Whitespotted Greenling			X
Artediellus ochotensis	Okhotsk Hookear Sculpin			X
Artediellus scaber	Hamecon			X
Enophrys diceraus	Antlered Sculpin			X
Gymnocanthus tricuspis	Arctic Staghorn Sculpin			X
Hemilepidotus papilio	Butterfly Sculpin		X	
Icelus bicornis	Twohorn Sculpin		X	
Icelus spatula	Spatulate Sculpin			X
Icelus spiniger	Thorny Sculpin	X	X	
Megalocottus platycephalus	Belligerent Sculpin			X
Microcottus sellaris	Brightbelly Sculpin		X	
Myoxocephalus jaok	Plain Sculpin		X	
Myoxocephalus polyacanthocephalus	Great Sculpin	X	X	
Myoxocephalus quadricornis	Fourhorn Sculpin			X
Myoxocephalus scorpioides	Arctic Sculpin			X
Myoxocephalus scorpius	Shorthorn Sculpin			X
Trichocottus brashnikovi	Hairhead Sculpin		X	
Triglops nybelini	Bigeye Sculpin	X	X	
Triglops pingelii	Ribbed Sculpin		X	
Blepsias bilobus	Crested Sculpin			X
Nautichthys pribilovius	Eyeshade Sculpin		X	
Cottunculus microps	Polar Sculpin		X	
Eurymen gyrinus	Smoothcheek Sculpin			X
Aspidophoroides monopterygius	Alligatorfish		X	
Aspidophoroides olrikii	Arctic Alligatorfish			X

Table 2.2. Changes in occurrence and geographic distribution of Arctic marine fishes in the Chukchi and Beaufort Seas since 2002.—Continued

Scientific name	Common name	New occurrence	Geographic distribution	
			Range change	No change
Hypsagonus quadricornis	Fourhorn Poacher	X	X	
Leptagonus decagonus	Atlantic Poacher		X	
Occella dodecaedron	Bering Poacher		X	
Pallasina barbata	Tubenose Poacher		X	
Podothecus veternus	Veteran Poacher		X	
Eumicrotremus andriashevi	Pimpled Lumpsucker			X
Eumicrotremus derjugini	Leatherfin Lumpsucker		X	
Careproctus reinhardti	Sea Tadpole	X	X	
Liparis bathyarcticus	Nebulous Snailfish	X	X	
Liparis fabricii	Gelatinous Seasnail		X	
Liparis gibbus	Variegated Snailfish			X
Liparis tunicatus	Kelp Snailfish			X
Paraliparis bathybius	Black Seasnail	X	X	
Gymnelus hemifasciatus	Halfbarred Pout		X	
Gymnelus viridis	Fish Doctor		X	
Lycenchelys kolthoffi	Checkered Wolf Eel	X	X	
Lycodes adolfi	Adolf's Eelpout	X	X	
Lycodes eudipleurostictus	Doubleline Eelpout			X
Lycodes frigidus	Glacial Eelpout	X	X	
Lycodes jugoricus	Shulupaoluk	X	X	
Lycodes marisalbi	White Sea Eelpout	X	X	
Lycodes mucosus	Saddled Eelpout			X
Lycodes palearis	Wattled Eelpout			X
Lycodes pallidus	Pale Eelpout	X	X	
Lycodes polaris	Polar Eelpout			X
Lycodes raridens	Marbled Eelpout		X	
Lycodes reticulatus	Arctic Eelpout	X	X	
Lycodes rossi	Threespot Eelpout			X
Lycodes sagittarius	Archer Eelpout			X
Lycodes seminudus	Longear Eelpout		X	
Lycodes squamiventer	Scalebelly Eelpout		X	
Lycodes turneri	Estuarine Eelpout		X	
Acantholumpenus mackayi	Blackline Prickleback			X
Anisarchus medius	Stout Eelblenny			X
Chirolophis snyderi	Bearded Warbonnet			X
Eumesogrammus praecisus	Fourline Snakeblenny		X	
Leptoclinus maculatus	Daubed Shanny		X	
Lumpenus fabricii	Slender Eelblenny			X
Lumpenus sagitta	Snake Prickleback	X	X	
Stichaeus punctatus	Arctic Shanny		X	
Pholis fasciata	Banded Gunnel		X	
Anarhichas denticulatus	Northern Wolffish	X	X	
Anarhichas orientalis	Bering Wolffish			X
Zaprora silenus	Prowfish	X	X	
Ammodytes hexapterus	Arctic Sand Lance			X
Hippoglossoides robustus	Bering Flounder		X	
Hippoglossus stenolepis	Pacific Halibut		X	
Limanda aspera	Yellowfin Sole			X
Limanda proboscidea	Longhead Dab		X	
Limanda sakhalinensis	Sakhalin Sole		X	
Liopsetta glacialis	Arctic Flounder			X
Platichthys stellatus	Starry Flounder			X
Pleuronectes quadrituberculatus	Alaska Plaice		X	
Reinhardtius hippoglossoides	Greenland Halibut			X
	Totals: 109	20	59	50

Species Range Extensions

Comparing Arctic marine fish distributions as described by recent studies to similar historical information reveals some significant changes. Some of the changes in distributional patterns relate to increased sampling and new discovery and others to changes in species classifications and nomenclature. Since 2002, 20 new species were confirmed from the Chukchi and Beaufort Seas. By family, the new Alaska records were reported from Somniosidae (1), Rajidae (2), Cottidae (3), Agonidae (1), Liparidae (3), Zoarcidae (7), Stichaeidae (1), Anarhichadidae (1), and Zaproridae (1). The new Alaskan records are valid range extensions resulting from BOEM-sponsored surveys by NOAA (Logerwell and others, 2009; Rand and Logerwell, 2011) and University of Alaska-Fairbanks (UAF) and NOAA's RUSALCA (Mecklenburg and others, 2014; Mecklenburg and Steinke, 2015) or changes in taxonomy and distribution reported by Mecklenburg and others (2011, 2015, 2016).

Extensions to the known ranges for five marine species were reported from trawl collections in the Beaufort Sea by Rand and Logerwell (2011): Walleye Pollock (*Gadus chalcogrammus*), Pacific Cod (*G. macrocephalus*), Festive Snailfish (*Liparis marmoratus*), Bigeye Sculpin (*Triglops nybelini*), and Eyeshade Sculpin (*Nautichthys pribilovius)*. Apparently, Rand and Logerwell (2011) did not notice that the Antlered Sculpin (*Enophrys diceraus*) listed in their tables also was an extension of this species' known range in the Beaufort Sea. This extension was confirmed by Maslenikov and others (2013).

Additional information about the Rand and Logerwell (2011) collection includes:

- **Walleye Pollock** (*Gadus chalcogrammus*): This probably was the first published record from the Beaufort Sea for *G. chalcogrammus*, since the previous record from Elson Lagoon (near Barrow, Alaska) was shown to pertain to *Boreogadus saida* (Mecklenburg and others, 2011, Online Resource 1, p. 15). Rand and Logerwell (2011, p. 484) reported this occurrence from Elson Lagoon incorrectly.

- **Pacific Cod (***Gadus macrocephalus*): "*Major changes in the composition of gadine genera in recent years mean patterns of species distribution are different*" (Mecklenburg and others, 2011, Online Resource 1, p. 120). Historically, *G. macrocephalus* from the Beaufort Sea were identified as *G. ogac* (Mecklenburg and others, 2002). Owing to recent DNA studies and similarity in morphology, and the consequent synonymization of *G. ogac* in *G. macrocephalus*, this species is now recognized to have a broad distribution from the Chukchi Sea and continuing eastward in the Arctic across Canada to Greenland and the White Sea (Mecklenburg and others, 2011, Online Resource 1, p. 120). Given this information, the range extension reported by Rand and Logerwell (2011) was not truly an extension of known range.

- **Bigeye Sculpin** (*Triglops nybelini*); From Maslenikov and others, 2013, p. 12): "*An Arctic species reported from northwest of Alaska in the international waters of the Chukchi Borderland (Mecklenburg et al., 2011), the Beaufort Sea off Alaska (eastward to 71.21836N, 149.90316W by benthic trawl in 2011; C.W. Mecklenburg, personnel [sic.] communication), and from western Canada in Mackenzie Bay and Amundsen Gulf eastward around the Arctic to the Laptev Sea (Pietsch, 1993). Captured in a midwater tow, the specimens reported here from the Beaufort Sea east of Point Barrow are vouchers for the 1st Alaskan records cited by Rand and Logerwell (2011).*"

- **Eyeshade Sculpin** (*Nautichthys pribilovius*); From Maslenikov and others, 2013, p. 12) "*Known from the Chukchi Sea off Wainwright south through the western and eastern Bering Sea, Sea of Okhotsk, and Sea of Japan, and the Aleutian and Commander Islands to southeastern Alaska, the record cited here provides a voucher for the northern range extension of* Nautichthys pribilovius *into the Beaufort Sea cited by Rand and Logerwell (2011).*"

As an additional note, the single specimen reported by Rand and Logerwell (2011) from their 2008 cruise is the first record from the Beaufort Sea, as described by Mecklenburg and others (2011, Online Resource 1, p. 27). Others have been collected in the same area since then (Mecklenburg and others, 2016).

- **Festive Snailfish:** Reports of *L. marmoratus* in the Bering Sea and the Alaskan Arctic have been questioned because the voucher specimens are similar morphologically and genetically to *L. tunicatus* (Mecklenburg and others, 2011, 2016; Mecklenburg and Steinke, 2015). The DNA sequences from all specimens collected in the Bering and Chukchi Seas in recent years with the external appearance described for *L. marmoratus* (Mecklenburg and others, 2002), are identical to sequences from *L. tunicatus*. Mecklenburg and others (2011) did not count this species among those considered valid in their review and list of Arctic marine fishes. The specimens reported by Rand and Logerwell (2011), which would be the only records from the U.S. Arctic, look morphologically the same as the barcoded specimens[2].

[2]Mecklenburg and others (2011) questioned the validity of collection records for *L. marmoratus* from the Beaufort Sea. DNA barcoding indicate the species is not valid from the Chukchi or Beaufort Seas but may be found in the Sea of Okhotsk (Mecklenburg and Steinke, 2015).

- **Longear Eelpout** (*Lycodes seminudus*); from Maslenikov and others (2013)**:** *L. seminudus* is an Arctic species known from the Beaufort Sea and the Chukchi slope north of Alaska (Mecklenburg and others, 2011), as well as the Norwegian and Kara Seas. The record cited here extends the range 200 km west in the Beaufort Sea and represents only the second Alaskan record.

Mecklenburg and others (2016, p. 197) reported a significant extension in the northern distribution of the Bearded Warbonnet in sampling conducted off Pt. Barrow:

- **Bearded Warbonnet** (*Chirolophis snyderi*): "The northernmost documented locality is Point Barrow, Alaska, at 71°23′N, 156°29′W, where juvenile specimens were taken in a beach seine in 2012 (e.g., CAS 237946, 2 specimens, each 31 mm). The previously reported northernmost record was from northwest of Point Franklin in the eastern Chukchi Sea (Mecklenburg et al., 2002, 2011; UAM 4582)."

These descriptions highlight the dynamic nature and taxonomic issues associated with documenting or confirming range extensions from the Arctic. In many instances, Alaska records seem to be new because there has been so little previous sampling. Researchers often are not able to review historical collections in light of new taxonomic knowledge. In fairness, the historical data are often difficult to access and interpret because of documented changes in taxonomy and geographical distribution. To illustrate, Rand and Logerwell (2011) noted that Bering Flounder (*Hippoglossoides robustus*) was not reported in Arctic fish sampling by Frost and Lowry (1983) in 1977, nor was it reported north of Point Barrow by Mecklenburg and others (2002). However, additional research by Mecklenburg and others (2011) discovered that this species was distributed eastward through the Beaufort Sea to Bathurst Inlet (Canadian Arctic) as early as 1965.

The Walleye Pollock catches reported by Logerwell and others (2011) were to the north of all larval, age-1, and adult pollock catches depicted by Wyllie Echeverria (1996) for the northeastern Chukchi Sea and the geographic distributions described by Mecklenburg and others (2002). The new Alaskan records, and size of fish captured, raise the possibility that this species, particularly juvenile pollock, may have been misidentified in earlier Beaufort Sea surveys as Polar Cod[3]. It also raises questions about their potential origins and dispersal into this part of the Arctic Ocean. Walleye Pollock are captured off Norway and thus their dispersal into the Beaufort Sea with possible genetic interchange along the upper slope is plausible. Cold temperatures are constraints to northerly movements and abundance of pollock; therefore, large expansions and swarms, such as those reported for Arctic Cod (*Boreogadus saida*) by Crawford and others (2012), would not be expected under present environmental conditions.

Other range extensions are reported in Love and others (2005), Mecklenburg and others (2011), Maslenikov and others (2013), Mecklenburg and Steinke (2015), or evaluated more conventionally in the *Pacific Arctic Marine Fishes* guide (Mecklenburg and others, 2016). In addition to the species discussed from the Rand and Logerwell (2011) collection, an annotated list of range extensions provides new distributional information with supporting documentation as available, or appropriate, for citation at this time. The new information results from an increased Arctic research sampling emphasis in offshore marine habitats in the Chukchi and Beaufort Seas. The annotated list of extensions is represented by lesser-known marine fishes having no commercial value that researchers are aware of and are presented as they relate to the (1) Beaufort Sea, (2) Chukchi Sea, and (3) Chukchi and Beaufort Seas:

1. From the Beaufort Sea:

   - **Arctic Skate** (*Amblyraja hyperborea*)**:** Mecklenburg and others (2016) report this species to be circumpolar; found in polar basins southward to Beaufort Sea of Alaska and Western Canada at depths ranging from 92 to 2,925 m. Size information is reported in Wienerroither and others (2011).

   - **Plain Sculpin** (*Myoxocephalus jaok*)**:** New record identified from the Beaufort Sea in 2011 (Mecklenburg and others, 2016).

   - **Alligatorfish** (*Aspidophoroides monopterygius*)**:** Identified by Catherine W. Mecklenburg from a specimen voucher in the NOAA RACE groundfish surveys 2012 survey collections (Mecklenburg and others, 2016).

   - **Black Seasnail** (*Paraliparis bathybius*)**:** Previously reported from the western Arctic Canada Basin north of Alaska in 2005 (Mecklenburg and others, 2016). Alaskan collections were from slope and deep waters of the Beaufort Sea in 2011.

   - **Checkered Wolf Eel** (*Lycenchelys kolthoffi*): One specimen was taken in the Alaskan Beaufort Sea near the U.S.–Canada border at 70°28′N, 141°09′W at a depth of 500 m (Mecklenburg and others, 2016). Otherwise, the species lives eastward from that point to Greenland and on to the Kara Sea. It is common at least around Greenland. It is mesobenthic, lives on sandy or muddy or mixed soft-stony sea floors, at depths of 202–930 m and temperatures of -0.9–4.1 °C. Maximum size is 29 cm TL.

[3]This is a common misidentification in museum collections (Mecklenburg and others, 2011; Mecklenburg and Steinke, 2015).

At least five new occurrences of eelpout species (table 2.2) from the Beaufort Sea sampling were confirmed in the processing of voucher specimens from University of Alaska Fairbanks fishery collections between 2010 and 2011 (Mecklenburg and Steinke, 2015; Mecklenburg and others, 2016). Specimens collected from the WEBSEC-71 survey in the Beaufort Sea (U.S. Coast Guard Cutter [USCGC] Glacier; Hufford, 1974) were evaluated in 2007 and new information gleaned from the specimens was reported by Mecklenburg and others (2016). Additional records and information on the following species may also be found in Mecklenburg and others (2016):

- **Adolf's Eelpout** (*Lycodes adolfi*)**:** A voucher specimen collected in the Beaufort Sea in University of Alaska Fairbanks surveys conducted between 2010 and 2012 (Mecklenburg and others, 2016). This species was also sampled on Chukchi slope, outside the 200-mi limit, by 2009 RUSALCA (Russian-American Long-term Census of the Arctic, 2009); no other records near or in the Chukchi Sea); see Mecklenburg and others (2011, Online Reference 1).

- **Glacial Eelpout** (*Lycodes frigidus*); From Mecklenburg and others (2011, Online Resource 1, p. 39): "*Arctic; Makarov Basin northwest of Ellesmere Island, deep slopes and basins of Greenland and Norwegian Seas, Nansen to Canada basins off Laptev, East Siberian, Chukchi, and Beaufort Seas. Benthic, at depths of 475 m to 3,000 m, rare in depths less than 1,000 m. The first vouchered collection from north of Alaska (California Academy of Sciences, Department of Ichthyology, San Francisco, USA CAS 230372; 2 specimens, 53–76 mm) was made by remotely operated vehicle (ROV) and suction sampler in 2005 north-northwest of Point Barrow at a depth of about 2,500 m.*"

- **Shulupaoluk** (*Lycodes jugoricus*)**:** The University of Alaska Fairbanks Beaufort Sea 2012 voucher specimen collection includes several *L. jugoricus*. (Mecklenburg and others, 2016).

- **White Sea Eelpout** (*Lycodes marisalbi*); From Mecklenburg and others (2011, Online Resource 1), p. 40: "*Arctic; White Sea and Beaufort Sea. Benthic, at depths of 6–335 m. Records from the Beaufort Sea off Alaska identified as* L. pallidus *(e.g., Mecklenburg et al. 2002) are* L. marisalbi *(Canadian Museum of Nature, Ottawa, Canada CMNFI 1974-279, 1974-285, 1974-287, 1978-302; CWM, 15 May 2008).*"

- **Arctic Eelpout** (*Lycodes reticulatus*)**:** Mecklenburg and Steinke (2015) investigated the validity of species in the family Lycodes from the Pacific Arctic Region using morphological observations and DNA barcoding sequences (http://dx.doi.org/10.5883/DS-LYCODES). Their genetic analysis revealed that specimens identified as *L. rossi* always fell into the Beaufort Sea clade for *L. reticulatus*.

- **Threespot Eelpout** (*Lycodes rossi*)**:** The inclusion of this species is based on information presented in Mecklenburg and others (2016).

- **Longear Eelpout** (*Lycodes seminudus*)**:** Based on UAF's fishery surveys in the Beaufort Sea (2011–12 records), an offshore pattern reflects a geographic distribution along the shelf deeper than 200–300 m to about 1,400 m. The species occurs only in the offshore-most tracts in the Beaufort Sea lease area.

- **Scalebelly Eelpout** (*Lycodes squamiventer*)**:** Catherine W. Mecklenburg tentatively identified this species from specimens collected from the Beaufort Sea in 2012 (Mecklenburg and others, 2016).

2. From the Chukchi Sea:

- **Ice Cod** (*Arctogadus glacialis*)**:** Identified from samples collected from the Chukchi Sea (Mecklenburg and others, 2016).

- **Sea Tadpole** (*Careproctus reinhardti*): Geographic distribution from Baffin Bay and Davis Strait, off eastern Greenland, off northern Russia (Kara, and Laptev Seas), and Chukchi Sea slope and northern Bering Sea (Mecklenburg and others, 2016). Benthic, at depth of 100–1,840 m. Preliminary genetic data suggest the sea tadpole could be a species complex (Mecklenburg and others, 2016).

- **Great Sculpin** (*Myoxocephalus polyacanthocephalus*)**:** Okhotsk Sea and eastern Japan Sea to Commander–Aleutian Island chain to Chukchi Sea, 70°20′N, 163°06′W (Mecklenburg and others, 2016) to southern Puget Sound, Washington. Benthic; intertidal and to 825 m.

- **Prowfish** (*Zaprora silenus*)**:** Hokkaido, Japan, and Sea of Okhotsk to Bering Sea (Mecklenburg and others, 2002) and to southeastern Chukchi Sea (west of Kivalina, 67°32′N, 165°54′W) (Mecklenburg and others, 2011) and Aleutian Islands (Mecklenburg and others, 2002) to San Miguel Island, southern California (Allen and Smith, 1988). At depths of 10–801 m. Adults found near bottom, young fish often collected near surface (Mecklenburg and others, 2002).

3. From the Chukchi and Beaufort Seas:
   - **Bigeye Sculpin** (*Triglops nybelini*)**:** Arctic Ocean, practically circumpolar, Chukchi Sea north of Alaska, western Beaufort Sea slope between 152°W and 155°W (Mecklenburg and others, 2011). Benthic, at depths of 30–1,354 m, usually deeper than 200 m (Mecklenburg and others, 2016).
   - **Nebulous Snailfish** (*Liparis bathyarcticus*)**:** Circumpolar, Beaufort and Chukchi Seas to southeastern Bering Sea (Mecklenburg and others, 2016). Benthic at depths of about 12–510 m (Mecklenburg and others, 2016).

Probable Occurrences in Alaska Arctic

More species are known to occur in the study area than are described in the species accounts in this catalog because the taxonomic examinations of these fish are in an early stage, and valid identifications are not possible without all results from the multi-faceted research (that is, meristic, morphological, and molecular genetic). The ongoing research approach will include formal descriptions of new species and documentation of significant distributional changes. For instance, Mecklenburg and others (2011) reported an unidentified sculpin, *Icelus sp.*, from the Chukchi Sea (*editor's note*: recently confirmed by Mecklenburg and Steinke, 2015), and Rand and Logerwell (2011) reported an unidentified snailfish, *Careproctus sp. cf. rastrinus*, from the Beaufort Sea. For this study, we determined that the biological information available for these two species to be too scant and preliminary to permit construction of dependable species accounts. Species accounts were not developed for *Sominiosus pacificus*, *Bathyraja parmifera*, or *Lycodes pallidus* due to their recent confirmation from the Chukchi Sea (December 2015); information about these species is available in the *Fishes of Alaska* and species accounts are presented in the *Pacific Arctic Marine Fishes* guide (Mecklenburg and others, 2016).

The additional species identified here are likely to be confirmed from Alaska waters. The information presented was primarily from an ongoing effort by several authors of this report to update Love and others (2005):

- **Atlantic Hookear Sculpin** (*Artediellus atlanticus*); From: Mecklenburg and others, (2011, Online Resource 1, p. 20): *Arctic–Boreal; to southern Baffin Island, northwest and northeast Greenland, Iceland, Jan Mayen, Faroe Islands, Norway, and Barents Sea, northern Kara Sea, and northwestern Laptev Sea; upper slope off the Chukchi Sea; south to Cape Cod, the Skagerrak, Irish Sea, and coasts of Ireland* (Fedorov, 1986, p. 1,245; Mecklenburg and others, 2011, fig. 2; this study). Benthic, at depths of 11–1,366 m. Found on the Chukchi slope (Chukchi Sea Borderlands, outside U.S. EEZ) in 2009: two at 74°29′N, 165°58′W, depth 365–370 m (California Academy of Sciences, Department of Ichthyology, San Francisco, USA CAS 228530, fig. 3; Zoological Institute of the Russian Academy of Sciences, St. Petersburg, Russia ZIN 54840); and five at 74°07′N, 166°00′W, depth 227–236 m (CAS 228533, University of Alaska Museum, University of Alaska Fairbanks 5534). This is the first record from the East Siberian-Chukchi-Beaufort region. The specimens fit the description of *A. a. corniger* (Andriashev, 1954) from the Kara and Laptev Seas, Russia, with large parietal spines, but the most recent review of the species in the western Atlantic (Van Guelpen, 1986) determined this character not to discriminate between taxonomic groups and did not recognize any subspecies of *A. atlanticus.* Parietal spine size resembled a cline, with the most strongly developed found in northern parts of the range. The large size fish length (Total Length) of specimens from the Chukchi Sea (as long as 153 mm) agrees with Van Guelpen's determination that the largest specimens are found in the north. The four Co-1 (Cytochrome C Oxidase 1) gene sequences from the Chukchi Sea slope specimens match those of three specimens from southern Baffin Bay (Canadian Museum of Nature, Ottawa, Canada CMNFI 2002-0028.3, 2002-0031.1, 2002-0033.1; 68°26′–69°37′N). The species was confirmed from the Chukchi Borderland by Mecklenburg and others (2014).
- **Spinyhook Sculpin** (*Artediellus gomojunovi*): From Mecklenburg and others (2011, Online Resource 1)—Boreal Pacific north to Gulf of Anadyr, Russia, and Bering Strait. Benthic, at depths of 37–380 m (Mecklenburg and others, 2002). Bering Sea records are no deeper than 90 m. A specimen collected in 1950 near Point Barrow (Smithsonian National Museum of Natural History, Washington, D.C., USNM 152901) and tentatively identified as *A. gomojunovi* (Andriashev, 1961 as cited by Mecklenburg and others, 2011 Online Resource 1) was misplaced (Mecklenburg and others, 2002), but was found in 2005, and subsequently identified as *A. scaber*. The current northernmost record of *A. gomojunovi* is a specimen caught in 1933 at Bering Strait (ZIN 33093).
- **Hookhorn Sculpin** (*Artediellus pacificus*): From Mecklenburg and others, (2011, Online Resource 1)—Boreal Pacific north to southern Gulf of Anadyr and northeast of St. Lawrence Island, Bering Sea. Benthic, at depths of 15–250 m (Mecklenburg and others, 2002). The northern records are not recent: Zoological

Institute of the Russian Academy of Sciences, St. Petersburg, Russia ZIN 33657, Gulf of Anadyr at 63°53′N, 178°48′W, depth 87 m, collected in 1952; and University of Washington Fish Collection at the Burke Museum, Seattle, WA UW 11740, at 63°40′N, 167°28′W, depth 22–40 m, in 1949.

- **Leister Sculpin** (*Enophrys lucasi*): Mecklenburg and others (2016, p. 55) described the distribution as "Southeastern Kamchatka, Commander Islands, Aleutian Islands, Gulf British Columbia, Bering Sea north to Bering Strait. The distribution is difficult to assess due to misidentifications in the literature and museum collections, and the distribution depicted on our map may not be accurate north of the Aleutian Islands and Gulf of Alaska."

- **Threaded Sculpin** (*Gymnocanthus pistilliger*): Mecklenburg and others (2016) suggested this species to be common from Bering Strait. The northernmost record is CAS 230370, taken in 2006 west of Port Clarence at 65°21′N, 167°41′W. Records from Port Clarence include CAS 230369, CAS 230370, CMNFI 1958-0093, UAM 1201, and UW 41676). The several records from Port Clarence and nearby suggest it also occurs in the southeastern Chukchi Sea and there are reliable identifications northward to Kotzebue Sound, but distribution in the Chukchi Sea has not been documented with voucher specimens. Historical records from the Chukchi Sea remain unverified or have been reidentified (Mecklenburg and others, 2016).

- **Yellow Irish Lord** (*Hemilepidotus jordani*): From Mecklenburg and others, (2011, Online Resource 1)—Boreal Pacific north to Bering Strait, perhaps to southeastern Chukchi Sea. Benthic, at depths of 15–400 m or more, typically shallower than 150 m. Reported from Chukchi Sea (Allen and Smith, 1988), but voucher specimens are lacking. A specimen from the Chukchi Sea southwest of Kivalina identified as *H. jordani* (University of British Columbia, Vancouver, B.C., UBC 61-0064) is *H. papilio* (Mecklenburg and others, 2016). The northernmost verified record is CAS 230368, two juveniles (77–82 mm) caught in 2006 near eastern Bering Strait at 64°59'N, 168°30'W, by bottom trawl in 25 m of water.

- **Frog Sculpin** (*Myoxocephalus stelleri*): This species, once believed to possibly be present rarely in Alaskan waters (Mecklenburg and others, 2002), has been determined from evaluation of all pertinent literature and voucher records identified as this species to be absent from the eastern Pacific and Alaskan waters (Mecklenburg and others, 2011, 2016). See also Mecklenburg and Steinke (2015, p. 176).

- **Polar Sculpin** (*Cottunculus microps*): One record is from the Arctic Ocean on the slope north of the Chukchi Sea, outside the 200-mi limit. Taxonomic revision is in progress; confirmed from the Chukchi Borderland (Mecklenburg and others, 2014).

- **Threaded Sculpin** (*Gymnocanthus pistilliger*): Mecklenburg and others (2016) extended the range for this species into the southeastern Chukchi Sea based on "reliable" identifications but not confirmed specimen vouchers. Although this species is likely to occur in the region, our list includes only species whose presence is known from voucher specimens.

- **Northern Sand Lance** (*Ammodytes dubius*): Predominantly in boreal western Atlantic; Canadian Arctic from Beaufort Sea to Baffin Bay, and Davis Strait. Benthic, shallows to 108 m (Coad and Reist, 2004). These authors also listed Alaska but provided no specific locality.

Other Changes in Species Distributions

In addition to the new occurrences and range extensions in table 2.2, mapping for this study (chapter 3) documents expansions in the known geographic distributions of another 45 species in this updating of information presented in the *Fishes of Alaska* (Mecklenburg and others, 2002). These shifts in range result from the new information and knowledge gained from recent field surveys and discoveries, improved identification techniques, evaluation of museum collections, and the wide-ranging search of data and literature for this study. In light of the recent field sampling, some changes in geographic, depth, or both, were realistic expectations. Marine ecosystems are dynamic and fish distributions may contract and expand due to various factors including, but not limited to, temperature changes, current patterns, changes in population size, and changes in predator and prey distribution.

Nomenclature and Previous Misidentifications

Genetic analysis, in concert with other species identification techniques, has greatly assisted ichthyological efforts to clarify and resolve existing taxonomic uncertainty surrounding many Arctic species. This work has resulted in several important changes in scientific and common names, which must be continually tracked for natural resource inventories to remain current. The changes in nomenclature in table 2.3 relate to the greater resolution in phylogenetic understanding that presently exists than was available at the time when the *Fishes of Alaska* (Mecklenburg and others, 2002) was published.

Many species relationships require further study and additional changes in synonymy are expected. As an example, the relationship between *Hippoglossiodes robutus* (Bering Flounder) and *H. elassodon* (Flathead Sole) are currently being investigated (Kartavtsev and others, 2008; Mecklenburg and Steinke, 2015; Mecklenburg and others, 2016); preliminary results suggest the two species are the same.

Table 2.3. Changes in scientific and common names of Arctic marine fishes in the Chukchi and Beaufort Seas since 2002.

[Changes were made since publication of Mecklenburg and others (2002). **Reference:** Information is critical for users. In some instances, specialists may disagree ("not clearly distinguishable" as supporting genetic information may not be available; for example, *Liparis herchelinus* not clearly distinguished from *L. tunicatus*), or species may be part of an evolving complex (for example, *Lycodes rossi* and *L. reticulatus*)]

Family	Common or scientific name	Change in common or scientific name		Reference
		From	To	
Squalidae	Spotted Spiny Dogfish	*Squalus acanthias*	*Squalus suckleyi*	Lynghammar and others, 2012
Osmeridae	Capelin	*Mallotus villosus*	*Mallotus catervarius*	Mecklenburg and Steinke, 2015
Osmeridae	*Mallotus catervarius*	Capelin	Pacific Capelin	Mecklenburg and Steinke, 2015
Osmeridae	Arctic Smelt	*Osmerus mordax*	*Osmerus dentex*	Mecklenburg and others, 2011
Gadidae	*Arctogadus glacialis*	Polar Cod	Ice Cod	Jørgen Schou Christiansen, oral commun, 2013[1]
Gadidae	Walleye Pollock	*Theragra chalcogramma*	*Gadus chalcogrammus*	Mecklenburg and others, 2011; Page and others, 2013
Gadidae	Pacific Cod	*Gadus ogac*	*Gadus macrocephalus*	Mecklenburg and others, 2011; Page and others, 2013
Psychrolutidae	Polar Sculpin	*Cottunculus sadko*	*Cottunculus microps*	Byrkjedal and others, 2014
Agonidae	Arctic Alligatorfish	*Ulcina olrikii*	*Aspidophoroides olrikii*	Mecklenburg and others, 2011; Page and others, 2013
Ammodytidae	*Ammodytes hexapterus*	Pacific Sand Lance	Arctic Sand Lance	Orr and others, 2015
Pleuronectidae	Arctic Flounder	*Pleuronectes glacialis*	*Liopsetta glacialis*	Eschmeyer and others, 2015; Mecklenburg and others, 2016

[1]From Jørgen Schou Christiansen, University of Tromsø, Norway, written commun., May 12, 2013, regarding common names for *A. glacialis* and *B. saida*: "*The scientific name is conclusive and should follow the vernacular name at first mention for these species. Whenever vernacular names are used, we suggest 'ice cod' for Arctogadus glacialis (Latin: glacialis = ice; Russian: ледовая треска) and 'polar cod' for Boreogadus saida. Fish names lists representing the official stand of national and international organizations such as the American Fisheries Society and American Society of Ichthyologists and Herpetologists (Nelson et al. 2004) and the Fisheries Society of the British Isles (Wheeler 1992) differ and, thus, preclude establishment of universal common names. Fortunately, use of scientific names at first mention allows preferential use of vernacular names.*" We acknowledge that our of use Ice Cod is different from other North American nomenclature (Page and others, 2013; Hoff and others, 2015; Mecklenburg and others, 2016). Mecklenburg and others (2013) list Ice Cod as one of the "English" names for *A. glacialis*.

Zoogeographic Patterns

Definitions of zoogeographic pattern are from Mecklenburg and others (2011, Online Resource 1) and relate to species endemism and ranges of their population viability:

- *Arctic*—Species that live and reproduce in Arctic waters and are not found, or only infrequently found, in adjacent boreal waters.
- *Predominantly Arctic*—Species that are usually found in Arctic waters.
- *Predominantly Boreal*—Species that are characteristic of boreal waters and common in the border regions of the Arctic (for example, eastern Barents Sea, Gulf of Anadyr [Russia], Norton Sound [Alaska]). Can be more specific, such as predominantly Boreal Pacific or predominantly Boreal eastern Atlantic.
- *Boreal*—Species that are characteristic of boreal waters and only rarely or temporarily found in the border regions of the Arctic. Can be more specific, such as Boreal Pacific or Boreal eastern Atlantic. Includes subtropical, southern boreal category of Andriashev and Chernova (1994).
- *Arctic-Boreal*—Species are distributed and spawn in both Arctic and Boreal waters.
- *Widely Distributed*—Species common in the temperate, boreal, and subtropical zones and in the warm waters of at least two oceans or known from the southern hemisphere, and occurring only rarely in the Arctic.

Abundance Terminology

Species distribution and abundance was determined from the reports of a large number of reconnaissance surveys and research expeditions. The wide variation in sampling times, areas, and collection methods reported raised issues of data comparability, which required reviewing existing abundance measures, defining appropriate relative abundance terms, and consistently applying operational definitions. Many methods and descriptors have been used to express fish abundance in Arctic studies. Relative abundance terms such as abundant, common, fairly common, present, occasional, uncommon, or rare are commonplace in the reported literature (for example, Coad and Reist, 2004). Existing baselines for Arctic marine fishes are not consistent for sampling in time, space, or methods to support a quantitative, multi-scaled classification that might be suggested by the definitions from Mecklenburg and others (2011) and Mecklenburg and Steinke, 2015). The challenge was to define a simple, but robust classification system that would have broad regional application.
Four ecological principles guided the definition process: (1) abundance is a continuum between rare and abundant, (2) abundance is scale dependent, (3) sampling bias affects estimates of abundance, and (4) environmental influences on species abundance are taxon-specific.

"Rare," "uncommon," and "common" terms are defined in this report to classify relative abundance in the species accounts. These terms also were used by Miller and Lea (1976) to describe the coastal marine fishes of California[4]. For the Arctic ichthyofauna, abundance was classified using the same terms but with different operational definitions determined by species compositions and capture rates of marine fishes. These descriptive statistics are commonly used to characterize catch and, with respect to a regional classification scheme, meet pragmatic criteria related to acceptability (are ecologically sound and reliable), practicality (are applicable to existing records), and effectiveness (are realistic with broad-scale[5] patterns). Species composition (percentage of occurrence of a species with respect to total number of individuals in the catch) provides a simple and scale dependent quantification of an assemblage on an acceptable[6] continuum. Capture rates are a lower resolution measure of abundance based on the presence or absence of a species detected per sampling session and frequency of capture (or rate) over sampling period and survey area.

[4]The decision to use three abundance categories used by Miller and Lea (1976) relates to the lack of consistent, long-term data sets needed for more precise estimates.

[5]Marine fishes are not uniformly distributed in time or space. This analysis was unable to capture seasonal and locality differences but rather portrays regional patterns in abundance.

[6]"Acceptable," as used here, refers to the precision of existing data with respect to the seasonal, geographic, and taxonomic qualities of data collection and how accurately they describe baseline conditions.

Detection rates allow a higher order, less precise comparison of abundance across gear-types and habitats and are a more subjective index. With respect to gear bias and comparability issues, the resultant abundance categories represent semi-quantitative composite metrics from descriptive analyses of catch and expert opinion about relative abundance across at the large-scales of distributional patterns (table 2.4).

Table 2.4. Relative abundance of Arctic marine fishes in the Chukchi and Beaufort Seas.

[**Symbols:** ≥, greater than or equal to; >, greater than; <, less than; ≤, less than or equal to]

Relative abundance term (ecological science)	Species composition (by geographic locale)	Frequency of capture (encounter rates in catch records)
Common	Regularly collected (comprise ≥10 to 50 percent of catch in terms of total numbers of individuals)	Constant rate of capture (>10 to 25 percent of records)
Uncommon	Infrequently observed or collected (<10 percent of catch in terms of total numbers of individuals)	Low rate of capture (≤10 percent of records)
Rare	Seldom reported	20 or fewer records in Arctic (or 1 to 2 captures per cruise)

Endemism and Relative Abundance

Mecklenburg and others, (2011) describe the zoogeographic pattern of 242 marine fish species from the Arctic zoogeographic province. This province includes the northern Bering Sea and North Atlantic Ocean at latitudes far south of this study area. These authors reported 41 percent of the zoogeographic patterns of the marine fauna were Arctic (that is, Arctic, Predominantly Arctic, and Arctic-Boreal zoogeographic patterns) and 59 percent were Boreal (that is, Predominantly Boreal, Boreal, and Widely Distributed zoogeographic patterns). Applying this approach to just the United States area of the Arctic Province, we determined that the Arctic pattern in 58 percent (n = 92) of the marine fishes was from the Chukchi Sea and 73 percent (n = 80) was from the Beaufort Sea. (Editors note: Analysis does not include newly confirmed species to the region—*Somniosus pacificus*, *Bathyraja parmifera*, *Icelus spiniger*, and *Lycodes pallidus*.) The Boreal pattern comprised 42 and 26 percent of the marine faunas, respectively. The ratio of Arctic to Boreal patterns for marine fish found in the U.S. Chukchi and Beaufort Seas is about 60:40 (table 2.5).

Table 2.5. Relative abundance and zoogeography of Arctic marine fishes in the Chukchi and Beaufort Seas.

[**Zoogeographic pattern:** Main references, Mecklenburg and others (2011) Online Resource 1, Mecklenburg and Steinke (2015), and Mecklenburg and others (2016). Blank cell indicates the species is unreported or unknown from the area]

Scientific name	Common name	Confirmed occurrence		Zoogeographic pattern
		Chukchi Sea	Beaufort Sea	
Entosphenus tridentatus	Pacific Lamprey	Rare		Boreal Pacific
Lethenteron camtschaticum	Arctic Lamprey	Common	Common	Arctic-Boreal
Squalus suckleyi	Spotted Spiny Dogfish	Rare		Boreal Pacific
Somniosus pacificus	Pacific Sleeper Shark	Rare		Boreal Pacific
Amblyraja hyperborea	Arctic Skate		Rare	Arctic
Bathyraja parmifera	Alaska Skate	Rare		Boreal Pacific
Clupea pallasii	Pacific Herring	Common	Uncommon	Arctic-Boreal Pacific
Hypomesus olidus	Pond Smelt	Rare		Predominantly Boreal Pacific
Mallotus catervarius	Pacific Capelin	Common	Common	Arctic-Boreal
Osmerus dentex	Arctic Smelt	Common	Common	Arctic Boreal Pacific
Coregonus autumnalis	Arctic Cisco	Rare	Common	Arctic
Coregonus laurettae	Bering Cisco	Common	Common	Predominantly Arctic
Coregonus nasus	Broad Whitefish	Common	Common	Predominantly Arctic
Coregonus pidschian	Humpback Whitefish	Common	Common	Predominantly Arctic
Coregonus sardinella	Least Cisco	Common	Common	Predominantly Arctic
Oncorhynchus gorbuscha	Pink Salmon	Common	Uncommon	Predominantly Boreal Pacific
Oncorhynchus keta	Chum Salmon	Common	Uncommon	Predominantly Boreal Pacific
Oncorhynchus kisutch	Coho Salmon	Uncommon	Uncommon	Predominantly Boreal Pacific
Oncorhynchus nerka	Sockeye Salmon	Uncommon	Uncommon	Predominantly Boreal Pacific
Oncorhynchus tshawytscha	Chinook Salmon	Uncommon	Uncommon	Predominantly Boreal Pacific
Salvelinus malma	Dolly Varden	Common	Common	Arctic-Boreal Pacific
Stenodus leucichthys	Inconnu	Common		Arctic-Boreal[1]
Benthosema glaciale	Glacier Lanternfish	Rare		Arctic-Boreal Atlantic
Arctogadus glacialis	Ice Cod		Rare	Arctic
Boreogadus saida	Arctic Cod	Common	Common	Arctic
Eleginus gracilis	Saffron Cod	Common	Common	Arctic-Boreal Pacific
Gadus chalcogrammus	Walleye Pollock	Uncommon	Uncommon	Predominantly Boreal Pacific and Atlantic
Gadus macrocephalus	Pacific Cod	Uncommon	Uncommon	Arctic-Boreal Pacific and western Atlantic
Gasterosteus aculeatus	Threespine Stickleback	Common	Rare	Predominantly Boreal
Pungitius pungitius	Ninespine Stickleback	Common	Common	Predominantly Boreal
Hexagrammos stelleri	Whitespotted Greenling	Uncommon	Rare	Predominantly Boreal Pacific
Artediellus ochotensis	Okhotsk Hookear Sculpin	Rare		Boreal Pacific
Artediellus scaber	Hamecon	Common	Common	Arctic
Enophrys diceraus	Antlered Sculpin	Common	Uncommon	Predominantly Boreal Pacific
Gymnocanthus tricuspis	Arctic Staghorn Sculpin	Common	Common	Arctic
Hemilepidotus papilio	Butterfly Sculpin	Common		Predominantly Boreal Pacific
Icelus bicornis	Twohorn Sculpin	Rare	Uncommon	Predominantly Arctic
Icelus spatula	Spatulate Sculpin	Common	Common	Arctic-Boreal
Icelus spiniger	Thorny Sculpin	Rare		Predominantly Boreal
Megalocottus platycephalus	Belligerent Sculpin	Common	Rare	Predominantly Boreal Pacific
Microcottus sellaris	Brightbelly Sculpin	Rare		Predominantly Boreal Pacific
Myoxocephalus jaok	Plain Sculpin	Rare	Rare	Predominantly Boreal Pacific
Myoxocephalus polyacanthocephalus	Great Sculpin	Rare		Boreal Pacific
Myoxocephalus quadricornis	Fourhorn Sculpin	Common	Common	Predominantly Arctic
Myoxocephalus scorpioides	Arctic Sculpin	Uncommon	Uncommon	Arctic
Myoxocephalus scorpius	Shorthorn Sculpin	Common	Common	Arctic-Boreal
Trichocottus brashnikovi	Hairhead Sculpin	Common	Uncommon	Predominantly Boreal Pacific
Triglops nybelini	Bigeye Sculpin	Uncommon	Uncommon	Arctic
Triglops pingelii	Ribbed Sculpin	Common	Uncommon	Arctic-Boreal
Blepsias bilobus	Crested Sculpin	Uncommon		Boreal Pacific
Nautichthys pribilovius	Eyeshade Sculpin	Common	Rare	Predominantly Boreal Pacific
Cottunculus microps	Polar Sculpin		Rare	Arctic-Boreal Atlantic
Eurymen gyrinus	Smoothcheek Sculpin	Rare		Predominantly Boreal Pacific

Table 2.5. Relative abundance and zoogeography of Arctic marine fishes in the Chukchi and Beaufort Seas.—Continued

Scientific name	Common name	Confirmed occurrence		Zoogeographic pattern
		Chukchi Sea	Beaufort Sea	
Aspidophoroides monopterygius	Alligatorfish	Common	Common	Predominantly Arctic
Aspidophoroides olrikii	Arctic Alligatorfish	Common	Common	Predominantly Arctic
Hypsagonus quadricornis	Fourhorn Poacher	Rare		Boreal Pacific
Leptagonus decagonus	Atlantic Poacher	Uncommon	Uncommon	Arctic-Boreal
Occella dodecaedron	Bering Poacher	Rare		Boreal Pacific
Pallasina barbata	Tubenose Poacher	Rare		Predominantly Boreal Pacific
Podothecus veternus	Veteran Poacher	Common	Common	Arctic-Boreal Pacific
Eumicrotremus andriashevi	Pimpled Lumpsucker	Rare		Arctic-Boreal Pacific
Eumicrotremus derjugini	Leatherfin Lumpsucker	Rare	Uncommon	Arctic
Careproctus reinhardti	Sea Tadpole	Rare	Rare	Arctic
Liparis bathyarcticus	Nebulous Snailfish	Common	Common	Predominantly Arctic
Liparis fabricii	Gelatinous Seasnail	Common	Common	Arctic
Liparis gibbus	Variegated Snailfish	Common	Uncommon	Arctic-Boreal
Liparis tunicatus	Kelp Snailfish	Common	Common	Arctic
Paraliparis bathybius	Black Seasnail	Rare	Rare	Arctic
Gymnelus hemifasciatus	Halfbarred Pout	Common	Common	Arctic-Boreal
Gymnelus viridis	Fish Doctor	Common	Common	Predominantly Arctic
Lycenchelys kolthoffi	Checkered Wolf Eel		Rare	Arctic
Lycodes adolfi	Adolf's Eelpout		Rare	Arctic
Lycodes eudipleurostictus	Doubleline Eelpout		Uncommon	Arctic
Lycodes frigidus	Glacial Eelpout	Rare	Rare	Arctic
Lycodes jugoricus	Shulupaoluk		Rare	Arctic
Lycodes marisalbi	White Sea Eelpout		Rare	Arctic
Lycodes mucosus	Saddled Eelpout	Common	Uncommon	Arctic
Lycodes palearis	Wattled Eelpout	Common	Uncommon	Predominantly Boreal Pacific
Lycodes pallidus	Pale Eelpout		Rare	Arctic
Lycodes polaris	Polar Eelpout	Common	Common	Arctic
Lycodes raridens	Marbled Eelpout	Common	Common	Arctic-Boreal Pacific
Lycodes reticulatus	Arctic Eelpout		Common	Arctic
Lycodes rossi	Threespot Eelpout		Rare	Arctic
Lycodes sagittarius	Archer Eelpout		Common	Arctic
Lycodes seminudus	Longear Eelpout	Rare	Rare	Arctic
Lycodes squamiventer	Scalebelly Eelpout		Rare	Arctic
Lycodes turneri	Estuarine Eelpout	Uncommon	Uncommon	Predominantly Arctic Pacific
Acantholumpenus mackayi	Blackline Prickleback	Uncommon		Predominantly Boreal Pacific
Anisarchus medius	Stout Eelblenny	Common	Uncommon	Arctic-Boreal
Chirolophis snyderi	Bearded Warbonnet	Uncommon		Predominantly Boreal Pacific
Eumesogrammus praecisus	Fourline Snakeblenny	Uncommon	Uncommon	Arctic-Boreal Pacific and western Atlantic
Leptoclinus maculatus	Daubed Shanny	Common	Common	Arctic-Boreal Pacific and Atlantic
Lumpenus fabricii	Slender Eelblenny	Common	Common	Arctic-Boreal
Lumpenus sagitta	Snake Prickleback	Rare		Boreal Pacific
Stichaeus punctatus	Arctic Shanny	Common	Common	Arctic-Boreal Pacific and western Atlantic
Pholis fasciata	Banded Gunnel	Uncommon	Rare	Arctic-Boreal
Anarhichas denticulatus	Northern Wolffish	Rare	Rare	Arctic-Boreal
Anarhichas orientalis	Bering Wolffish	Uncommon	Uncommon	Predominantly Boreal Pacific
Zaprora silenus	Prowfish	Rare		Boreal Pacific
Ammodytes hexapterus	Arctic Sand Lance	Common	Common	Arctic-Boreal Pacific
Hippoglossoides robustus	Bering Flounder	Common	Common	Arctic-Boreal Pacific
Hippoglossus stenolepis	Pacific Halibut	Rare		Boreal Pacific
Limanda aspera	Yellowfin Sole	Common	Rare	Predominantly Boreal Pacific
Limanda proboscidea	Longhead Dab	Uncommon	Rare	Predominantly Boreal Pacific
Limanda sakhalinensis	Sakhalin Sole	Uncommon		Predominantly Boreal Pacific
Liopsetta glacialis	Arctic Flounder	Common	Common	Predominantly Arctic
Platichthys stellatus	Starry Flounder	Uncommon	Uncommon	Arctic-Boreal Pacific
Pleuronectes quadrituberculatus	Alaska Plaice	Uncommon		Predominantly Boreal Pacific
Reinhardtius hippoglossoides	Greenland Halibut	Uncommon	Uncommon	Arctic-Boreal Pacific and Atlantic

[1]Author determination.

Acknowledgments

The personal observations and ichthyologic data and insights provided by Catherine W. Mecklenburg (California Academy of Sciences, San Francisco and Point Stephens Research, Auke Bay, Alaska) were critical during early planning and review phases of this study. Her participation in RUSALCA, BOEM, Conservation of Arctic Flora and Fauna, U.S. Fish and Wildlife Service, National Park Service, NOAA Auke Bay Laboratories, and other Arctic research provided biogeographic expertise, taxonomic and diversity insights, and critical scientific reviews of developing project information. Her scientific contributions to and review of chapter 2 were especially significant with respect to development of a provisional checklist of valid marine fishes from the Chukchi and Beaufort Seas as well the identification of probable and questionable species occurrences. Special appreciation is extended to Jørgen Schou Christiansen (University of Tromsø, Norway) and Robert Lea (formerly of State of California) for their thoughtful insights on the consistent nomenclature (vernacular names) for *Boreogadus saida* and *Arctogadus glacialis*.

Summary

One hundred nine (109) marine fishes from 24 families are described and compared regarding their occurrence in the United States Chukchi and Beaufort seas. Ninety-seven (97) species are confirmed from the Chukchi Sea and 83 from the Beaufort Sea. Twenty species are newly confirmed to the U.S. Arctic since the publication of *Fishes of Alaska* in 2002. The taxonomy of Arctic marine fishes has improved since 2002, but issues in the naming and acceptance and validity of several species in the Liparidae and Zoarcidae require additional resolution. Many of the common species are benthic or demersal in their habitat orientation. Small-sized marine species such as those representing Cottidae, Liparidae, Stichaeidae, and Zoarcidae families, were common to both seas. The diversity of Salmonidae species reflects the plasticity of this group of fishes and its adaptive linkage to freshwaters. Our analysis supports high rates of Arctic endemism in both seas, especially in the Beaufort Sea. Numerous range extensions and their sources are noted. The estimates of species diversity can be expected to increase with new sampling, with greater reliance on genetic and molecular identification aids, and in response to large-scale effects of changing environmental conditions on present patterns of regional fish distribution and abundance. *Fishes of Alaska* remains an important reference for species taxonomy and identification of more than 600 species from the Gulf of Alaska and Bering Sea to the Arctic but is not complete with respect to species in the Chukchi and Beaufort Seas.

Chapter 3. Alaska Arctic Marine Fish Species Accounts

By Milton S. Love[1], Nancy Elder[2], Catherine W. Mecklenburg[3], Lyman K. Thorsteinson[2], and T. Anthony Mecklenburg[4]

Abstract

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

Purpose and Design of Species Accounts

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

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

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

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Limitations of Data

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

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

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

Operational Definitions

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

Vertical Distribution

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

Location of Shelf Break

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

Keystone Species

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

Outline of Species Accounts

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

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

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

Taxonomic—Scientific and Common Names

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

Iñupiat Name

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

Ecological Role

Fishes play a pivotal role in marine ecosystems as secondary and higher-level consumers in many marine food webs. In many instances, information about predator-prey relationships is so limited that only preliminary, qualitative assessments of the relative role of each species are possible. The ecological niche describes how an organism or population responds to resources and competitors. Importance or significance descriptors do not diminish the fact that all organisms contribute in ways large or small to the provision

of ecosystem goods and services. These descriptors however, may provide useful information about the relative importance of a particular species as an indicator of ecosystem condition and trajectories of change associated with climate change, habitat fragmentation, ecosystem stress, effect of pollutants, or other anthropogenic effects.

Physical Description/Attributes

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

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

Range

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

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

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

Relative Abundance

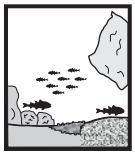
Relative abundance refers to the contribution a species makes to the total abundance of the fishery community. It is a measure that provides an index of the number of individuals present, but not the actual numbers. Relative abundance terms, such as "common," "uncommon," or "rare" often are used to express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

Depth Range

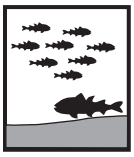
Benthic distribution refers to the spatial arrangement of a particular species at different depths over continental shelf and slope waters. The life cycle of fishes occurs in multiple dimensions in time and space and generally reflects genetically determined life history or behavior that has evolved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

Life History, Population Dynamics, and Biological Interactions

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



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



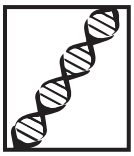
Behavior (see also Glossary [chapter 7]).—Behavior is the manner in which a fish operates or functions within its environment (that is, home range, territoriality, and many others) to procure food, orient to specific locations, or relate to other organisms. Knowing how individuals respond to the environment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

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

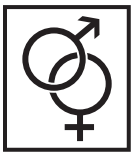
Schooling (that is, social structure of fish of the same species moving in more or less harmonious patterns in the sea) often is related to survival and reproduction. Schooling confers physical benefits to fish movement, safety against predators, search behaviors (for example, foods), population immunology,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

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

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

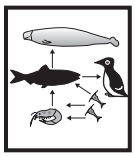


Populations or Stocks—A population often is defined as a group of organisms of the same species occupying a particular space at a particular time with the potential to breed with each other (Williams and others, 2002). Stocks are subpopulations of a particular species of fish that result from reproductive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

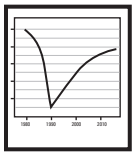


Reproduction Mode—Little information is available about the spawning times and locations, mating behaviors (breeders or nonbreeders), and genetic diversity of Arctic marine fishes. What is known is drawn largely from observations from populations studied outside the United States. For most Arctic marine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

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



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



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

Traditional, Cultural, and Economic Values

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

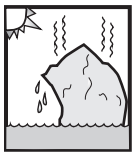
Chukchi and Beaufort Seas, and acknowledges that changing climate may potentially favor the development of commercial fisheries. However, until adequate fisheries resource assessments are completed, the region remains closed to commercial fishing in federal waters. A small salmon fishery exists in Kotzebue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

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

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

Climate Change

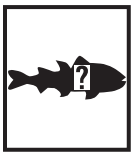
Alaska's climate is changing at more than twice the rate of the rest of the United States (Mellilo and others, 2014). Year-to-year and regional variability in air temperatures are evident and the warming trend currently is being moderated by large-scale cooling associated with the Pacific Decadal Oscillation.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



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

Research Needs

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



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

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

References Cited and Bibliography

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

Pacific and Arctic Lampreys

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

Family Petromyzontidae

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

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

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

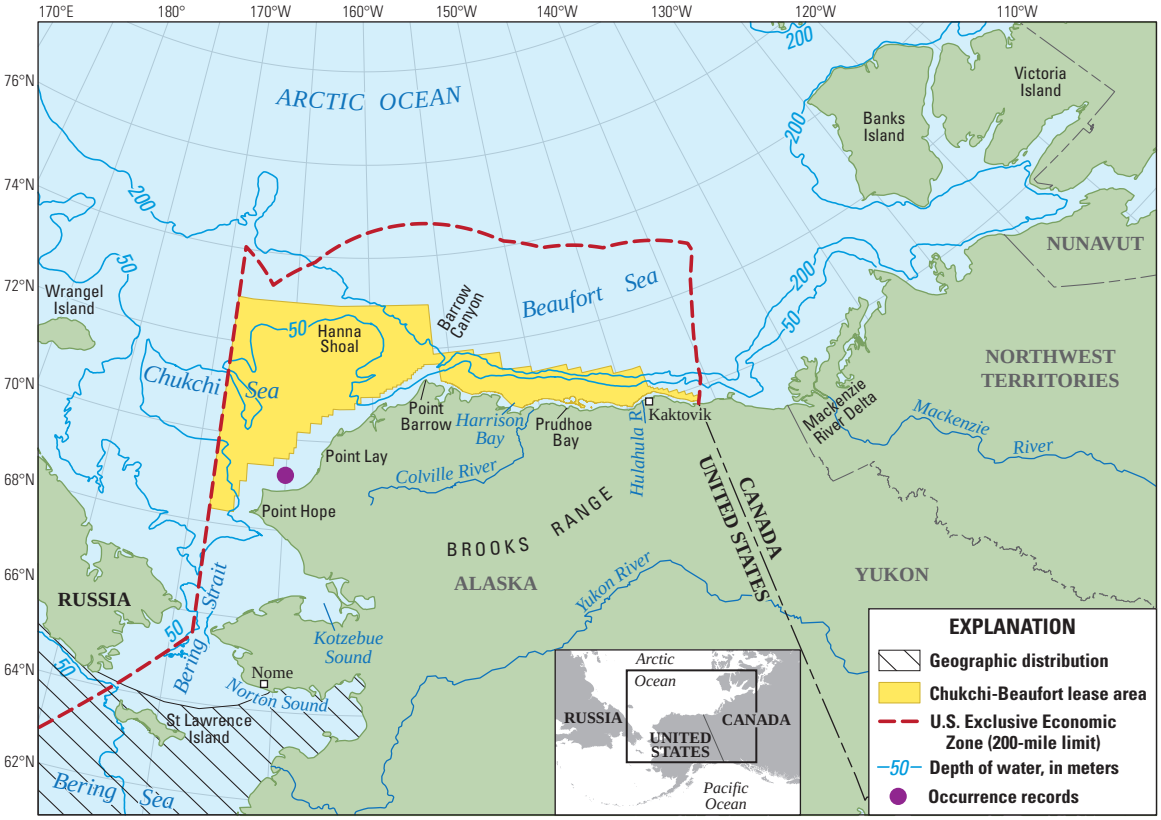
Ecological Role: Its rarity in the U.S. Chukchi Sea and absence from the U.S. Beaufort Sea implies an insignificant role in regional ecosystem dynamics.

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

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

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

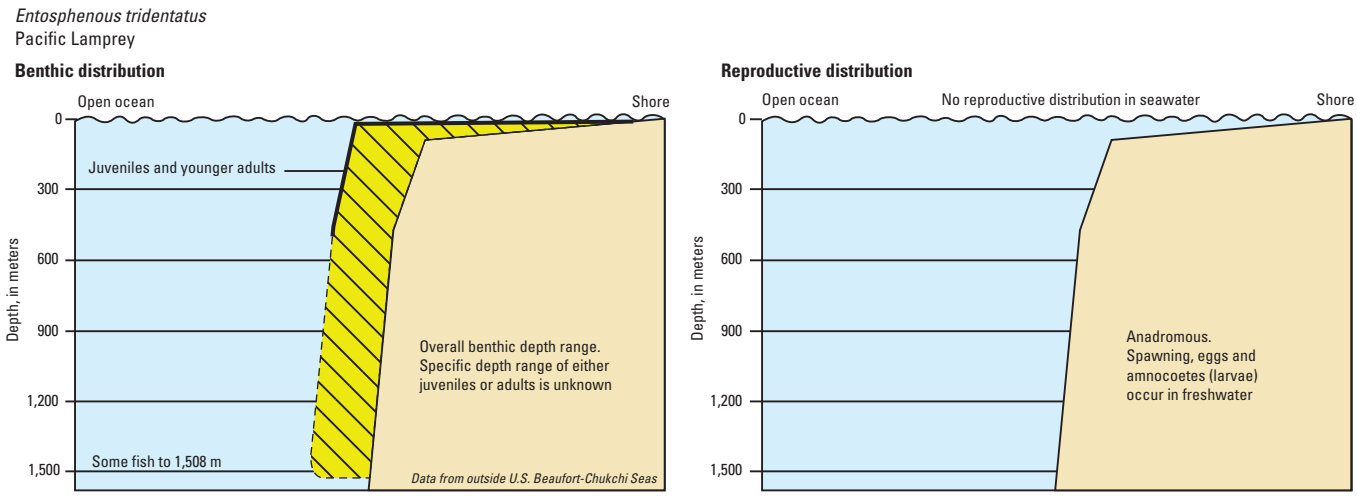
Pacific Lamprey
Entosphenus tridentatus



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

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

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



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

Habitats and Life History

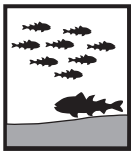
Eggs—Size: Small, 1.1–1.2 mm [8]. Time to hatching: 10–24 days, depending on temperature [9, 10]. Habitat: Freshwater, benthic [3]; attached to rocks among gravel nests near riffles in rivers [9, 11].

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

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

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

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



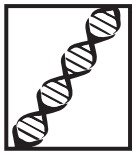
Behavior

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

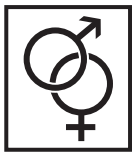
Seasonal—Ammocoete generally transform into juveniles during July through late November [15, 16]. Ammocoetes migrate downstream year-round but mainly from autumn through spring. Migration times differ among populations. In British Columbia, Canada, after leaving their mud-silt habitat they reside in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

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

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

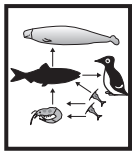


Populations or Stocks
There have been no studies within the study area. Elsewhere, recent studies show low levels of genetic differentiation between populations separated by large geographic distances [19].

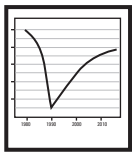


Reproduction
Mode—Oviparous, external fertilization [1].
Spawning season—Differs with regions, spawning earlier farther north. April–July in British Columbia [12]; in southern California occurs as early as January and may continue into at least May [23].
Fecundity—10,000–238,000 eggs [12, 16].

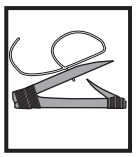
Food and Feeding
Food items–Ammocoetes: Detritus, diatoms and algae [19]. Parasitic macropthalmia and adults: Fishes and mammals including Greenland and Pacific Halibut, Arrowtooth and Kamchatka Flounders; Sablefish, Pacific Hake, Walleye Pollock, Pacific Cod, and Lingcod; Pink, Sockeye, Coho, and Chinook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



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

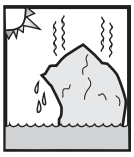


Resilience
Low, minimum population doubling time: 4.5–14 years (t_m 6–8; Fecundity=10,000–106,000) [18].

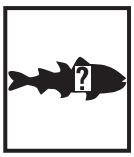


Traditional and Cultural Importance
None reported.

Commercial Fisheries
Currently, Pacific Lamprey are not commercially harvested.



Potential Effects of Climate Change
Unknown.



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

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Arctic Lamprey (*Lethenteron camtschaticum*)
(Tilesius, 1811)

Family Petromyzontidae

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

Colloquial Name: Iñupiat: *Nimiqiaq* [24]

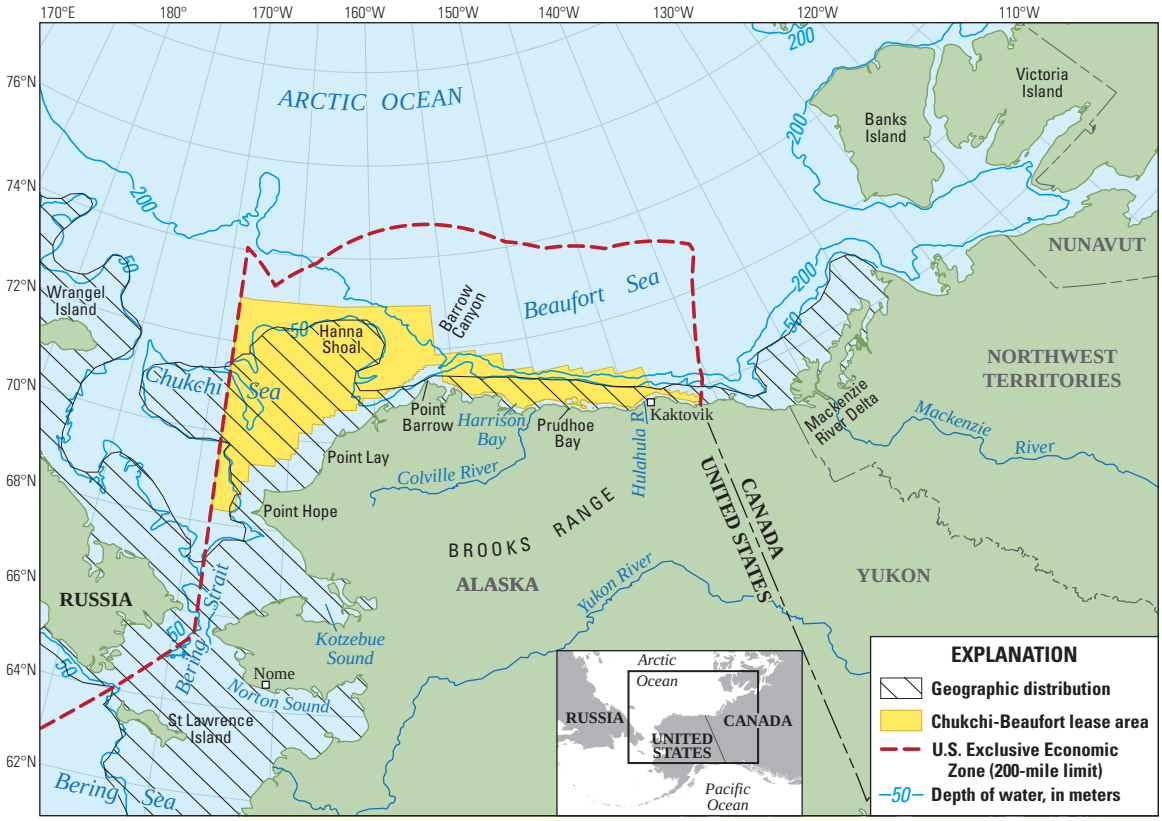
Ecological Role: The extent of this lamprey's parasitisms is *unknown in U.S. Chukchi and Beaufort Seas*.

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

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

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

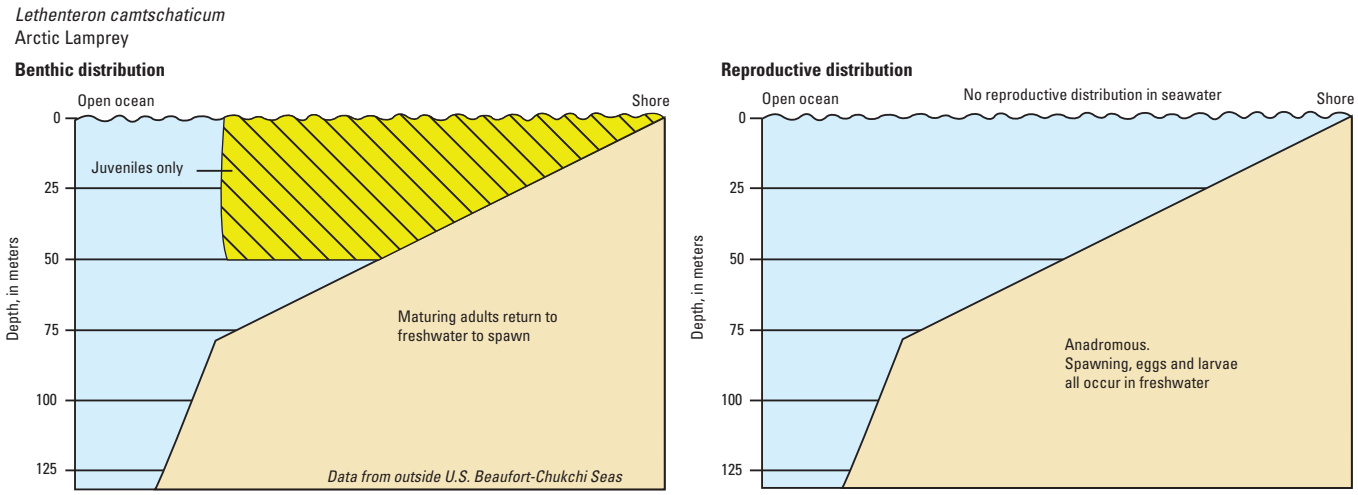
Arctic Lamprey
Lethenteron camtschaticum



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

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



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

Habitats and Life History

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

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

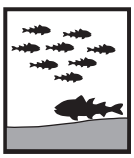
Ammocoetes (larvae)—Size at hatching: 6.8 mm long. Size at juvenile transformation: 13.1–16.8 cm [9]. Time to juvenile transformation: 4 years and longer [9]. Habitat: Sedentary burrowers in river and lake bottoms [11].

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

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

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

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



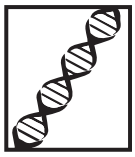
Behavior

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

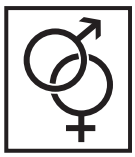
Seasonal—Metamorphosed ammocoetes migrate downstream to sea during August–November in Alaska [10] and May–July in Russia [9].

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

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

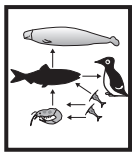


Populations or Stocks
There have been no studies.

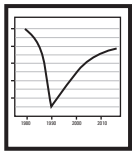


Reproduction
Mode—Separate sexes, oviparous [9, 13].
Spawning season—Spring in southwestern Alaska, generally late May to early July [12].
Fecundity: 12,272–34,586 eggs [9].

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



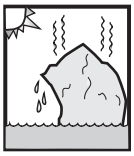
Biological Interactions
Predators—All life stages are preyed on by various fishes including Burbot, Northern Pike, Dolly Varden, and Inconnu; also taken by gulls, especially when lamprey are concentrated in shallow streams during migration [19].
Competitors—Pacific Lamprey in seawater [14]. In Alaska,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



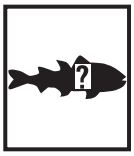
Resilience
Low, minimum population doubling time: 4.5–14 years (t_m 4–5) [18].

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

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



Potential Effects of Climate Change
Unknown.



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

Remarks

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

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Spotted Spiny Dogfish to Bering Cisco

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

Family Squalidae

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

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

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

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

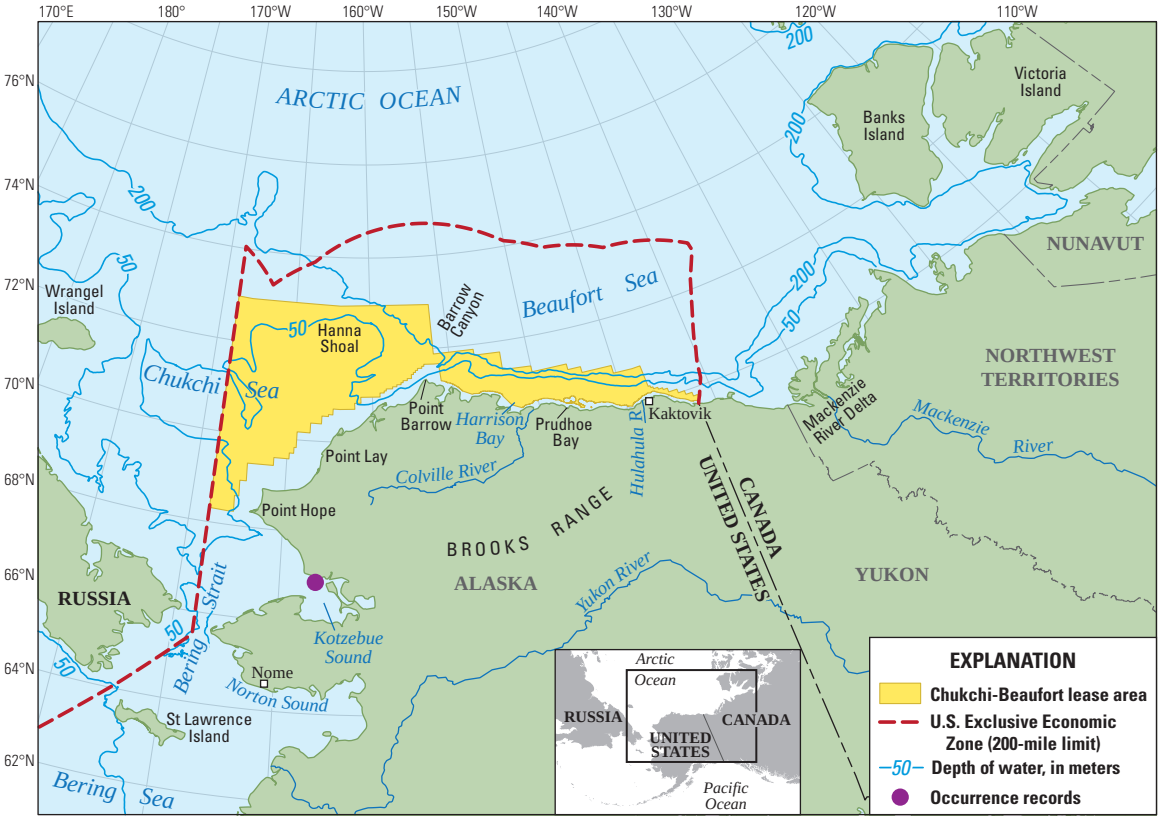
Ecological Role: A rare species in the U.S. Chukchi Sea and absent from the U.S. Beaufort Sea. The species has a very limited role and little significance in regional food webs.

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

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

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

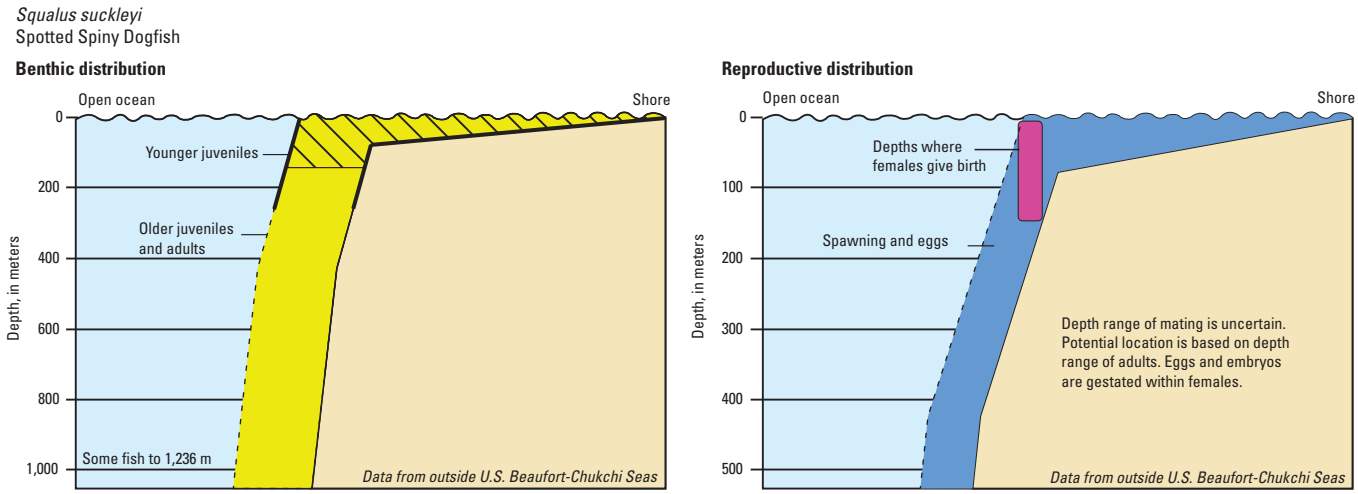
Spotted Spiny Dogfish
Squalus suckleyi



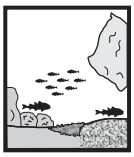
Base modified from USGS and other digital data. U.S.-Russia Maritime Boundary follows the EEZ/200-mile limit line, western edge. Coordinate reference system: projection, Lambert Azimuthal Equal Area; latitude of origin, 75.0°; horizontal datum, North American Datum of 1983.

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

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

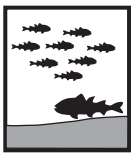


Benthic and reproductive distribution of Spotted Spiny Dogfish (*Squalus suckleyi*).



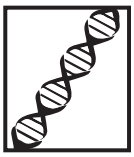
Habitats and Life History

Eggs—Size: 3–4 cm [14]. Time to hatching: Fertilized eggs are contained within candles (a thin membrane containing multiple eggs) and incubated within the female's uterus. Candle membrane dissolves and embryos become free within the uterus within 4–6 months [5]. Habitat: In utero [5].
Embryos—Age and size: From about 4–6 months to 22 months (<10 to 22.5–30 cm TL) [5, 13]. Habitat: Embryos are completely dependent on their yolk-sacs and are gestated within the uterus [5, 13].
Juveniles—Size: 22.5–26.3 cm at birth to about 60 cm TL [5, 13]. Habitat: Pelagic, in water column, near surface and becoming benthic as they grow larger and near sexual maturity [5, 13].
Adults—Age and size at first maturity: Based on the most recent study (off British Columbia), a few females mature at about 80 cm TL (24 years), 50 percent matured at 93.9 cm (36 years), and almost all fish are mature at 110 cm (62 years) [15]. 100 percent of females matured at 119 cm [14]. A few males off British Columbia matured at 72 cm TL (15 years), 50 percent at 78 cm TL (19 years), and all at 94 cm [14]. In the North Pacific median size and age at maturity is 80–100 cm TL. (35.5 years) for females and 70–80 cm TL 18.5 for males [2]. Maximum age: 80 to possibly 100 years [5]. Maximum size: About 140 cm [10]. Habitat: Benthopelagic, in a wide depth range [5].
Substrate—Unknown. Have been taken over cobble [16].
Physical/chemical—Temperature: 0–15 °C [17]; prefers less than 7 °C, often migrating horizontally and vertically to follow temperature preference [9]. Salinity: Marine, but can tolerate freshwater for short periods [5].



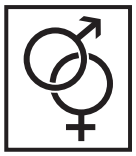
Behavior

Diel—Migrates closer to surface at night [5, 10] and may be more active at night [16].
Seasonal—Makes seasonal feeding migrations, moving north and inshore as waters warm in spring [10]. Highly mobile in many areas, though movements are not completely predictable. In the North Pacific, many tagged fish were recaptured close to their release site, but some made extensive migrations (as far as 7,000 km) [16].
Reproductive—Males mate every year and females every other year. Smaller males mate earlier in the season [18]. Because of the female's long gestation period (22–24 months), she does not release young every year [9, 18, 19]. Females commonly give birth in shallow bays and estuaries or in mid-water at depths of 50–111 m [13].
Schooling—Forms large schools [5]. Sexes tend to segregate into separate schools around time of parturition [13].
Feeding—Opportunistic feeders [5], congregating in schools where prey is abundant and sensed by smell [20].



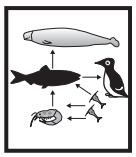
Populations or Stocks

There have been no studies.

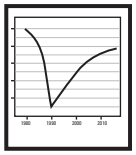


Reproduction
Mode—Aplacental viviparous. Internal fertilization [2].
Parturition season—September–January, probably peaks in late autumn [14, 18].
Fecundity—Litters as high as 20, averaging between 2–12 [9, 12, 14]. Number of pups increases as size of female increases [13].

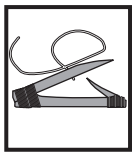
Food and Feeding
Food items—Fishes are a very important, particularly for larger individuals. However, squids, octopuses, medusae, ctenophores, crustaceans (for example, shrimps, euphausiids, and amphipods) and polychaetes also are often consumed [21–25].
Trophic level—4.3 (standard error 0.67) (based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



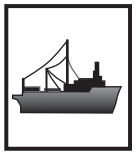
Biological Interactions
Predators—Various larger sharks (for example, Salmon Sharks, White Sharks, Pacific Sleeper Sharks), bald eagles, and marine mammals such as Steller sea lion, northern elephant seal, and sperm whale [21, 27–31].
Competitors—Likely various larger cods, flatfishes, and other macrocarnivores.



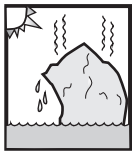
Resilience
Low, minimum population doubling time is more than 14 years (r_m=0.034; K=0.03–0.07; t_m=10–30; t_{max}=75; Fecundity=1) (based on resilience of *S. acanthias*) [26].



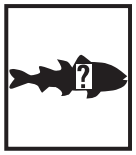
Traditional and Cultural Importance
None reported



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



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



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

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Arctic Skate (*Amblyraja hyperborea*)

(Collett, 1879)

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

Family Rajidae

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

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

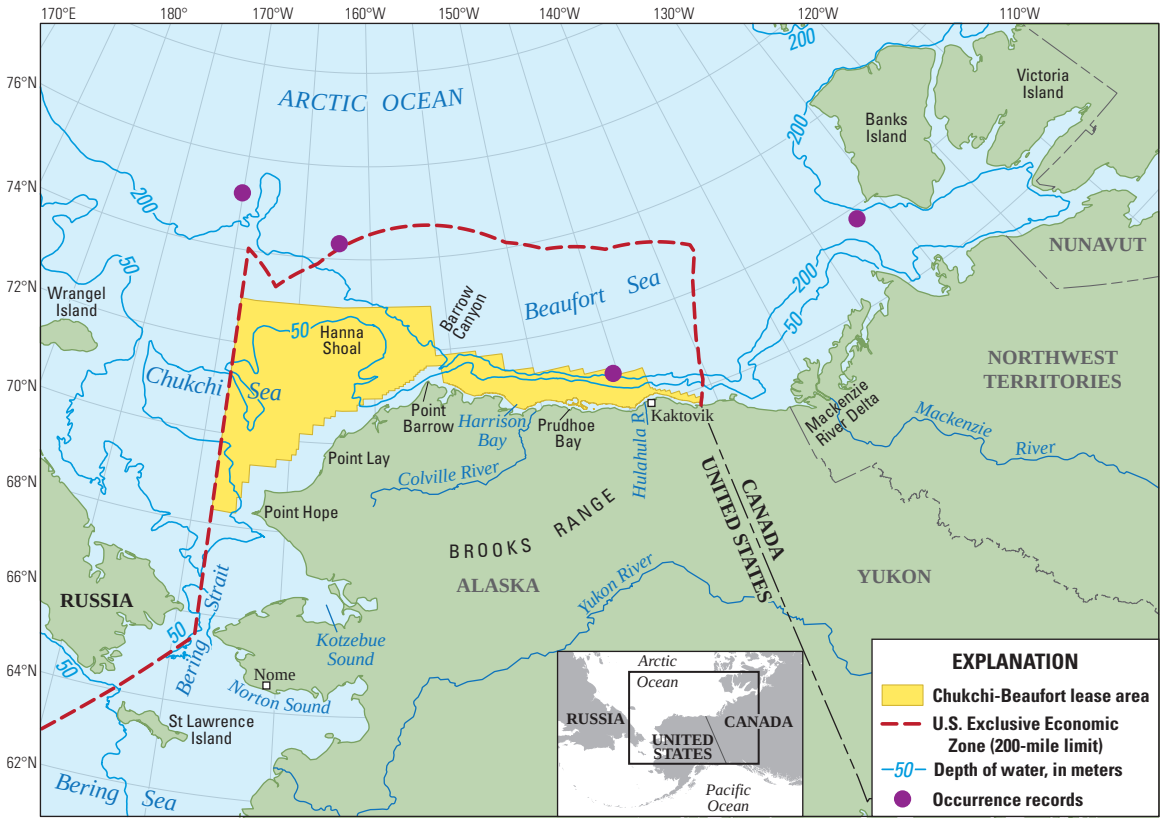
Ecological Role: Arctic Skate have only rarely been observed in deeper waters of the Alaska Beaufort Sea. Its role in benthic ecosystem dynamics, especially over shelf break and slope habitats is presently unknown.

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

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

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

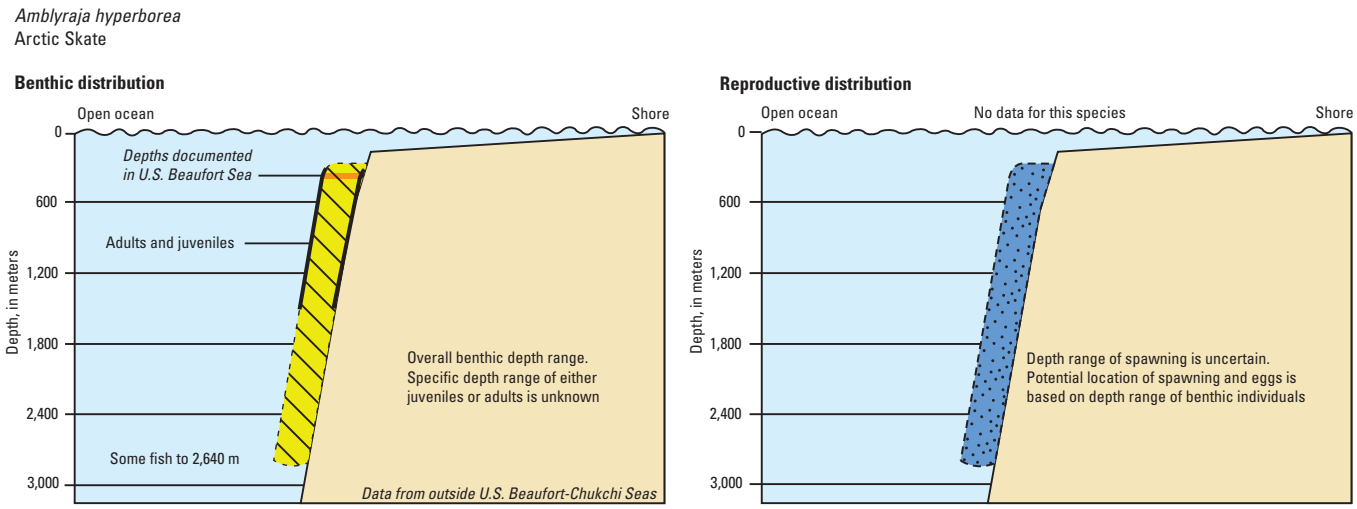
Arctic Skate
Amblyraja hyperborea



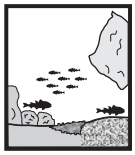
Base modified from USGS and other digital data. U.S.-Russia Maritime Boundary follows the EEZ/200-mile limit line, western edge. Coordinate reference system: projection, Lambert Azimuthal Equal Area; latitude of origin, 75.0°; horizontal datum, North American Datum of 1983.

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

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

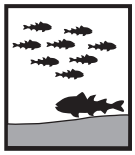


Benthic and reproductive distribution of Arctic Skate (*Amblyraja hyperborea*).



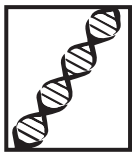
Habitats and Life History

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



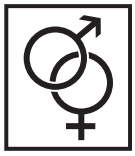
Behavior

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



Populations or Stocks

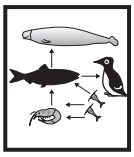
There have been no studies.



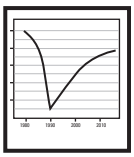
Reproduction

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

Food and Feeding
Food Items—Benthic and pelagic crustaceans such as shrimp, as well on fishes [1, 5].
Trophic level—3.84 (standard error 0.58) [10]



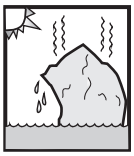
Biological Interactions
Predators—Unknown.
Competitors—Perhaps eelpouts and other benthic feeders.



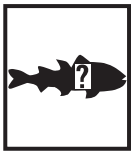
Resilience
Low, minimum population doubling time is 4.5–14 years (Fecundity assumed to be <100) [10].

Traditional and Cultural Importance
None reported.

Commercial Fisheries
Currently, Arctic Skate are not commercially fished.



Potential Effects of Climate Change
Unknown.



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

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Pacific Herring (*Clupea pallasii*)

Valenciennes, 1847

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

Family Clupeidae

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

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

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

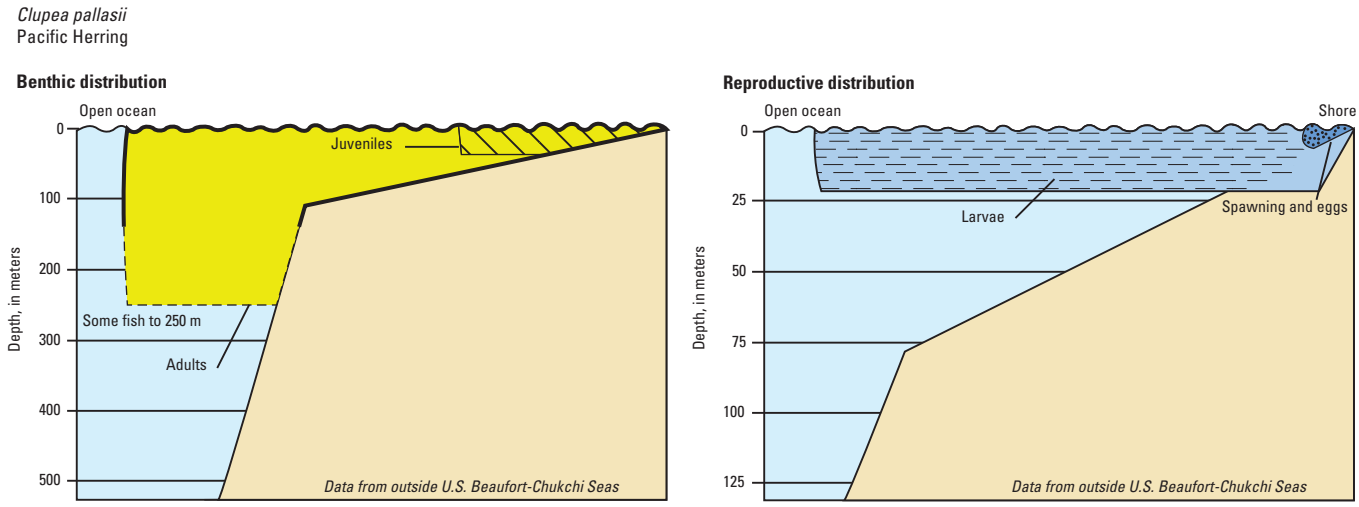
Range: *U.S. Chukchi and Beaufort Seas* [3]. Elsewhere in Alaska, occurs in all marine waters. Worldwide, from Korea and Japan and the White Sea to Arctic Canada (as far north and east as Viscount Melville Sound and south and east to Bathurst Inlet [4]) and along the Pacific Coast south to northern Baja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

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

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

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



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

Habitats and Life History

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

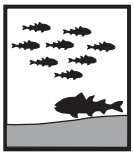
Larvae—Size at hatching: 5.6–7.5 mm SL [21]. Size at juvenile transformation: Metamorphosis starts at 26 mm TL and completes by 35 mm TL [24]. Days to juvenile transformation: About 2–3 months [24]. Habitat: Epipelagic, in ocean currents [24]. Most abundant near surface in estuarine-influenced waters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

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

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

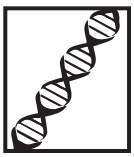
Substrate—Kelp, eelgrass, other plant material, rocks and other solid surfaces for spawning [23].

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



Behavior

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



Populations or Stocks

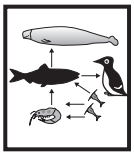
Coastal sampling and aerial surveys have provided limited information about abundance. No detailed studies regarding populations or stocks have been conducted.

Reproduction

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

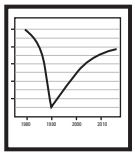
Food and Feeding

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



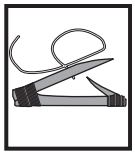
Biological Interactions

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



Resilience

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

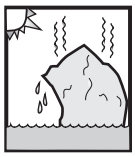


Traditional and Cultural Importance

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

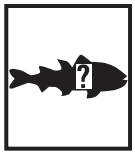
Commercial Fisheries

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



Potential Effects of Climate Change

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



Areas for Future Research [A]

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

Remarks

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

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Pond Smelt (*Hypomesus olidus*)

(Pallas, 1814)

Family Osmeridae

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

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

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

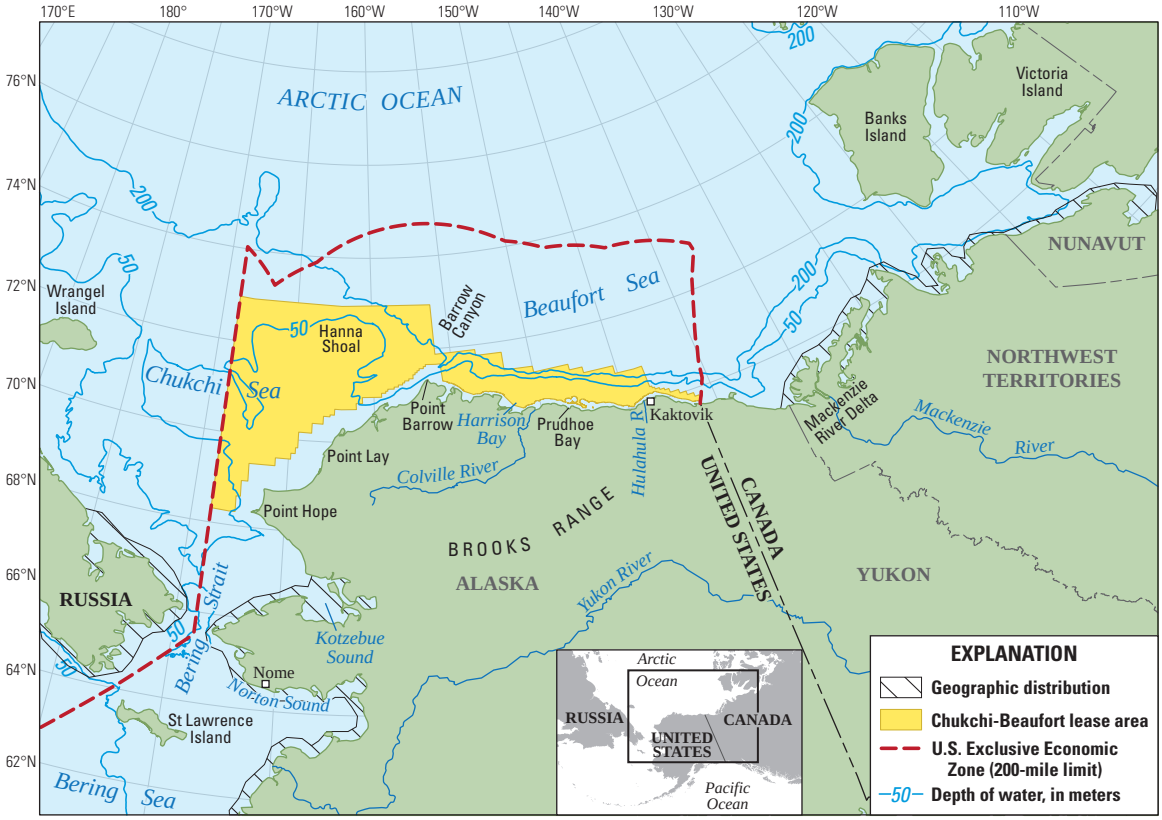
Pond Smelt (*Hypomesus olidus*) 114 mm, northeastern Bering Sea, 2007. Photograph by C.W. Mecklenburg, Point Stephens Research.

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

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

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

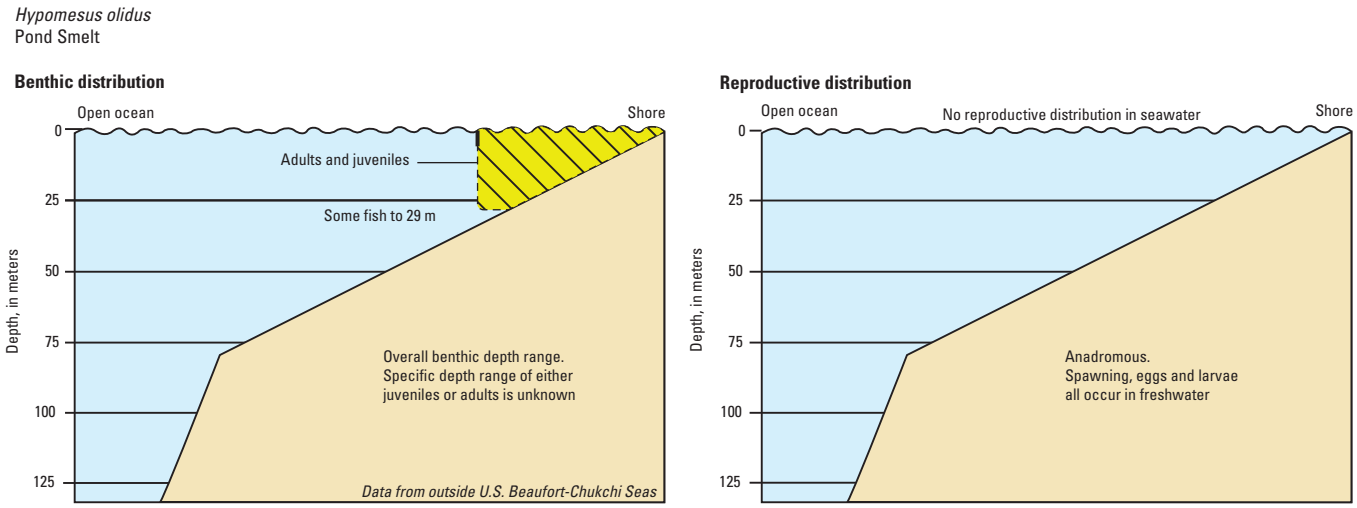
Pond Smelt
Hypomesus olidus



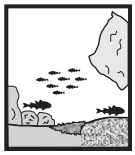
Base modified from USGS and other digital data. U.S.-Russia Maritime Boundary follows the EEZ/200-mile limit line, western edge. Coordinate reference system: projection, Lambert Azimuthal Equal Area; latitude of origin, 75.0°; horizontal datum, North American Datum of 1983.

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

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



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



Habitats and Life History

Many populations are anadromous, although some stocks are landlocked [3].

Eggs—Size: 0.9 mm [12]. Time to hatching: 10–38 days at 5.0–15.0 °C [12, 13]. Habitat: Shallow depths of lakes and rivers, on submerged vegetation or rocks [12–14].

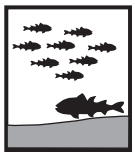
Larvae—Size at hatching: 4.6 mm long [12, 13]. Size at juvenile transformation: Unknown. Days to juvenile transformation: Unknown. Habitat: Pelagic, in freshwater rivers and lakes [12–15].

Juveniles—Age and size: As small as 24 mm FL [9, 12, 16]. Habitat: Pelagic in coastal marine and estuarine waters, and rivers and lakes [3]. Remain in their natal habitats 1 to 1 year before migrating to coastal waters [9, 12, 16].

Adults—Age and size at first maturity: 1–4 years for anadromous fish [2, 8, 12, 17–19]. In southwestern Bering Sea drainages, anadromous fish mature at age-3, whereas non-anadromous type matures at age-1 and age-2 [20]. Size is about 10.0 cm FL or more in Asia [2, 12–14]. In the Sea of Okhotsk, females are slightly larger at age than males [2]. Fish living in the Sea of Okhotsk grow faster than those in the Mackenzie Delta or a landlocked Yukon Lake population [2, 12–14]. Maximum age: About 6 years for anadromous fish in Asia, though few survive to that age [12, 20]. Maximum size: 20 cm TL [3]. Habitat: Pelagic, in coastal marine and estuarine waters, rivers and lakes [2, 3, 10, 12, 13, 17, 21].

Substrate—Taken over sand-gravel in Bristol Bay [22].

Physical/chemical—Temperature: As warm as 17 °C [20]. Salinity: Mainly freshwater, occasionally enters brackish river deltas and nearshore marine waters [3, 7].



Behavior

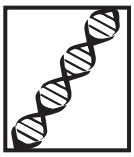
Diel—Unknown. Unidentified osmerid larvae in Auke Bay (southeastern Alaska) migrated to surface waters at midnight [23].

Seasonal—Large downstream migrations to Tuktoyaktuk Harbor occur August and September [9]. Migrations upstream may begin while the rivers are still under ice and be as long as 70 km (44 mi) [12].

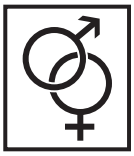
Reproductive—Spawning occurs in rivers and lakes. Some populations in Asia ascend rivers from coastal waters in spring, just before spawning, whereas others migrate into fresh waters in autumn and overwinter prior to spawning [17]. Spawning takes place at dusk. Eggs are laid on submerged vegetation or rocks in shallow, swift-flowing, waters [12–14]. In many, but not all populations, fish die after spawning [10, 12, 17, 19]. Surviving fish migrate downstream shortly after spawning [12].

Schooling—Forms schools [13].

Feeding—Some populations do not feed during spawning season [20] although this is not a universal behavior [12].

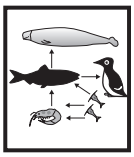


Populations or Stocks
There have been no studies.

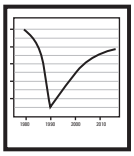


Reproduction
Mode—Oviparous [15].
Spawning season—Spawning in North America takes place at least during May–July [10, 19] and as early as April in Asia [13].
Fecundity—4,820–33,010 adhesive egg, spawned in a single batch (around Sakhalin Island, Russia) [12].

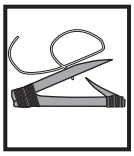
Food and Feeding
Food items—Primarily midwater crustaceans (for example, mysids, copepods, amphipods, and isopods), insects, snails, and small fishes [10, 18, 20, 24, 25].
Trophic level—3.21 (standard error 0.42) [11].



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

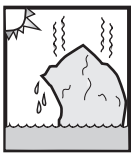


Resilience
Medium, minimum population doubling time: 1.4–4.4 years (t_m=2; t_{max}=5) [11].



Traditional and Cultural Importance
None reported.

Commercial Fisheries
Currently, Pond Smelt are not commercially harvested.



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

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

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Pacific Capelin (*Mallotus catervarius*)
(Pennant, 1784)

Family Osmeridae

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

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

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

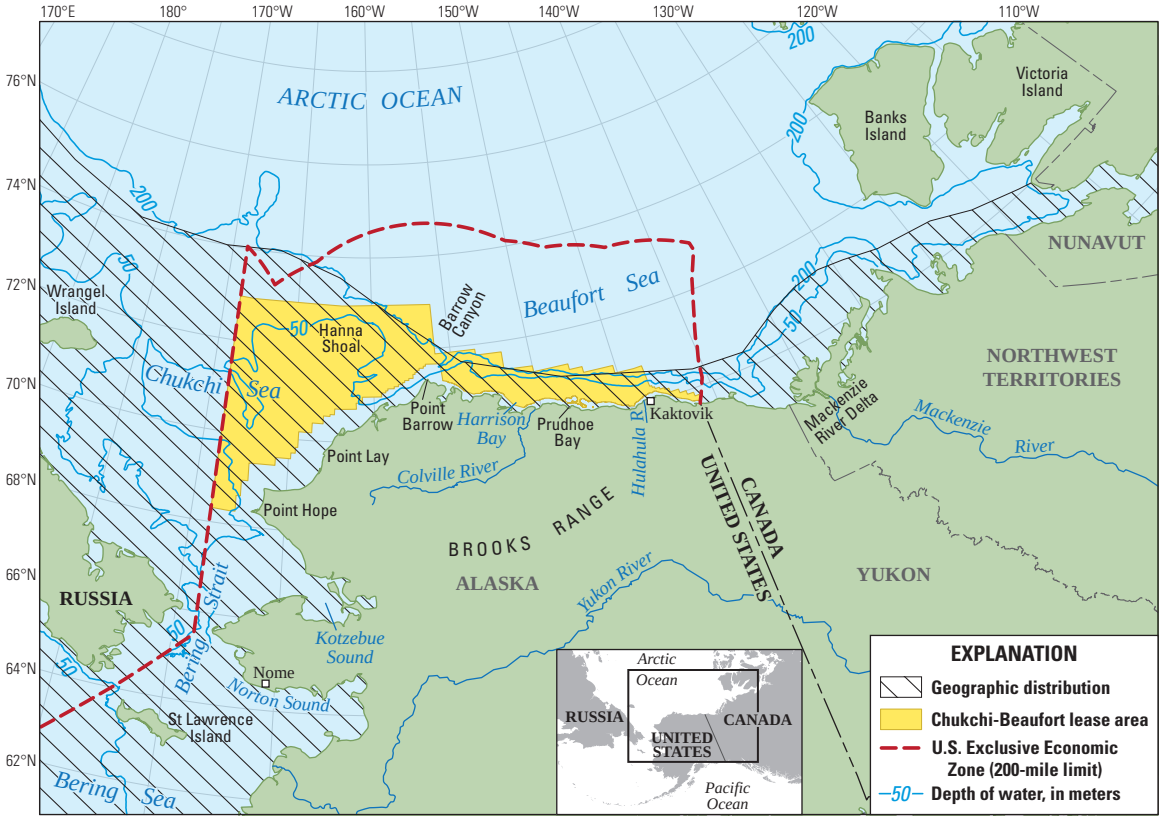
Ecological Role: The true abundance of Pacific Capelin is probably underestimated in existing survey data, but this species is hypothesized to be a major prey of many fish, birds, and marine mammals in the U.S. Chukchi and Beaufort Seas. Although its forage fish status is uncertain, its life history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

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

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

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

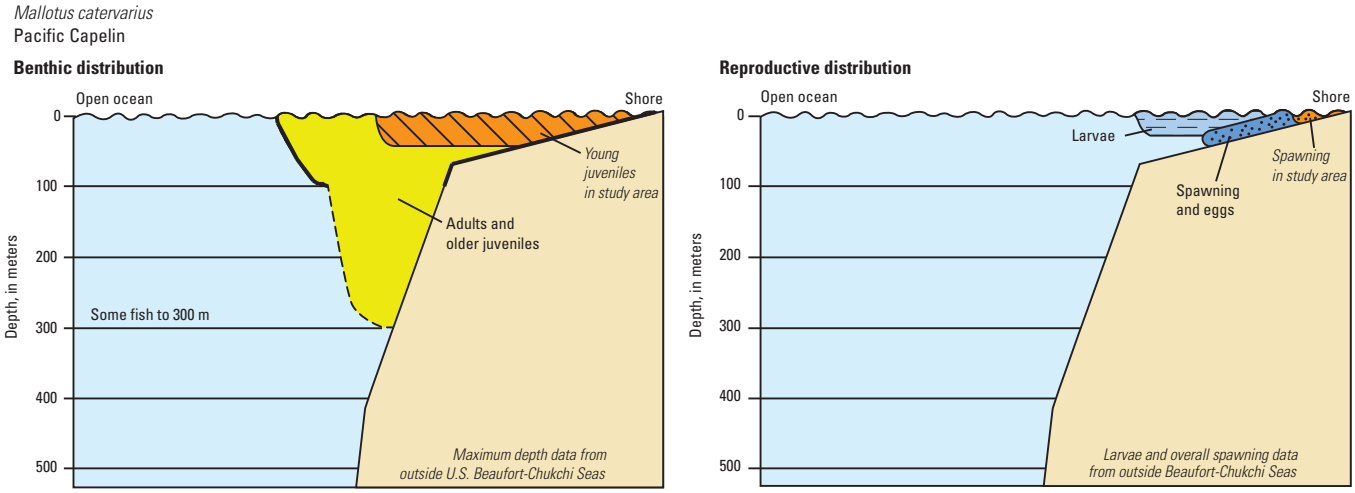
Pacific Capelin
Mallotus catervarius



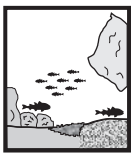
Base modified from USGS and other digital data. U.S.-Russia Maritime Boundary follows the EEZ/200-mile limit line, western edge. Coordinate reference system: projection, Lambert Azimuthal Equal Area; latitude of origin, 75.0°; horizontal datum, North American Datum of 1983.

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

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



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



Habitats and Life History

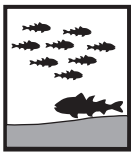
Eggs—Time to hatching: Unknown. Time to hatching: Unknown, but in *Mallotus villosus*, as much as 80 days at 2 °C, 30 days at 5 °C, and 15 days at 10 °C [22]. Size: Unknown. Once laid, eggs can survive as long as 6 hours at temperatures as low as -5 °C [25]. Habitat: *Spawning substrate has not been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

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

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

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

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



Behavior

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

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

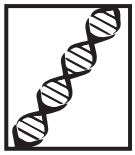
Seasonal—*Unknown.* Some Capelin aggregations make extensive migrations to offshore feeding sites [35] where single sex schools are formed prior to migrating to spawning grounds [26].

Reproductive—*Poorly known.* Larger fish spawn earlier and males usually reach spawning grounds first [26]. Most spawning takes place in marine waters although some occurs in brackish conditions [26] and in very shallow, barely subtidal waters [13, 20]. However, there is some evidence that spawning in eastern Bering Sea

and perhaps U.S. Chukchi and Beaufort Seas also may occur somewhat deeper [11, 46], although the maximum spawning depth is not known. In eastern Bering Sea and Gulf of Alaska, there is a tendency for spawning to occur or at least begin at night and around the highest tides. However, spawning can begin at any time of the day or night and has been known to continue over several days [26].

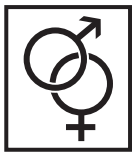
Schooling—*Capelin school in U.S. Chukchi and Beaufort Seas, but the extent of schools is unknown.* In the Gulf of Alaska, schools may be more than 1 km long and 20 m or more thick, and aggregations of schools may extend to 10 km [47].

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



Population or Stocks

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



Reproduction

Mode—Separate sexes, oviparous. Fertilization is external.

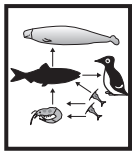
Spawning season—*In the U.S. Chukchi and Beaufort Seas, spawning is primarily in July and August* [9, 19, 36, 52], *although some may take place in June* [53] *and early September* [54].

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

Food and Feeding

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

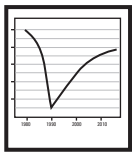
Trophic level—3.5 [60].



Biological Interactions

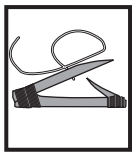
Predators—Besides the seabirds found at Capes Lisburne and Thompson, *Capelin are rarely reported in food habit studies in the U.S. Chukchi and Beaufort Seas. Ringed seals have eaten Capelin during the winter in the U.S. Chukchi Sea* [61]. In the Bering Sea, Gulf of Alaska, and eastern Canadian Arctic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

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



Resilience

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

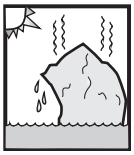


Traditional and Cultural Importance

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

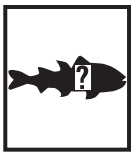
Commercial Fisheries

Currently, Pacific Capelin are not commercially harvested.



Potential Effects of Climate Change

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



Areas for Future Research [A]

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

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Arctic Smelt (*Osmerus dentex*)

Steindachner & Kner, 1870

Family Osmeridae

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

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

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

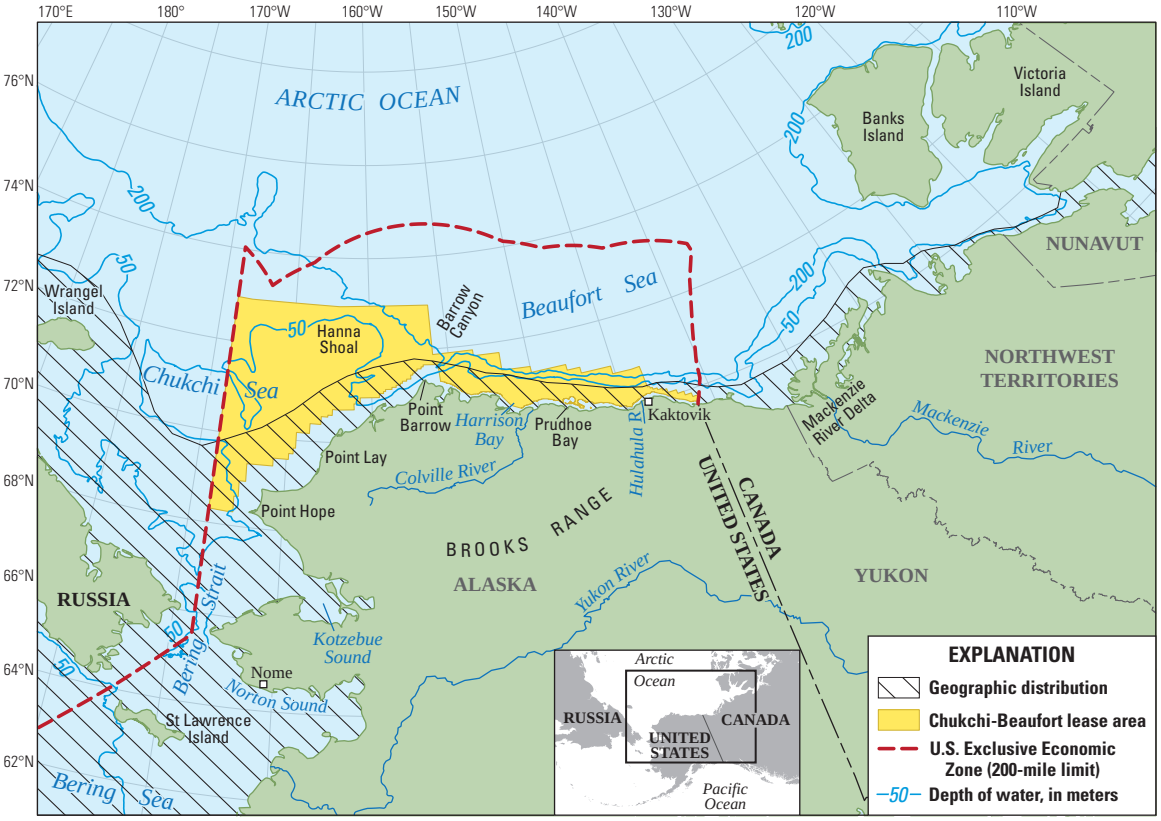
Ecological Role: Likely of considerable importance as a prey species, at least in the Chukchi Sea.

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

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

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

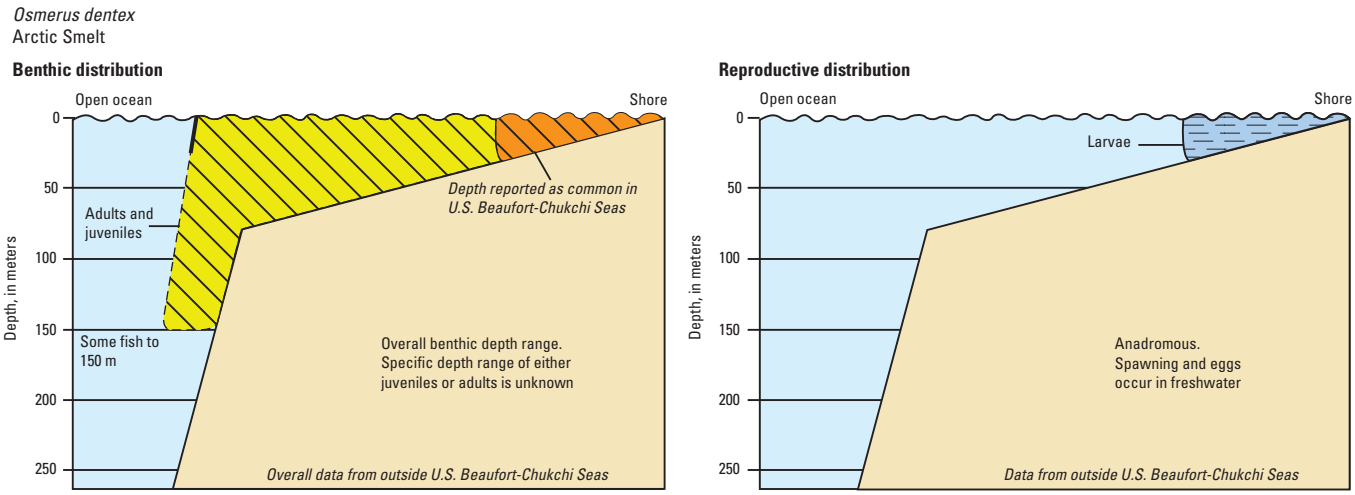
Arctic Smelt
Osmerus dentex



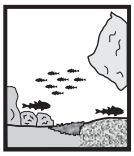
Base modified from USGS and other digital data. U.S.-Russia Maritime Boundary follows the EEZ/200-mile limit line, western edge. Coordinate reference system: projection, Lambert Azimuthal Equal Area; latitude of origin, 75.0°; horizontal datum, North American Datum of 1983.

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

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



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



Habitats and Life History

Anadromous [8].

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

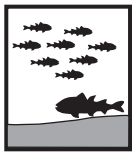
Larvae (fry)—Size at hatching: 5–8 mm SL [20, 27]. Size at juvenile transformation: Reported as post-larval at 14.7 mm TL [27]. Days to juvenile transformation: Unknown. Habitat: Pelagic in brackish to marine waters [5, 8]. Soon after hatching in freshwater, larvae are carried downriver and recruit to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

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

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

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

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



Behavior

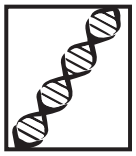
Diel—Enters rivers and spawns at night at least in Asia and eastern North America, [24, 25].

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

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

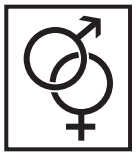
Schooling—*Schooling, water column fish* [18].

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



Populations or Stocks

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



Reproduction

Mode—Oviparous [8].

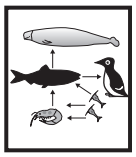
Spawning season—*March–July, peaking in May–June in the U.S. Chukchi and Beaufort Sea drainages* [12, 22, 29, 34, 45]. May–July in Bering Sea and Asia [20, 25, 46].

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

Food and Feeding

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

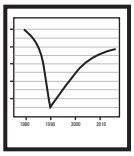
Trophic level—4.2 (standard error 0.73) [47].



Biological Interactions

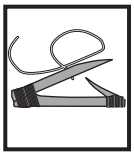
Predators—Dolly Varden and other Arctic Smelt in Canadian Beaufort Sea [16, 30]. *May be a major food for Beluga Whales between May and July in U.S. Chukchi Sea, at least in Wainwright area*, and in eastern Bering Sea [48]. *Extensively preyed upon by spotted seals in summer near Point Lay* [26] *and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

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



Resilience

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

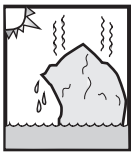


Traditional and Cultural Importance

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

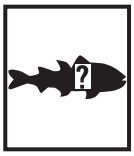
Commercial Fisheries

Currently, Arctic Smelt are not commercially harvested.



Potential Effects of Climate Change

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



Areas for Future Research [A]

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

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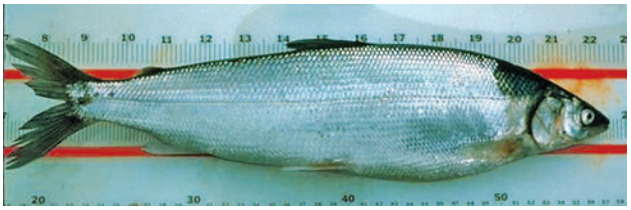
Arctic Cisco (*Coregonus autumnalis*)
(Pallas, 1776)

Family Salmonidae

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

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



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

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

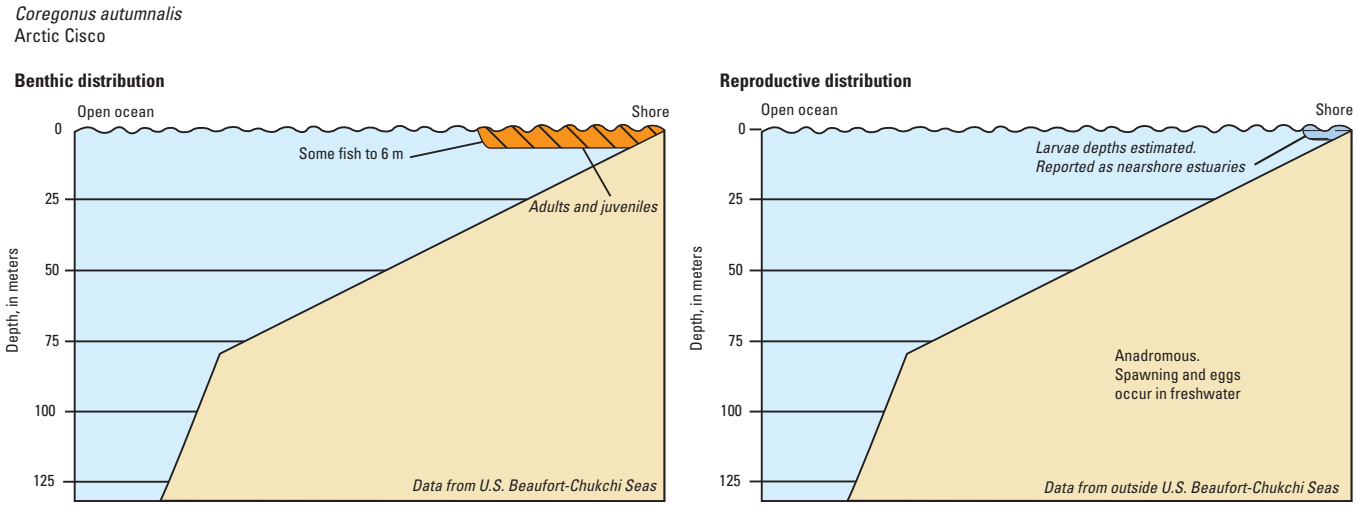
Range: *U.S. Beaufort Sea westward to northeastern Chukchi Sea at Point Lay* [7]. Worldwide, along coasts from the White Sea east through Siberia and to Mackenzie River, Canada [8].

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

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

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



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

Habitats and Life History

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

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

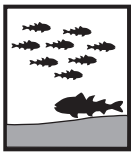
Larvae—Size at hatching: As small as 19 mm FL [15, 22]. Size at juvenile transformation: *About 45–54 mm FL* [12, 15, 23]. Days to juvenile transformation: Unknown. Habitat: Freshwater rivers to nearshore estuaries [22, 24, 25].

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

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

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

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



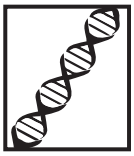
Behavior

Diel—Unknown.

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

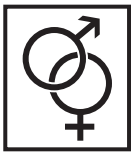
Juveniles migrate to overwintering grounds as autumn approaches. In Alaska, most fish winter under ice in brackish, deep channels of the Colville River, and some in lower parts of the Sagavanirktok River [15, 24, 46]. *However, the Sagavanirktok River may not provide sufficient annual winter refuge to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

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



Populations or Stocks

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



Reproduction

Mode—Iteroparous [26].

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

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

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

Although common along much of the Beaufort Sea coast, most, or perhaps all Arctic Cisco are believed to spawn in Mackenzie River tributaries such as Great Bear, Arctic Red, Peel, and Liard Rivers, the latter being more than 1,700 km from the Beaufort Sea [15, 42, 53]. Evidence for limited spawning in other waterways is discussed in the section, "Remarks." Intertidal or subtidal spawning in estuaries and perhaps the sea has been reported in Russian waters [27] but has not been observed in North America.

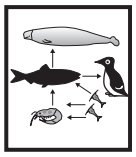
Schooling—*Forms schools, often in groups of tens to several hundreds. Sometimes schools with Dolly Varden* [12, 18, 26]. *Individuals may stay together in same school for months at a time (specifically, several fish tagged on same date at Simpson Lagoon were recaptured together several months later)* [12].

Feeding—*Opportunistic feeders. Feed under ice during winter (at a reduced rate)* [46], *although food habits may change, reflecting differences in food availability* [12]. Rarely feeds during spawning migrations [48, 51, 52, 54].

Food and Feeding

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

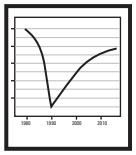
Trophic level—3.57 (standard error 0.56) [55].



Biological Interactions

Predators—Dolly Varden, Arctic Smelt, and Arctic Cisco [21, 26].

Competitors—Shallow, nearshore species such as Dolly Varden, Arctic Cod, other whitefishes, and sculpins.

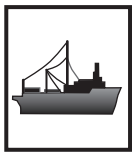


Resilience

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

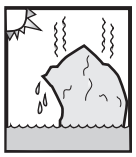
Traditional and Cultural Importance

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



Commercial Fisheries

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



Potential Effects of Climate Change

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

Areas for Future Research [A]

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

Remarks

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

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

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Bering Cisco (*Coregonus laurettae*)

Bean, 1881

Family Salmonidae

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

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

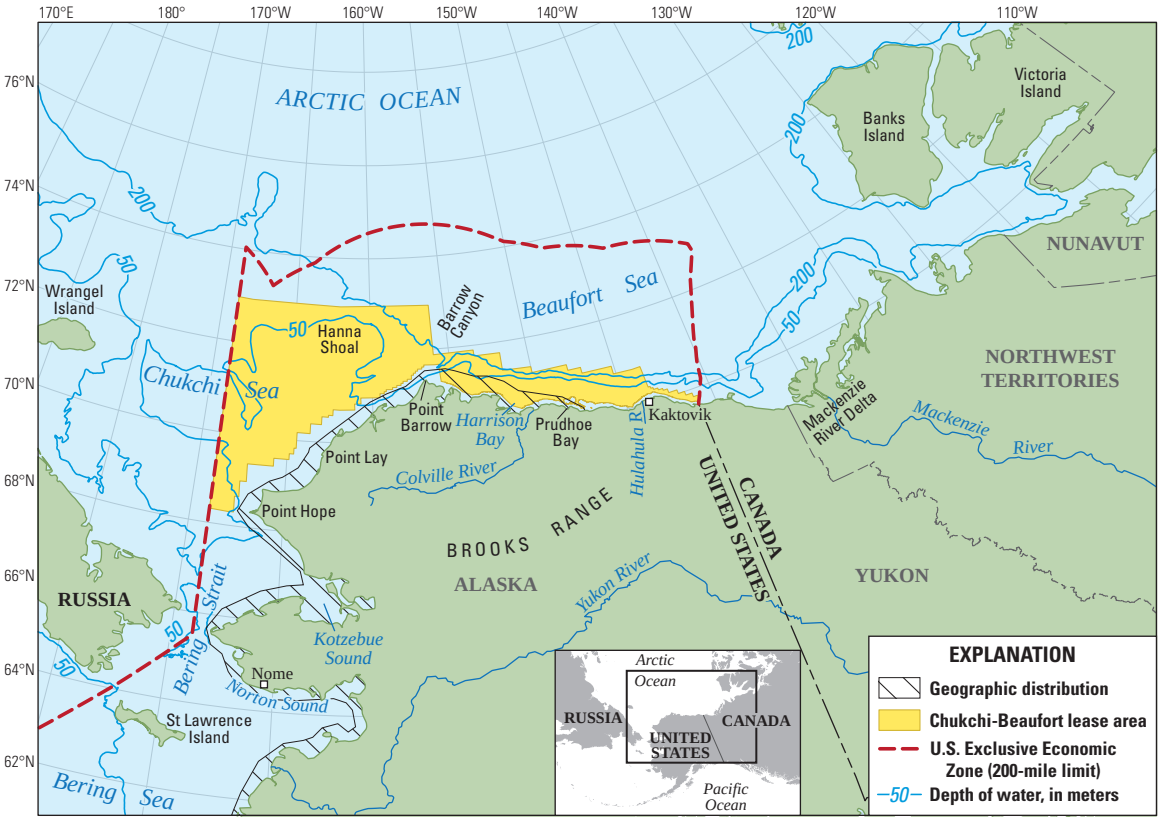
Ecological Role: Although data are lacking, this is a schooling species, and may be of some ecological importance in the nearshore of the U.S. Chukchi Sea and perhaps western part of U.S. Beaufort Sea.

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

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

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

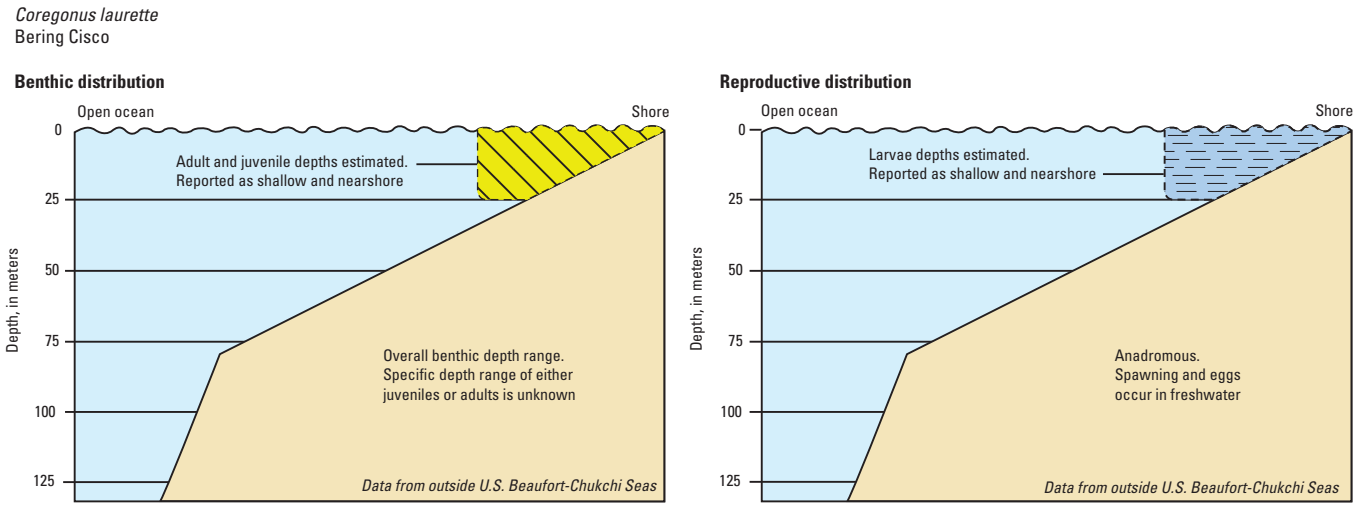
Bering Cisco
Coregonus laurettae



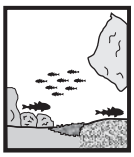
Base modified from USGS and other digital data. U.S.-Russia Maritime Boundary follows the EEZ/200-mile limit line, western edge. Coordinate reference system: projection, Lambert Azimuthal Equal Area; latitude of origin, 75.0°; horizontal datum, North American Datum of 1983.

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

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



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



Habitats and Life History

Anadromous [12].

Eggs—Size: Specific size unknown. 2.3–3.0 mm for whitefish in general [12]. Time to hatching: Specific time unknown. 150–200 days for northern whitefish in general [12]. Habitat: Benthic, in gravel beds of fast-flowing rivers [11, 12].

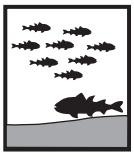
Alevins (larvae)—Size at hatching: Unknown. Size at juvenile transformation: Unknown. Days to juvenile transformation: Unknown. Habitat: Pelagic, in freshwater rivers to nearshore estuaries [11].

Juveniles—Age and size: Minimum size unknown. Matures at about 4 years and 310 mm [11, 13]. Habitat: Nearshore marine and brackish waters [11].

Adults—Age and size at first maturity: 4 years and as small as 310 mm (Yukon River) [11, 13]. Maximum age: At least 13 years [12], *and at least 8 years in Colville River area* [9]. Maximum size: 48 cm [2]. Habitat: Pelagic, mainly in marine and estuarine nearshore waters. Fast-flowing rivers for spawning [11].

Substrate—Sand and gravel for spawning [11, 12].

Physical/chemical—Temperature: Unknown. Salinity: Fresh to full seawater. The most marine-tolerant of all coregonids within the study area range [13].



Behavior

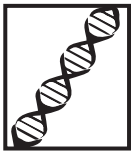
Diel—Unknown.

Seasonal—Eggs hatch in spring. Alevins (larvae) likely move downstream soon after and enter coastal waters where they spend their first years [11]. Upon maturity, adults migrate up river. Anadromous fish, probably on spawning runs, have been found at least 2,000 km [14] or perhaps as much as 2,150 km [15] upstream in the Yukon River. Spawning occurs in Yukon, Kuskokwim, and Susitna Rivers [11, 12, 16]. Yukon River spawning migrations are continuous throughout the summer with major pulses varying from year to year [12]. Spawning occurs in autumn [11]. *Juveniles and adults overwinter beneath ice of river deltas and other coastal waters* [7, 11, 17].

Reproductive—Spawns annually [12]. Broadcast spawners over gravel beds in fast-flowing rivers [11]. Returns to sea after spawning [11].

Schooling—Forms schools [11].

Feeding—Feeding likely occurs in nearshore waters, especially near river mouths and brackish estuaries [11]. Does not feed during spawning migrations [11].

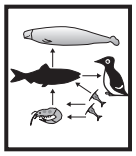


Populations or Stocks

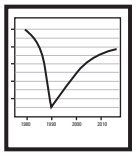
There have been no studies within the study area.

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

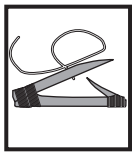
Food and Feeding
Food items—Mysids as well as harpacticoid copepods, isopods, gammarid amphipods, crangonid shrimps, insects, and small fishes [18].
Trophic level—3.79 (standard error 0.59) [19].



Biological Interactions
Predators—Unknown.
Competitors—Unknown.

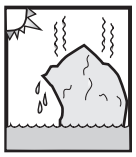


Resilience
Medium, minimum population doubling time: 1.4–4.4 years (Preliminary *K* or Fecundity) [19].

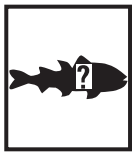


Traditional and Cultural Importance
There are subsistence fisheries for Bering Cisco wherever the species is found. *The species is most important near Wainwright* [20] *and Kotzebue Sound* [7]*, although occasional anomalously large runs are known from the Colville River region* [8]*. Bering Cisco are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

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



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



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

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Broad Whitefish to Dolly Varden

Broad Whitefish (*Coregonus nasus*)

(Pallas, 1776)

Family Salmonidae

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

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

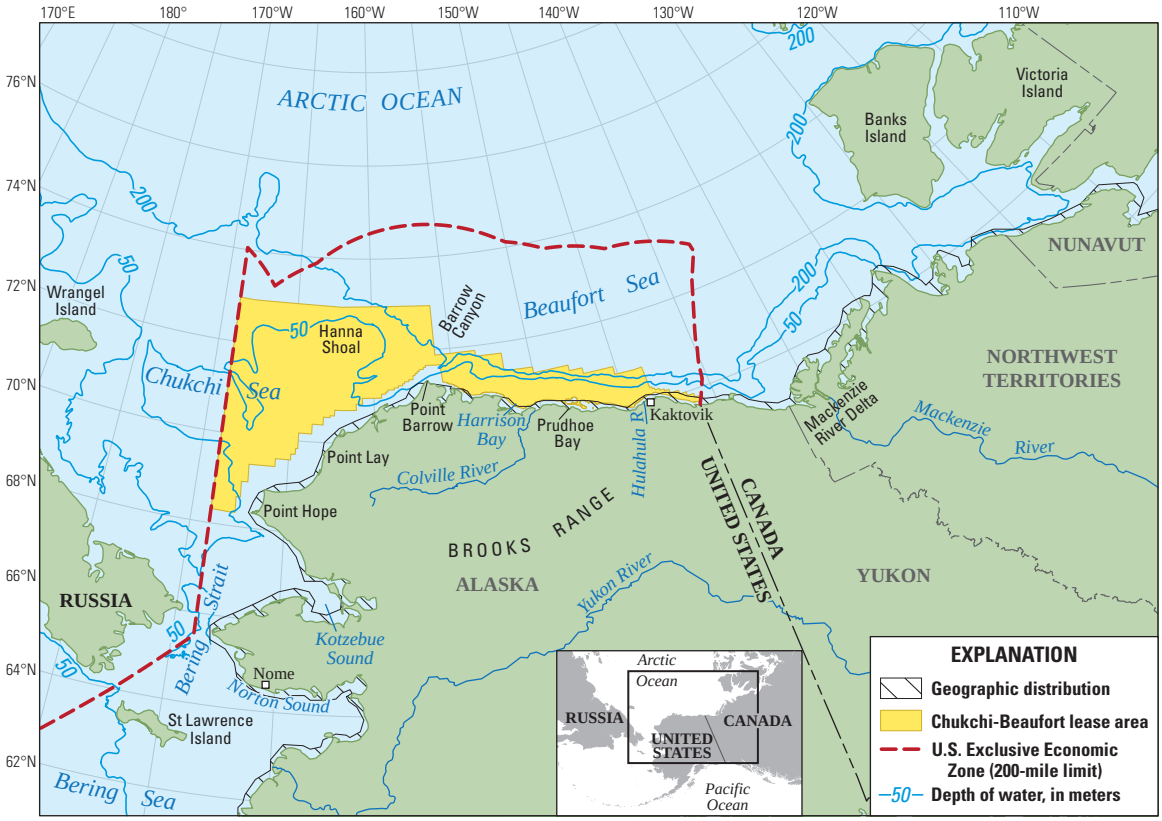
Ecological Role: This species rarely ventures into marine waters, preferring fresh and nearshore brackish conditions. It is one of the most prominent members of the coastal fish community and is important in seasonal food webs during ice-free periods.

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

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

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

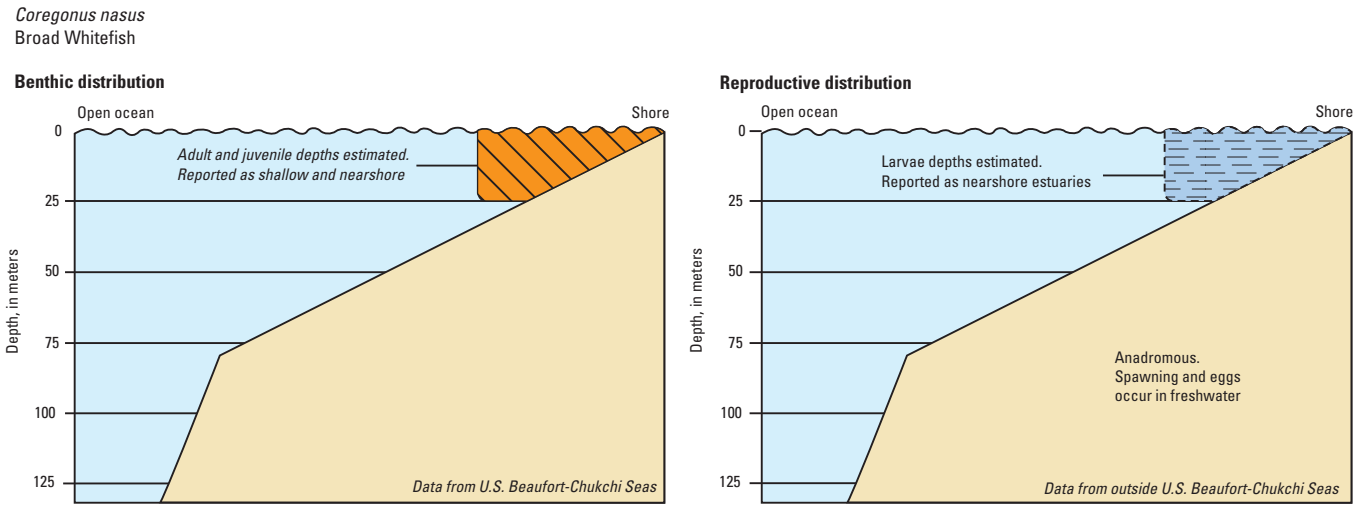
Broad Whitefish
Coregonus nasus



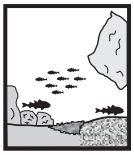
Base modified from USGS and other digital data. U.S.-Russia Maritime Boundary follows the EEZ/200-mile limit line, western edge. Coordinate reference system: projection, Lambert Azimuthal Equal Area; latitude of origin, 75.0°; horizontal datum, North American Datum of 1983.

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

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



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



Habitats and Life History

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

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

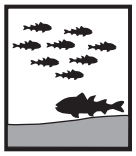
Fry—Size at hatching: Unknown. Days to juvenile transformation: Unknown. Habitat: *Freshwater rivers to nearshore estuaries* [14, 16, 27, 34].

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

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

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

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



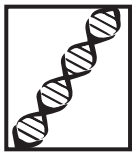
Behavior

Diel—Unknown. Seasonal—*In spring eggs hatch under ice (perhaps in April and May)* [23, 27] and young-of-the-year are flushed out of the river into the river's estuary during break-up [12, 13, 16, 23, 27, 37]. *In June fish migrate into the smaller estuarine river deltas of the U.S. Beaufort Sea* [19] [20], *and generally do not migrate far* [12, 40, 41]. *For instance, Sagavanirktok River fish remain in the river delta until they are at least 3 years old* [41]. *In that population, the somewhat older fish are more tolerant of saline conditions and may migrate farther along coasts, typically moving between the Sagavanirktok and Colville Rivers* [25]. *At the extreme, a fish tagged in Prudhoe Bay was recaptured in Kaktovik Lagoon, 175 km to the east* [42]. *However, once mature, many adult fish also exhibit restricted movements* [26]. At least in the Mackenzie River, once a fish has spawned it remains within the river's influence for the rest of its life and never returns to its Tuktoyaktuk Peninsula nursery grounds [23]. *Fish destined to spawn begin to enter rivers mostly in July and August* [19, 27, 38]. *Mature fish preparing to spawn tend to move to staging areas in river mouths earlier than do mature, non-spawning individuals. Regardless of maturation state, by September all broad whitefish have returned to rivers, with spawning fish migrating earliest* [27, 37]. Fish overwinter in a wide range of habitats. Depending on location, overwintering grounds include nearshore brackish waters, river deltas, deep pools in rivers, and a variety of lakes [16, 19, 23, 27, 43]. In Alaska, overwintering in nearshore waters is not known to occur.

Reproductive—Spawning occurs in fresh water, likely in their natal streams [23]. In some river systems, fish may travel great distances to spawning sites. For instance, Yukon River fish may migrate at least 1,700 km [44]. In the Mackenzie River, fish first congregate in the river delta for a few months before moving upstream to the spawning grounds, perhaps waiting for water temperatures to be to near 0 °C before migrating [13, 23, 27]. *In U.S. Chukchi and Beaufort Seas, spawning occurs in many rivers, from the Sagavanirktok River to at least the Meade River* [12, 19], *and in the Kobuk and Selawik Rivers in the Kotzebue region [3]. In most northern Alaskan rivers, spawning occurs in the lower parts of the waterways in deeper pools* [19, 27], *except the Colville River where fish may spawn a significant distance from the mouth* [27]. *With the possible exception of the Canning River, none of the "mountain" rivers or streams of the eastern Alaskan and Yukon coasts harbor spawning populations* [12, 25, 45]. However, scattered non-spawning fish have been captured in a number of Canadian rivers west of the Mackenzie River [12]. Upon reaching maturity, spawning may occur annually or every other year [31]. Broad Whitefish are broadcast spawners that release gametes into the water column over gravel beds; eggs sink to the bottom after fertilization [27, 46].

Schooling—Unknown.

Feeding—*Opportunistic predators* [27]. Adults undertaking spawning migrations only occasionally feed [47]. Mature individuals or current-year spawners spend the summer prior to spawning feeding in delta habitats, peninsula lakes, or brackish water environments [23]. In the Alaska Beaufort Sea, nearshore brackish habitats are annually colonized by a rich benthic invertebrate community that forms the base of the coastal food web.



Populations or Stocks

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

Reproduction

Mode—Gonochoristic, oviparous, and iteroparous with external fertilization [27].

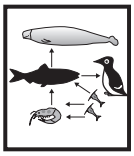
Spawning season—*Mainly in October and November, at freeze-up under the ice* [3, 21, 23, 27].

Fecundity—10,070–117,687 pale-colored eggs [3, 33].

Food and Feeding

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

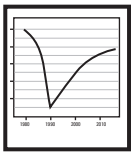
Trophic level—3.28 (standard error 0.44) [53].



Biological Interactions

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

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



Resilience

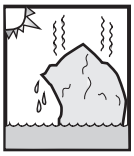
Low, minimum population doubling time 4.5–14 years (K=0.10–0.30; t_m=7; t_{max}=15; Fecundity=10,000) [53].

Traditional and Cultural Importance

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

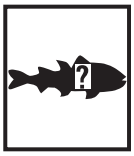
Commercial Fisheries

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



Potential Effects of Climate Change

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



Areas for Future Research [A]

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

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

Family Salmonidae

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

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

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

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

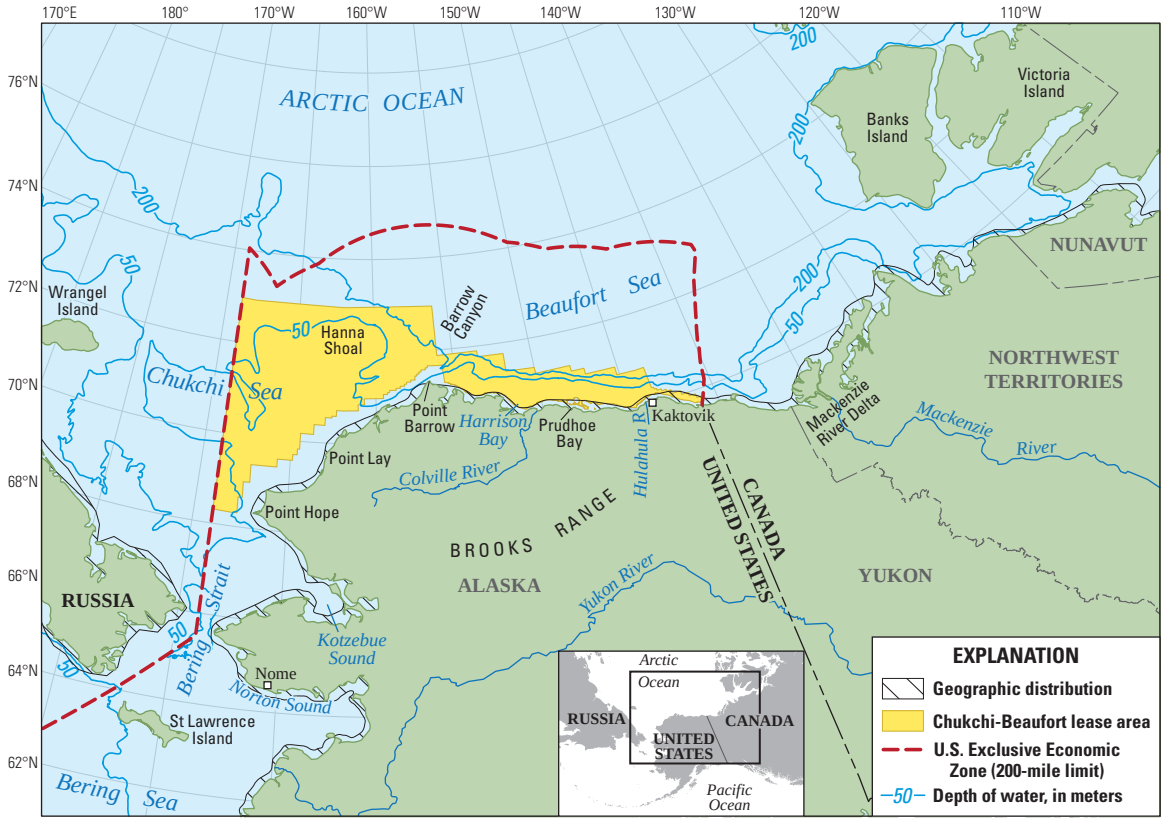
Ecological Role: This species rarely ventures into marine waters, and prefers freshwaters and nearshore brackish waters. It likely is of considerable ecological importance only within this relatively proscribed area.

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

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

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

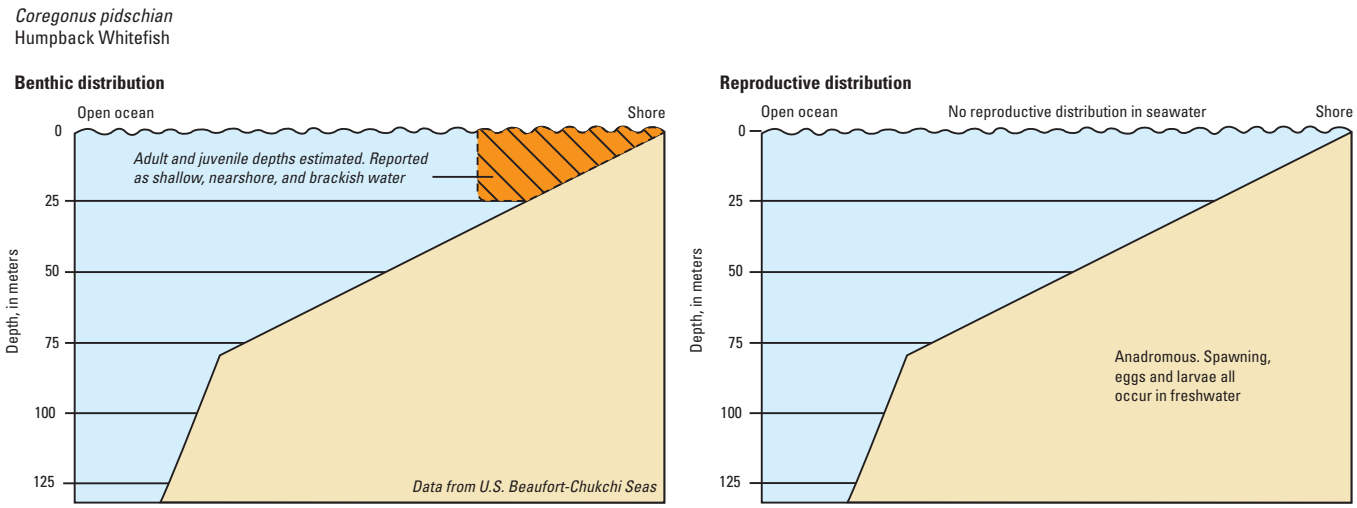
Humpback Whitefish
Coregonus pidschian



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

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



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

Habitats and Life History

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

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

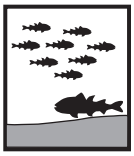
Larvae—Size at hatching: Unknown. Size at juvenile transformation: Unknown. Days to juvenile transformation: Unknown. Habitat: Freshwater [18].

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

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

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

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



Behavior

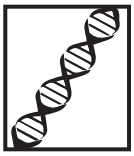
Diel—Unknown.

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

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

Schooling—Unknown.

Feeding—Unknown.



Populations or Stocks

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

Reproduction

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

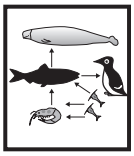
Spawning season—*Primarily September–October, but may extend into November and December* [2, 22, 29]. *At least some mature individuals spawn only every other year* [19, 26].

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

Food and Feeding

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

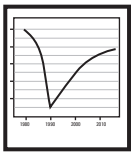
Trophic level— 3.2 (standard error 0.40) [35].



Biological Interactions

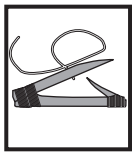
Predators—Unknown.

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



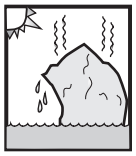
Resilience

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

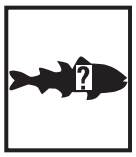


Traditional and Cultural Importance
A very important part of several subsistence fisheries, particularly those in the Kotzebue Sound [2]. Humpback Whitefish also are taken in some numbers in the Barrow area and in the lower Colville River [36, 37]. In Kotzebue Sound, their ease of scaling and lower oil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

Commercial Fisheries
Currently, Humpback Whitefish are not commercially harvested.



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



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

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Least Cisco (*Coregonus sardinella*)

Valenciennes, 1848

Family Salmonidae

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

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

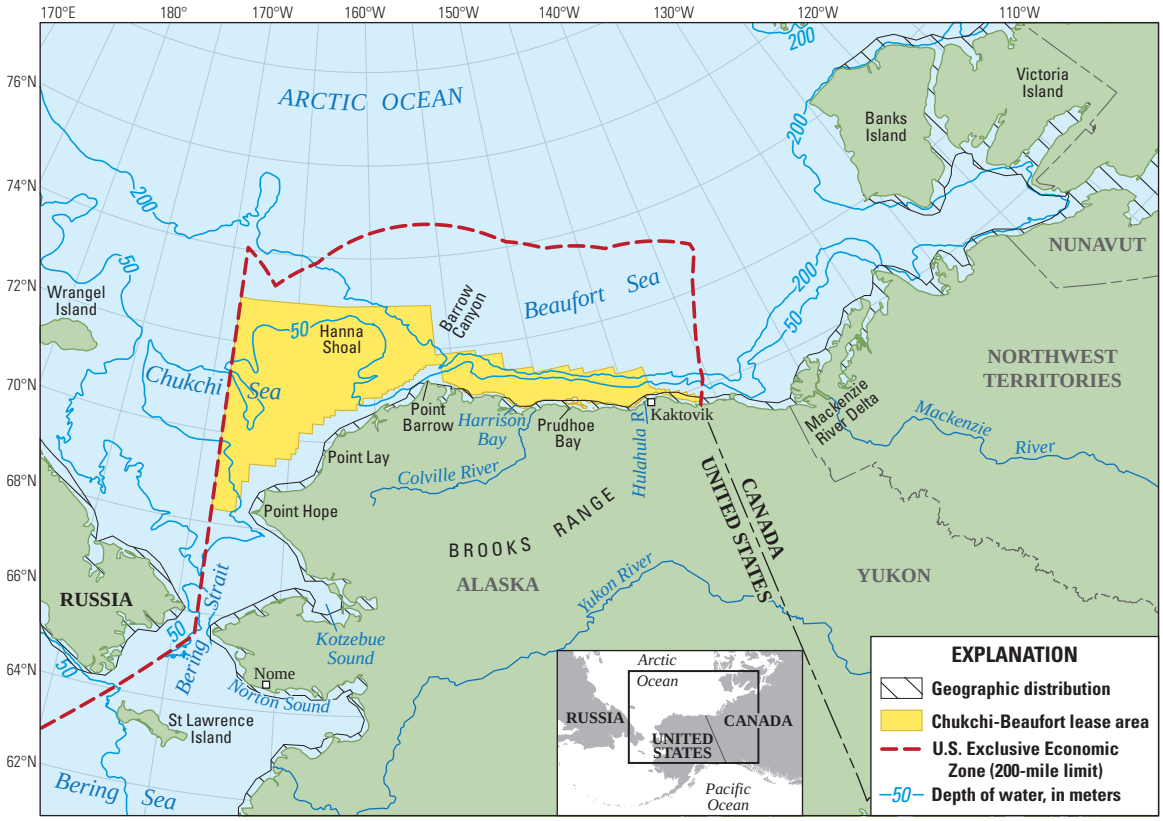
Ecological Role: This species rarely ventures into marine waters, preferring fresh and nearshore brackish conditions. Least Cisco are seasonally common in nearshore waters and are important in coastal food webs.

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

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

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

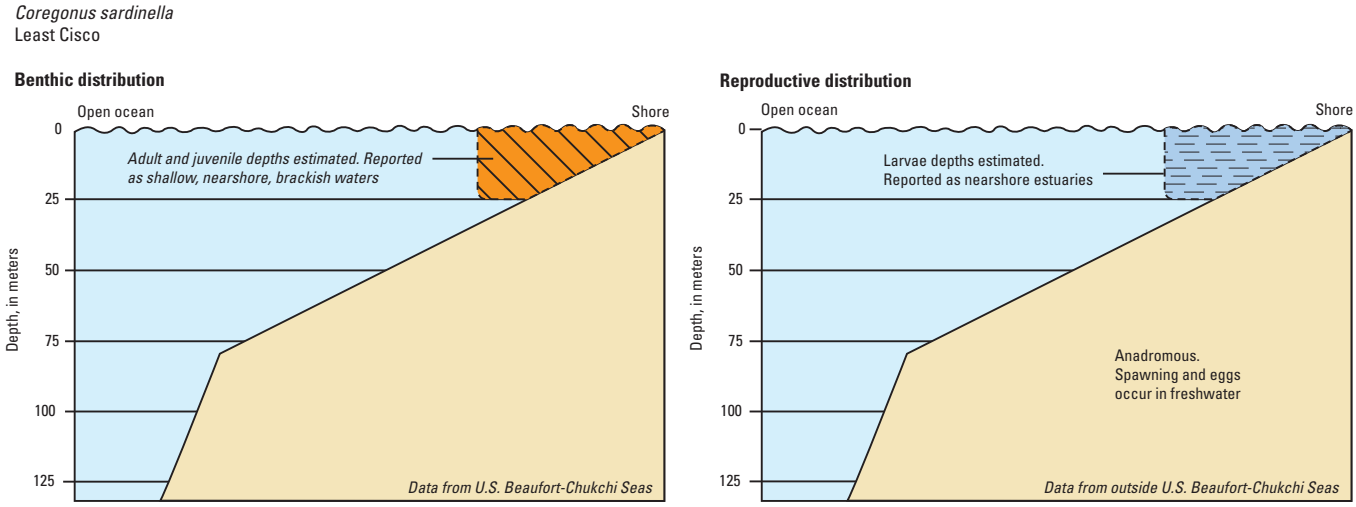
Least Cisco
Coregonus sardinella



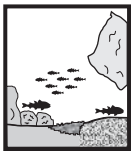
Base modified from USGS and other digital data. U.S.-Russia Maritime Boundary follows the EEZ/200-mile limit line, western edge. Coordinate reference system: projection, Lambert Azimuthal Equal Area; latitude of origin, 75.0°; horizontal datum, North American Datum of 1983.

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

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



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



Habitats and Life History

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

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

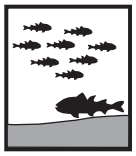
Larvae—Size at hatching: Unknown. Size at juvenile transformation: Unknown. Some fish as small as 25 mm migrate to sea [34]. Days to juvenile transformation: Unknown. Habitat: *Hatches in freshwater rivers* [5]. In Siberia, amphidromous fish move downstream to sea soon after hatching [35].

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

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

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

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



Behavior

Diel—Unknown.

Seasonal—*Fish enter U.S. Beaufort Sea following ice breakup in June and July, and begin to disperse and feed along the coast* [21, 29, 30, 34, 38]. *Young fish may remain in rivers for several years before entering the sea* [16]. *Due to higher temperature and lower salinity preferences, juveniles do not migrate as far as adults, who disperse farther along the coast* [5, 8, 16, 22–24]. *Most Least Cisco found along the North Slope originate from spawning and overwintering grounds in the Colville River* [8]. *Colville River fish migrate farther east in years of strong westerly winds.* Similarly, Mackenzie River fish move westward to a greater extent in years with strong easterly winds [8, 39, 40]. *Along the North Slope, larger fish can swim faster and reach distant feeding grounds before smaller individuals* [41]. *Given the short summer season, Least Cisco can travel substantial distances when conditions are favorable. For instance a fish tagged in Simpson Lagoon was recaptured off Barrow, 300 km to the west* [29]. *However, fish leaving the Colville River generally migrate eastward along the Arctic National Wildlife Refuge coast, because nearshore marine waters between Smith Bay and Cape Halkett may block westward movements* [20, 40]. *Return migrations to spawning and overwintering grounds begin between July and September* [8, 29, 41]. Both juveniles and adults overwinter in brackish waters of river deltas (for example, Colville River, Alaska, and Mackenzie River, Canada, are the largest overwintering areas along the Beaufort Sea), open coast (for example, Tuktoyaktuk Harbor), and freshwater lakes of the Tuktoyaktuk Peninsula, Canada [21, 41, 42]. *Except for the Sagavanirktok River (where some overwintering occurs in delta waters), Least Cisco do not seem to either spawn or overwinter in any waterway between the Colville and Mackenzie Rivers* [41].

Reproductive—*Spawning occurs under ice in the shallow waters of rivers over gravel and sand* [5, 31–33]. During spawning, males and females move toward the surface, perpendicular to the current, while the eggs are released and fertilized [43]. Sea-run fish spawn in lower reaches of rivers or, as in the Yukon-Koyukuk River system, may migrate at least as much as 1,600 km upstream [44]. *In U.S. Chukchi and Beaufort Sea drainages, spawning by the Least Cisco is known to occur in various rivers including the Kobuk River* [2], *Colville River* [45], and Mackenzie River and its tributaries [42]. Individuals have been variously reported to spawn annually [25], in alternate years, or perhaps for some fish, less often [5, 16, 24, 28]. After spawning, fish quickly migrate downstream to freshwater overwintering grounds [22].

Schooling—*In coastal waters, forms schools that can maintain their integrity for months* [29].

Feeding—*Generalists, feeding throughout the water column with planktonic organisms dominating* [28]. *Feeds both during winter and during spawning migrations, although feeding intensity in both instances may be low* [7, 29, 33, 42, 46].

Populations or Stocks

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

Reproduction

Mode—Gonochoristic, oviparous, and iteroparous with external fertilization [5].

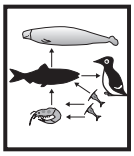
Spawning season—*September–November* [2, 5].

Fecundity—10,505–100,939 eggs in North America [24, 47].

Food and Feeding

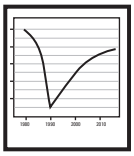
Food items—*Primarily crustaceans (for example, copepods, mysids, isopods, and amphipods) and insects, along with some polychaetes, clams, snails, fishes, fish eggs, fish larvae, and plant material* [5, 24, 28, 29, 48, 49].

Trophic level—3.24 (standard error 0.50) [50].



Biological Interactions

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



Resilience

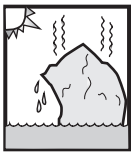
Medium, minimum population doubling time 1.4–4.4 years (K=0.40; t_m=2–4; t_{max}=11; Fecundity=2,500) [50].

Traditional and Cultural Importance

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

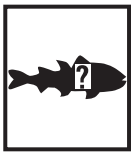
Commercial Fisheries

Currently, Least Cisco are not commercially harvested.



Potential Effects of Climate Change

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



Areas for Future Research [A]

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

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Pink Salmon (*Oncorhynchus gorbuscha*)

(Walbaum, 1792)

Family Salmonidae

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

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

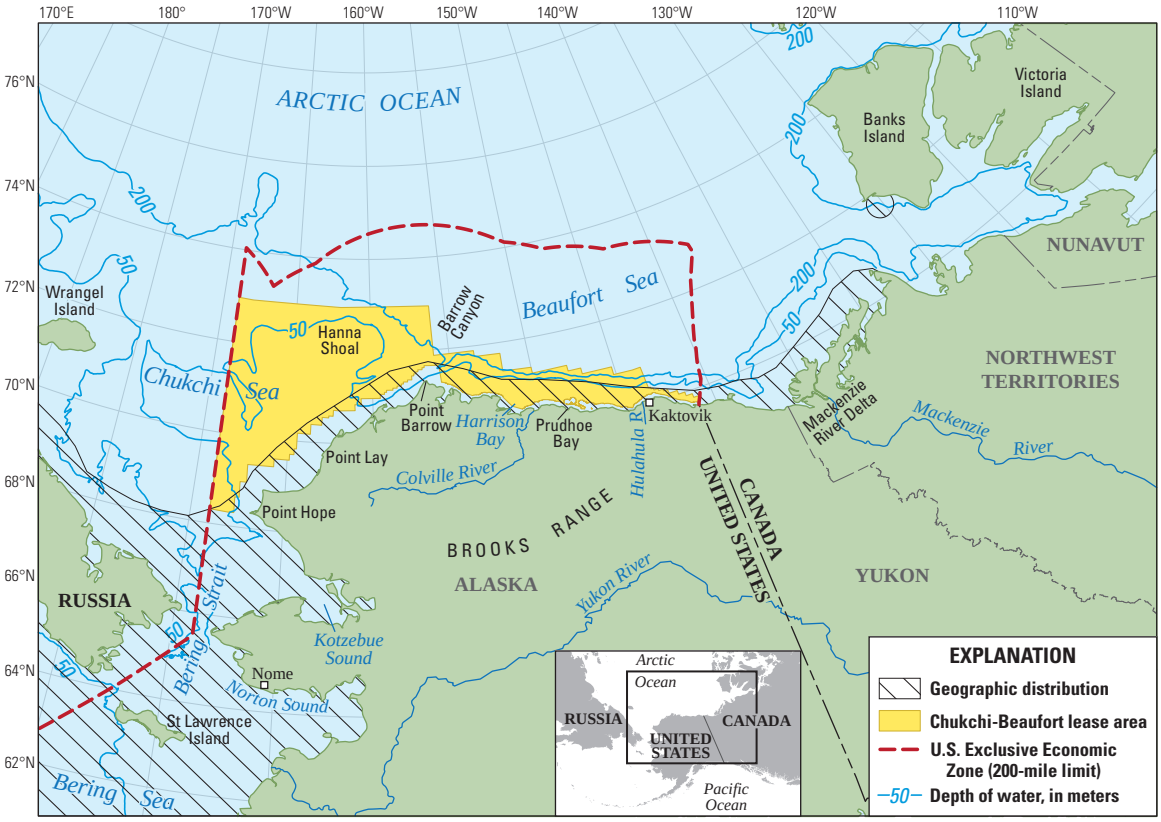
Ecological Role: The seeming relatively recent increase in abundance of this species north and eastward to at least the Barrow area implies that this species is becoming of some ecological importance in coastal waters of the U.S. Chukchi Sea.

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

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

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

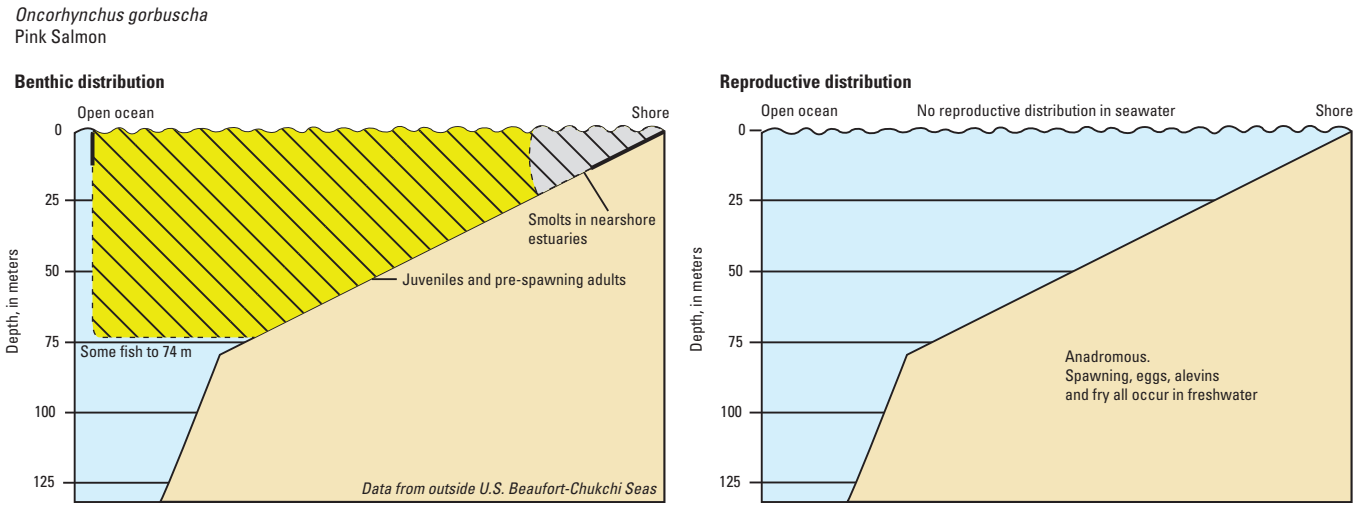
Pink Salmon
Oncorhynchus gorbuscha



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

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



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

Habitats and Life History

Anadromous.

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

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

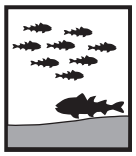
Fry—Size at emergence: About 28–34 mm [18]. Time as fry: Relatively short, as little as a few days [17]. Habitat: Benthopelagic in shallow waters of streams and rivers [16, 17].

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

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

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

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



Behavior

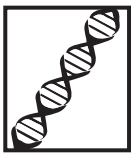
Diel—Migrations of fry to sea take place at night [17].

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

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

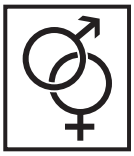
Schooling—Newly emerged fry may or may not school; fry do school when they reach the lower reaches of rivers [17]. Juveniles school in nearshore waters during early phases of their seaward migration [17]. Schooling behavior during ocean phases of migration may be less structured and include intermingling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

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



Populations or Stocks

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

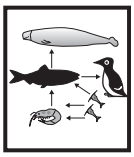


Reproduction

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

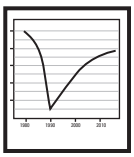
Food and Feeding

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



Biological Interactions

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



Resilience

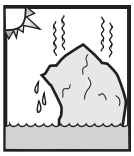
Medium, minimum population doubling time 1.4–4.4 years (t_m=2; t_{max}=3; Fecundity=800) [24].

Traditional and Cultural Importance

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

Commercial Fisheries

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



Potential Effects of Climate Change

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

Areas for Future Research [A]

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

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Chum Salmon (*Oncorhynchus keta*)

(Walbaum, 1792)

Family Salmonidae

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

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

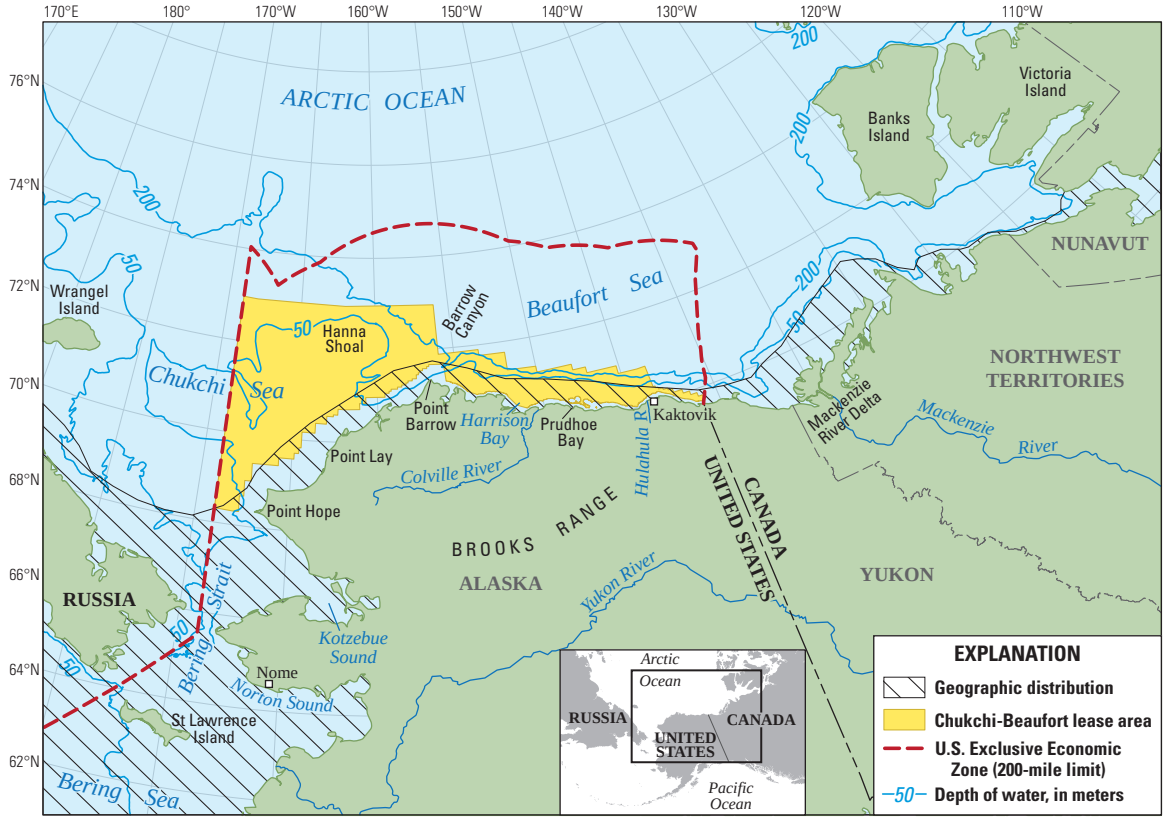
Ecological Role: The abundance of this species north and eastward to at least the Barrow area implies that this species is likely of some ecological importance. Especially important member of the nearshore marine in Kotzebue Sound.

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

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

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

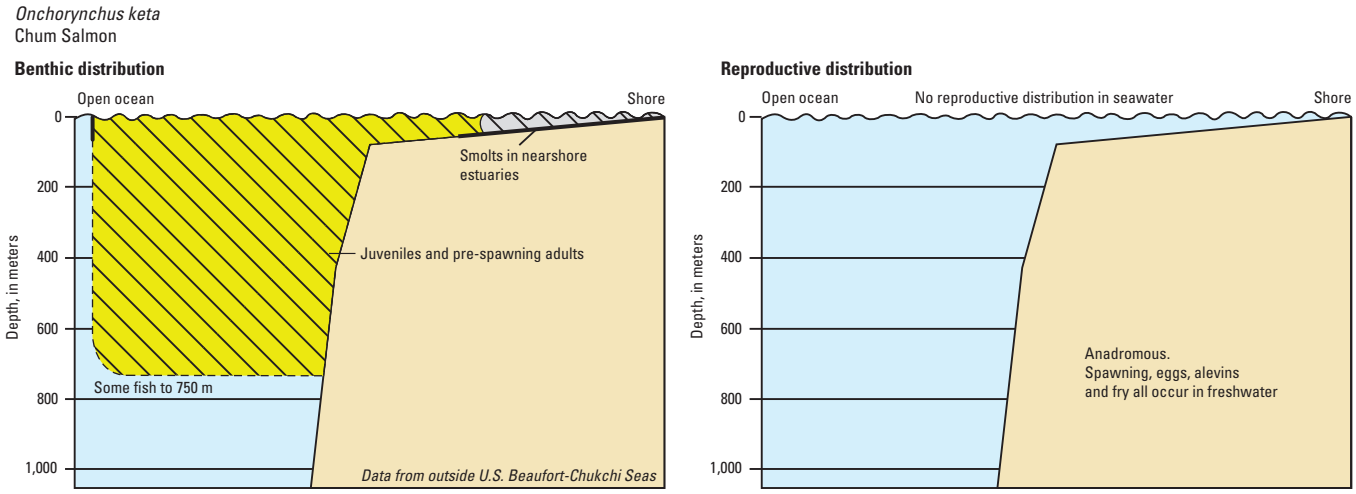
Chum Salmon
Oncorhynchus keta



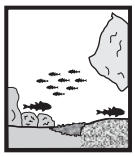
Base modified from USGS and other digital data. U.S.-Russia Maritime Boundary follows the EEZ/200-mile limit line, western edge. Coordinate reference system: projection, Lambert Azimuthal Equal Area; latitude of origin, 75.0°; horizontal datum, North American Datum of 1983.

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

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



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



Habitats and Life History

Anadromous.

Eggs—Size: At least 6.0–10.0 mm [13, 14]. Time to hatching: Highly variable, 52–182 days [14]. Size at hatching: 20–25.0 mm [13, 15]. Habitat: Benthic, buried under gravel of streams and rivers [13, 14].

Alevins (larvae)—Size range: 20–35.0 mm [13] Habitat: Under gravel of streams and rivers until yolk sac absorbed (30–50 days) [14, 16].

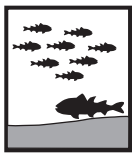
Fry—Size at emergence: About 30–39 mm [15]. Length of time as fry: 1 month or more. May remain in fresh water for several weeks or may immediately migrate downstream and enter marine or estuarine waters [14, 17]. Habitat: Demersal, in streams and rivers [13, 14].

Smolt (juveniles) and ocean phase—Size when entering ocean: Between 30–70.0 mm, depending on distance from spawning grounds [13]. Habitat: Juveniles spend their first few months to a year in nearshore, marine waters, often inhabiting eelgrass or algal beds [18], and then two to five winters offshore [19].

Adults: Age and size at first maturity: Highly variable, 2–6 years, primarily 3–5 years, and 60–80 cm [14]. Maximum age: 7 years [16]. Maximum size: 109 cm [14]. Habitat: Adults return to freshwater streams and rivers to spawn [13, 14].

Substrate—Gravel for spawning [14].

Physical/chemical—Temperature: At sea, -0.8–22.5 °C [20], most common between 2 and 11 °C [21]. Salinity: Fresh water to marine, depending on life stage [14]. Fry are euryhaline and can withstand daily fluctuations of 0–27 parts per thousand [14].



Behavior

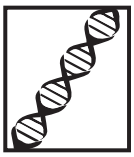
Diel—Fry typically emerge from gravel and migrate downstream at night [14]. At sea, many individuals may ascend into surface waters at night and return to depth during the day [20].

Seasonal—Fry emerge from gravel beds in spring [17]. *At-sea behavior in U.S. Chukchi and Beaufort Seas is unknown.* It is speculated that fish entering the Beaufort Sea from various drainages may overwinter either in deeper waters of the Beaufort Sea or in the North Pacific [9].

Reproductive—Spawning occurs in freshwater in streams and rivers. Females prepare a gravel nest and lay their eggs, which are fertilized by a male [14]. All adults die after spawning [13].

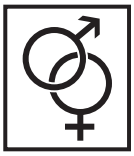
Schooling—Fry do not strongly school [14]. Juveniles in estuaries and nearshore waters may form loose aggregations [14].

Feeding—Juveniles in estuaries feed most intensely at high tides when marsh is submerged [14].



Populations or Stocks

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



Reproduction

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

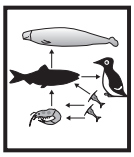
Spawning season—*Unknown in U.S. Chukchi and Beaufort Seas watersheds except for stocks from Kotzebue Sound.* In the Mackenzie River, Canada, spawning migrations are during July and August with spawning in autumn [24]. In other regions, spawning is in June–January [17].

Fecundity—At least 900–8,000 eggs [17].

Food and Feeding

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

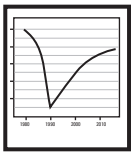
Trophic level—3.47 (standard error 0.48) [28].



Biological Interactions

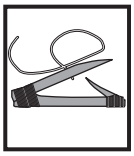
Predators—A wide variety of fishes, sea birds, and mammals. Examples include Pacific Halibut, Pacific Sleeper Shark, Walleye Pollock, rhinoceros auklet, pigeon guillemot, marbled murrelet, pelagic cormorant, northern fur seal, beluga whale, and orca [16, 29–31] [32–35].

Competitors—Likely other planktivores (for example, salmonids, Pacific Herring, and Polar and Saffron cods).



Resilience

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

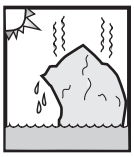


Traditional and Cultural Importance

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

Commercial Fisheries

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



Potential Effects of Climate Change

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

Areas for Future Research [A]

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

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Coho Salmon (*Oncorhynchus kisutch*)

(Walbaum, 1792)

Family Salmonidae

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

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

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

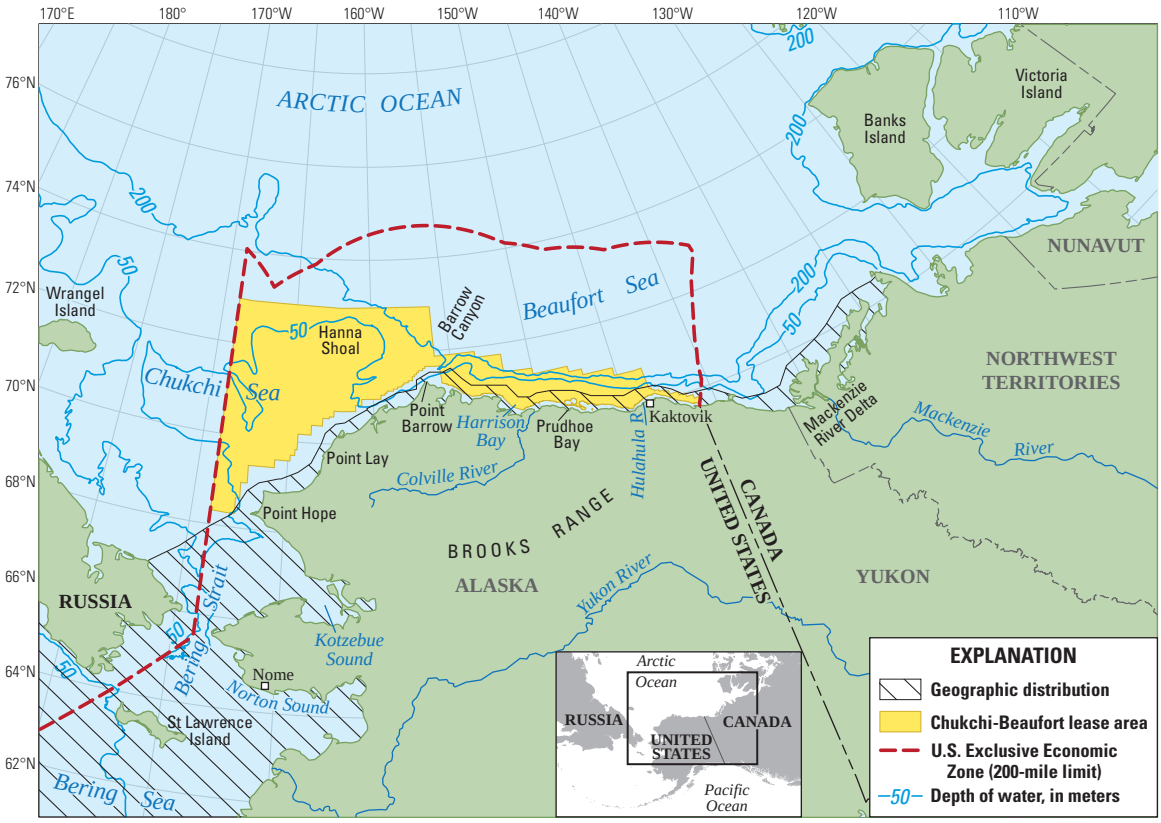
Coho salmon (*Oncorhynchus kisutch*), freshwater spawning stage. Photograph by Thomas Kline, http://www.salmonography.com.

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

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

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

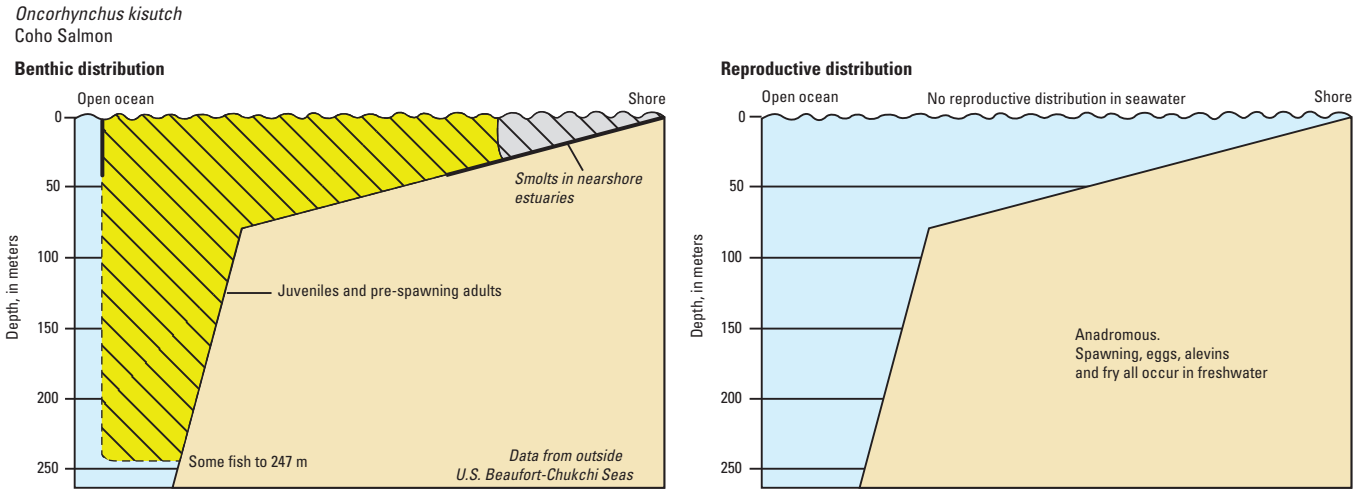
Coho Salmon
Oncorhynchus kisutch



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

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

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



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

Habitats and Life History

Anadromous.

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

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

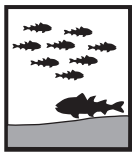
Fry—Size at emergence: About 27–30 mm [14, 15]. Length of time as fry: 1–4 years, typically 1 year [15]. Habitat: Benthic, in streams and rivers [15].

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

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

Substrate—Gravel for spawning [15].

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



Behavior

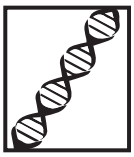
Diel—Fry and smolts migrate primarily at night [15]. At sea, many or most individuals may ascend into surface waters at night and return to depth during day [19].

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

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

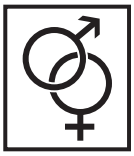
Schooling—Smolts and marine individuals form schools [15].

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



Populations or Stocks

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

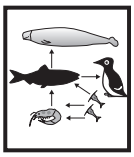


Reproduction

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

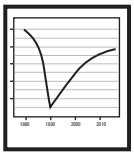
Food and Feeding

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



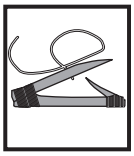
Biological Interactions

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



Resilience

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

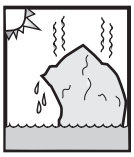


Traditional and Cultural Importance

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

Commercial Fisheries

Currently, Coho Salmon are not commercially harvested.



Potential Effects of Climate Change

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

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

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Sockeye Salmon (*Oncorhynchus nerka*)
(Walbaum, 1792)

Family Salmonidae

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

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

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

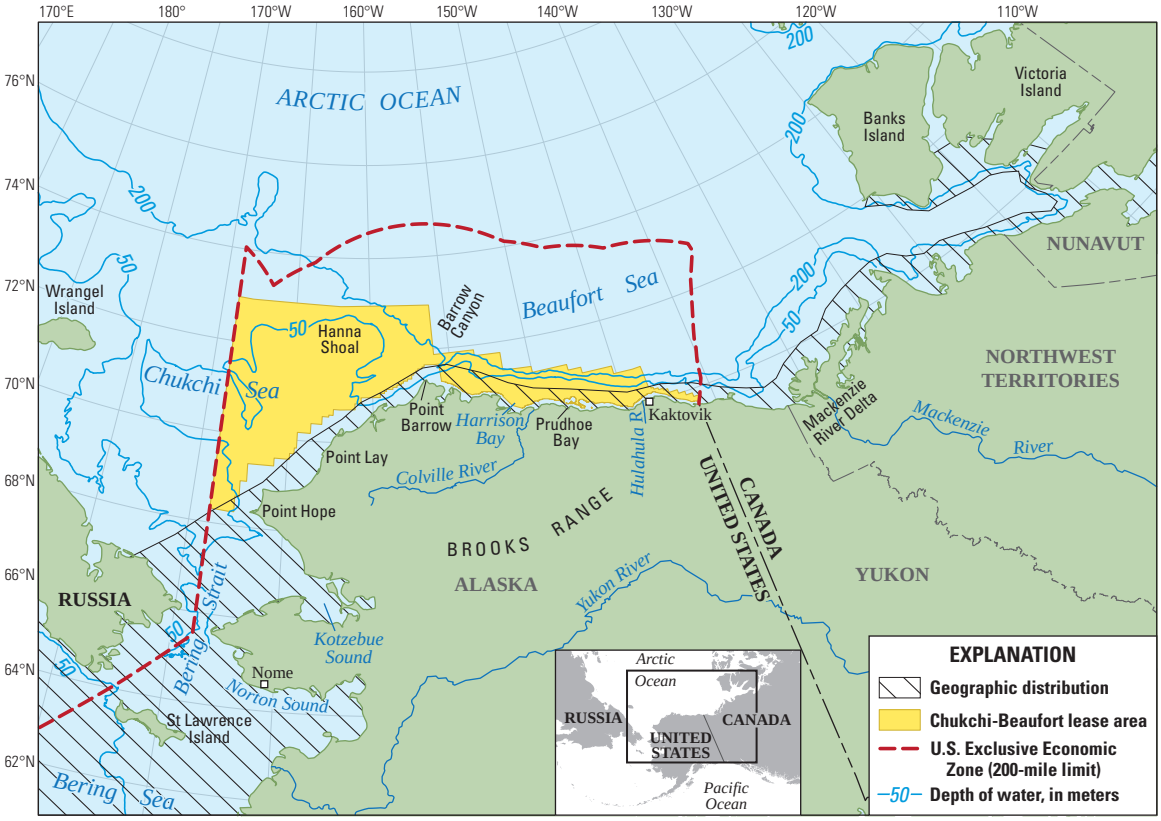
Ecological Role: Of limited ecological importance in the U.S. Chukchi and Beaufort Seas. Harvested in small numbers in Kotzebue Sound; therefore, this fish may play a seasonal role in pelagic ecosystems in the southeastern Chukchi Sea.

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

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

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

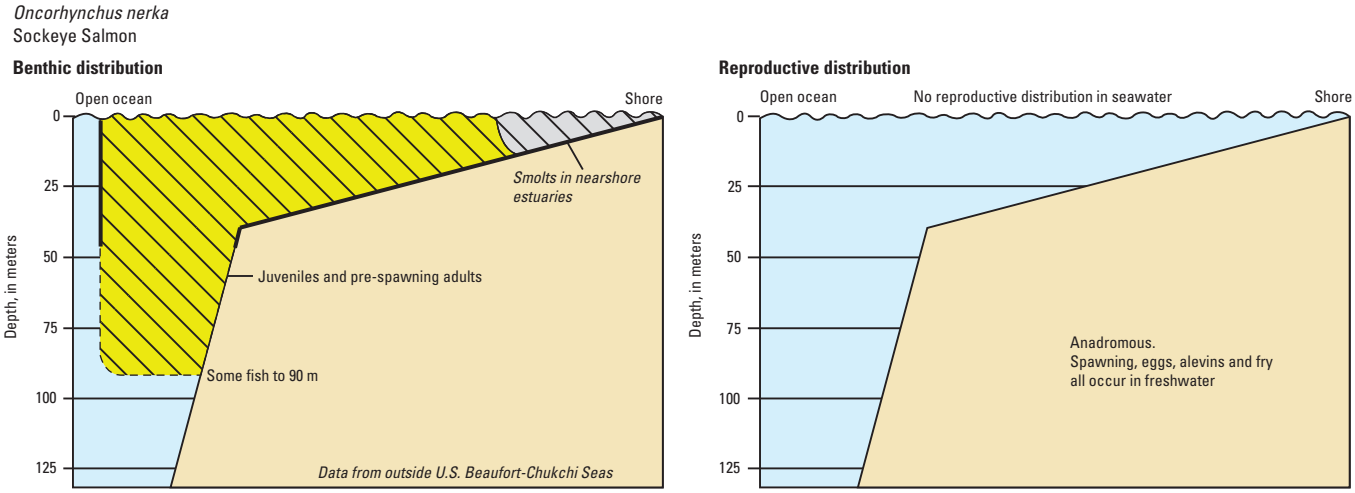
Sockeye Salmon
Oncorhynchus nerka



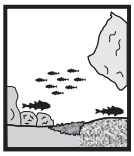
Base modified from USGS and other digital data. U.S.-Russia Maritime Boundary follows the EEZ/200-mile limit line, western edge. Coordinate reference system: projection, Lambert Azimuthal Equal Area; latitude of origin, 75.0°; horizontal datum, North American Datum of 1983.

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

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



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



Habitats and Life History

Anadromous.

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

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

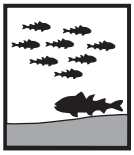
Fry—Size at emergence: 25–31 mm [10]. Length of time as fry: Several weeks to 3 years (although stream-reared juveniles and juveniles that migrate to sea within a few weeks are known) [10]. Habitat: Lakes and streams [10].

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

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

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

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



Behavior

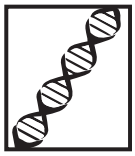
Diel—Fry emerge from substrate and make initial downstream migration at night. Smolt migrations to sea tend to be at night [10].

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

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

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

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

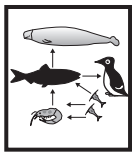


Populations or Stocks
There have been no studies.

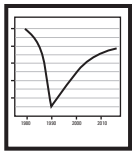
Reproduction
Mode—Gonochoristic, oviparous, and semelparous with external fertilization [15].
Spawning season—Late July through January, typically from midsummer through late autumn [10].
Fecundity—Highly variable, 2,000–5,000 eggs on average [10].

Food and Feeding

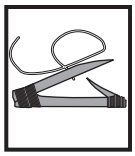
Food items—Primarily zooplankton (for example, euphausiids, hyperiid amphipods, copepods, pteropods, and crustacean larvae), as well as small fishes and squids. Diets vary with area and year [16, 17].
Trophic level—3.4 [18].



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

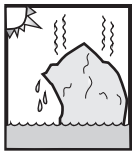


Resilience
Medium, minimum population doubling time 1.4–4.4 years (K=0.37–0.58; t_m=2–4; t_{max}=7; Fecundity=300) [18].



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

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



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

Areas for Future Research [B]

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

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Craig, P.C., and Haldorson, L.J., 1986, Pacific salmon in the North American Arctic: Arctic, v. 39, no. 1, p. 2–7. [7]

Emmett, R.L., Stone, S.L., Hinton, S.A., and Monaco, M.E., 1991, Distribution and abundance of fishes and inverteprates in west coast estuaries, Volume II—Species life history summaries: NOAA/NOS Strategic Environmental Assessments Division, ELMR Report no. 8, 327 p. [11]

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Chinook Salmon (*Oncorhynchus tshawytscha*)

(Walbaum, 1792)

Family Salmonidae

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

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

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

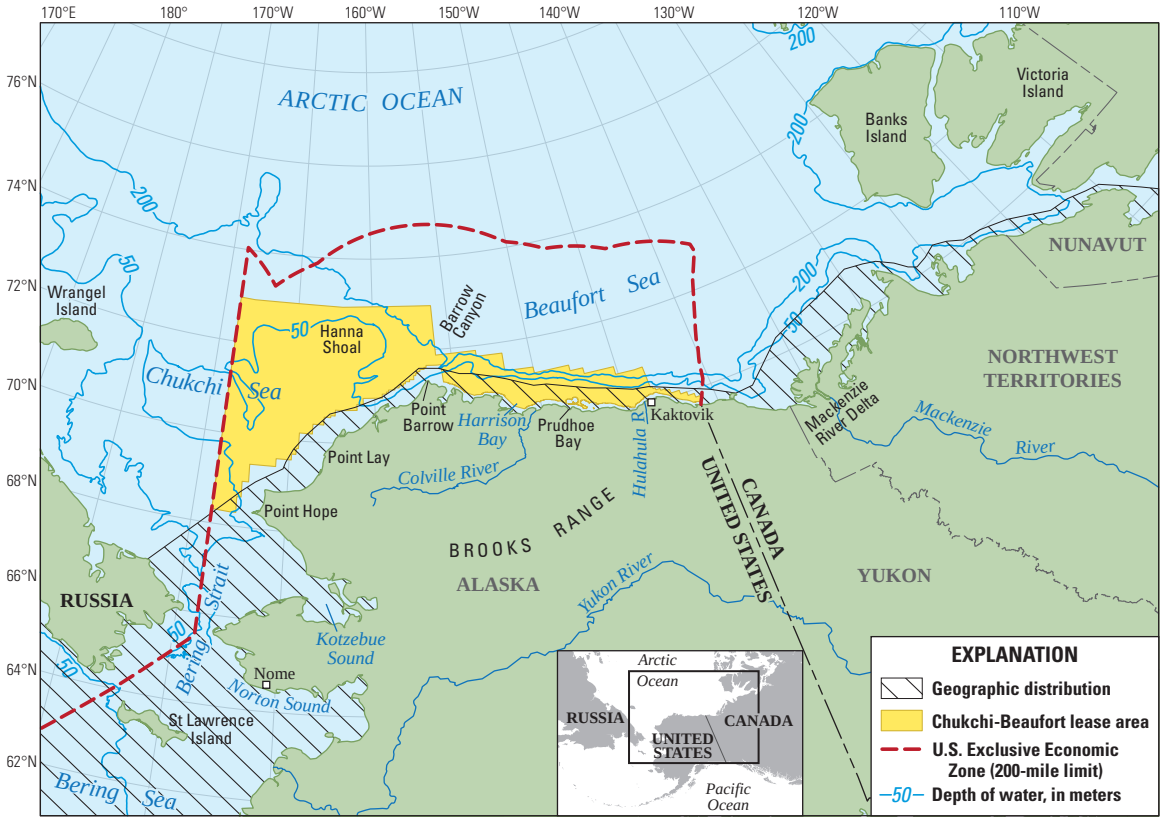
Ecological Role: With its apparent increase in abundance in the U.S. Chukchi and Beaufort Seas [1], this species is likely to be of increasing ecological importance. Chinook Salmon are occasionally captured in recreational fisheries at Point Barrow.

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

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

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

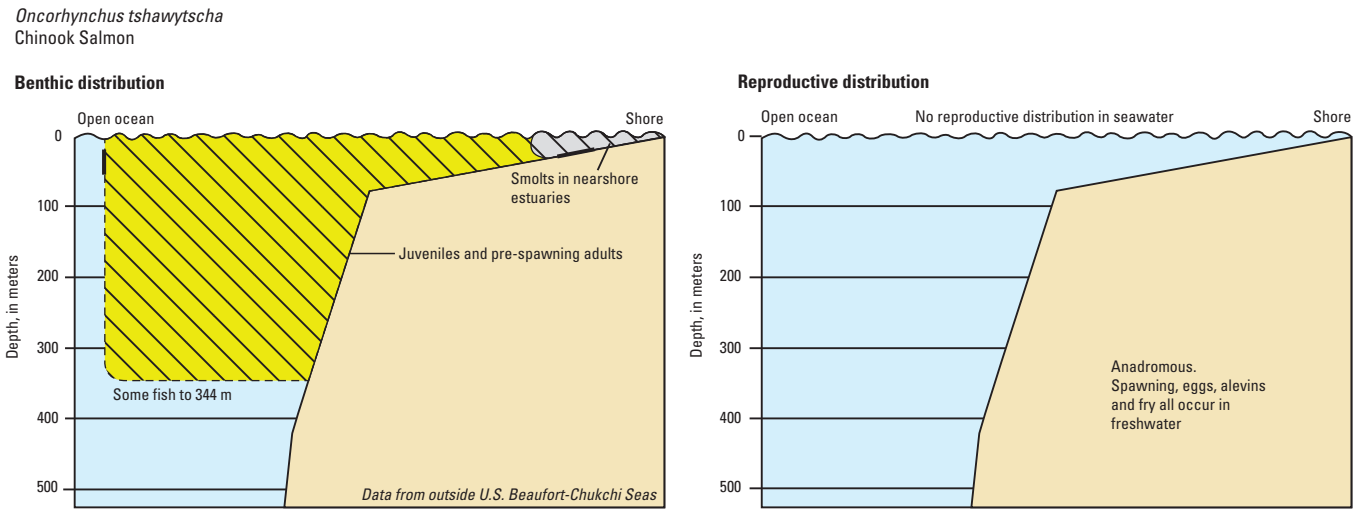
Chinook Salmon
Oncorhynchus tshawytscha



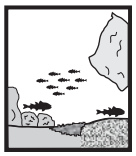
Base modified from USGS and other digital data. U.S.-Russia Maritime Boundary follows the EEZ/200-mile limit line, western edge. Coordinate reference system: projection, Lambert Azimuthal Equal Area; latitude of origin, 75.0°; horizontal datum, North American Datum of 1983.

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

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



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



Habitats and Life History

Anadromous.

Eggs—Size: 6.0–8.5 mm [14]. Size at hatching: About 20–24 mm [14, 15]. Time to hatching: 30–160 days, warmer temperatures speed hatching time [16]. Habitat: Benthic, buried in gravel in streams and rivers [10].

Alevins (larvae)—Size range: 20–35 mm [14]. Habitat: Benthic, buried in gravel in streams and rivers [10]. Stay under gravel until yolk sac absorbed (4–6 weeks) [17].

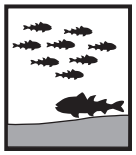
Fry—Size at emergence: About 33–37 mm [15]. Length of time as fry: Several weeks to more than 1 year [10]. Habitat: Epipelagic in streams, rivers, and estuaries [10].

Smolt (juveniles) and ocean phase—Age and size at smoltification: Several weeks to at least 18 months and at least 35 mm to perhaps 160 mm [17]. Habitat: Epipelagic [10, 14, 18]. Smolts that quickly leave fresh water reside in estuaries for at least a few months, although length of residence varies annually and with location [10]. Two life history types: Ocean-type enters the ocean in their first year and migrates less. Stream-type spends first year in fresh water, enters the ocean in their second year, and tends to migrate farther [18]. Generally, ocean-type does not migrate out of nearshore waters when at sea, whereas stream-type disperses much broader and farther from shore [10].

Adults—Age at first maturity: Highly variable, depending on stock and ranges from 1 year for males to 7–8 years for females [10]. Mean ages per stock range from 3–6 years [10]. Maximum age: 8 years [10]. Maximum size: 160 cm [2]. Habitat: At maturity, ascends rivers and streams to spawn [10].

Substrate—Gravel for spawning [10]. Mud, sand, gravel, and over eelgrass for juveniles in estuaries [14].

Physical/chemical—Temperature: At sea, 2–16.9 °C [19, 20], may prefer 7–12 °C [13, 20]. Salinity: Fresh to marine waters, depending on life stage [10].



Behavior

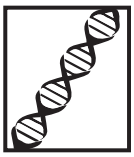
Diel—Fry emerge from gravel and travel downstream primarily at night [10]. In at least some areas, fry settle to the bottom at dusk and move into shallow waters at night. Juveniles entering estuaries do so at night [17]. At sea, appears to move toward surface waters in evening and returns to depth in morning [21].

Seasonal—Depending on geographical location, Chinook Salmon may return to natal rivers during almost any month of the year [10]. *In the U.S. Chukchi and Beaufort Seas, utilization of ocean waters as well as migrations are unknown.*

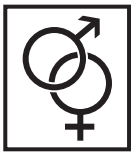
Reproductive—Spawning occurs in freshwater streams and rivers. Females prepare a gravel nest and lay their eggs, which are fertilized by a male [10]. All adults die after spawning except for a few “jack” males [14].

Schooling—Fry form schools [22].

Feeding—Juveniles and adults are carnivorous, opportunistic feeders [10, 14].

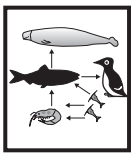


Populations or Stocks
There have been no studies in the U.S. Chukchi and Beaufort Seas.

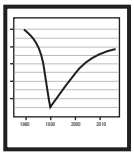


Reproduction
Mode—Gonochoristic, oviparous, and semelparous with external fertilization [23].
Spawning season—May–January, depending on run, fish in the more northerly parts of the range tend to spawn earlier in the season [10].
Fecundity—Highly variable, less than 2,000 to more than 17,000 eggs [10].

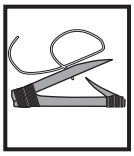
Food and Feeding
Food items—At sea, primarily fishes, although zooplankton (for example, euphausiids, amphipods, copepods, and pteropods) also is consumed [24].
Trophic level—4.4 (standard error 0.76) [25].



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

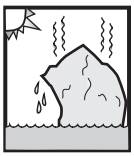


Resilience
Medium, minimum population doubling time 1.4–4.4 years (t_m=4; t_{max}=9; Fecundity=4,000) [25].



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

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



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

Areas for Future Research [B]

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

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

Family Salmonidae

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

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

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

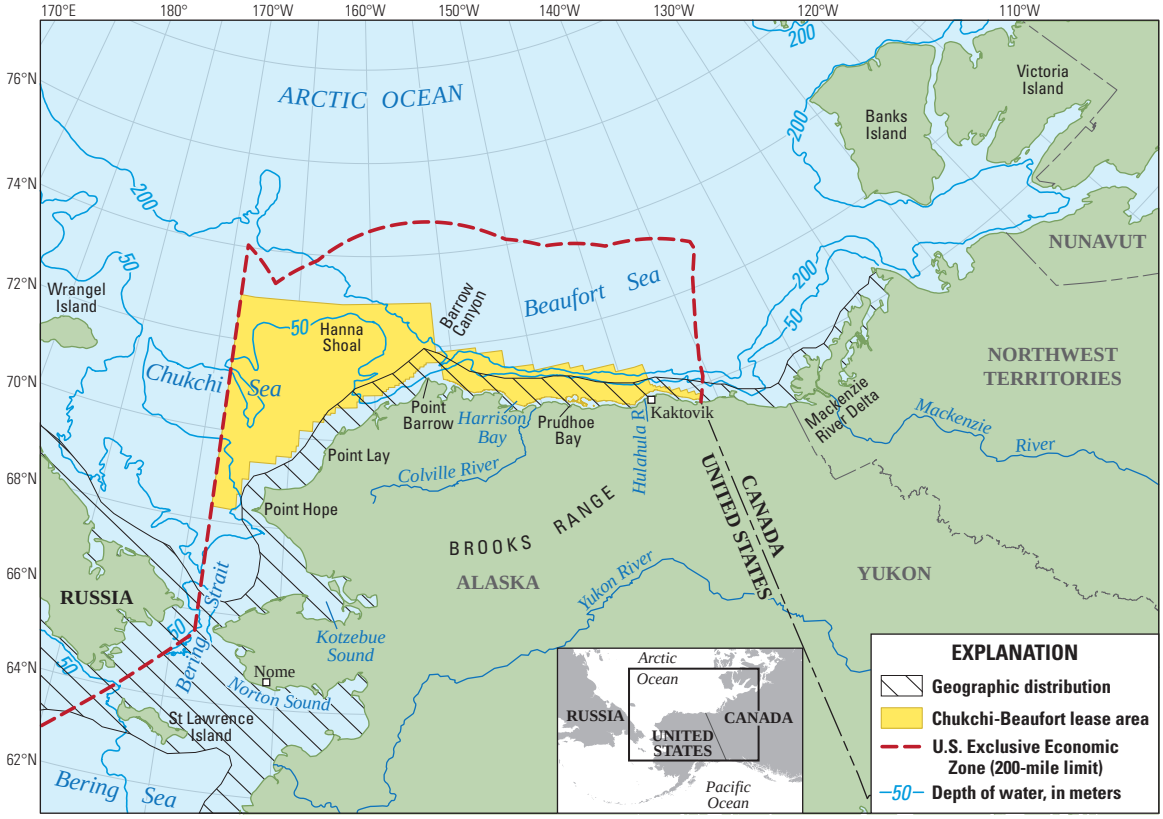
Dolly Varden (*Salvelinus malma)*. Photograph by Alfred L. DeCicco, Alaska Department of Fish and Game.

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

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

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

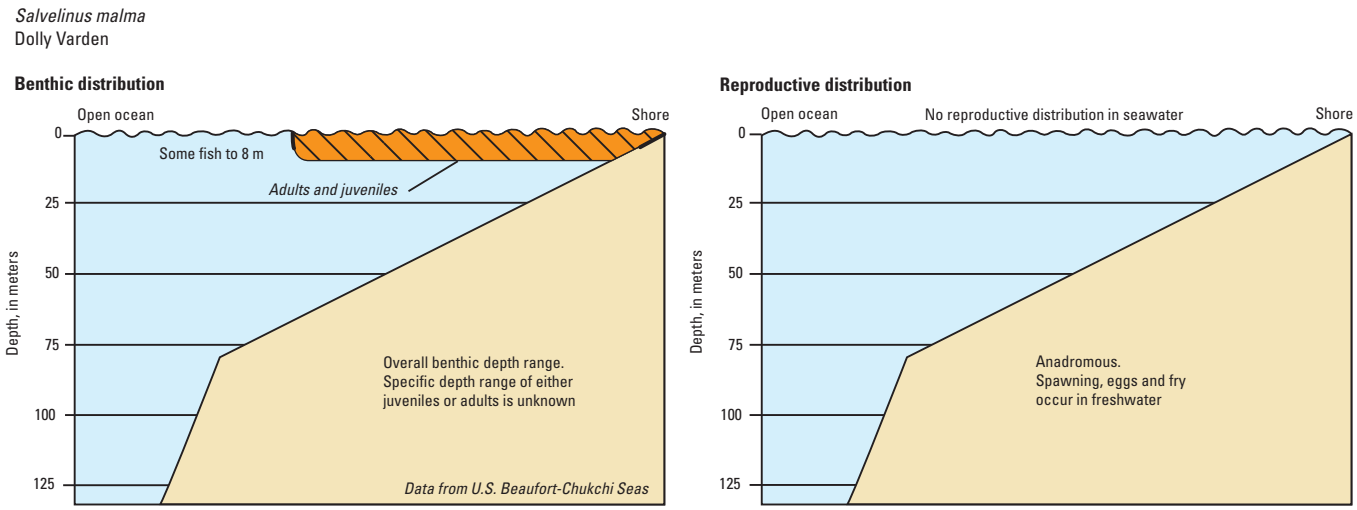
Dolly Varden
Salvelinus malma



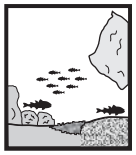
Base modified from USGS and other digital data. U.S.-Russia Maritime Boundary follows the EEZ/200-mile limit line, western edge. Coordinate reference system: projection, Lambert Azimuthal Equal Area; latitude of origin, 75.0°; horizontal datum, North American Datum of 1983.

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

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



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



Habitats and Life History

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

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

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

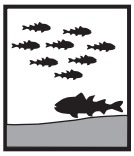
Fry and parr—Size at emergence: *20–27 mm* [5, 19]. Length of time as fry and parr: *1 to 5 years, mostly at 3–5 years* [1, 19, 20, 23]. Habitat: *Freshwater, in streams and rivers.*

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

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

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

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



Behavior

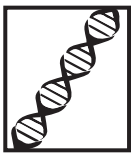
Diel—Unknown.

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

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

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

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



Populations or Stocks

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

Reproduction

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

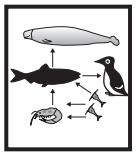
Spawning season—*August–December, peaking in September and October* [5, 19, 20, 23, 27, 32].

Fecundity—1,500–7,000 eggs [1].

Food and Feeding

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

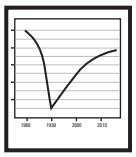
Trophic level—4.5 [43].



Biological Interactions

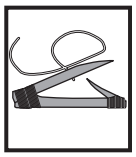
Predators—*Beluga whales, ringed seals, polar bears, and other Dolly Varden* [39, 44–46].

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



Resilience

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

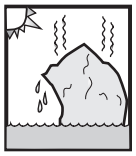


Traditional and Cultural Importance

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

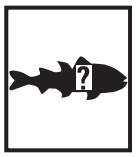
Commercial Fisheries

Currently, Dolly Varden are not commercially harvested.



Potential Effects of Climate Change

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



Areas for Future Research [A]

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

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Inconnu and Glacier Lanternfish

Inconnu (*Stenodus leucichthys*)
(Güldenstadt, 1772)

Family Salmonidae

Inconnu (*Stenodus leucichthys*). Photograph by R.J. Brown, U.S. Fish and Wildlife Service.

Colloquial Name: Iñupiat—*Siiġruaq* [1]. Most often called sheefish in Alaska.

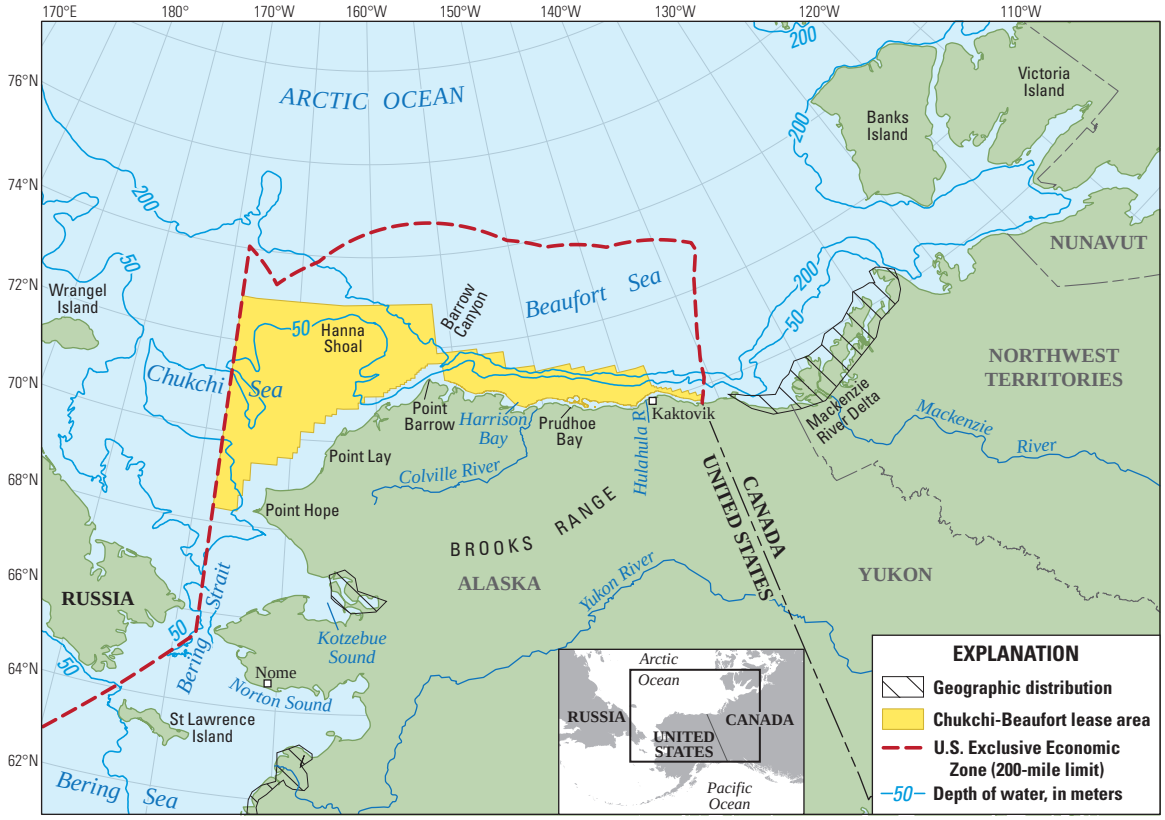
Ecological Role: Rarely enters marine waters and thus is not of ecological importance in the U.S. Chukchi and Beaufort Seas. Common in coastal lagoons in Kotzebue Sound, this fish is a major predator of pelagic species, such as Pacific Herring and possibly juvenile salmon. Inconnu is an important subsistence species in western Alaska including the southeastern Chukchi Sea.

Physical Description/Attributes: Body not much compressed; and colored green, blue, or brown dorsally and silvery white ventrally. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 181) [2]. Swim bladder: Present [3]. Antifreeze glycoproteins in blood serum: Unknown.

Range: *Northward to Kobuk River* [2] *and probably Noatak River drainages of U.S. Chukchi Sea* [4]. Elsewhere in Alaska, this fish has been found as far south as Kuskokwim River [2]. Worldwide, Inconnu are found from Firth to Anderson Rivers, Canada [5], and in Caspian, Siberian, and White Sea drainages, south to Kamchatka, Russia [2]. Reported in nearshore semi-saline waters of Canadian Beaufort Sea to at least as far west as Herschel Island and Nunaluk Lagoon, Yukon Territory; most numerous just west of Mackenzie River, Northwest Territory [6].

Relative Abundance: *Common in the Kobuk River. Despite earlier reports of scattered fish in the Meade and Colville Rivers, there have been no recent reports of fish from any North Slope drainage* [2].

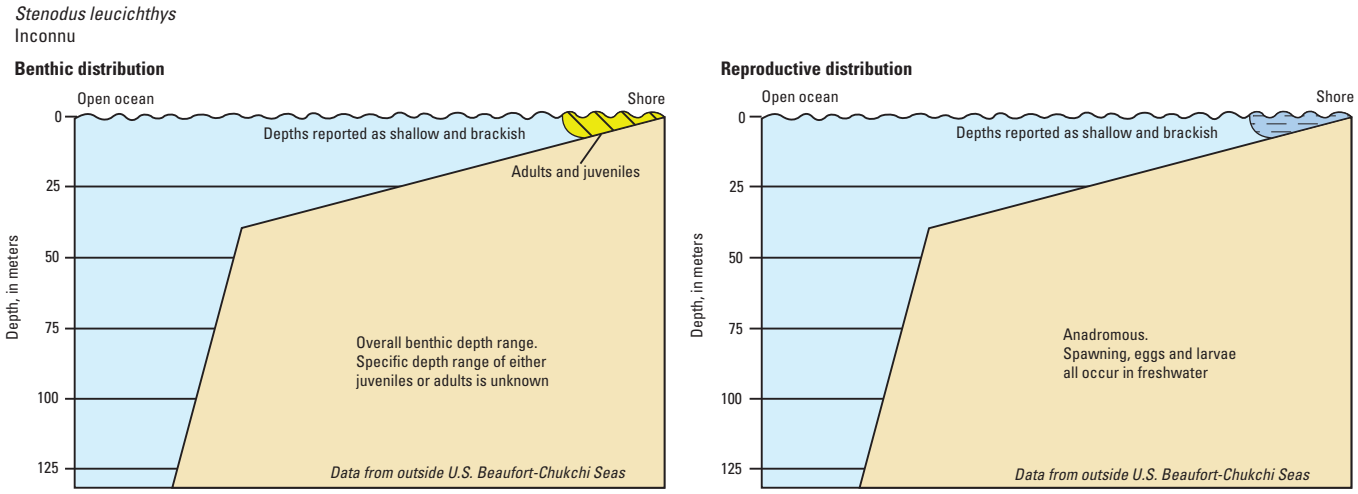
Inconnu
Stenodus leucichthys



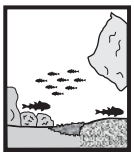
Base modified from USGS and other digital data. U.S.-Russia Maritime Boundary follows the EEZ/200-mile limit line, western edge. Coordinate reference system: projection, Lambert Azimuthal Equal Area; latitude of origin, 75.0°; horizontal datum, North American Datum of 1983.

Geographic distribution of Inconnu (*Stenodus leucichthys*), in brackish nearshore and delta waters within Arctic Outer Continental Shelf planning areas [7] based on review of published literature and specimens from historical and recent collections [2, 8].

Depth Range: Shallow waters in rivers and brackish, near-shore coastal systems [9].



Benthic and reproductive distribution of Inconnu (*Stenodus leucichthys*).



Habitats and Life History

Amphidromous.

Eggs—Size: 2.5–2.7 mm [5, 10–13]. Time to hatching: 6–9 months. Habitat: Benthic, buried in gravel in freshwater rivers [5, 10, 14].

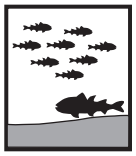
Larvae—Size at hatching: 11.0–11.3 mm [15]. Size at juvenile transformation: 7.0 cm [15]. Days to juvenile transformation: Unknown. Habitat: Newly hatched larvae are carried down river to nursery and overwintering areas in river deltas, estuaries, or lower reaches of watersheds [11].

Juveniles—Age and size: 0–7 years and about 70 cm average [5, 10, 14]. Habitat: Fresh and brackish water [5, 10, 14].

Adults—Age and size at first maturity: Males mature at 4–11 years (70–85 cm) [10, 11, 14] and females at 6–14 years (75–90 cm) [10, 14]; most fish mature at 8–12 years [16]. On average, males mature when younger and smaller than females [5]. Maximum age: At least 41 years [17]. Older studies using scales to age fish rather than otoliths underestimated fish ages beginning at about 10 years [18]. Females grow larger than males, live longer, and tend to reach maturity later [9–11, 14]. Growth rates, life spans, and size and age at maturity vary between watersheds and between populations within watersheds [11, 19]. For instance, fish in Kobuk and Selawik Rivers live longer and grow larger than those in Yukon and Kuskokwim systems; however, Kobuk and Selawik fish grow slower [14]. Maximum size: 140 cm [2]. Habitat: Large and slow moving rivers and estuaries. Entire life is spent within or adjacent to their home rivers [5, 11, 16].

Substrate—Coarse gravel and cobble mixed with sand for spawning [10, 11, 16].

Physical/chemical—Temperature: Spawning occurs at least between 0–7 °C [5, 13]. Salinity: Primarily freshwater, but some in brackish waters to about 20 parts per thousand [5, 20].



Behavior

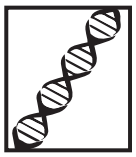
Diel—Unknown.

Seasonal—Many watersheds contain a relatively small resident freshwater population that migrate within a river system and a larger amphidromous population that may or may not enter estuarine waters in a given year [5, 10]. For example, Mackenzie River sea-going inconnu spend their first 1–2 years in freshwater and then tend to move annually into brackish and more marine coastal waters. Among these stocks, some regularly migrated to sea throughout their lives, whereas others made only occasional estuarine migrations or sea migrations followed by extended periods in freshwater or in estuaries [9]. In some rivers, resident and amphidromous forms do not share feeding, overwintering, or spawning grounds [20, 21]. Overwintering areas vary with watershed. Fish in Kobuk and Selawik Rivers overwinter in brackish waters of Hotham Inlet and Selawik Lake. Fish in the lower Yukon and Kuskokwim Rivers spend winter in those rivers' deltas [11], whereas Mackenzie River fish winter both in the delta and nearshore coastal waters of Canadian Beaufort Sea [9]. Slightly before or at about ice break-up time, adults and some juveniles begin to leave overwintering grounds [14, 22], although in some areas (for example, Selawik Lake) juveniles remain on nursery grounds throughout the year [10]. Individuals that will spawn in autumn migrate with other fish to feeding grounds during summer, but do not feed, instead they continue on to spawning grounds [5, 14]. Feeding (non-spawning) fish migrate back to overwintering grounds during August and September [5, 10, 16].

Reproductive—Spawn in their natal rivers. Spawning migrations may be long; as much as 1,800 km on the Mackenzie River [23], 1,500 km on the Yukon River [4], and 2,400 km on Siberian rivers [5]. Arrive on spawning grounds as early as 1–2 months before spawning in early autumn [5, 14, 24]. In the Selawik and Kobuk Rivers, spawning occurs in late afternoon and evening between at least 1500 and 1800 hours (local), perhaps peaking between 1545 and 2200 hours (local) [5, 10, 14]. Spawning sites are in relatively small and restricted areas, although these may change with time [5]. Inconnu are broadcast spawners in shallow and fast moving waters over coarse gravel and cobble mixed with sand [10, 11, 16]. Females release eggs at the surface and males release sperm just below the surface and rarely come to the surface [5, 11]. A female emits eggs in a series of discrete spawning spurts, returning to the bottom between each episode [5]. Eggs fall to the riverbed and are slightly adhesive to gravel and cobble [11]. Eggs are deposited in autumn and reportedly hatch around time of ice break-up in early spring [12, 16]. Some populations spawn annually [17]. However, in other populations, most individuals do not spawn annually; however, males are more likely to spawn in sequential years [16, 25, 26]. Although many migrate downstream immediately after spawning (arriving in October), others remain on spawning grounds for some length of time (as late as January) [5, 10, 16].

Schooling—Forms schools [5, 10, 14].

Feeding—Migrating juveniles and non-spawning adults travel to feeding areas. In western Alaska, foraging areas tend to be in lower reaches of rivers, upstream of overwintering grounds [22], but also include the brackish waters of Kotzebue Sound (for Kobuk and Selawik River fish) [5] and the Beaufort Sea (for Mackenzie River fish) [20]. Does not feed during spawning migrations (about 1–4 months) [14].



Populations or Stocks

Two distinct spawning locations have been identified, one in the upper Kobuk River and one on the refuge in the upper Selawik River. In cooperation with the Native Village of Kotzebue and Alaska Department of Fish and Game, genetic mixed stock analysis is ongoing to understand the proportion of the winter inconnu harvest that comes from each of the two spawning populations.

Reproduction

Mode—Gonochoristic, oviparous, iteroparous with external fertilization [5, 10, 11].

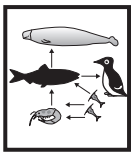
Spawning season—Autumn, primarily September and October [9, 16, 27].

Fecundity—26,000–455,000 eggs [5, 10–12, 17].

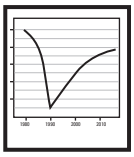
Food and Feeding

Food items—Plankton and insects for juveniles. For fish 2 years and older, food is primarily fishes (for example, whitefishes, Arctic Lamprey, Pacific Herring, and salmon) and secondarily on small invertebrates such as isopods, mysids, and insects [5, 6, 11].

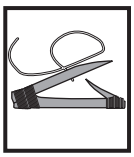
Trophic level—4.15 (standard error 0.75) [28].



Biological Interactions
Predators—Unknown, although grayling, whitefish, and char consume newly spawned eggs [10].
Competitors—Likely omnivores such as various whitefish species, char, and grayling.

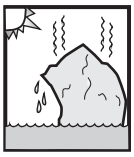


Resilience
Low, minimum population doubling time: 4.5–14 years (K=0.05–0.10; t_m=9–12; t_{max}=22; Fecundity=80,000) [28].

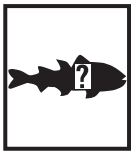


Traditional and Cultural Importance
Inconnu are an important subsistence species for humans and dogs. In many watersheds, they are usually taken around the time of spawning, but in the Selawik-Kobuk river system a large fishery operates during winter in the Hotham Inlet area [4, 9, 10]. Many fish are taken by gill nets; however, seines and hook and line also account for large numbers. The fish are eaten fresh, dried, or aged and frozen, and the fat-riddled large intestines are boiled for the oil [27].

Commercial Fisheries
Currently, inconnu are not commercially harvested. A small barter and trade fishery exists in the Kotzebue area and in Great Slave Lake [9, 25] and Inconnu are popular with recreational anglers, particularly on the Kobuk River [5].



Potential Effects of Climate Change
Unknown. Generally, Durand and others (2011) [60] predict that, at least for anadromous fishes in subarctic rivers, shifts in biology will be effected by spring ice break-up and resultant peak flows and surrounding permafrost processes: both of which affect the supply of nutrients and (or) sediment to the watershed of climate change on spring break-up intensity. Climate change and its effects on the spawning recruitment of inconnu in the Selawik River are being studied in cooperative research between U.S. Fish and Wildlife Service and U.S. Geological Survey.



Areas for Future Research [A]
Research needs include: movements and migrations, behavior of larval and juveniles in response to environmental variables, and enumeration of predator-prey relationships in coastal waters. Catch and subsistence use patterns should continue to be monitored.

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Glacier Lanternfish (*Benthosema glaciale*)
(Reinhardt, 1837)

Family Myctophidae

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

Glacier Lanternfish (*Benthosema glaciale*). Photograph by Rudolf Svensen, http://www.uwp.no.

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

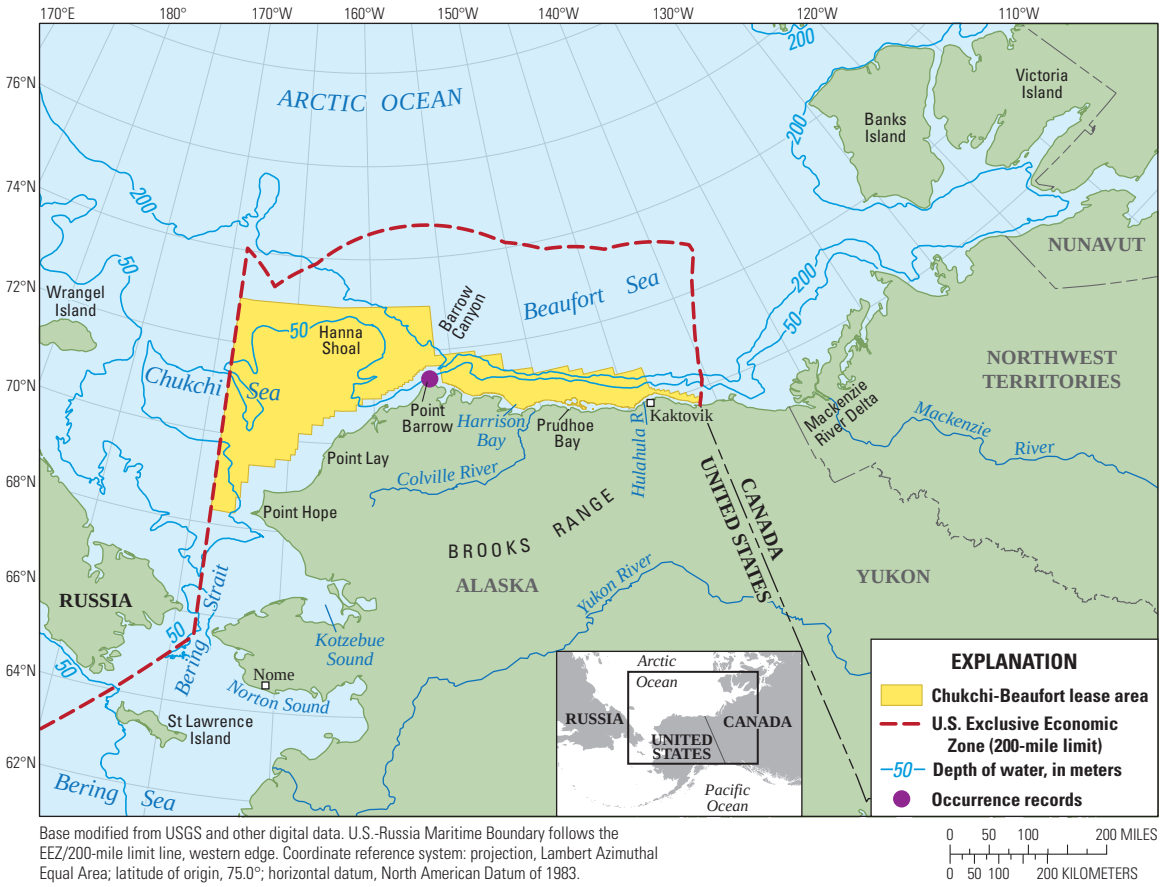
Ecological Role: Rarely observed in the U.S. Chukchi Sea. The role of the species in regional food webs is minimal.

Physical Description/Attributes: Small, silvery fish with compressed body, blunt head, large eyes, and numerous round photophores in a specific pattern. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 249) [1]. Swim bladder: Present [2]. Antifreeze glycoproteins in blood serum: Unknown.

Range: *U.S. Chukchi Sea* [1, 3]. Elsewhere, from Baffin Bay and northwest Greenland, east to Svalbard Islands, Norway; Barents Sea; and Kara Sea [3].

Relative Abundance: *Rare, one record from U.S. Chukchi Sea near Point Barrow, Alaska* [1, 3]. Elsewhere, common in Barents Sea [6].

Glacier Lanternfish
Benthosema glaciale

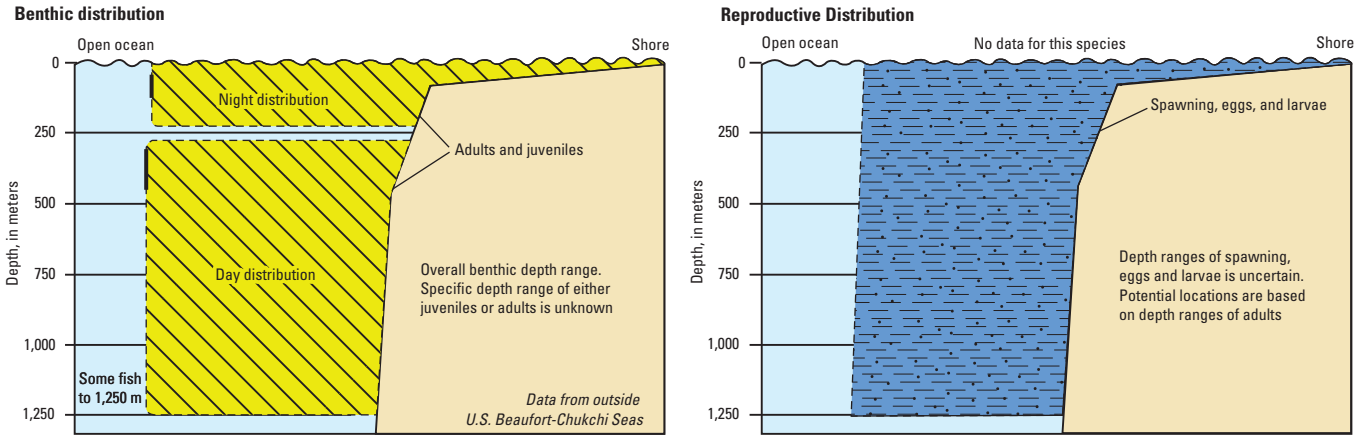


Base modified from USGS and other digital data. U.S.-Russia Maritime Boundary follows the EEZ/200-mile limit line, western edge. Coordinate reference system: projection, Lambert Azimuthal Equal Area; latitude of origin, 75.0°; horizontal datum, North American Datum of 1983.

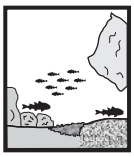
Geographic distribution of Glacier Lanternfish (*Benthosema glaciale*), within Arctic Outer Continental Shelf planning areas [4] based on review of published literature and specimens from historical and recent collections [1, 3, 5].

Depth Range: Near surface to 225 m at night [1], mainly 30–90 m [7]; descending to 275–1,456 m during day [1, 5], mainly 350–450 m [7].

Benthosema glaciale
Glacier Lanternfish

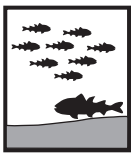


Benthic and reproductive distribution of Glacier Lanternfish (*Benthosema glaciale*).



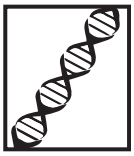
Habitats and Life History

Eggs—Size: 0.75–0.80 mm [8].Time to hatching: Unknown. Habitat: Pelagic [9].
Larvae—Size at hatching: *Unknown*. 5 mm or less [8]. Size at juvenile transformation: 11–15 mm [8]. Days to juvenile transformation: Unknown. Habitat: Pelagic [9].
Juveniles—Age and size: Age unknown. 1.1–5.0 cm [6, 8]. Habitat: Epipelagic to mesopelagic [1].
Adults—Age and size at first maturity: 2–3 years and 4.5–5.0 cm [6]. Maximum age: 8 years in Barents Sea [6]. Maximum size: As long as 10.3 cm (reported as both TL and SL) [10], usually less than 7.0 cm [1]. Habitat: Epipelagic to mesopelagic, typically offshore [1].
Substrate—Unknown.
Physical/chemical—Temperature: Common between 4 and 16 °C in northwest Atlantic Ocean. Has been captured at temperatures of -0.1–21 °C [5]. Salinity: Marine [9].



Behavior

Diel—Mesopelagic by day, epipelagic by night [1].
Seasonal—Unknown.
Reproductive—Spawns pelagically [6].
Schooling—Forms schools [6].
Feeding—Filter feeder [6]. Feeds year-round, but activity is most intensive in spring and summer [11].



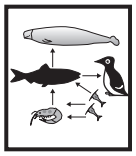
Populations or Stocks

There have been no studies.

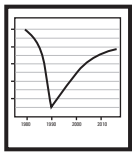
Reproduction

Mode—Oviparous, separate sexes [9].
Spawning season—June–July in Barents Sea [6]. Early spring off Nova Scotia, Canada [8].
Fecundity—750–800 eggs [6].

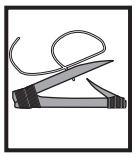
Food and Feeding
Food items—Mainly copepods and euphausiids [6, 7, 11].
Trophic level—2.99 (standard error 0.29) [12].



Biological Interactions
Predators—Leach's Storm-Petrels off Newfoundland, Canada [13]. For lanternfish in general, predators are squids, larger fishes, and marine mammals [1].
Competitors—As one of the few mesopelagic species in the U.S. Chukchi Sea, Glacier Lanternfish probably have few fish competitors, especially at depth. Arctic Cod and Ice Cod co-occur with Glacier Lanternfish and may compete for zooplankton prey.

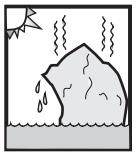


Resilience
Medium, minimum population doubling time: 1.4–4.4 years (K=0.20–0.45; t_m=2–3; t_{max}=8; fecundity=700) [12].

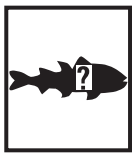


Traditional and Cultural Importance
None reported.

Commercial Fisheries
Glacier Lanternfish are not currently harvested commercially.



Potential Effects of Climate Change
Unknown.



Areas for Future Research [B]
Little is known about the ecology and life history of this species. 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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Ice Cod to Pacific Cod

Ice Cod (*Arctogadus glacialis*)

(Peters, 1872)

Family Gadidae

Ice Cod (*Arctogadus glacialis*) 221 mm, Chukchi Borderland, 2009. Photograph by C.W. Mecklenburg, Point Stephens Research.

Note on taxonomy: *Evidence from morphology and molecular genetics demonstrates that* Arctogadus borisovi *(Dryagin, 1932) is a junior synonym of* A. glacialis [1]. *Data on fish originally identified as* A. borisovi *are included here*. Commmonly referred to as Polar Cod in North America.

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

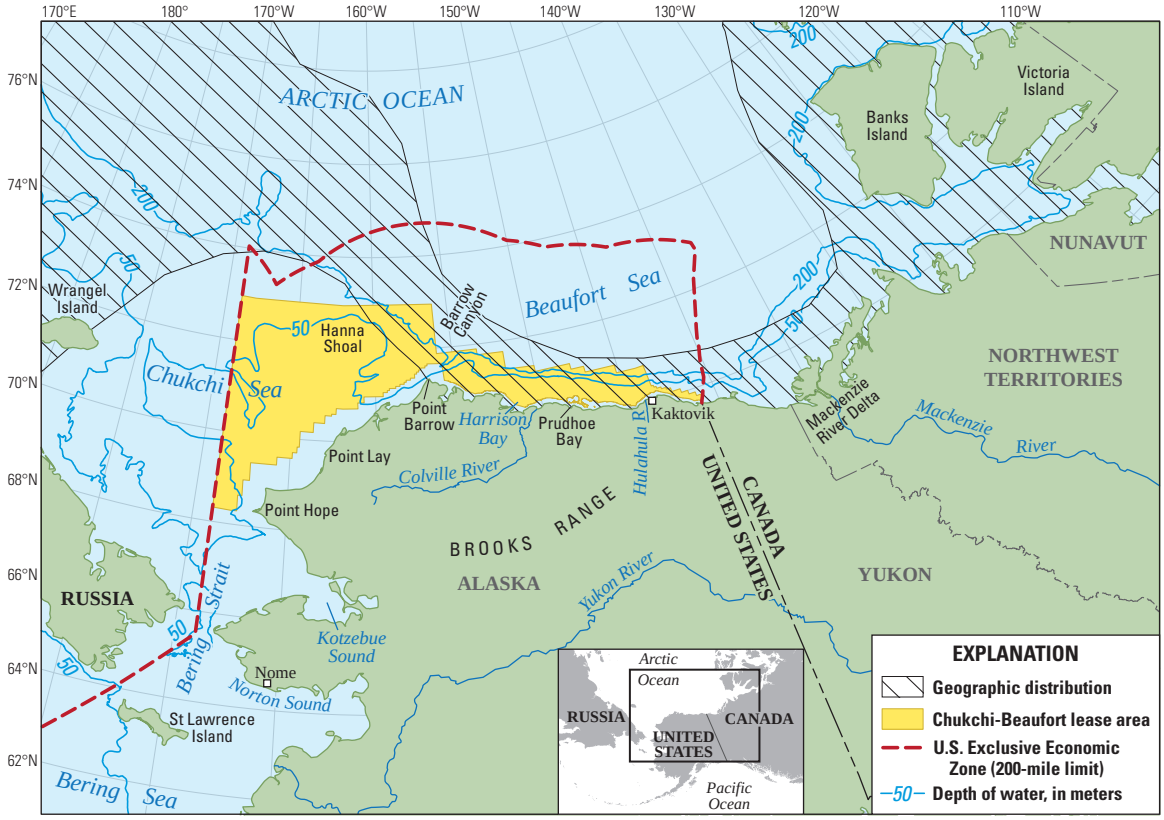
Ecological Role: The ecological role of the species in marine ecosystems of the U.S. Chukchi and Beaufort Seas is not as significant as Polar and Saffron Cod.

Physical Description/Attributes: An olive brown to bluish gray cod with darker fins and head. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 291–292) [2]. Swim bladder: Present; no otophysic connection [2]. Antifreeze glycoproteins in blood serum: Unknown.

Range: *U.S. Beaufort* [2] *and Chukchi Sea* [3, 4]. Worldwide, circumpolar, northward to at least 81°41’N; Arctic Canada south to southern tip of Greenland, east through Barents Sea to East Siberian Sea and Chukchi Sea [2–4].

Relative Abundance: *Rare in U.S. Beaufort Sea (two specimens captured north of Point Barrow)* [2] *and Chukchi Sea (one specimen found on beach at Wainwright)* [4].Abundant to at least as far eastward to deep waters off Tuktoyaktuk Peninsula and off Capes Bathurst and Parry, Canada [6–8].

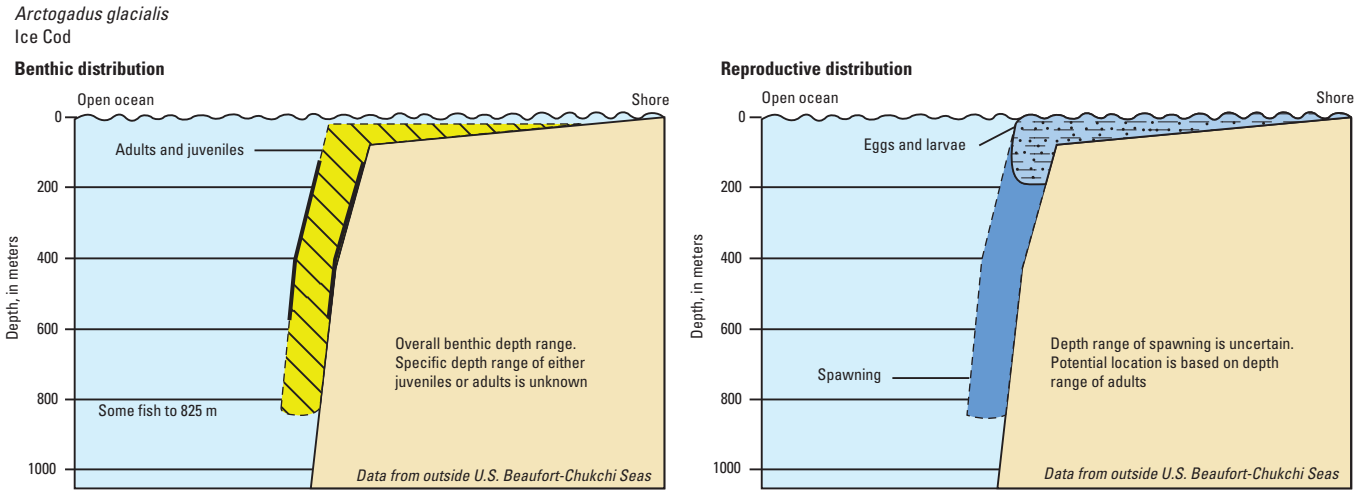
Ice Cod
Arctogadus glacialis



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 within Arctic Outer Continental Shelf planning areas [5] of Ice Cod (*Arctogadus glacialis*) based on review of published literature and specimens from historical and recent collections [3, 4].

Depth Range: 5–930 m, on continental shelf and upper slope [1, 2]. Highest abundance is found off Europe at 300–400 m [9]. In northeast Greenland fjords, abundant at 120–575 m [10]. Eggs and larvae are pelagic [11] but specific depths unknown.



Benthic and reproductive distribution of Ice Cod (*Arctogadus glacialis*).

Habitats and Life History

Eggs—Size: Unknown. Time to hatching: Unknown. Size: Unknown. Habitat: Pelagic [11].

Larvae—Size at hatching: Unknown. Size at juvenile transformation: Unknown. Days to juvenile transformation: Unknown. Habitat: Pelagic [11].

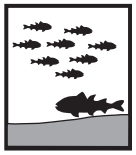
Juveniles—Age and size: Unknown. Habitat: Cryopelagic and benthic [9].

Adults—Age and size at first maturity: Unknown. Females 25–26 cm long (TL) have been found with ripening gonads [12]. Maximum age: At least 11 years [13]. Maximum size: 60 cm TL [2] and 1.2 kg [12]. Habitat: Nearshore to well offshore [4, 8, 14]. Cryopelagic and benthic [5], throughout the water column (including near the seafloor) as well as under ice and within ice cracks [10, 15, 16].

Substrate—Unknown.

Physical/chemical—Temperature: -1.7 to about 4 °C [10], may prefer temperatures of about 1 °C or less [1, 10]. Salinity: Marine, estuarine, and occasionally fresh waters from near the coast to well offshore [8, 14].

Ice dependence—Although characterized as an ice-associate, also found well away from ice, sometimes in large numbers [10, 17].



Behavior

Diel—Unknown.

Seasonal—Unknown.

Reproductive—Unknown.

Schooling—Forms schools [2].

Feeding—Opportunistic pelagic feeder [9].

Populations or Stocks

There have been no studies.

Reproduction mode

Mode—Oviparous [11].

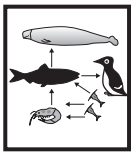
Spawning season—Ripe fish were observed in October and during the summer in the European Arctic [9, 10].

Fecundity—Unknown.

Food and Feeding

Food items—Crustaceans (for example, mysids, copepods, and amphipods), fishes, and polychaetes comprise much of the diet of this species. Fishes assume a greater part of the diet in larger cod [15, 18, 19].

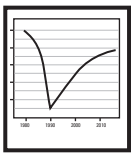
Trophic level—3.82 (standard error 0.61) [20].



Biological Interactions

Predators—Commonly, bearded seals and narwhals in the Canadian Arctic [21, 22].

Competitors—Unknown.



Resilience

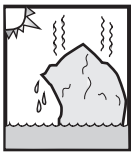
Medium, minimum population doubling time: 1.4–4.4 years (Preliminary *K* or Fecundity) [20].

Traditional and Cultural Importance

None reported. Form only a small part of the subsistence fisheries in the Canadian Arctic [8]. Commercially fished for fishmeal and oil in Norway, Greenland and northern Siberia [23].

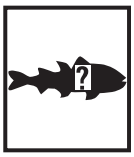
Commercial Fisheries

Currently, Ice Cod are not commercially harvested.



Potential Effects of Climate Change

Unknown.



Areas for Future Research [B]

Little is known about the ecology and life history of this species. Although information should improve with increased sampling, the role of this species in the gadid assemblage and how this might change with global warming is of research interest. Spawning areas and other important habitats remain to be described.

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Arctic Cod (*Boreogadus saida*)

(Lepechin, 1774)

Family Gadidae

Arctic Cod (*Boreogadus saida*) 174 mm TL, Chukchi Sea, 2004. Photograph by B.A. Sheiko and C.W. Mecklenburg, Russian Academy of Sciences and Point Stephens Research.

Colloquial Name: Iñupiat: *Iqalugaq*, *Uugaq* [1]. *Tomcod* [2].

Notes on Taxonomy: *Boreogadus saida is referred to as both "Arctic Cod" and "Polar Cod" in North American scientific literature. The American Fisheries Society and Society of Ichthyologists and Herpetologists recommend using "Polar Cod" for Boreogadus saida to bring consistency with European conventions and this recommendation is gaining in acceptance in contemporary reporting and publications. We chose to use "Arctic Cod" for Boreogadus saida in this report to ensure consistency with the vast majority of Alaskan literature and to avoid confusion with Ice Cod, which has been referred to as Polar Cod by North American researchers. Anyone using literature that does not specify the scientific name must read carefully to decide which species is meant. However,* A. glacialis *is rare in Arctic Alaska waters, and most references to Polar Cod from that region that do not provide the scientific name will refer to* B. saida.

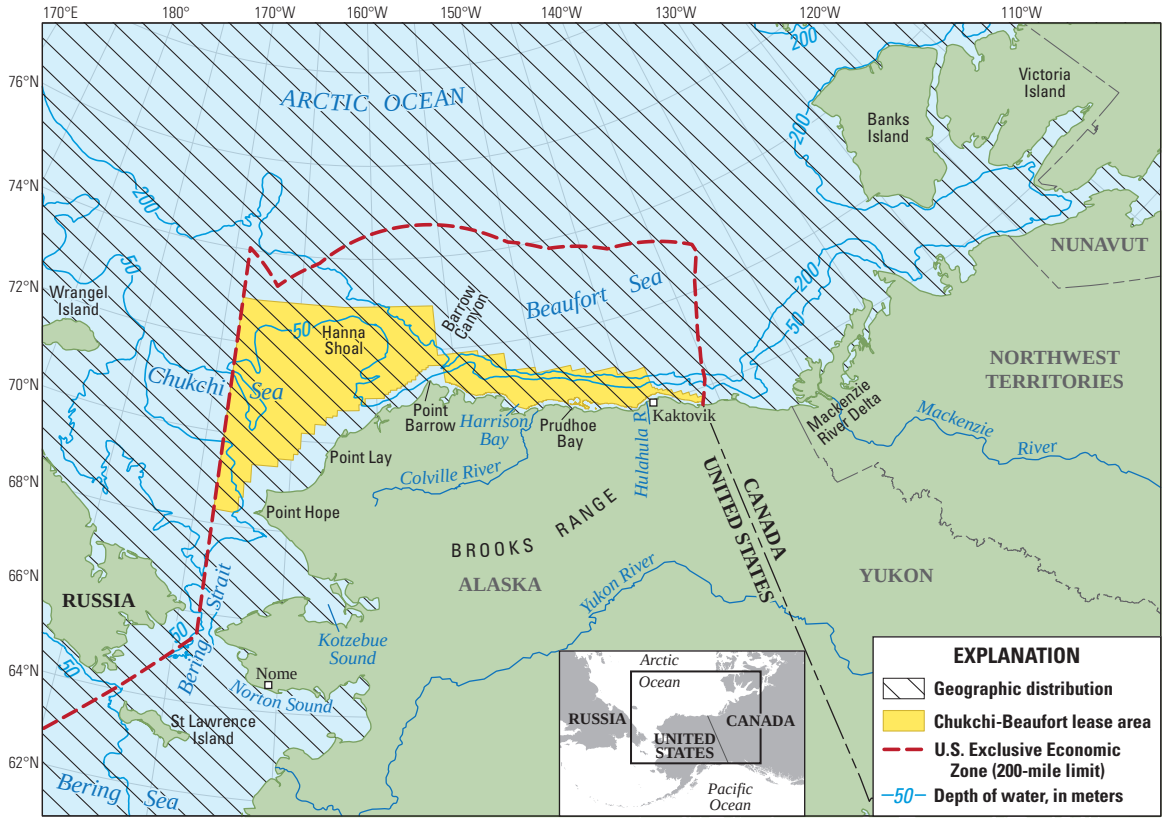
Ecological Role: Arctic Cod play a vital role in anchoring Arctic food webs in the U.S. Chukchi and Beaufort Seas. The small fish is one of the main consumers of plankton that flourish around sea ice. Arctic Cod compose 92 percent of all fish in numbers and 80 percent in weight in a 2008 western Beaufort Sea fish survey [3], and this species comprises the forage base for a wide range of marine mammals and birds. A recent model predicted a mass loss of most Arctic Cod within 30 years because of rising temperatures and receding ice pack. Key interactions between sea ice, Arctic Cod biology, and marine ecosystem function must be better understood to identify possible effects of climate change and cumulative effects of human activities.

Physical Description and Attributes: Brownish back and sides with violet or yellowish sheen covered with tiny black dots, and silvery white lower sides and belly. Fins are dusky yellow or gray, and dorsal and caudal fins are edged in white. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 290) [4]. Swim bladder: present. Antifreeze glycoproteins in blood serum: Present [5].

Range: *Throughout U.S. Chukchi and Beaufort Seas from very shallow, neritic waters to well offshore (although abundance hundreds of kilometers offshore is poorly known)* [6–9]. A circumpolar species, documented in Chukchi Sea northward nearly to the North Pole at 88°26′N, 126°26′E. In continental shelf waters, west and south of U.S. Chukchi Sea from Siberian Arctic to Olyutorskiy Bay in western Bering Sea and to Bristol Bay in eastern Bering Sea; and east of U.S. Beaufort Sea continuous throughout the Canadian Beaufort Sea [10, 11].

Relative Abundance: *Very abundant in U.S. Chukchi and Beaufort Seas* [9, 12–15].

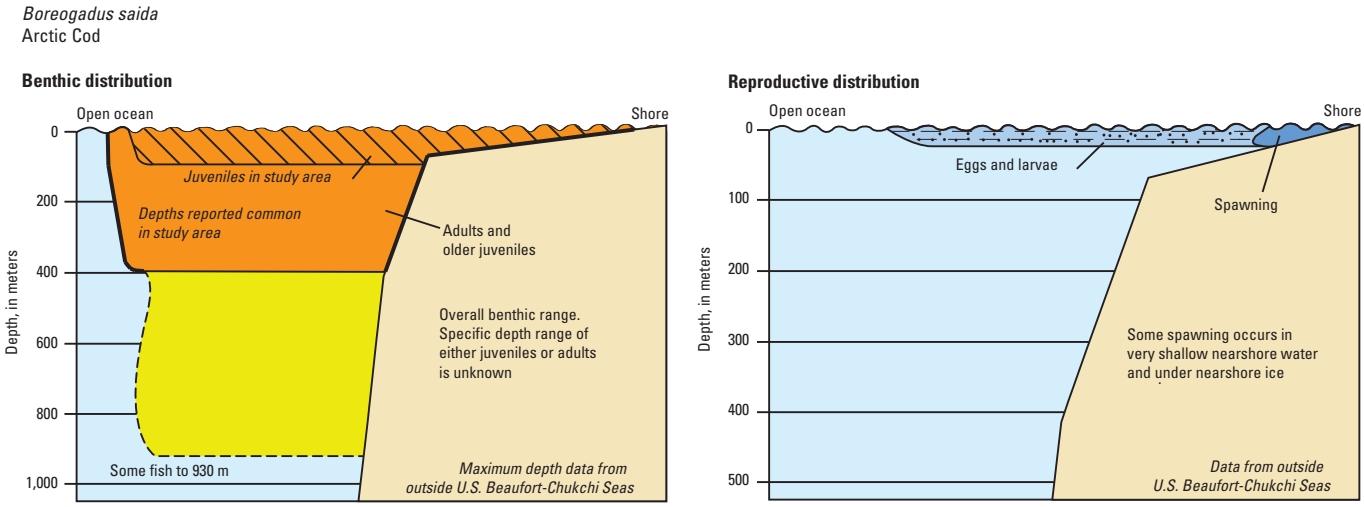
Arctic Cod
Boreogadus saida



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 within Arctic Outer Continental Shelf Planning Areas [16] of Arctic Cod (*Boreogadus saida*) based on review of published literature and specimens from historical and recent collections [11, 17].

Depth Range: Larvae: *Maximum depth unknown. Surface to at least 20 m* [12]. Juveniles: *Maximum depth unknown. Near surface to 75 m* [9, 18]. Older juveniles and adults: *Maximum depth could be 930 m (the species' maximum recorded depth) but such depths have not been sampled in the U.S. Chukchi and Beaufort Seas. Found throughout the water column, abundant from surface waters to at least 400 m* [9, 12, 19] and deeper (500 to 1,000 m in the United States Beaufort Sea, Kathleen Wedemeryer, Bureau of Ocean Energy Management, Alaska OCS Region, oral commun., October 13, 2015). Elsewhere, Arctic Cod are found from barely subtidal waters to depths of 930 m [20]. Spawning: Shallow nearshore waters and under nearshore ice [21, 22].



Benthic and reproductive distribution of Arctic Cod (*Boreogadus saida*).

Habitats and Life History

Although Arctic Cod are assumed to both spawn and live *under* ice in Arctic Alaskan waters, virtually no surveys have been conducted to determine the importance of this habitat to Arctic Cod in the Alaskan Arctic. Throughout its range, Arctic Cod occupy a remarkably wide breadth of habitats. They occupy all parts of the water column in estuaries and off river mouths and in shallow subtidal waters, and are found many hundreds of kilometers off the coast [6, 21, 23, 24]. *These fish are often associated with ice* although they have been captured during spring and summer in the northern Bering Sea at least 300 km (186 mi) away from the nearest floe or pack ice *and are abundant along the U.S. Chukchi and Beaufort Seas in seasonally ice-free areas* [6, 25]. However, they can be found in very large numbers under ice and are often seen in cracks, crevices, and in melt-water ponds on the ice [20, 26, 27].

Eggs—Size: 1.5–1.9 mm [28, 29]. Time to hatching: *Unknown.* Elsewhere, between 26–90 days; highly variable, apparently dependent on water temperature [30, 31]. Habitat: *Planktonic. Location unknown.*

Larvae—Size at hatching: *6 mm* [32] Size at juvenile transformation: 27–50 mm [30, 33]. Days to juvenile transformation: *Unknown.* In the Russian Arctic, the larval stage lasts about 2 months [30]. Habitat: *Pelagic. Location poorly understood.* Elsewhere, found under ice [34].

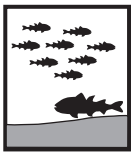
Juveniles—Habitat: *Poorly known. Some pelagic juveniles are found in near-surface waters away from ice* [18, 35]. *Some young-of-the-year recruit from the plankton directly into inshore habitat, but it is likely that others remain well offshore (to at least 175 km off Prudhoe Bay)* [6, 18] *in near-surface waters* [6, 32]. *Large numbers of juveniles were found in shallow U.S. Beaufort Sea lagoons* [36]. Elsewhere, juveniles are common under ice [20, 26, 27, 37]. *However, in the Alaskan Arctic, they also are very abundant in the summer well away from ice* [6, 8, 38]. In other areas, in offshore waters and in the absence of ice, smaller fish tend to inhabit shallower depths in the water column than do larger individuals [32, 39, 40].

Adults—Age and size at first maturity: *A few fish, possibly only males, are mature at 1year and around 100 mm FL. Most fish mature at –3 years (120 mm FL and larger) and males may mature about 1 year earlier than females* [6, 19]. Maximum age: *In study area, 7–8 years* [15]. Maximum size: 46 cm TL [41]. Habitat: Adults are common under ice [20, 26, 27, 37]. *However, in the Alaskan Arctic, they also are very abundant in the summer well away from ice* [6, 8, 38].

Physical/Chemical—Temperature: *Preferred temperatures poorly known, but probably about –1.5–5 °C* [12, 13, 42], *although sometimes they are abundant in waters as warm as 10 °C* [8, 43]. *Documented between -2.0 and 13.5 °C* [43, 44]. Elsewhere, to -2.1 °C [45]. In Bering Sea, mainly -2.0 to -0.7 °C [45]. In the Canadian High Arctic, larvae are reported to develop only at temperatures less than 3.0 °C [46] and in the Russian Arctic, less than 5 °C [30]. Juveniles may favor warmer waters than adults [8, 39]. Salinity: *Documented from 0 to 32.6 practical salinity units (psu)* [10, 43, 44] and elsewhere to 34.9 psu [17]. All life stages live in marine waters. Although occasionally abundant in brackish waters [43], low abundance in such areas as the Mackenzie River estuary may reflect general avoidance of very low salinity waters [47].

Ice Dependence—Although it is clear that many Arctic Cod live under ice, it is unclear whether these fish are ice *associated or ice dependent* [27, 48]. The hypothesis that Arctic Cod are ice dependent is derived from a number of inconclusive observations. Examples include:

4. Known to spawn along the ice edge [49] and under ice [23, 50]. However, whether spawning is limited to ice or a near-ice area is unknown. For instance, Arctic Cod eggs have been taken in May around the ice-free Pribilof Islands, Alaska [51]. In addition, surveys of possible spawning in ice-free areas have not been conducted during the overwinter, for instance, the Bering Sea.
5. *Juveniles and adults are very abundant under ice* [52], *but can be extremely abundant during summer in relatively warm water and ice-free conditions* [9, 12, 32, 44].
6. The relationship between ice densities, water temperatures, and fish growth and survival is uncertain. In the Greenland Sea, larvae living in low-ice, relatively warm waters survived better than those in thicker ice and colder (<0 °C) temperatures, implying that the lengthening of the ice-free season may result in improved recruitment and larger populations in Arctic Cod in the short term [50]. This has also been noted among polynyas in Arctic Canada [48]). In addition, juvenile and adult Arctic Cod in the northeast Chukchi Sea grew fastest in a warmer-water year [15]. However, this position has been challenged by some authors based on the hypothesis that Arctic sea warming will reduce sea ice habitat and allow sub-Arctic or temperate taxa to replace this species [50].



Behavior

Diel—*Unknown.* Elsewhere, from January to April, post-spawning adults in the eastern Beaufort Sea rise in the water column at night [52].

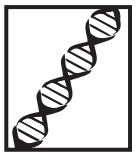
Seasonal—*Poorly understood* [6]. *Current information suggests that throughout their range, fish move into nearshore waters in the summer. Precise time and intensity varies between locations and between years at the same location* [6, 13, 53, 54]. *In the U.S. Beaufort Sea, relatively scarce in shallow waters immediately after ice-out, but move into shallow waters as the season progresses* [6, 7, 53]. *However, ringed seal diet studies in the nearshore of Arctic Alaska* [55], *and other fish surveys* [44, 56], *imply that at least some Arctic Cod overwinter in nearshore waters under ice. In nearshore waters, schools can move quickly through an area* [44, 57] or reside in the same location for weeks [58]. *Proportion of population migrating into shallow waters is unknown; many fish might not migrate into the shallowest waters* [19, 38]. *In summer, Arctic Cod are by far the most abundant fish in Alaska Arctic nearshore waters* [14, 15]. *For example, estimates of summer cod abundances in Simpson Lagoon have been as high as 12–27 million fish* [44].

Data regarding the environmental parameters driving inshore migrations are often contradictory. *For instance, in the U.S. Chukchi Sea, catches increased when water temperatures rose and salinities decreased* [38], *but was the opposite in the Sagavanirktok River Delta of the U.S. Beaufort Sea* [59]. *In Prudhoe Bay of the U.S. Beaufort Sea, highest densities were noted in frontal areas bordering low salinity and high temperature surface waters, and high salinity and low temperature bottom waters, perhaps an area of high productivity* [60]. *Another U.S. Chukchi Sea study found no environmental-parameter-associated abundance; authors hypothesized that food availability might underlay fish movements* [15].

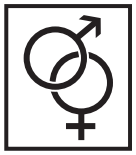
Thus far, the most complete study of winter behavior was in Franklin Bay, eastern Canadian Beaufort Sea. It was documented that after spawning during the early winter (perhaps over deep waters in the Amundsen Gulf; (D. Benoit, Université Laval, 2010), very large numbers of fish either migrated, or were passively carried, into 180 m or deeper depths and did not feed during this time. Migration out of these waters began with an abrupt upward migration and coincided with phytoplankton blooms and the onset of feeding [52]. Similar work in the nearby Amundsen Gulf demonstrates a similar pattern [61].

Reproductive—*Poorly known.* In the Arctic in general, spawning occurs near the bottom along the ice edge [49] and under ice [23], whether limited to under-ice areas is unknown. For instance, eggs have been found in

May around the ice-free Pribilof Islands [51]. The winter (spawning-season) behavior throughout the Arctic is very poorly known. *In the U.S. Chukchi and Beaufort Seas, at least some fish spend winters under nearshore ice (presumably spawning)* [38, 44, 56, 62]. *However, whether the bulk of the population overwinters and spawns in shallow waters is unknown. For instance, spawned-out cod were reported both near the coast and 175 km off Prudhoe Bay* [6]. In the autumn and winter, large, spawning-oriented migrations occurred in the Russian Arctic and spawning in the Barents Sea may have occurred from near shore to hundreds of kilometers off the coast [49].
Schooling—*Schooling behavior under ice has not been studied. In ice-free areas, very large schools are formed, often millions of individuals* [6, 44]. *This species often schools by size class* [8]. *The amount of cohesion of fish schools in Arctic Alaska is unknown*, although in the Canadian Arctic some schools stay together for at least 1–2 months in summer [24, 58].
Feeding—*Prior to spawning, a few nearly ripe fish in Simpson Lagoon were still feeding* [44], whereas in the Canadian Arctic, feeding ceases for several months beforehand [52].

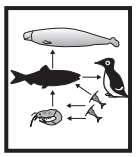


Population or Stocks
Initial research underway in U.S. Chukchi and Beaufort Seas and Arctic Ocean. Microsatellite markers imply some population structure among Chukchi Sea, Canadian and Siberian Arctic Cod, and potentially low differentiation between those from Hudson Bay and the eastern Beaufort Sea [63]. The genetics research indicates very little structuring across the United States Beaufort Sea with respect to the three dichotomies of east/west; coastal/slope; and riverine/marine water influence (Kathleen Wedemeyer, Bureau of Ocean Energy Management, oral commun,, October 13, 2015). A single circum-artctic population with only minor differences is currently hypothesized.



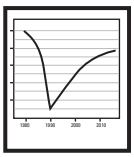
Reproduction
Mode—Separate sexes, oviparous. Fertilization is external.
Spawning season— *Poorly understood*. Over the species' entire geographic range, spawning occurs under ice floes from November to at least April, perhaps peaking in January and February in the Beaufort Sea [6, 15, 31, 49]. *The capture of spawned-out adults in May, 175 km off Prudhoe Bay, implies that some spawning may continue well into the spring* [6]. *The capture of newly hatched larvae in July in the northeastern Chukchi Sea* [33] and as late as July and August in Tuktoyaktuk Harbor, Northwest Territories, and near Baffin Bay [64, 65], also may imply late spawning. However, eggs fertilized in February will often remain as larvae into July [30].
Fecundity—*Unknown.* Elsewhere, 9,000–33,251 eggs, apparently in one batch [28, 29]. Females may not spawn every year [6]. However, in a laboratory study, several females spawned in two successive years, implying that some fish are capable of spawning more than once in their lives and in sequential years [46].

Food
Food items—Larvae: *Unknown.* In Hudson Bay, pelagic larvae under ice feed on nauplii and eggs of those copepods feeding on under-ice phytoplankton [34]. Juveniles and Adults: *Diets vary with fish size and location, although epibenthic or pelagic crustaceans (for example, mysids, isopods, copepods, gammarid and hyperiid amphipods, and shrimps), as well as larval fish, polychaetes, chaetognaths, and small fishes (such as other Arctic Cod), are important. Fish living under ice often target ice-associated crustaceans such as amphipods* [6, 57, 66-68]. Feed primarily on copepods and amphipods in northern Bering Sea [69]. *Diets also may vary with season. In Simpson Lagoon of the Alaskan Beaufort Sea, mysids, amphipods, isopods were most important during the summer and mysids dominated during the winter* [44].
Trophic level—3.6 [70].



Biological Interactions
Predators—Arctic Cod are an extremely important prey for a wide range of predators and are possibly the most important forage fish in the U.S. Chukchi and Beaufort seas. *They are consumed by at least 8 fish species, 17 bird species, and 3 marine mammal species* [19, 38, 67, 71–75]. *The major predators of Arctic Cod in the Alaska Beaufort Sea are considered to be, in order of importance, Arctic Cod (cannibalism), ringed seals, Beluga whales, and seabirds (particularly Black-legged Kittiwake, Thick-billed Murre, Ivory Gull, Black Guillemot, Glaucous Gull, loons, Ross' Gull, Arctic Tern, and Sabine's Gull)* [67]. *Almost all studies were conducted during summer months, although it has been shown that in the Alaskan High Arctic they form a major part of the diet of ringed seals (particularly important to pups) throughout the year* [55, 67] *and bearded seals in the U.S. Chukchi Sea from at least November through June* [71]. Arctic Cod appear to be particularly susceptible to beach strandings, caused by predators or storms [6, 58].

Competitors—*Likely competitors are other schooling midwater feeders, particularly Walleye Pollock, but also Dolly Varden, whitefish species, Capelin, and Pacific Sand Lance*.



Resilience

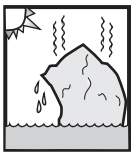
Medium, minimum population doubling time: 1.4–4.4 years (K=0.22; t_m=2-5; Fecundity =30,000) [76].

Traditional and Cultural Importance

In the past, this was a fairly important human subsistence species in the Alaskan High Arctic. For instance, it was reported that Arctic Cod were heavily fished through the ice off Barrow in the winter [77]. *Over time and today, Arctic Cod are of only limited importance as food fish* [1, 78–80]. Arctic Cod appear to be of more importance in Canadian subsistence fisheries of the Barrow Strait and Hudson Bay where they are widely caught and consumed [58, 81].

Commercial Fisheries

Arctic Cod are not commercially harvested in the U.S. Chukchi and Beaufort Seas. The commercial fishery for Arctic Cod is small and limited to Russian vessels fishing primarily in the northwest Russian Arctic [82].



Potential Effects of Climate Change

Climate change may influence the numbers of Arctic Cod through a number of mechanisms. (1) Assuming that this species is in some way ice-dependent, a poleward shift in distribution would be expected with retreating ice. (2) There is some evidence that survivorship of Arctic Cod larvae increases with earlier ice break-up, more frequent winter polynyas, a warmer (ocean) surface layer, and increased river discharge [83], all possible effects of warming conditions. (3) Arctic Cod coming under increased competition for resources from some northward-migrating species would be expected, particularly from Saffron Cod and possibly Walleye Pollock. (4) Greater periods of ice-free conditions likely will alter predation patterns, but in ways that are not yet predictable. Receding ice may increase predation. In Resolute Bay, North West Territories, fish under heavy ice cover were less aggregated than when the bay was relatively ice-free. When ice drifted into the bay, fish would move under it [84]. In Hudson Bay, a sharp decrease in the abundance of Arctic Cod coincided with an approximately 50 percent decrease in summer ice cover [85]. However, the millions of Arctic Cod inhabiting the ice-free Simpson Lagoon in the summer do not appear to suffer heavy predation [44]. Reduced ice pack can be argued to cause an increase or decrease predation depending on predator. For instance, reduced ice pack would decrease resting habitat for seals, while making Arctic Cod perhaps more available to cetaceans or seabirds [48]. (5) Food availability and growth rates will change, although the direction and intensity of this change are unknown. As an example, fish in the northeast Chukchi Sea grew fastest in warmer water years [15] and larvae residing in the low-ice, relatively warm waters in Greenland survived better than those under thicker ice [50]. (6) Effects on Arctic Cod predators are unknown, but may be substantial. For instance, retreating pack ice near Point Barrow led to reduced Arctic Cod availability for Black Guillemots and subsequent reductions in nestling growth and brood size [86]. (7) Effects of predation by Arctic Cod on prey are unknown but the species mid-level role in transferring energy from low to high trophic levels is hypothesized to be significant. Local effects of Arctic Cod predation on prey concentrations also may be significant. For instance, feeding by large schools of adult Arctic Cod in the Canadian Arctic may be sufficiently intense as to cause localized depletion of zooplankton [24]. The effects of possible changes in Arctic Cod distribution and abundance, in association with climate warming, may have profound, cascading effects on the Arctic marine ecosystems. The effects of increasing ocean acidification on Arctic Cod food webs dynamics and developmental biology are of concern. The protocols for capturing, transporting, breeding, and rearing larvae through adult stages in the laboratory have been tested and described [87, 88] making empirical studies of thermal sensitivity to warming using an Arctic Cod model possible. New information is available describing the thermal limits of cardiac function on Arctic Cod [89, 90], effects of warming and ocean acidification on metabolism and performance on Arctic Cod and Atlantic Cod (*Gadus morhua*) [91], and temperature-dependent growth and swimming behaviors of Arctic Cod, Saffron Cod, Walleye Pollock, and Pacific Cod [92]. In general, the results suggest optimal food conversion for juvenile Arctic

Cod in Cold waters (0 °C), near optimal growth at 5 °C, and diminished growth and condition with increasing temperatures above this (detrimental effects above 16 °C). Differential acute effects of warming on larvae and adults further suggest the potential role thermal limitations of younger-aged cod may have on the Arctic Cod distribution in coastal waters.

Areas for Future Research [A]

Considering the species central role in Arctic marine ecosystems dynamics, relatively little focused research attention has been given to Arctic Cod in Arctic Alaska. In particular, the role of sea ice in the species' life cycle, though speculated, is not well understood. The location and timing of spawning locations and presence of stock structures are unknown. Information is needed regarding population movements and behaviors, particularly during winter months, and with respect to the relative important habitats in slope, shelf, and nearshore, and deeper areas of the Canada Basin. The latter need is of particular importance because a recent model predicted a mass extinction of most Arctic Cod within 30 years [93]. However, the model appears to be at least partially based on the assumption that there are no Arctic Cod well offshore of northern Alaska, although no surveys have been conducted there. The use of Autonomous Underwater Vehicles to investigate Arctic Cod ecology should be explored. There needs to be new and continued empirical research to determine the seasonal effects of changing temperatures, ocean acidification, and ice coverage on the reproduction ecology and population growth and condition of Arctic Cod. An additional experimental priority is for toxicological research on the potential effects of spilled, dispersed, and weathered oil on Arctic Cod under Arctic conditions. Accurate assessments of species interactions and effects of human developments and climate changes will require that the population dynamics of the species are understood and that abundance patterns and population parameters are monitored over time.

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Saffron Cod (*Eleginus gracilis*)

(Tilesius, 1810)

Family Gadidae

Saffron Cod (*Eleginus gracilis*), 233 mm, Chukchi Sea, 2007. Photograph by C.W. Mecklenburg, Point Stephens Research.

Colloquial Name: Iñupiat: *Uugak* [1]. This species and the Arctic Cod are called Tomcod (not to be confused with *Microgadus proximus*).

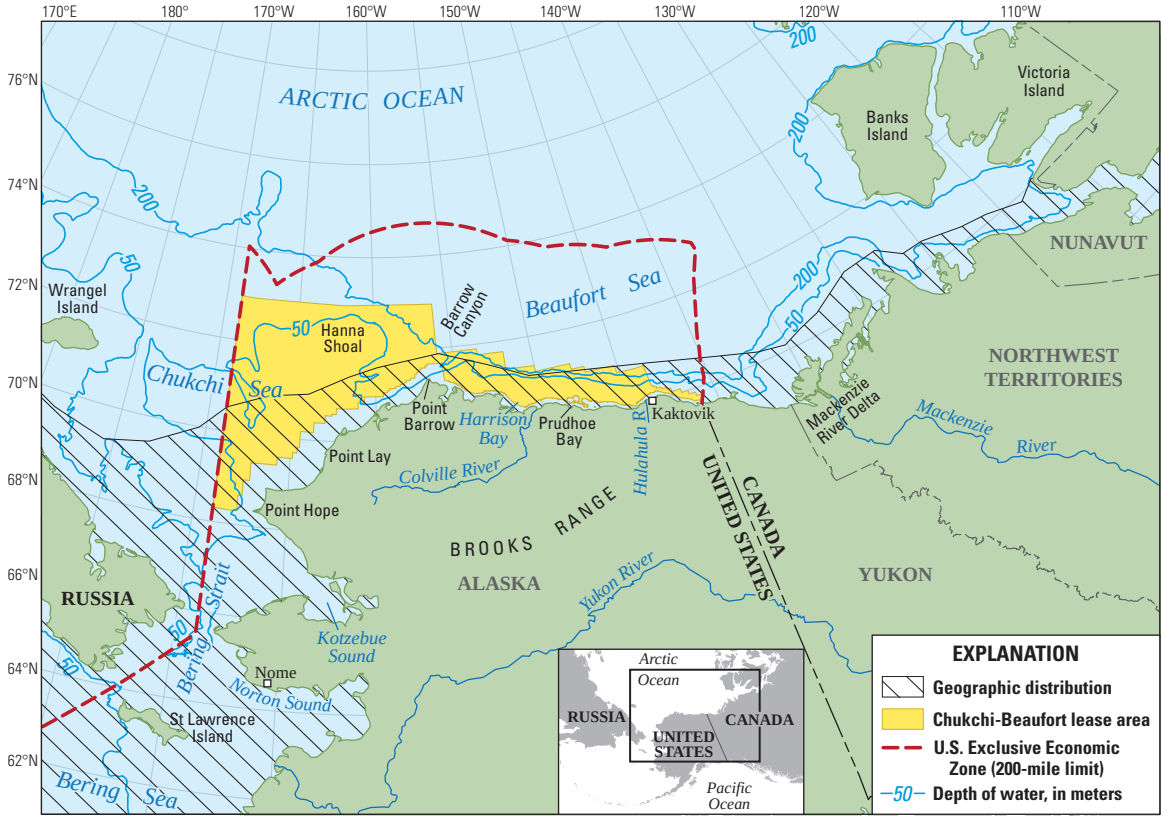
Ecological Role: This is a species of major ecological importance, particularly in the Chukchi Sea. Saffron Cod are believed to be a major competitor of Arctic Cod and changes in sea ice associated with warming may give the species a competitive advantage.

Physical Description/Attributes: Mottled brown to gray-green body washed with yellow. Ventral areas are white to yellow, pectoral fins are yellow, and margins of dorsal and anal fins are white. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 293) [2]. Swim bladder: Present [2]. Antifreeze glycoproteins in blood serum: Present [3].

Range: *U.S. Chukchi and Beaufort Seas* [4]. Elsewhere in Alaska, from Bering Sea and Gulf of Alaska to Sitka, southeastern Alaska. Worldwide, from Sea of Japan and Sea of Okhotsk to East Siberian Sea and eastward in Arctic to Melville Sound, Bathurst Inlet, Nunavut [4].

Relative Abundance: *Patchily abundant in U.S. Chukchi and Beaufort Seas* [7–10] eastward to Cambridge Bay, Nunavut [6]. Most abundant species during summer in northern Bering and southern U.S. Chukchi Seas [12]. Abundant from Sea of Japan and Sea of Okhotsk to eastern Bering Sea [13–15] and central Gulf of Alaska [16]. Appears to be increasing in abundance in Prince William Sound [17].

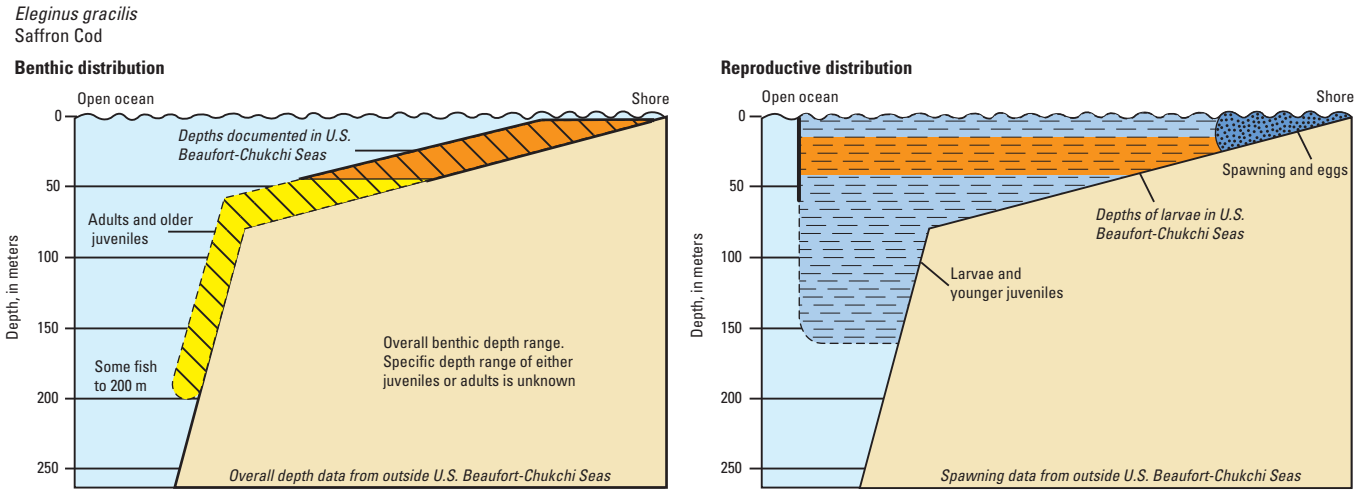
Saffron Cod
Eleginus gracilis



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 Saffron Cod (*Eleginus gracilis*) within Arctic Outer Continental Shelf Planning Areas [5] based on review of published literature and specimens from historical and recent collections [2, 4, 6].

Depth Range: Shallow, nearshore to 200 m, typically less than 50 m [18–20]. *Four pelagic larvae taken in U.S. Chukchi Sea between 18 and 36 m* and in Bering Sea from 0–162 m. Largest catches were in less than 60 m [21]. *One pelagic juvenile was taken in U.S. Chukchi Sea in midwaters between 45 m and surface* [22]. Older juveniles recruit to very shallow near-shore waters [23–26]. However, off Hokkaido, Japan, and the Kuril Islands, Russia, juveniles are abundant to depths of at least 200 m [27]. Spawning occurs in shallow waters [23, 28, 29] to at least 32 m in the western Pacific Ocean [27].



Benthic and reproductive distribution of Saffron Cod (*Eleginus gracilis*).

Habitats and Life History

Eggs—Size: 0.8–1.7 mm [27, 30]. Time to hatching: 28–49 days [30]. Habitat: Demersal, non-adhesive [27, 30–32].

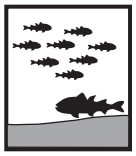
Larvae—Size at hatching: *3.5–3.9 mm SL* [31]. Size at juvenile transformation: 24–27 mm SL [21]. Days to juvenile transformation: Unknown. Habitat: Pelagic [17, 21].

Juveniles—Age and size: 21–35 cm FL [21, 31]. Habitat: Early juveniles are pelagic, becoming more benthic as fish mature [21]. In Gulf of Alaska, closely associated with nearshore eelgrass beds [16, 17].

Adults—Age and size at first maturity: *Very little research has been conducted*. Generally, maximum age, growth rates, and age at first maturity vary with location. Off Hokkaido, Japan, few mature as early as one year and all are mature by 2 years [33]. In Siberian Chukchi Sea, fish mature at 4–5 years. Overall, fish mature at 21.0–35.0 cm FL [31]. Maximum age: 19 years in Canadian Beaufort Sea, [34]. Maximum ages are highly variable among geographic locations [7, 27, 35]. In Siberian Chukchi Sea, fish live to 15 years. Maximum life spans steeply decline to the south. Fish living in Peter the Great Bay, in Sea of Japan, only reach about 8 years of age [27]. Maximum size: 55 cm TL [2] and possibly to 63 cm TL [6]. Females are slightly heavier at length than males. Habitat: Benthic and midwater [2, 36–39]. Shallow, nearshore and, at least around Kodiak Island and Sea of Japan, often associated with eelgrass [16, 40].

Substrate—Soft and hard sea floors [41]. Sandy-stone or gravel bottoms for spawning [32].

Physical/chemical—Temperature: *Unknown.* Elsewhere, between -1.7 and 11.7 °C in southeastern Bering Sea [42]. In Amundsen Gulf, a large mortality event occurred when fish encountered 18.0 °C waters flowing out of Coppermine River [11]. Spawn between -1.8 and 1.8 °C [27, 32, 34, 43]. Eggs remain viable at water temperatures of somewhat greater than -3.8–8.0 °C [43]. Salinity: Primarily marine and brackish waters [36–39], although described as entering both rivers and lakes [43], and not ascending upstream of river mouths [32]. In Russia, spawning occurred only at 27 parts per thousand or more [32]. Temperatures higher than 1.2 °C and salinities less than 21 parts per thousand are reportedly unfavorable for egg and larval survival [27, 32, 44].



Behavior

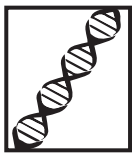
Diel—Unknown.

Seasonal—*Juveniles recruit to very shallow near-shore waters in summer* [23–26]. *Movements of juvenile and adults are not well known.* Generally, Saffron Cod have relatively circumscribed movements, with a limited winter inshore and summer offshore migration [29]. However, large numbers move into shallow waters of the Yukon Territory, Canada and southeastern Beaufort Sea in early summer [28] and *fish in northern Bering Sea may move northwards into U.S. Chukchi Sea in summer* [45]. *Alongshore movements may be quite limited. One fish tagged in the Arctic National Wildlife Refuge only moved 30 km in 3 years* [46]. *Locations of overwintering grounds are not well known. Some fish overwinter in nearshore estuarine and marine waters and these aggregations may be limited to specific geographic areas* [34, 47–49].

Reproductive—*Spawning behavior and locations are poorly understood.* Throughout their geographic range, some spawning occurs in shallow waters [23, 28, 29]. In Russia, fish spawned in areas with strong tidal currents and sandy-stone or gravel bottoms [32].

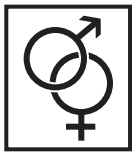
Schooling—Schools, sometimes in high densities [40].

Feeding—*Feed throughout the year at least in U.S. Chukchi Sea and* northern Bering Sea [23]. Juveniles in White Sea feed during day and night. Fish fed among rockweed patches during day and over sand at night. They also fed in the water column on the flood tide [50].



Populations or Stocks

Initial investigations on genetic diversity and stock structure are underway at the University of Alaska Fairbanks.



Reproduction

Mode—Separate sexes, oviparous. Fertilization is external.

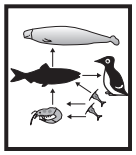
Spawning season—*Winter in U.S. Chukchi Sea* [23]. Mainly, December–February throughout Alaska [31]. Elsewhere, from December to at least May [29, 37] and off Kamchatka Peninsula, Russia, perhaps as late as June [43].

Fecundity—4,900–690,000 eggs, varies with location [27].

Food and Feeding

Food items—*Fishes (for example, Arctic Cod, Capelin, Fourhorn Sculpin, and Saffron Cod) and crustaceans (for example, amphipods, isopods, mysids, and shrimps) often are very important, and priapulids, polychaetes, clams, insects, pteropods, and plant material also are consumed* [11, 23, 35, 36, 51–53]. Juveniles prey on zooplankton [35]. Larger fish prey on a wide range of benthic and epibenthic organisms. During spawning season, adults reportedly feed heavily on Saffron Cod eggs [19].

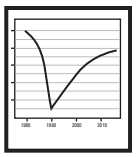
Trophic level—4.1 [54].



Biological Interactions

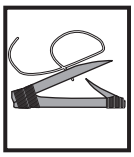
Predators: *Very important prey for ringed seals from at least Nome, Alaska (during at least mid-summer to December) to the U.S. Chukchi Sea (throughout the year)* [55, 56]. *Important summer food for belugas to at least as far north as Wainwright* [57, 58]. *Other predators include Arctic Lamprey and Fourhorn Sculpin* [20, 23]. Additional predators that have been reported include Great, Plain, and Thorny Sculpins, Pacific Cod, Pacific Halibut, Arctic Smelt, Saffron Cod, Black-legged Kittiwake, Common and Thick-billed Murres, bearded and ribbon seals, Steller sea lion, harbor porpoise, Beluga, Fin, Humpback, Ninke, and Sperm whales [59–67].

Competitors: *Likely co-occurring gadids including Arctic Cod, Ice Cod, Pacific Cod (including ogac), and Walleye Pollock* [7, 21, 68].



Resilience

Medium, minimum population doubling time: 1.4–4.4 years (t_m=2–3; Fecundity=4,900) [69].

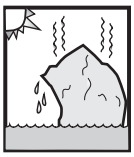


Traditional and Cultural Importance

Commonly taken in subsistence fisheries in both the U.S. Chukchi and Beaufort Seas and in the Bering Sea, usually through the ice by both hook and line and gill nets [1, 24, 37, 70]. Historically, this was an extremely important species to the Inuits residing along the Bering Sea of Alaska where fish were commonly taken during spring as soon as the ice melted from the nearshore, but were particularly important in November, when the pack ice returned. Large numbers of Saffron Cod were utilized by the inhabitants of Norton Sound. They are used as food for both man and dog [71].

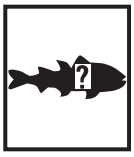
Commercial Fisheries

Currently, Saffron Cod are not commercially harvested.



Potential Effects of Climate Change

Uncertain. Reproducing in Arctic as well as Boreal waters [4], this is a somewhat eurythermic species, apparently able to function within a relatively wide temperature range. Assuming that such coldwater-adapted competitors as Arctic Cod are negatively effected, the reduced competition could be beneficial to the Saffron Cod population. This is supported by new experimental studies that indicate juvenile Saffron Cod growth rate responded positively to increasing temperatures ranging from 0 to 16 °C and above [72].



Areas for Future Research [A]

Little is known about the ecology of this species. It is an important forage fish, subsistence resource, and competitor of Arctic Cod. Information about seasonal habitats and life history and stocks structure of the populations is needed. Initial laboratory and modeling studies suggest the competitive capacity of Saffron Cod with respect to Arctic Cod and other gadids. Additional studies are needed to evaluate the effects of temperature and other population limiting factors, including competition, on this species.

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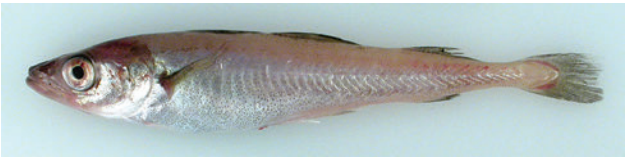
Walleye Pollock (*Gadus chalcogrammus*)

Pallas, 1814

Family Gadidae



Walleye Pollock (*Gadus chalcogrammus*) juvenile, 141 mm, Bering Strait, 2007. Photograph by C.W. Mecklenburg, Point Stephens Research.

Scientific name: Previously called *Theragra chalcogramma* (Pallas, 1814), this species was recently returned to its original genus *Gadus* on the basis of morphological and molecular evidence [1].

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

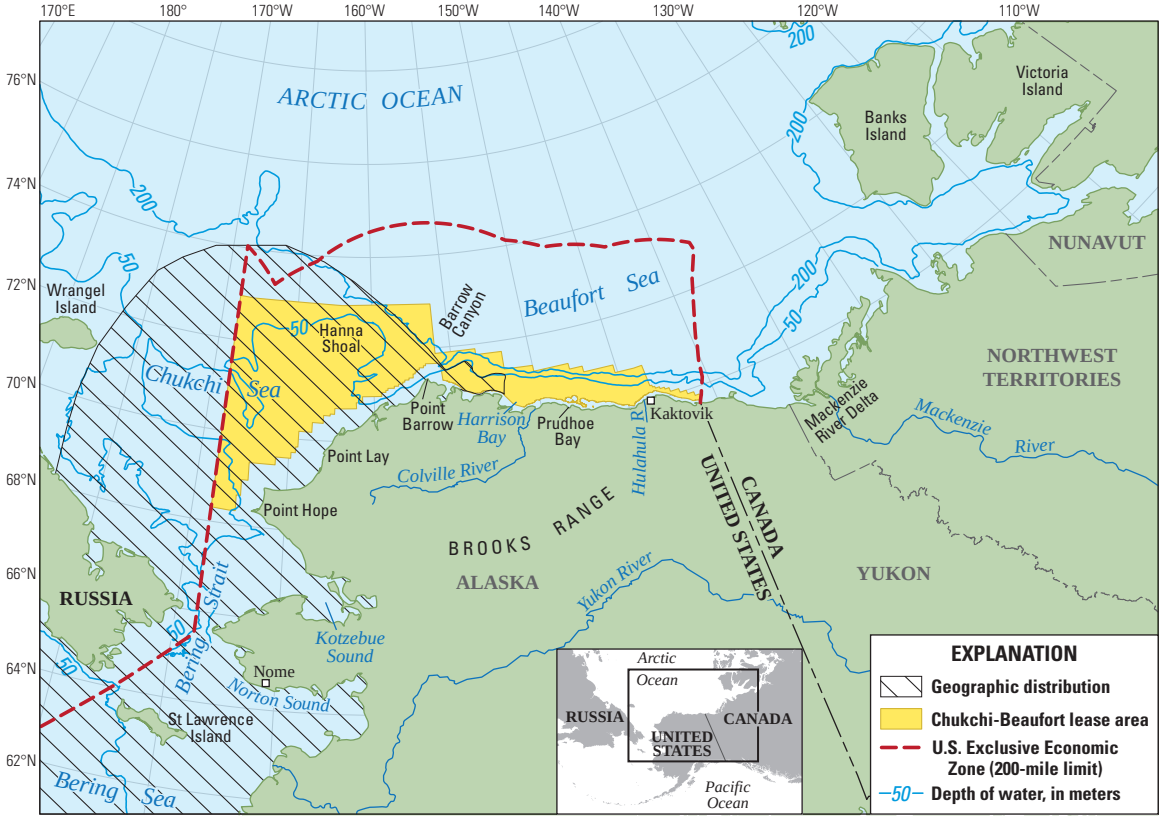
Ecological Role: Current information on the distribution and abundance of this species suggests it could be of low to moderate ecological importance in some parts of the Chukchi Sea and offshore waters north of Barrow, Alaska. This is a key species in ecosystem dynamics of the Gulf of Alaska, Prince William Sound, and Bering Sea [2].

Physical Description/Attributes: Olive green to brown with dark mottling and blotches on back, and interrupted dark brassy olive stripes on upper sides. Fins are brown, dusky gray, or black. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 295) [3]. Swim bladder: Present; no otophysic connection [3]. Antifreeze glycoproteins in blood serum: Unknown.

Range: *U.S. Chukchi and Beaufort Seas* [4–6]. Elsewhere, through Bering Sea, Aleutian Islands and Gulf of Alaska south to Carmel, central California and west to Seas of Okhotsk and Japan [3]. Also found in Barents Sea off Norway, where it used to be called *Theragra finnmarchica* [1].

Relative Abundance: *Common in U.S. Chukchi and rare in U.S. Beaufort Sea* [1, 4, 5, 8, 9]. Elsewhere, abundant in Sea of Japan, northern Kuril Islands, Kamchatka Peninsula, Russia, and throughout Bering Sea southward to southeastern Alaska and Puget Sound [10–15].

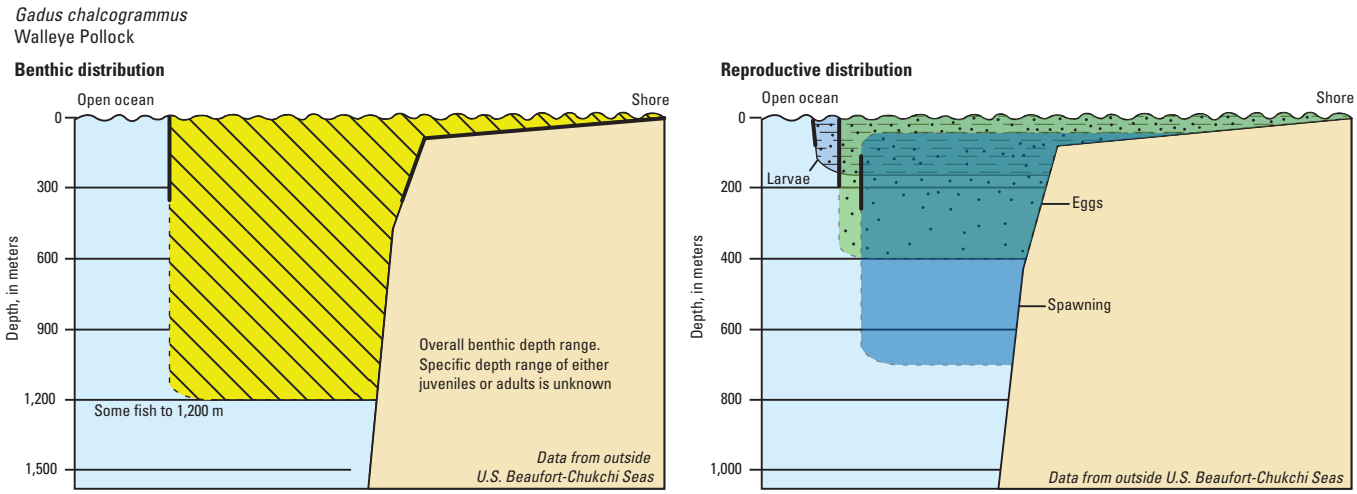
Walleye Pollock
Gadus chalcogrammus



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 Walleye Pollock (*Gadus chalcogrammus*) within Arctic Outer Continental Shelf Planning Areas [7] based on review of published literature and specimens from historical and recent collections [1, 3, 8].

Depth Range: Entire water column, from surf zone to 1,200 m, commonly at 400 m or less, though large numbers have been taken at 800–1,000 m in Bering Sea [13, 16, 17]. Spawning occurs from 46 to 700 m, most commonly between 100 and 250 m on deeper continental shelf and upper continental slope [18–20]. Pelagic eggs are from 0 to 400 m, typically less than 200 m in Gulf of Alaska and eastern Bering Sea [21–23]. Pelagic larvae are from 0 to 153 m, typically 60 m or less in Gulf of Alaska and eastern Bering Sea [22, 24–26].



Benthic and reproductive distribution Walleye Pollock (*Gadus chalcogrammus*).

Habitats and Life History

Eggs—Size: 1.2–1.8 mm [27, 28]. Time to hatching: 25.5 days at 2 °C and 14 days at 5 °C [29]. Habitat: Pelagic, in deep water, rising to shallower water as they develop [3, 22, 30].

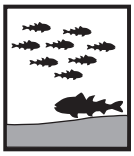
Larvae—Size at hatching: 3.0–4.0 mm SL [28]. Size at juvenile transformation: About 2.5–4.0 cm SL [20, 29]. Days to juvenile transformation: 60 days [29]. Habitat: Epipelagic, over continental shelf and slope [3, 27, 28, 31].

Juveniles—Age and size: 2 months to 2–7 years [29] and 2.5 cm SL to 20–48 cm FL [32, 33]. Habitat: Semi-benthic, in nearshore waters [3, 34, 35] and then migrate somewhat deeper as they mature [34–36]. Taken among eelgrass and kelp [37].

Adults—Age and size at first maturity: In eastern Bering Sea, a few males matured at 20 cm FL (2 years), 50 percent were mature at 31 cm (3 years), and 100 percent were mature at 48 cm (about 7 years) [32]. For females, size and age at maturity varied somewhat with location and year. On average, a few matured at 25 cm FL, 50 percent at 37.4 cm (4 years), and virtually all by 56 cm [33]. In the Gulf of Alaska, 50 percent of females matured at 42 cm FL and 5 years [38]. Older females are perhaps somewhat larger at age than are males. Maximum age: 33 years [20]. Maximum size: 91 cm TL [3]. Habitat: Semi-demersal to pelagic [3]; commonly associated with outer shelf and slope but also uses a wide variety of habitats including nearshore eelgrass and kelp beds, large estuaries (such as the Puget Sound), coastal embayments, and open ocean basins (such as the Aleutian Basin of Bering Sea) [30, 37].

Substrate—Sand, gravel, mud, silt, and bedrock [20, 37].

Physical/chemical—Temperature: -*1.8*–12 °C; rare in waters less than 0 °C [6, 30, 39, 40]. Salinity: Marine [20]. *Found at 31.3–33.5 ppt in U.S. Chukchi Sea* [6].



Behavior

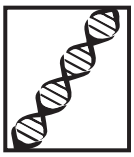
Diel—They make limited day-night vertical migrations, moving into shallow waters at dusk and night, then deeper during day [25, 41, 42]. Juveniles aggregate near sea floor during day then disperse and move shallower at night [30, 35, 43]. Juveniles often associated with tentacles of medusae during day [43, 44]. Some adults migrate into near-surface waters at night [42].

Seasonal—Young-of-the-year recruit to nearshore waters from early summer through autumn [34, 35]. Make seasonal inshore-offshore migrations, overwintering in deep part of their depth range [45]. Strong year classes have been linked to warm water years when juveniles are transported offshore and away from cannibalistic adults [46].

Reproductive—Spawning occurs in a number of discrete locations in Strait of Georgia, Gulf of Alaska, Bering Sea, and in western Pacific Ocean off Asia [30]. Fish may return to their natal sites to spawn. Females are batch spawners [27, 47], spawning at least 14 times in a season [20]. Spawning of an individual female probably takes less than 1 month [18].

Schooling—Forms large schools [34–36].

Feeding—Juveniles and adults are mainly nocturnal feeders [48] whereas most feeding of larvae occurs during the day [25].



Populations or Stocks

There is evidence for semi-discrete populations in the Gulf of Alaska and Bering Sea, although the degree of genetic isolation of these stocks is unclear. As many as 12 stocks in waters between Japan and southeastern Alaska have been postulated [30, 38, 49, 50].

Reproduction

Mode—Oviparous [20].

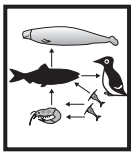
Spawning season—Over all their range, some spawning may occur throughout the year [51]. However, most spawning takes place in winter and spring, varying somewhat with location. For instance, in Gulf of Alaska, fish spawn around Shumagin Island, Alaska from about 15 February to 1 March, 15 March to 1 April in Shelikov Strait [38] and mostly April to Mid-May in southeastern Bering Sea [30].

Fecundity—58,000–1,400,000 non-adhesive eggs per season, in batches [27, 47, 52].

Food and Feeding

Food items—Larvae: Copepod naupli, larval copepods and small euphausiids [29]. Juveniles: Mainly euphausiids [48] as well as copepods and other planktonic crustaceans [29]. Adults: A wide array of midwater and benthic organisms. Smaller pollock feed primarily on zooplankton (for example, euphausiids, copepods, and gammarid amphipods). Among larger fish, copepods and euphausiids are often very important, as are a number of fish species (for example, capelin, eulachon, and lanternfishes) and shrimps. Other frequently eaten organisms include mysids, crabs, polychaetes, and cephalopods and crustacean larvae [53–56].

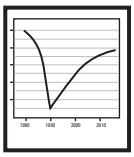
Trophic level—3.7 [57]



Biological Interactions

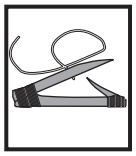
Predators—Walleye Pollock are extremely important prey for many fishes, seabirds, and mammals. A literature search discloses that at least 42 species of fishes, 18 species of seabirds, 7 species of pinnipeds, 9 species of cetaceans, and river otters prey on pollock. In Gulf of Alaska, pollock are very important prey to Arrowtooth Flounder, Pacific Cod, Pacific Halibut, and Steller sea lion [38]. In some years, juvenile pollock are a major part of the diet of older pollock [30].

Competitors—Walleye Pollock, an ecologically generalist species, compete with a very wide range of other fish species [30].



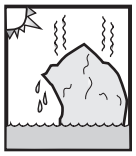
Resilience

Low, minimum population doubling time: 4.5–14 years [58].

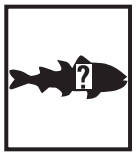


Traditional and Cultural Importance
None in study area.

Commercial Fisheries
In the United States, Walleye Pollock are not commercially harvested north of the Bering Sea. Walleye Pollock was a major food fish in southeastern Alaska and the Gulf of Alaska [59]. Commercial catches by foreign fleets began in the early 1950s and increased substantially with the advent of at-sea processing of fish for surimi. Currently, the average Alaskan harvest of pollock is 1.1 million metric tons with processed catches destined for U.S. and export markets [30, 38, 60].



Potential Effects of Climate Change
It is hypothesized that this species will become more abundant in the U.S. Chukchi and Beaufort Seas marine ecosystem changes resulting from climate change. Increased abundance will result in changes in food web dynamics such as competition with other gadid species, especially in the Chukchi Sea if benthic-pelagic energy flows become decoupled. New experimental results indicate that Walleye Pollock and Pacific Cod grow at 2–3 times the rate of other Arctic gadids when exposed to increasing temperature regimes in the laboratory that are similar to field conditions in summer in the coastal Chukchi and Beaufort Seas. This suggests a potential competitive advantage for Walleye Pollock under warming conditions [61].



Areas for Future Research [A]
Field identifications of young pollock may be confused with other gadid species, especially Arctic Cod. A rapid diagnostic (genetic) identification tool is needed for field applications as these cods may occur in mixed assemblages. Pollock are not well adapted to cold-water environments and, as temperatures warm, monitoring programs should be sufficient to detect abrupt changes in abundance. Predator-prey relationships should be established to investigate competition with other gadid species. Important spawning and overwintering habitats require delineation. Improved information about the species physiological tolerances and growth rate in Arctic waters is needed to evaluate potential climate change effects.

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Pacific Cod (*Gadus macrocephalus*)

Tilesius, 1810

Family Gadidae

Pacific Cod (*Gadus macrocephalus*) 597 mm, western Gulf of Alaska, 2005. Photograph by C.W. Mecklenburg, Point Stephens Research.

Note on taxonomy: *Based on analyses of both morphology and mtDNA, the Greenland Cod, Gadus ogac (Richardson, 1836), is a subspecies of* G. macrocephalus [1, 2].

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

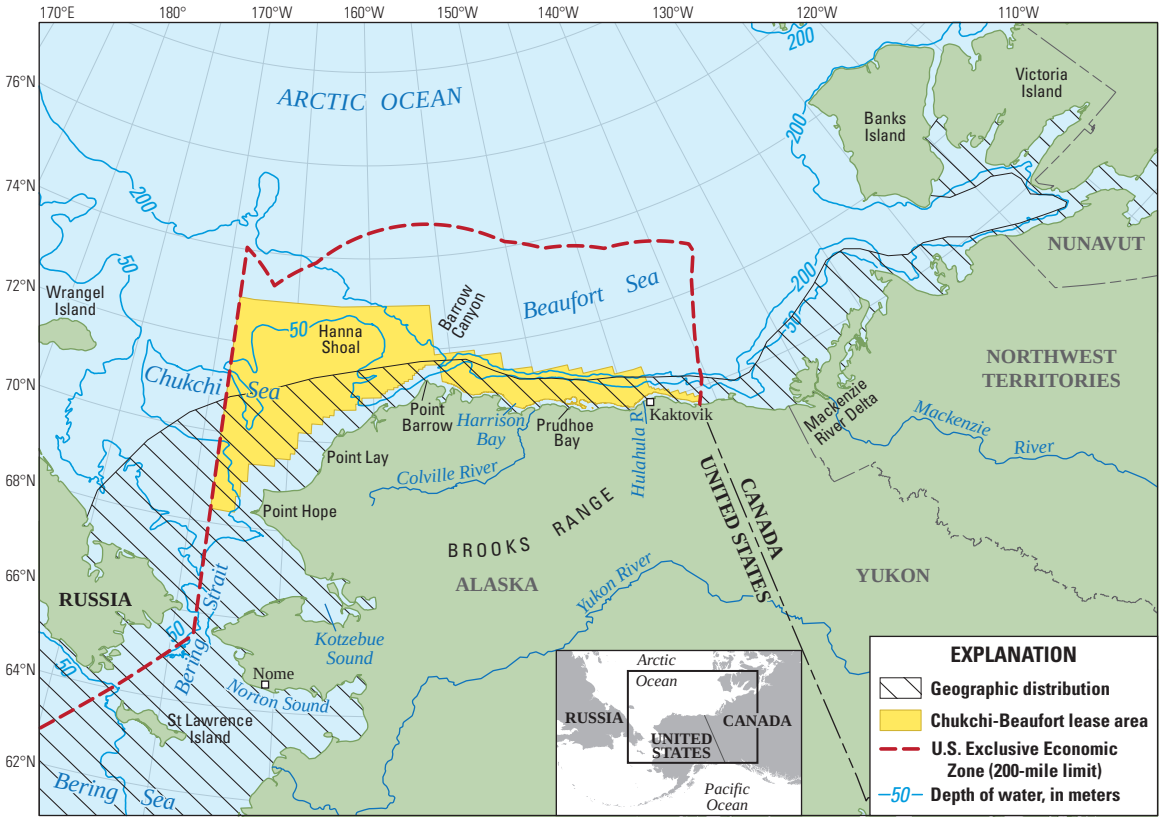
Ecological Role: Of little known ecological importance in U.S. Chukchi and Beaufort Seas. Maybe of small seasonal importance in food webs in the Bering Strait and southeastern Chukchi Sea.

Physical Description/Attributes: Robust body, large head. Light gray-brown with brown to bright golden yellow spots on back and sides to olive-blackish with no distinct spots [3, 4]. For specific diagnostic characteristics see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 296) [3]. Swim bladder: Present [3]. Antifreeze glycoproteins in blood serum: Unknown.

Range: *U.S. Chukchi and Beaufort Seas* [1, 3]. Elsewhere in Alaska, throughout Bering Sea, Aleutian Islands and Gulf of Alaska. Worldwide, in Pacific Ocean south to southern California and to Yellow Sea off Manchuria, China; east across Canada to west Greenland and south to Gulf of St. Lawrence. Isolated population in White Sea [1, 3].

Relative Abundance: *Uncommon in U.S. Chukchi and Beaufort Seas* [1, 3]. Uncommon in northern Bering Sea [1]. Abundant throughout Bering Sea northward to Norton Sound and Gulf of Anadyr [1, 6, 7], and southward to Seas of Japan and Okhotsk [8, 9] and Washington [10].

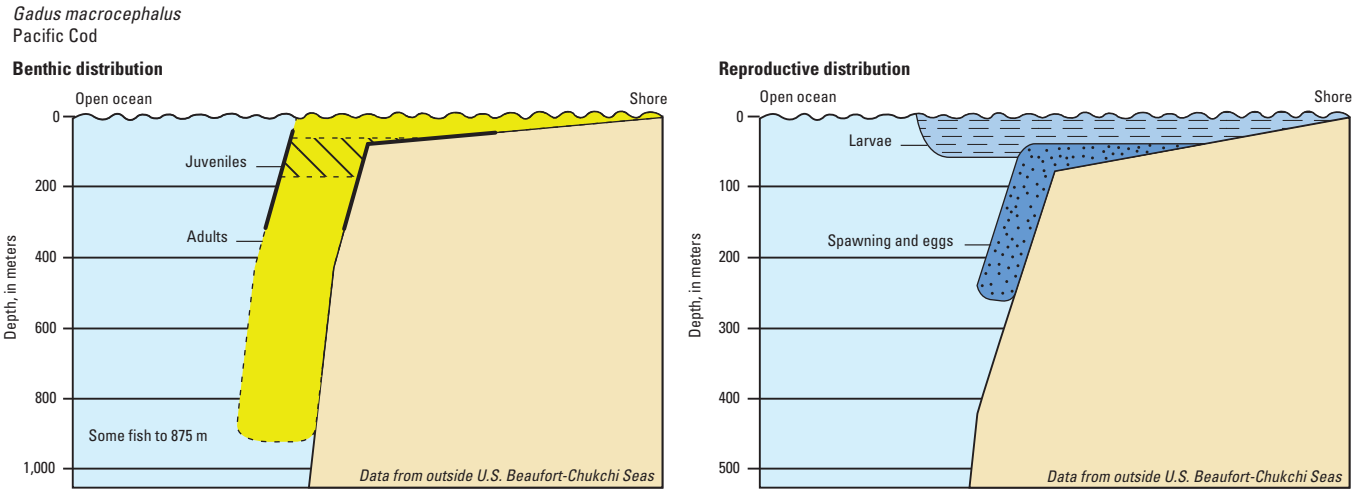
Pacific Cod
Gadus macrocephalus



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

Geographic distribution of Pacific Cod (*Gadus macrocephalus*) within Arctic Outer Continental Shelf Planning Areas [5] based on review of published literature and specimens from historical and recent collections [1, 3, 4].

Depth Range: In water column, near surface to near bottom depth of 875 m [3], typically 50–300 m; sometimes in surf zone [11–13]. Spawning takes place at 40–265 m [14]. Fertilized eggs are benthic on continental shelf [10]. Newly hatched larvae are primarily in upper 45 m of water column (highest abundances at 15–30 m) [14], moving downward as they grow [15]. Juveniles are mainly at 60–150 m in Gulf of Alaska and eastern Bering Sea [15].



Benthic and reproductive distribution of Pacific Cod (*Gadus macrocephalus*).

Habitats and Life History

Eggs—Size: 1.0–1.2 mm [16, 17]. Time to hatching: 8.5–28 days at 11–4.5 °C. Hatching is most successful at lower temperatures [16, 18]. Habitat: Benthic [10, 16].

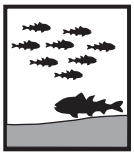
Larvae—Size at hatching: 3.0–4.0 mm [16, 17]. Size at juvenile transformation: 2.5–3.5 cm FL [14, 19]. Days to juvenile transformation: Unknown. Yolk sac is absorbed in 10 days [14]. Habitat: Pelagic and neritic [17].

Juveniles—Age and size: 2.5 cm FL to 38–81 cm TL [13, 14, 19]. Habitat: Shallow nearshore waters at [14, 17, 20], initially associated with algae and eelgrass but later in their first year some fish migrate into deeper water and over a wide range of habitats including plants, soft substrates, and mounds formed by sea cucumbers [10, 18, 21–23].

Adults—Age and size at first maturity: In eastern Bering Sea, 50 percent of females were mature at 58.0 cm TL and 4.9 years, whereas 50 percent of those in the Gulf of Alaska were mature at 50.3 cm TL and 4.4 years. A few females were mature at as small as 38 cm TL and a few were immature until about 81 cm TL [13]. Length at maturity is highly dependent on environmental factors and varies widely between areas and years. For example, off British Columbia. Canada, length at 50 percent maturity differed by almost 10 cm between samples taken in the mid-1970s and mid-1980s [24]. In Gulf of Alaska and eastern Sea of Okhotsk, females grow larger than males, although both sexes reach about the same maximum length in the eastern Bering Sea [13]. In Gulf of Alaska (although not in the eastern Bering Sea), male and female growth rates differ. Apparently, cod living in Alaskan waters grow more slowly but reach a larger size and live longer than those living off British Columbia and Washington [14]. Maximum age: 17 years [25], but rarely beyond 14 years [13]. Maximum size: 120 cm TL [3]. Habitat: Pelagic, both near the bottom and in the midwaters [14] over soft sea floors [10, 17, 22, 23].

Substrate—Cobble and rocky bottoms [10, 22, 23]. Coarse sand and cobble for spawning and eggs [14].

Physical/chemical—Temperature: -1.7–18 °C, mainly 0–10 °C [21, 26, 27]. Salinity: Eggs are in polyhaline to euhaline waters. Marine and estuarine [14].



Behavior

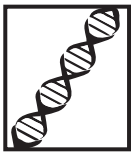
Diel—Pelagic juveniles have been found in surface waters in association with medusae [28].

Seasonal—Make annual inshore and offshore movements linked to spawning and feeding. The timing and extent of annual migrations vary with location. Annual migrations in eastern Bering Sea, eastern Aleutian Islands, and Gulf of Alaska, occur when fish attempt to avoid temperature extremes that accompany the seasonal changes [29]. Fish move offshore during winter, as nearshore waters get very cold, and move inshore during summer [30]. Farther south on both sides of the Pacific Ocean (for example, Puget Sound, Korea, and Japan), migrations to deeper waters occur during summer months to avoid excessively heated coastal waters and return inshore for the winter [10]. Some fish move fairly long distances. Pacific Cod in the eastern Bering Sea, for instance, summer on the eastern Bering Sea shelf, then move southward and deeper to the Bering Sea in the vicinity of Unimak Pass and Unalaska Island, Alaska, and in the nearby Gulf of Alaska to spawn [14].

Reproductive—Single batch spawners, releasing all eggs in a few minutes [14]. Spawning depth depends on its depth-temperature profile. For instance, off Washington and southwest Vancouver Island, British Columbia, Pacific Cod spawn in more shallow waters than those in northern British Columbia [10].

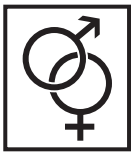
Schooling—Forms schools [14].

Feeding—Juveniles and adults are carnivorous and feed at night [14]. Feeding increases during the summer and decreases in winter [31].



Populations or Stocks

Fish in Puget Sound and the Strait of Georgia may form several semi-isolated populations from fish on the outer coast [14, 32]. Based on analyses of morphology and mtDNA, Pacific Cod are most closely related to Ogac (*Gadus ogac*) and are now considered by taxonomists to be the same species [1, 2, 33].



Reproduction

Mode—Oviparous, external fertilization [14].

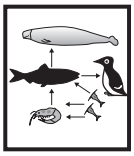
Spawning season—Can occur between January and July, although peak spawning takes place in spring in Alaska [13, 34].

Fecundity—225,000 –6,400,000 semi-adhesive eggs [14, 35]. The number of eggs produced per body length decreases with higher latitude [21].

Food and Feeding

Food items—Very wide range of benthic and water column organisms. Cod less than about 20 cm FL feed primarily on a wide range of crustaceans, such as copepods, gammarid and caprellid amphipods, mysids, and euphausiids, and some small fishes [36–39]. Larger fish add large numbers of fishes to their diets as well as shrimps, crabs, hermit crabs, polychaetes, snails, clams, squids, and octopuses [38, 40–42]. As Pacific Cod grow, they feed more heavily on fishes and less on invertebrates [43–44].

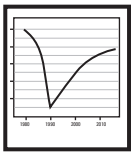
Trophic level—4.1 [45].



Biological Interactions

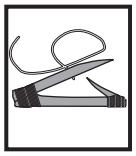
Predators—A large number of fishes, sea birds, and marine mammals. Major fish predators include Arrowtooth Flounder, Flathead Sole, Pacific Cod, Pacific Halibut, Sablefish, Spotted Spiny Dogfish, Walleye Pollock, and Yellowfin Sole [40, 46–48]. Seabirds include Common Murres, Horned and Tufted Puffins [49, 50]. Marine mammals include beluga, fin, minke, and sperm whales and orcas; bearded, harbor, northern fur, and ribbon seals; and Stellar sea lions [51–55].

Competitors—Other gadids, along with flatfishes, sculpins, poachers, and eelpouts.



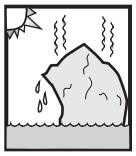
Resilience

Low, minimum population doubling time: 4.5–14 years [56].

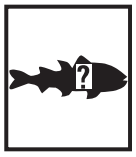


Traditional and Cultural Importance
None reported.

Commercial Fisheries
Currently, Pacific Cod are not commercially harvested.



Potential Effects of Climate Change
It might be expected that Pacific Cod abundance will increase in Arctic waters if fish from the Bering Sea move northward. The probability of this species' colonization of Arctic marine environments may be lower than for other gadid species because of its apparent fidelity to spawning locations in the Bering Sea. However, new experimental results indicate that Pacific Cod and Walleye Pollock grow at 2–3 times the rate of other Arctic gadids when exposed to increasing temperature regimes in laboratory that are similar to field conditions in summer in the coastal Chukchi and Beaufort Seas [57]. This suggests a potential competitive advantage for Pacific Cod under warming conditions.



Areas for Future Research [A]
Little is known about the ecology of this species in the study area. Whether Pacific Cod spawn in the Chukchi or Beaufort Seas is of major interest. Researchers believe that the cod display high fidelity to spawning areas in the Bering Sea and thus improved information about their migratory behavior is needed.

Remarks

This species has long been known to be present in the Beaufort Sea (see [Walters, 1955], between Point Barrow and Smith Bay) [58], under the name, *Gadus ogac* [3], and is common just over the U.S-Canadian border in Canadian waters.

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Threespine Stickleback to Antlered Sculpin

Threespine Stickleback (*Gasterosteus aculeatus*)

Linnaeus, 1758

Family Gasterosteidae

Note: *Exhibits highly variable life history patterns with marine, anadromous, riverine, and lacustrine populations* [1, 2]. *Data in this account are from marine and anadromous populations.*

Colloquial Name: Iñuit—Kakalisauraq [3].

Ecological Role: In locations where common, for instance in Kotzebue Sound, this species may be of ecological importance in local food webs.

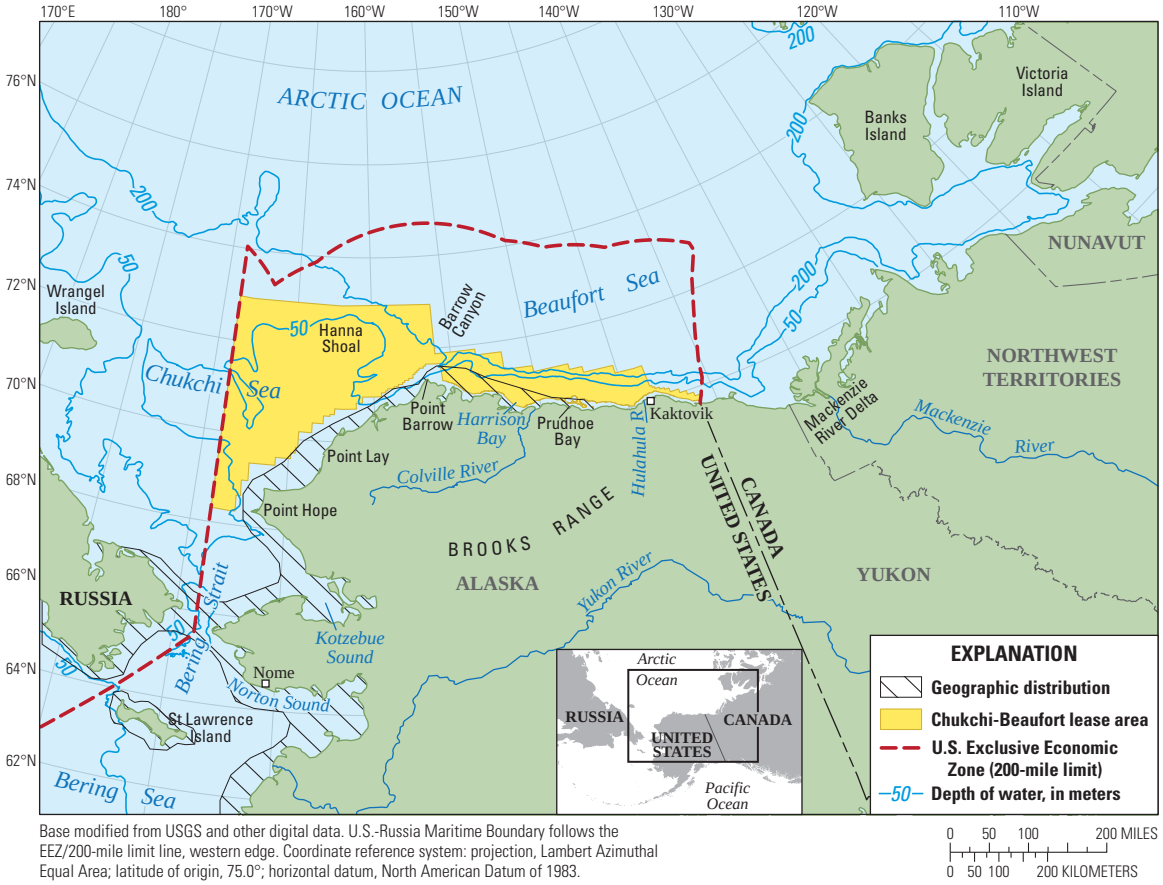
Threespine Stickleback (*Gasterosteus aculeatus*), 42 mm TL, northeastern Chukchi Sea, 2007. Photograph by C.W. Mecklenburg, Point Stephens Research.

Physical Description/Attributes: Moderately elongate body. Anadromous type is blue-black to silvery or greenish with yellow, silvery, or white bellies. Breeding males become bright blue or green with red or orange throats and bellies. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 333) [4]. Swim bladder: Present, without pneumatic duct [5]. Antifreeze glycoproteins in blood serum: Unknown.

Range: *U.S. Chukchi and Beaufort Seas* [6]. Elsewhere in Alaska, in all coastal waters. Worldwide, from Bering Sea south to Monterey Bay, central California, and to Seas of Okhotsk and Japan; in Atlantic Ocean from Hudson Bay to southern Greenland, Iceland, and southern Barents Sea to Novaya Zemlya, Russia [6].

Relative Abundance: *Common in brackish water at least as far north as Kotzebue Sound, U.S. Chukchi Sea, and occasional or rare east in U.S. Beaufort Sea* [1, 9–11]. Rare in Northwest Territories, Canada [1]. Common in southwestern Barents Sea and Sea of Japan [6, 12].

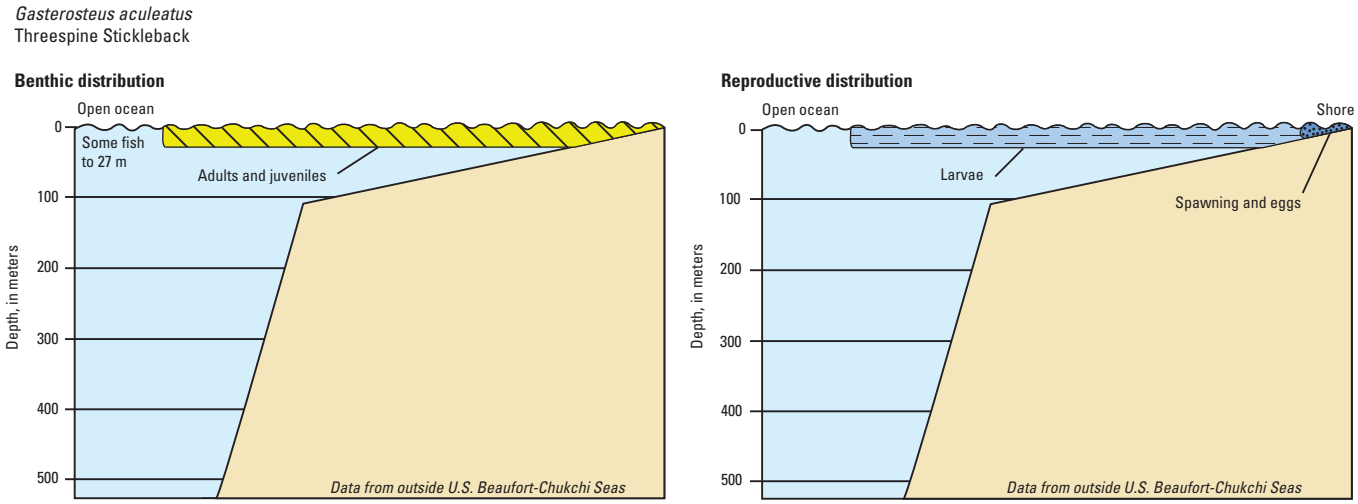
Threespine Stickleback
Gasterosteus aculeatus



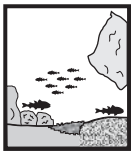
Base modified from USGS and other digital data. U.S.-Russia Maritime Boundary follows the EEZ/200-mile limit line, western edge. Coordinate reference system: projection, Lambert Azimuthal Equal Area; latitude of origin, 75.0°; horizontal datum, North American Datum of 1983.

Geographic distribution of Threespine Stickleback (*Gasterosteus aculeatus*), within Arctic Outer Continental Shelf Planning Areas [7] based on review of published literature and specimens from historical and recent collections [6, 8].

Depth Range: Intertidal to 27 m, as far as 805 km offshore for juveniles and adults [4, 13]. Larvae are abundant in surface waters [14]. Marine type spawns in shallow waters, such as tidepools [15].



Benthic and reproductive distribution of Threespine Stickleback (*Gasterosteus aculeatus*).



Habitats and Life History

Anadromous and marine [1, 2].

Eggs—Size: 0.11–0.16 cm [16]. Time to hatching: 5–20 days [12]. Habitat: Benthic, in tidepools for marine type [2].

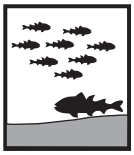
Larvae—Size at hatching: 2.0–5.5 mm [17, 18]. Size at juvenile transformation: About 10.0 mm [19]. Days to juvenile transformation: About 30 days [19, 20]. Habitat: Benthic to pelagic [14].

Juveniles—Age and size: 1–12 months [19], and 11–30 mm TL [19]. Habitat: Benthic to pelagic, staying close to nests for 4–6 days [4], around eelgrass, filamentous algae, and other plants, as well as over sand and rocks [21, 22].

Adults—Age and size at first maturity: Some mature after 1 year (fish spawn once and die), others take 2 years [16]. Growth rates vary with area [16, 23]. Maximum age: 5 years [18], typically 1–3.5 years. Varies with area [16, 23]. Maximum size: 11 cm TL [18]. Habitat: Benthic to pelagic [4], around eelgrass, filamentous algae, and other plants, as well as over sand and rocks, and in offshore waters [21, 22, 24, 25].

Substrate—Over rocks, silt, and sand for spawning [15].

Physical/chemical—Temperature: Marine type has been shown to tolerate temperatures as low as 4 °C and as high as 28 °C in laboratory experiments [26]. Salinity: Fresh to marine waters. *More common in brackish than marine waters in Kotzebue* and Norton sounds [9].



Behavior

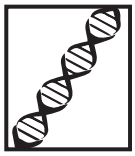
Diel—In Puget Sound, both juveniles and adults inhabit surface waters at night [27, 28].

Seasonal—Some fish migrate into coastal water in autumn to over winter [15]. Other fish winter in deep water [16].

Reproductive—Off Alaska, anadromous fish enter freshwaters to spawn in late spring [1]. Anadromous fish may spawn in brackish or fresh waters [15]. Marine fish spawn in quiet areas such as tide pools [2]. Spawning occurs over rocks, eelgrass, silt, and sand [15]. Males construct nests composed of bits of plants and other debris held together by secretions formed in the kidneys. Through a series of courting behaviors, a male leads a female into the nest where she lays her eggs. Many nests contain eggs from more than one female and males guard the eggs until they hatch. Neighboring males not guarding eggs often “sneak” into a nearby nest and fertilize some of the eggs [16, 29]. Some individuals may spawn once and die [16, 30].

Schooling—Forms schools except in spawning season [12].

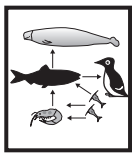
Feeding—Feeds throughout water column [12].



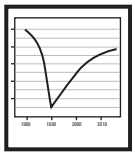
Populations or Stocks
There have been no studies.

Reproduction
Mode—Oviparous, separate sexes [20].
Spawning season—May–August in Alaska [1, 16].
Fecundity—Batch spawners, laying 50–200 eggs at a time with overall fecundity ranging from 65 to 1,300 [16, 31].

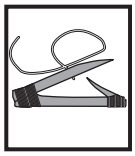
Food and Feeding
Food items—Benthic and midwater prey. Small crustaceans (for example, copepods, euphausiids, mysids, and gammarid and caprellid amphipods) often are quite important, and crustacean larvae, insects, worms, mollusks, fish eggs, and small fishes are also frequently consumed [18, 32–35].
Trophic level—3.51 (standard error 0.49) [36].



Biological Interactions
Predators—Off Alaskan and British Columbia coasts, are a large number of fishes, sea birds, and marine mammals [12].
Competitors—Likely Polar and Saffron cods, whitefishes, and flatfishes.

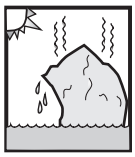


Resilience
High, minimum population doubling time less than 15 months (K=0.6–1.8; t_m=1; t_{max}=4; Fecundity=80) [36].



Traditional and Cultural Importance
None reported.

Commercial Fisheries
Currently, Threespine Stickleback are not commercially harvested.



Potential Effects of Climate Change
Uncertain; however, this is a species with a very plastic life history pattern, with an ability to adapt to a wide range of environmental conditions. Increasing abundance is possible.

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

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Ninespine Stickleback (*Pungitius pungitius*)
(Linnaeus, 1758)

Family Gasterosteidae

Ninespine Stickleback (*Pungitius pungitius*) 62 mm, northeastern Bering Sea (2007). Photograph by C.W. Mecklenburg, Point Stephens Research.

Note on taxonomy: *Some authors recognize more species in this complex than others. North American Arctic populations have been considered a separate species* P. occidentalis *or to comprise two subspecies:* P. p. pungitius, *and* P. p. occidentalis [1].

Colloquial Name: Iñupiat—*Kakaliqauraq* [2].

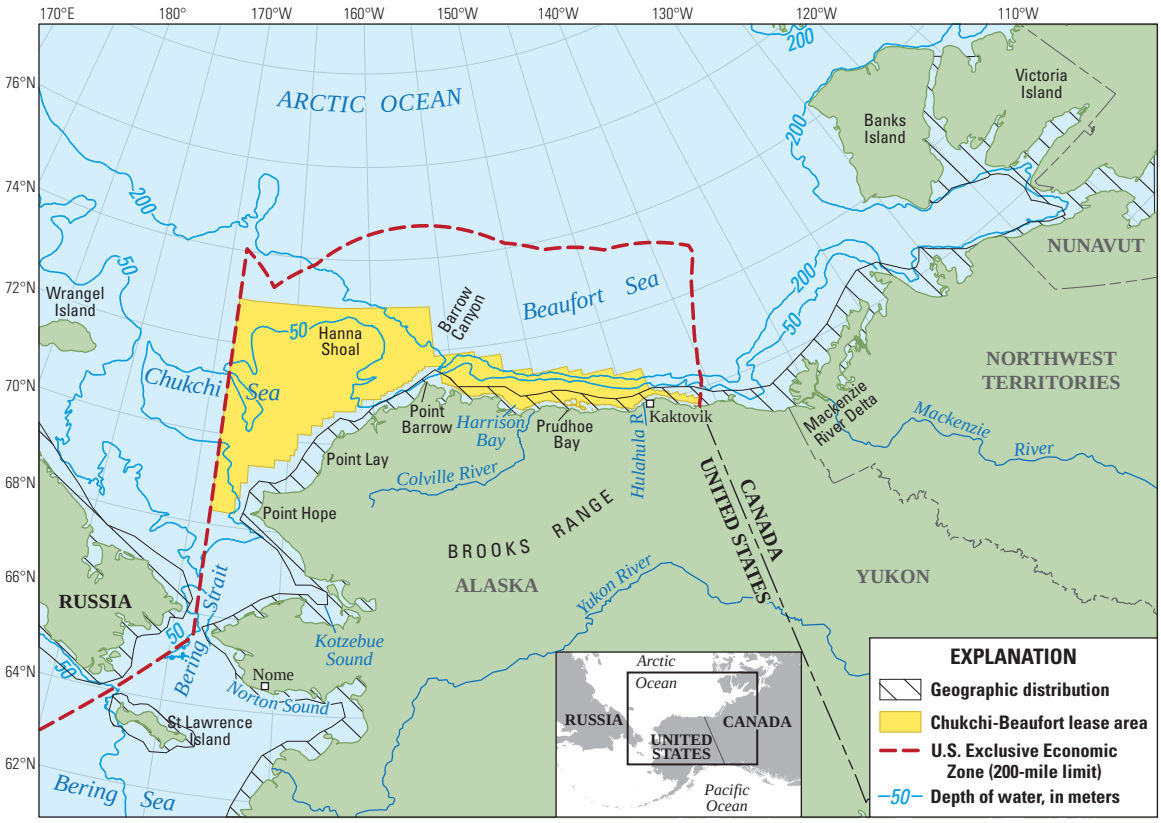
Ecological Role: Likely of considerable seasonal importance as a prey of fishes, sea birds, and marine mammals; occurs in brackish and marine waters near the coast.

Physical Description/Attributes: Slender, elongate body. Olive to pale brown on back, silvery or brassy yellow on sides and belly. Breeding colors vary with population; spawning males often have a great deal of black on sides, belly, and chins [3, 4]. Pure black males have been noted [3]. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 334) [4]. Swim bladder: Present, without pneumatic duct [5]. Antifreeze glycoproteins in blood serum: Unknown.

Range: *Along shores of U.S. Chukchi and Beaufort Seas* [1]. Elsewhere in Alaska, along Bering Sea and western and northern Gulf of Alaska coasts inland to northeastern British Columbia. Worldwide, western Pacific Ocean in Seas of Japan and Okhotsk, and along Arctic shores except absent from Canadian high Arctic Archipelago, Greenland, and Iceland [1].

Relative Abundance: *Common, although overall abundance is poorly described. Occasionally taken in large numbers along coasts in U.S. Chukchi and Beaufort Seas* and in Canadian Beaufort Sea [8–12].

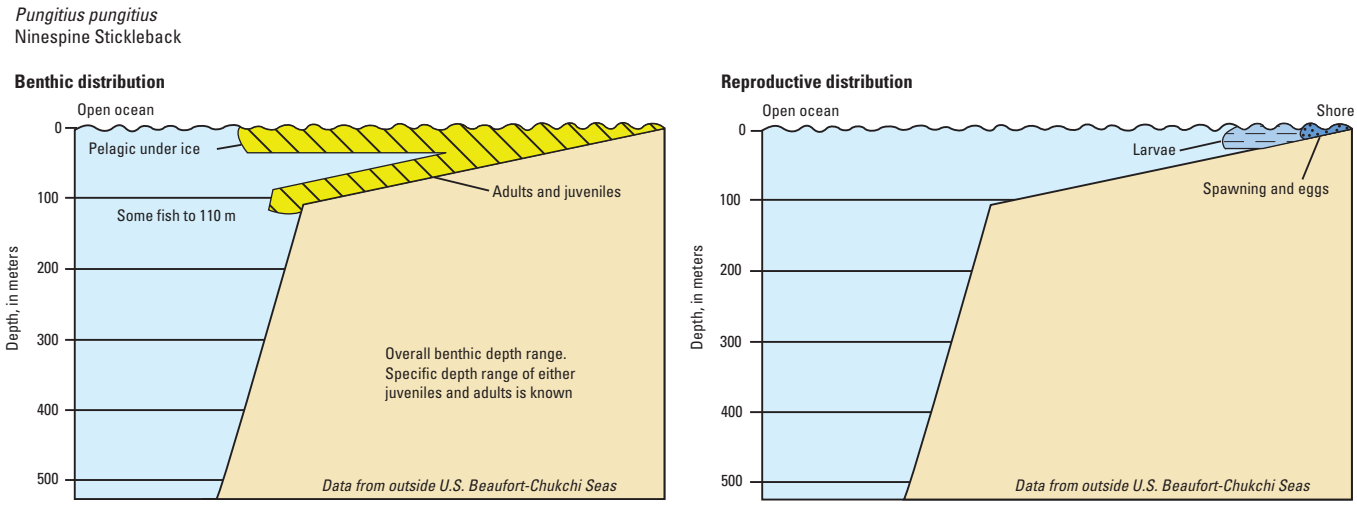
Ninespine Stickleback
Pungitius pungitius



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 Ninespine Stickleback (*Pungitius pungitius*), within Arctic Outer Continental Shelf Planning Areas [6] based on review of published literature and specimens from historical and recent collections [1, 4, 7].

Depth Range: Nearshore, surface waters to depths of 110 m [4]. In ocean, spawning occurs nearshore, in estuary tide pools [13]. Larvae remain near spawning nests [14].



Benthic and reproductive distribution of Ninespine Stickleback (*Pungitius pungitius*).

Habitats and Life History

Anadromous, riverine, and lacustrine forms [15].

Eggs—Size: 1.0–1.5 mm [16, 17]. Time to hatching: Unknown. Habitat: Benthic, in nests made of algae and plant material [3, 16].

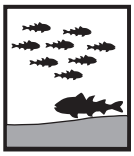
Larvae—Size at hatching: 5.7 mm on average [17]. Size at juvenile transformation: About 15 mm [14]. Days to juvenile transformation: Perhaps 3 months [14]. Habitat: Benthic, remaining near nests [14].

Juveniles—Size range: About 15–38 mm [14, 18]. Habitat: *In ocean, benthic, and midwaters, often under ice* [9, 19, 20].

Adults—Age and size at first maturity: 1–2 years [16, 21, 22] and at least 38 mm in Baltic Sea [18]. Maximum age: At least 2 years in North America [21]. Freshwater fish in Great Britain live to 3.5 years [23]. Maximum size: 9 cm TL [4]. Habitat: *In ocean, benthic, and midwaters, often under ice* [9, 19, 20].

Substrate—Rocks and sand for spawning [3].

Physical/chemical—Temperature:–1.9–20 °C [19, 21]. Salinity: Fresh to marine [15]. In Baltic Sea, prefers warmer, brackish waters for spawning [14].



Behavior

Little is known of the behaviors of these fish in Arctic waters.

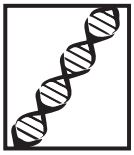
Diel—*Once at sea, makes offshore excursions, as much as 6 km off the coast in Beaufort Sea* [22, 24].

Seasonal—Toward autumn some fish migrate to marine waters. *Over wintering can occur in estuaries and river deltas* [10, 11, 25, 26].

Reproductive—Spawning occurs at shallow depths in fresh and brackish waters [3, 16]. Nesting occurs in dense vegetation or in more exposed areas, such as in the crevices of boulder fields or under rocks. Males construct tunnel-shaped nests of plant material and lure females to them through a series of courtship behaviors [3, 16]. Males often mate with more than one female [15–17]. Females are batch spawners. Males protect fertilized eggs and larvae through and somewhat after hatching, often retrieving errant young and spitting them back into the nest [3].

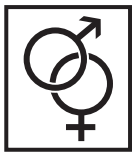
Schooling—Juveniles school, adults may form small groups [27].

Feeding—Appears to occur during daylight hours [27].



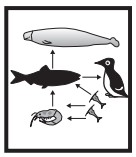
Populations or Stocks

There have been no studies.

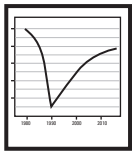


Reproduction
Mode—Oviparous, separate sexes.
Spawning season—*Spring and summer* [3, 16].
Fecundity—350–960 eggs, in batches of 20–80 eggs [28]

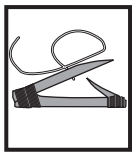
Food and Feeding
Food items—Zooplankton (for example, mysids and ostracods), adult and larval insects, mollusks, and fish eggs [8, 29, 30].
Trophic level—3.29 (standard error 0.40) [31].



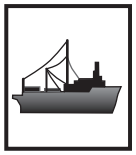
Biological Interactions
Predators—*In U.S. Beaufort and Chukchi Seas, other fishes including Arctic Cisco, Least Cisco, Dolly Varden, Fourhorn Sculpin, and Humpback Whitefish* [8, 32], *as well as belugas (off Point Barrow in May)* [33], *and ringed seals (over much of the year in northeastern Chukchi Sea* [34]. Generally, Ninespine Stickleback are an important prey species for other fishes, birds, and mammals.
Competitors—Likely such zooplanktivores as whitefishes, Pacific Herring, sculpins, and gadids.



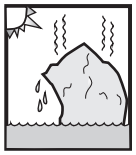
Resilience
Medium, minimum population doubling time 1.4–4.4 years (t_m=1–2; t_{max}=5; Fecundity=350) [31].



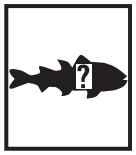
Traditional and Cultural Importance
Historically, Ninespine Stickleback were used as both human and dog food, although currently this species is not used [2, 16].



Commercial Fisheries
Currently, Ninespine Stickleback are not commercially harvested.



Potential Effects of Climate Change
Ninespine Stickleback are a predominantly boreal species with widespread presence along Arctic shores [1], which could be expected to increase in abundance and continue expanding to localities where suitable habitat can be found, as the climate warms.



Areas for Future Research [B]
Little is known about the biology and ecology of this species from the 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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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.

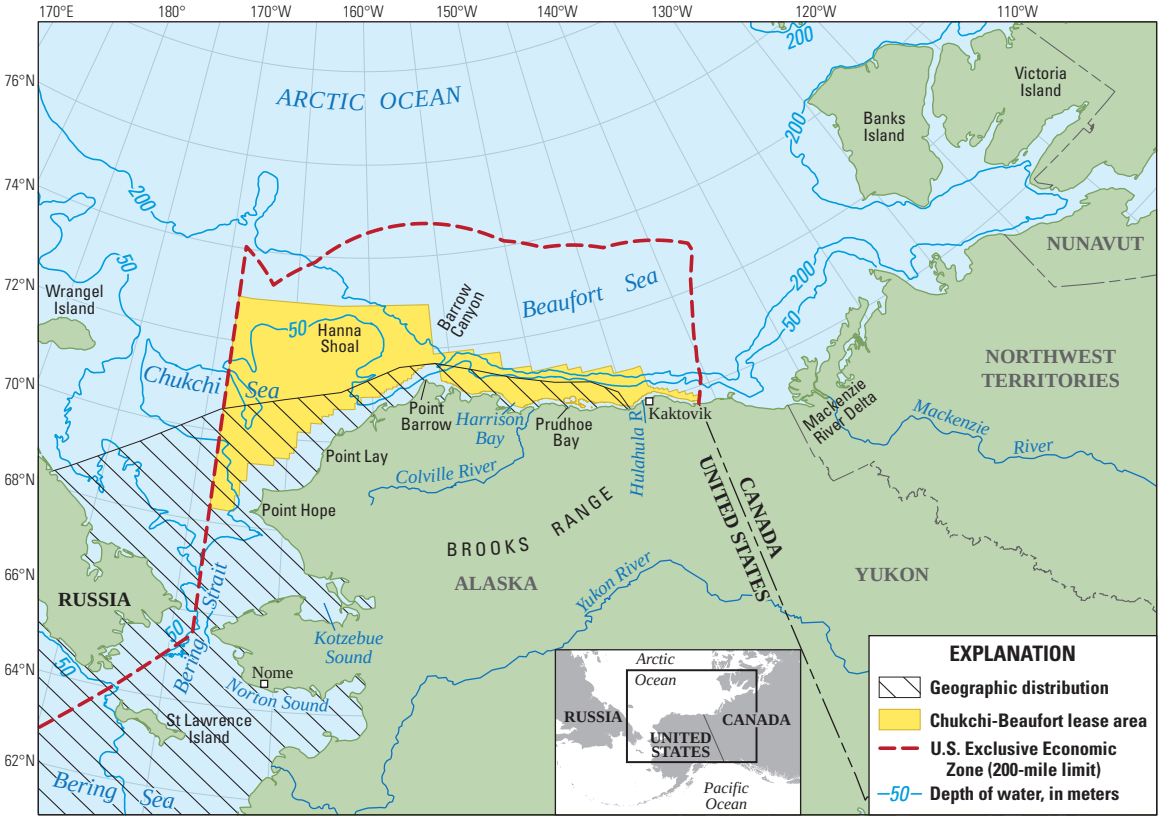
Physical Description/Attributes: Brown to green tinged with orange and yellow. Body and head usually have small white spots and anal fin is yellow often with brown bars. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 392) [1]. Swim bladder: Absent [1].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

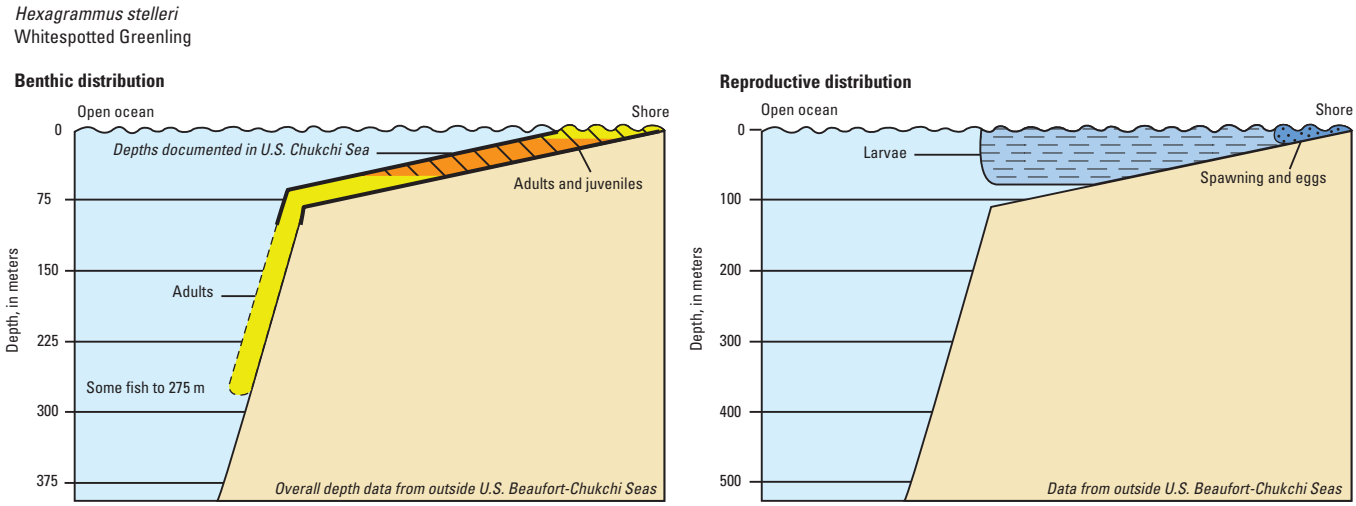
Whitespotted Greenling
Hexagrammos stelleri



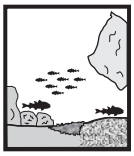
Base modified from USGS and other digital data. U.S.-Russia Maritime Boundary follows the EEZ/200-mile limit line, western edge. Coordinate reference system: projection, Lambert Azimuthal Equal Area; latitude of origin, 75.0°; horizontal datum, North American Datum of 1983.

Geographic distribution of 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].

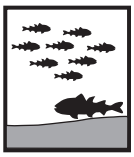
Larvae—Size at hatching: 7.0–9.0 mm SL [11, 19]. Size at juvenile transformation: 30–40 mm FL [14, 19]. Days to juvenile transformation: About 1 year [14]. Habitat: Pelagic, near surface [16, 20].

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

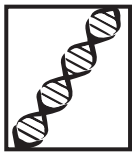
Diel—Substrate-oriented; remains within 1.5 m of sea floor, occasionally rising to 5–6 m in midwaters [29]. Strictly diurnal (Sea of Okhotsk) [29] and active, moving into shallow waters to feed at night (eastern Bering Sea) [9]. More agonistic toward each other than toward other species [29].

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].

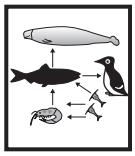
Feeding—Both juveniles and adults move into shallow, often intertidal waters, to feed [9]. Often roots around in substrate for prey [29].



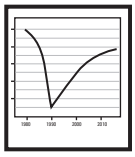
Populations or Stocks
There have been no studies.

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].

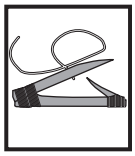
Food and Feeding
Food items—A very diverse array of benthic and midwater prey in Bering Sea and Gulf of Alaska. Pelagic larvae: Such zooplankters as copepods, amphipods, ostracods, crab larvae, and euphausiids. Benthic juveniles and adults: Crustaceans (for example, gammarid and caprillid amphipods, 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.

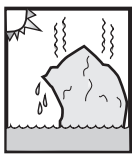


Resilience
Medium, minimum population doubling time 1.4–4.4 years (Fecundity=6,679–38,408) [37].



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

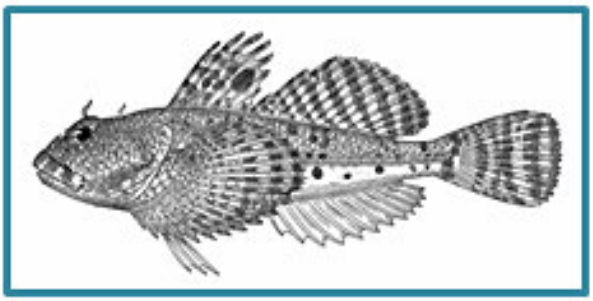
Family Cottidae

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.

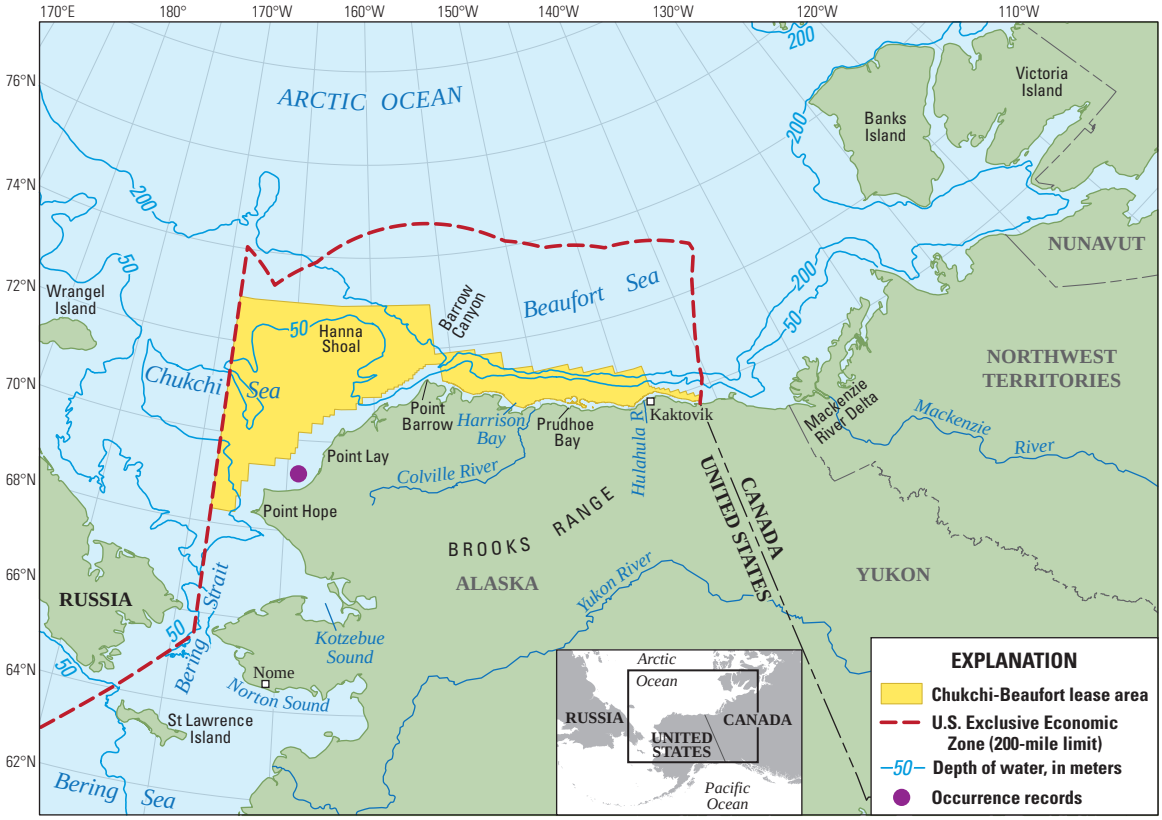


Okhotsk Hookear Sculpin (*Artediellus ochotensis*). From Mecklenburg and others (2002, p. 494) citing others; drawing of fish from off western Kamchatka Peninsula, Russia.

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

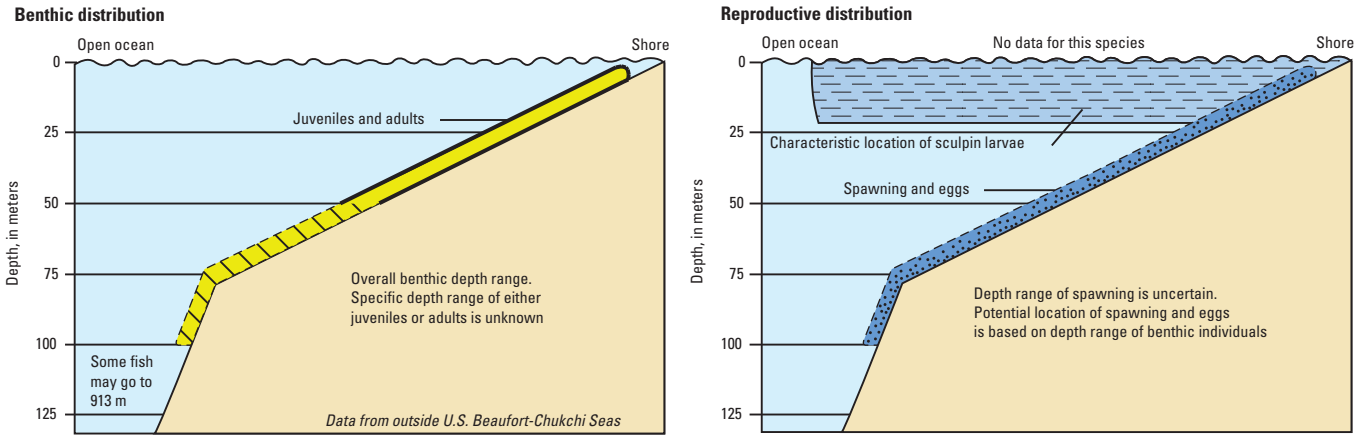


Base modified from USGS and other digital data. U.S.-Russia Maritime Boundary follows the EEZ/200-mile limit line, western edge. Coordinate reference system: projection, Lambert Azimuthal Equal Area; latitude of origin, 75.0°; horizontal datum, North American Datum of 1983.

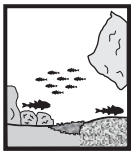
Geographic distribution of Okhotsk Hookear Sculpin (*Artediellus ochotensis*), within Arctic Outer Continental Shelf Planning Areas [3] based on review of published literature and specimens from historical and recent collections [2, 4].

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

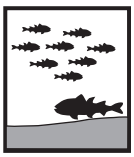
Artediellus ochotensis
Okhotsh Hookear Sculpin



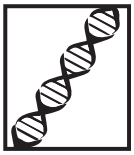
Benthic distribution and reproductive distribution of Okhotsh Hookear Sculpin (*Artediellus ochotensis*).



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].



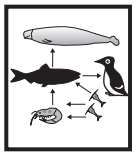
Behavior
Diel—Unknown.
Seasonal—Unknown.
Reproductive—Unknown.
Schooling—Unknown.
Feeding—Unknown.



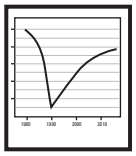
Populations or Stocks
There have been no studies.

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

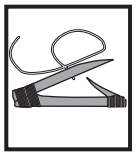
Food and Feeding
Food items—Unknown.
Trophic level—3.33 (standard error 0.40) [8].



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.

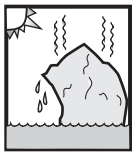


Resilience
High, minimum population doubling time less than 15 months (Preliminary *K* or Fecundity) [8].

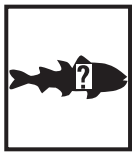


Traditional and Cultural Importance
None reported.

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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Hamecon (*Artediellus scaber*)

Knipowitsch, 1907

Family Cottidae

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.

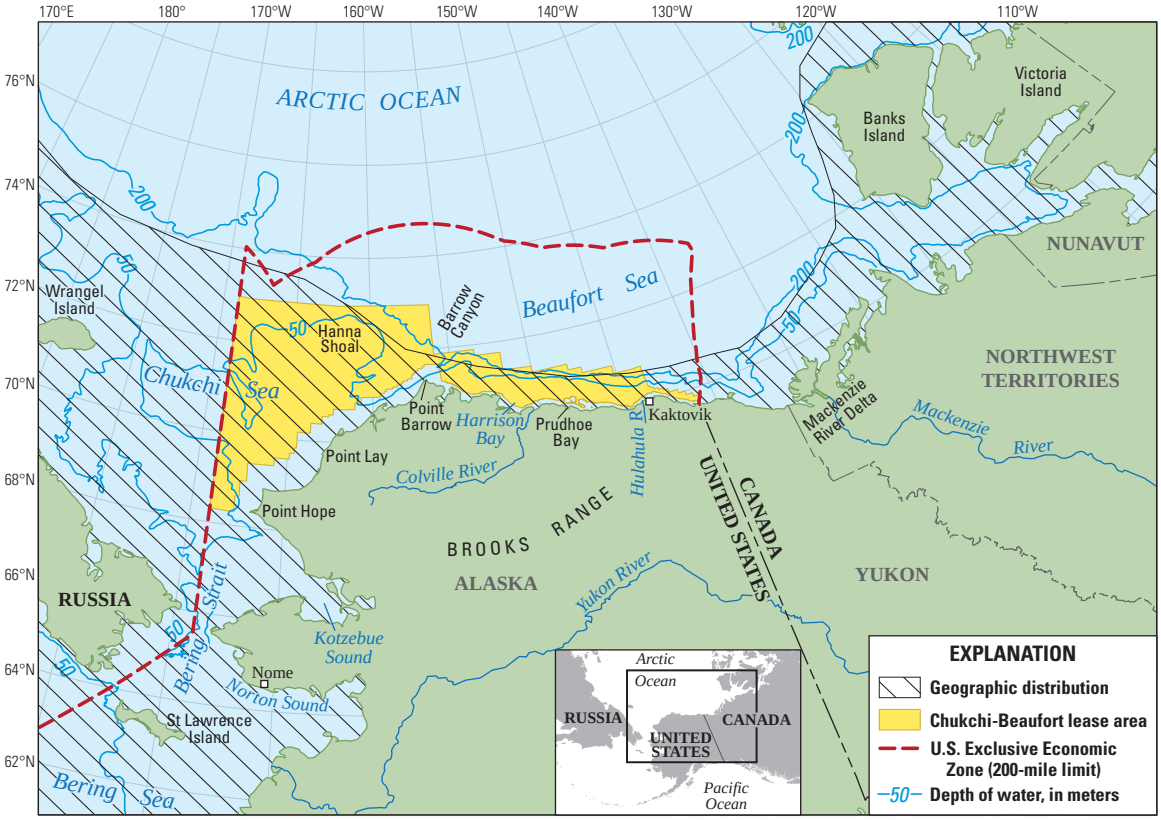
Physical Description/Attributes: Grayish brown with large blotches and bars; fins have orange bars. Males have a dark blotch on posterior part of first dorsal fin. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 491) [1]. Swim bladder: Absent [1]. Antifreeze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

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

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].

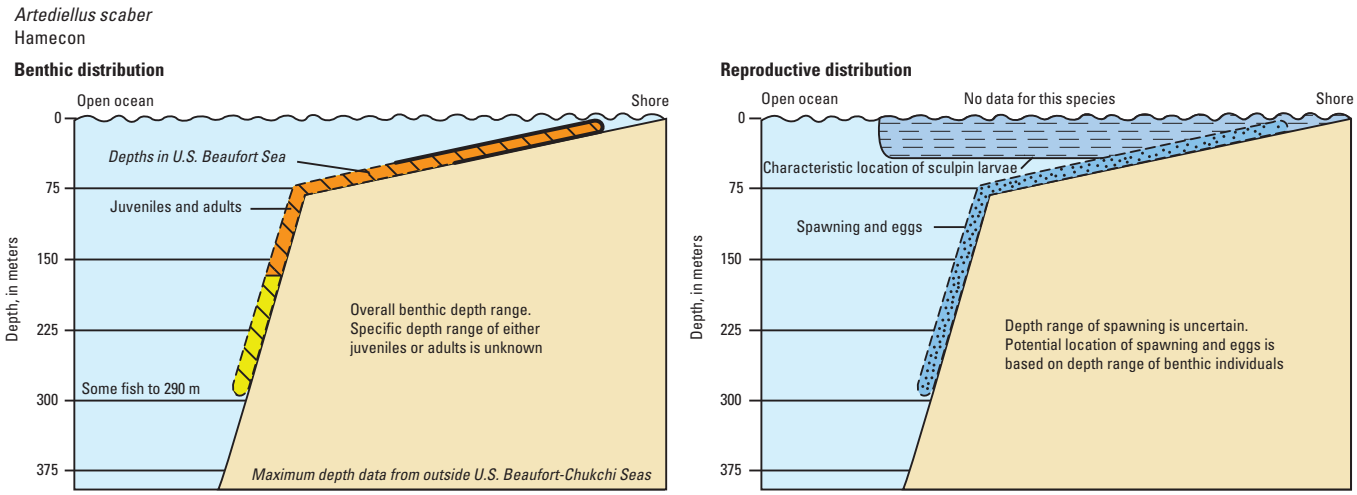
Hamecon
Artediellus scaber



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].

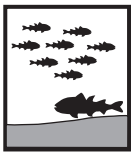
Depth Range: *At depths of 4–159 m, mostly shallower than 55 m* [2]. Elsewhere, overall depth range given for benthic individuals is 7 m [9] to 290 m [12], although depths greater than 159 m are likely in error [2].



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

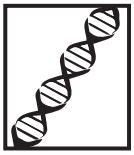
Habitats and Life History

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],



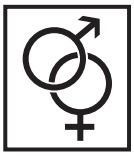
Behavior

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



Populations or Stocks

There have been no studies.



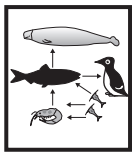
Reproduction

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.

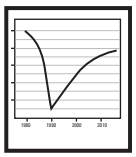
Trophic level—3.5 (standard error 0.38) [18].



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.

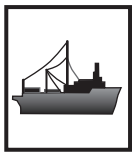


Resilience

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

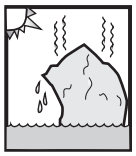
Traditional and Cultural Importance

None reported



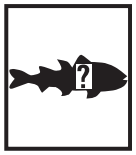
Commercial Fisheries

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.*

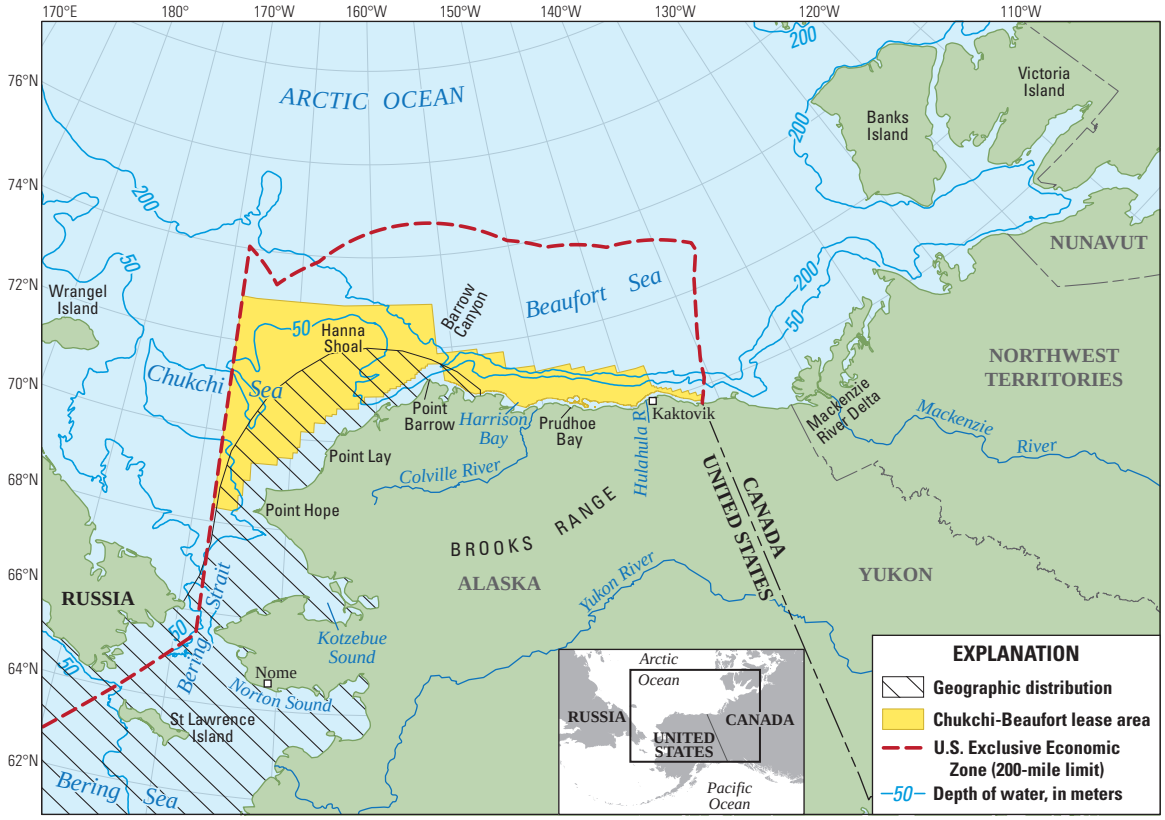
Ecological Role: Antlered Sculpin are common in the U.S. Chukchi Sea and uncommon in the U.S. Beaufort Sea. Their respective roles in marine ecosystem dynamics, although unknown, probably are more significant than many other species, and correspond to this abundance pattern.

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].

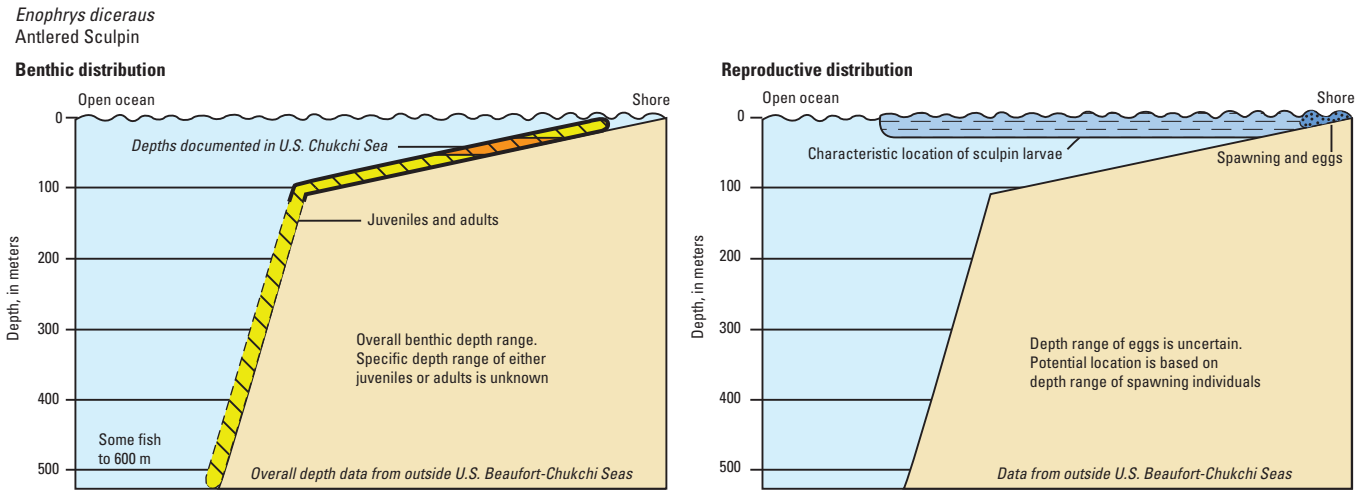
Antlered Sculpin
Enophrys diceraus



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 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].

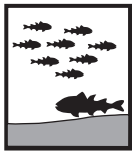
Depth Range: *Documented at 26–50 m in U.S. Chukchi Sea* [7, 12]. In other areas, primarily between 2–120 m deep [3, 13], but has been reported to 600 m in Peter the Great Bay, Sea of Japan [13]. Depth range of larvae and juveniles is unknown. Spawning occurs in nearshore waters as shallow as 2–15 m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



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

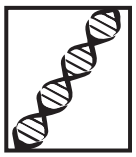
Habitats and Life History

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

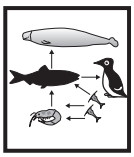
Mode—Separate sexes; oviparous [17].

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].

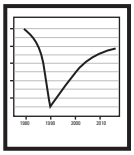
Trophic level—3.26 (standard error 0.43) [19].



Biological Interactions

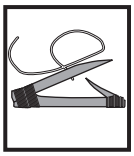
Predation—Off Kamchatka Peninsula, Russia, both great and plain sculpins eat this species [20]. At Tee Harbor, southeastern Alaska, commonly eaten by river otters [21].

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].

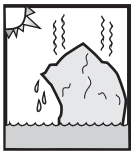


Traditional and Cultural Importance

None reported.

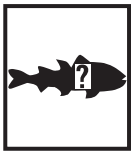
Commercial Fisheries

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

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.

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

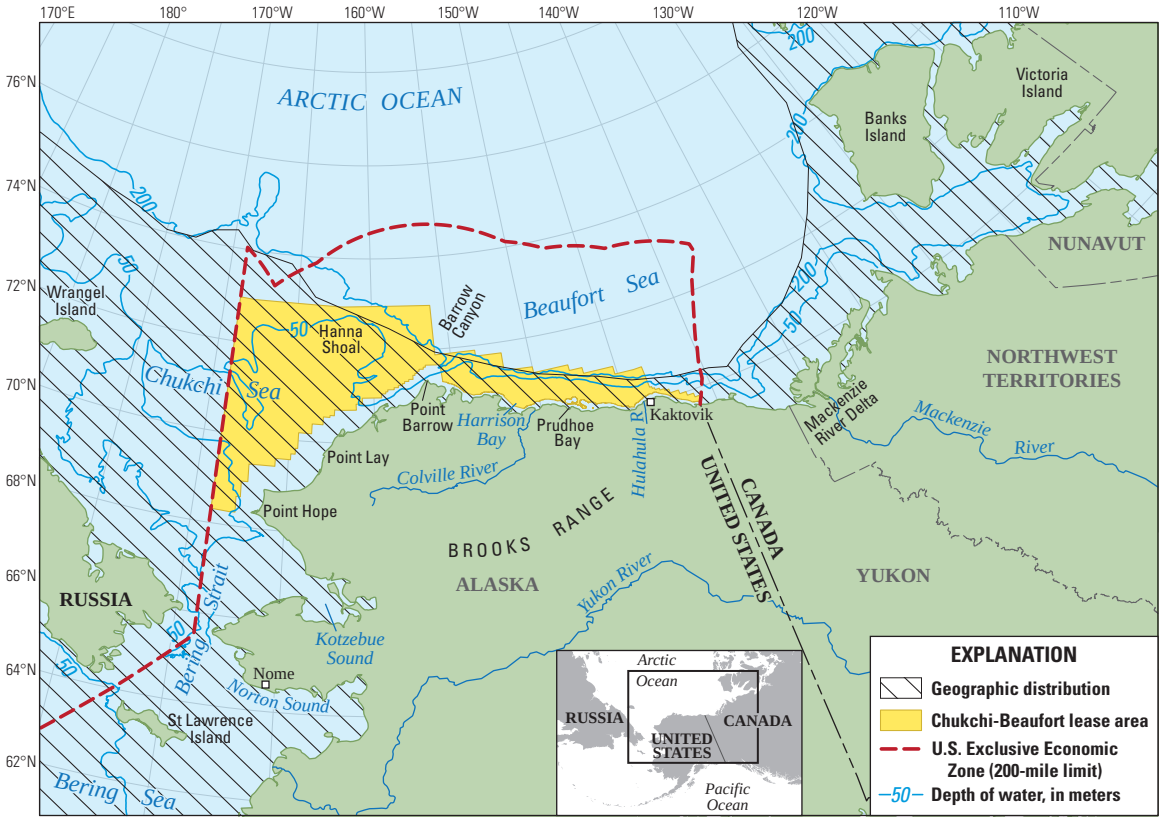
Ecological Role: Largely unknown. Current information about the precise occurrence in the U.S. Chukchi and Beaufort Seas is limited, although it appears to be one of the more common benthic fish species in the Arctic Ocean [1, 2]. Information regarding most of the biology and ecology of this species 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.

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].

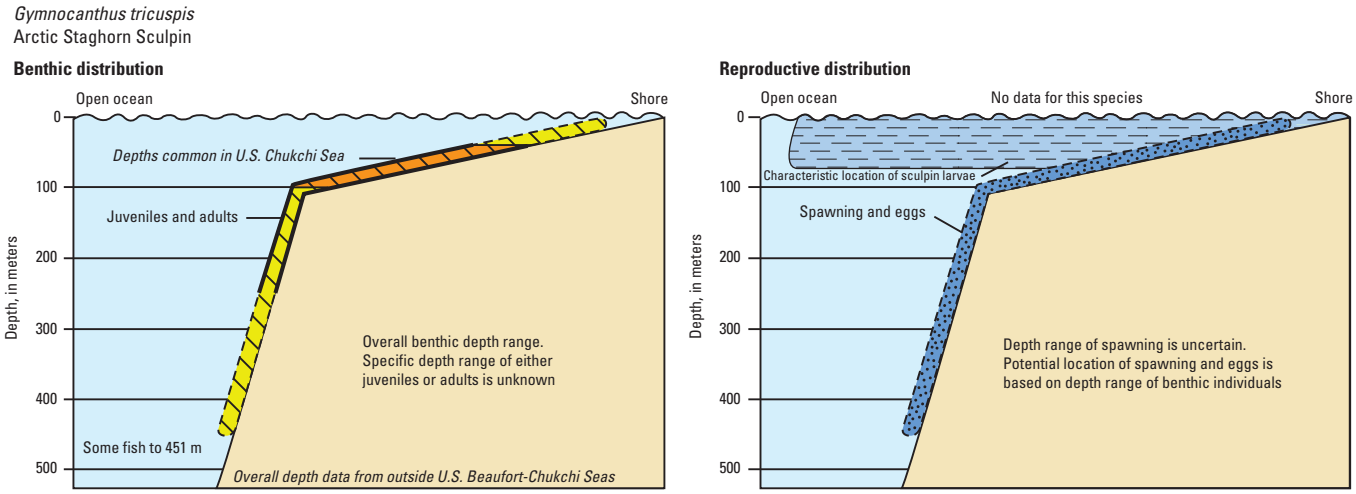
Arctic Staghorn Sculpin
Gymnocanthus tricuspis



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.

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].

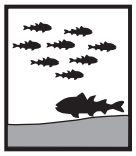
Depth Range: *In northern U.S. Chukchi Sea common from 40–100 m. One juvenile taken in midwaters at 37 m to surface and one at 81 m to surface. A few juveniles and larvae documented from midwaters with maximum tow depths varying from 51 to 29 m* [11]. Elsewhere, 2–451 m, but uncommon less than 10–20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



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

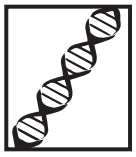
Habitats and Life History

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.

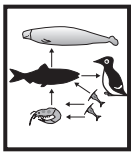


Populations or Stocks

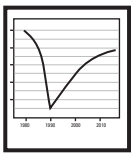
There have been no studies.

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].

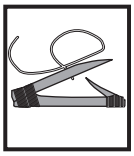
Food and Feeding
Food items—*In U.S. Chukchi Sea, prey varies with site, but crustaceans (for example, amphipods, cumaceans, and hermit crabs), polychaetes, clam siphons, echiurioids, gastropods, bivalves, and larvaceans are all important* [24]. In general, benthic and water column invertebrates [24,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

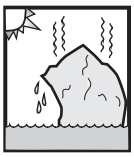


Resilience
Medium, minimum population doubling time: 1.4–4.4 years (t_m=2–4; t_{max}=9; Fecundity=3,030) [26].

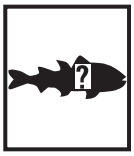


Traditional and Cultural Importance
None reported.

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

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.

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

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.

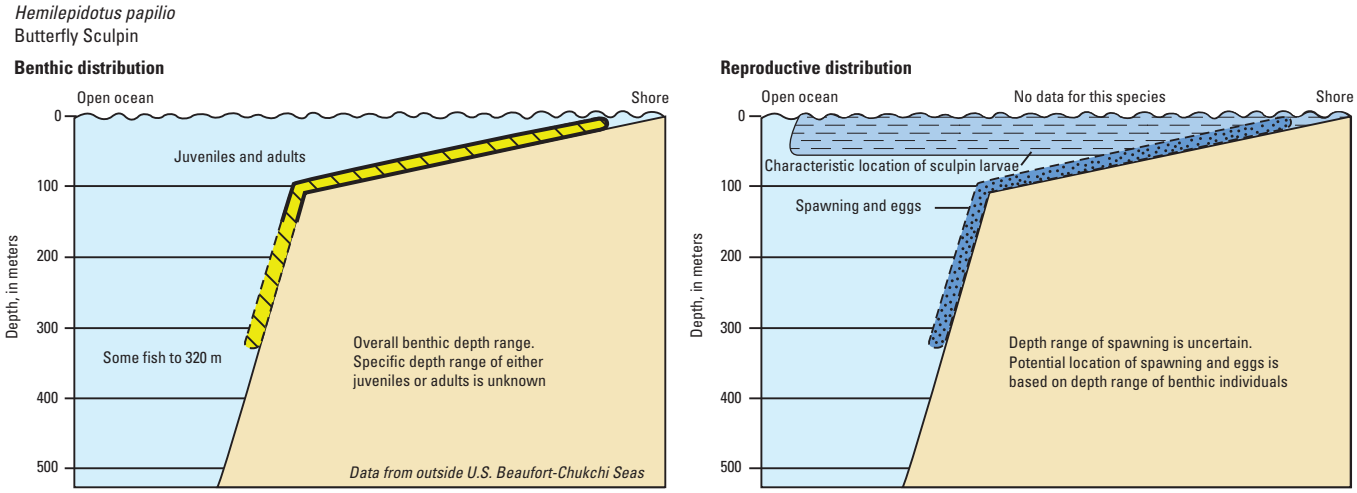
Range: *U.S. Chukchi Sea as far north as 69°55'N, 168°00'W* [3]. Elsewhere in Alaska, eastern Bering Sea and along Aleutian Islands west to Buldir Island. Worldwide, from western Bering Sea to Sea of Okhotsk and Sea of Japan off Hokkaido, Japan [3].

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].

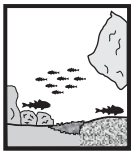
Base modified from USGS and other digital data. U.S.-Russia Maritime Boundary follows the EEZ/200-mile limit line, western edge. Coordinate reference system: projection, Lambert Azimuthal Equal Area; latitude of origin, 75.0°; horizontal datum, North American Datum of 1983.

Geographic distribution of 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].

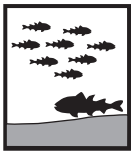
Larvae—Size at hatching: Unknown. Size at juvenile transformation: Unknown. Days to juvenile transformation: Unknown. Habitat: Likely pelagic. Larvae of the related *Hemilepidotus hemilepidotus* are found over continental shelf, slope, and in oceanic waters [12].

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].



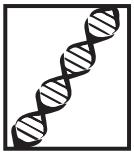
Behavior

Diel—Unknown.

Seasonal—Unknown.

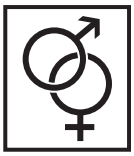
Reproductive—Unknown.

Schooling—Unknown.



Populations or Stocks

There have been no studies.



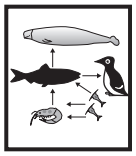
Reproduction

Mode—Separate sexes; oviparous [15].

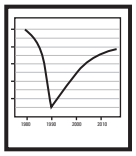
Spawning season—July in Bering Sea [16].

Fecundity—Unknown.

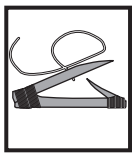
Food and Feeding
Food items—In eastern Bering Sea, primarily benthic and epibenthic prey such as Tanner crabs, gammarid amphipods, young Walleye Pollock, and ostracods [17].
Feeding—Unknown.
Trophic level—4.0 [18].



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

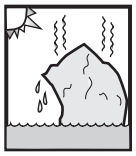


Resilience
Low, minimum population doubling time: 4.5–14 years (Preliminary *K* or Fecundity) [19].

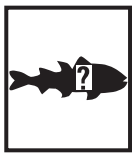


Traditional and Cultural Importance
None reported. Occasionally used as food by Alaska Natives on the Pribilof Islands. [20].

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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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. [6]

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Tokranov, A.M., 1981, Distribution of sculpins (Pisces, Cottidae) on the west Kamchatka shelf in summer: Zoologicheskii Zhurnal, v. 60, no. 2, p. 229–237. [9]

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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*.

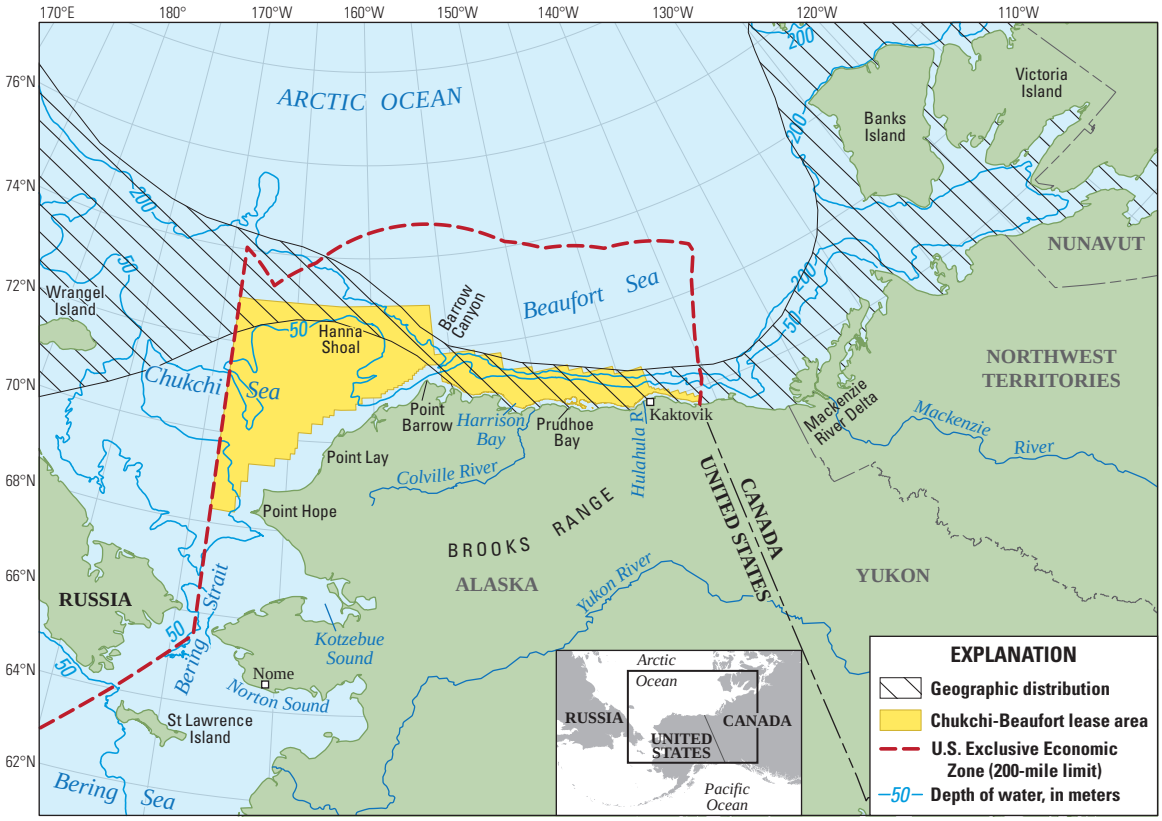
Ecological Role: Twohorn Sculpin are uncommon in the U.S. Chukchi and Beaufort Seas. Their ecological role in benthic ecosystems, though not fully known, is thought to be minor with respect to predation and energy flows.

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].

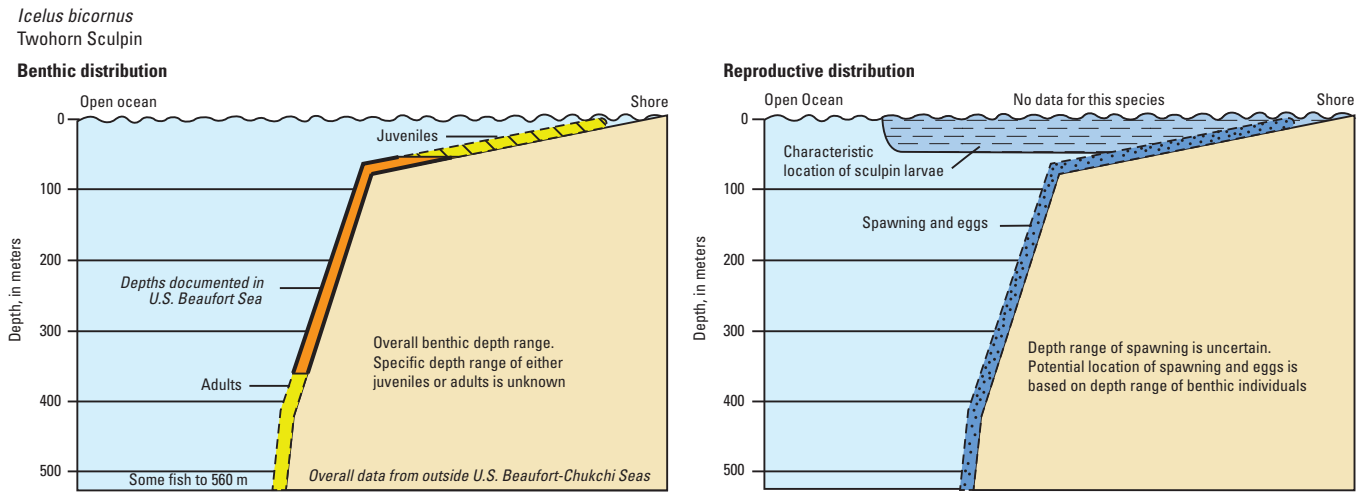
Twohorn Sculpin
Icelus bicornis



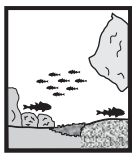
Base modified from USGS and other digital data. U.S.-Russia Maritime Boundary follows the EEZ/200-mile limit line, western edge. Coordinate reference system: projection, Lambert Azimuthal Equal Area; latitude of origin, 75.0°; horizontal datum, North American Datum of 1983.

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].

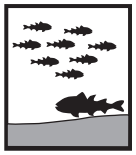
Larvae—Size at hatching: Unknown. Size at juvenile transformation: Unknown. Days to juvenile transformation: Unknown. Habitat: Likely pelagic based on life history patterns of many other members of this family [1].

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

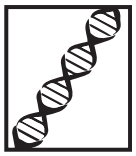
Diel—Unknown.

Seasonal—Unknown.

Reproductive—Unknown.

Schooling—Unknown.

Feeding—Unknown.



Populations or Stocks

There have been no studies.

Reproduction

Mode—Separate sexes; oviparous [9].

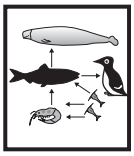
Spawning season—August –October [5].

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].

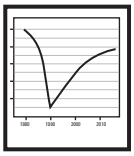
Trophic level—3.13 standard error 0.35 [10].



Biological Interactions

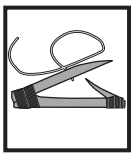
Predators—Unknown.

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].

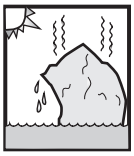


Traditional and Cultural Importance

None reported.

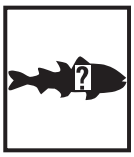
Commercial Fisheries

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.

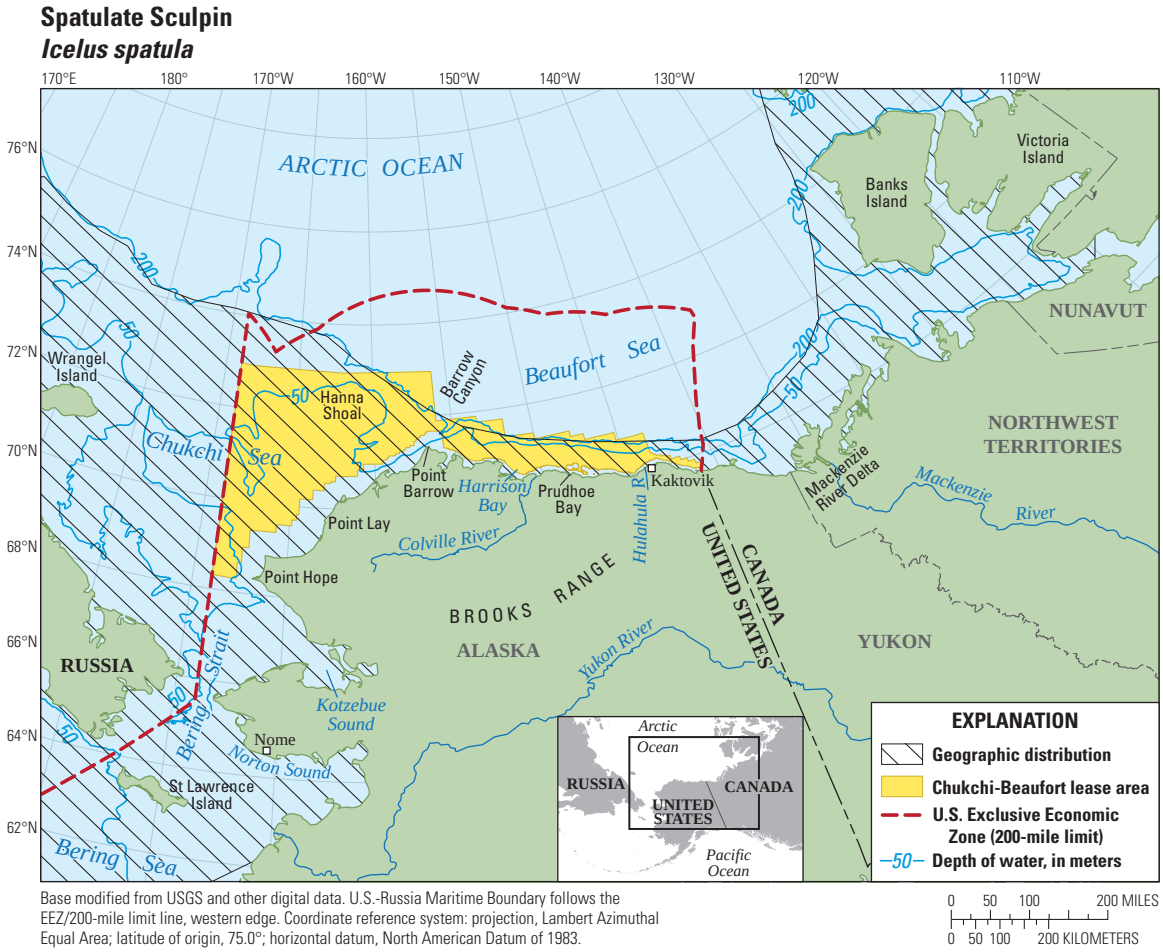
Colloquial Name: *None within U.S. Chukchi and Beaufort Seas*.

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].

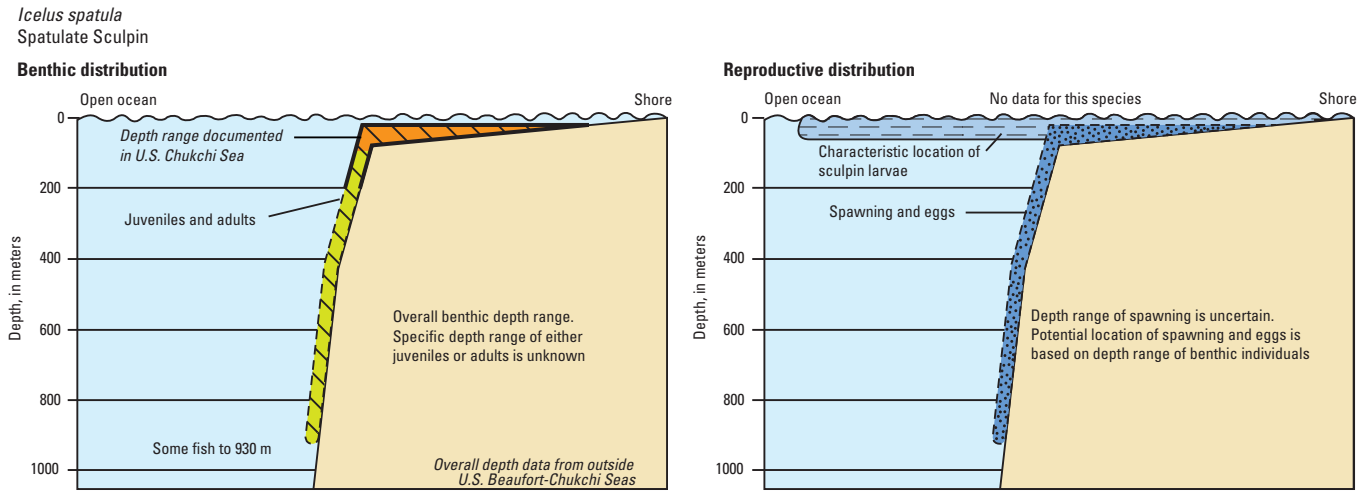
Relative Abundance: *Common in U.S. Chukchi and Beaufort Seas* [1–4, 7]. Elsewhere, common in Sea of Okhotsk, along Kuril Islands and Kamchatka Peninsula, Russia, and in Bering Sea [1, 3, 8, 9].



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 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].

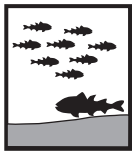
Depth Range: *In U.S. Chukchi Sea, documented in 100 m or less* [3]. Elsewhere, 12–930 m [10], mainly shallower than 200 m [11]. Larvae of *Icelus* sp. are abundant in surface waters in Gulf of Alaska [12]. *In U.S. Chukchi Sea, one Icelus sp. juvenile was found in midwaters between 37 m and the surface*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



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

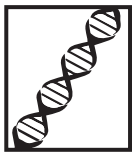
Habitats and Life History

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].



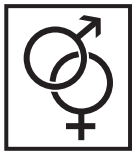
Behavior

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.



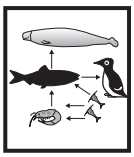
Reproduction

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].

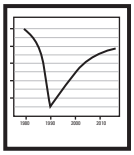
Trophic level—3.92 standard error 0.67 [17].



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

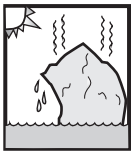
Medium, minimum population doubling time: 1.4–4.4 years (Preliminary *K* or Fecundity) [17].

Traditional and Cultural Importance

None reported.

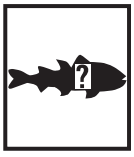
Commercial Fisheries

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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Belligerent Sculpin (*Megalocottus platycephalus*)
(Pallas, 1814)

Family Cottidae

Belligerent Sculpin (*Megalocottus platycephalus*). Photograph by Doyne W. Kessler, National Marine Fisheries Service.

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

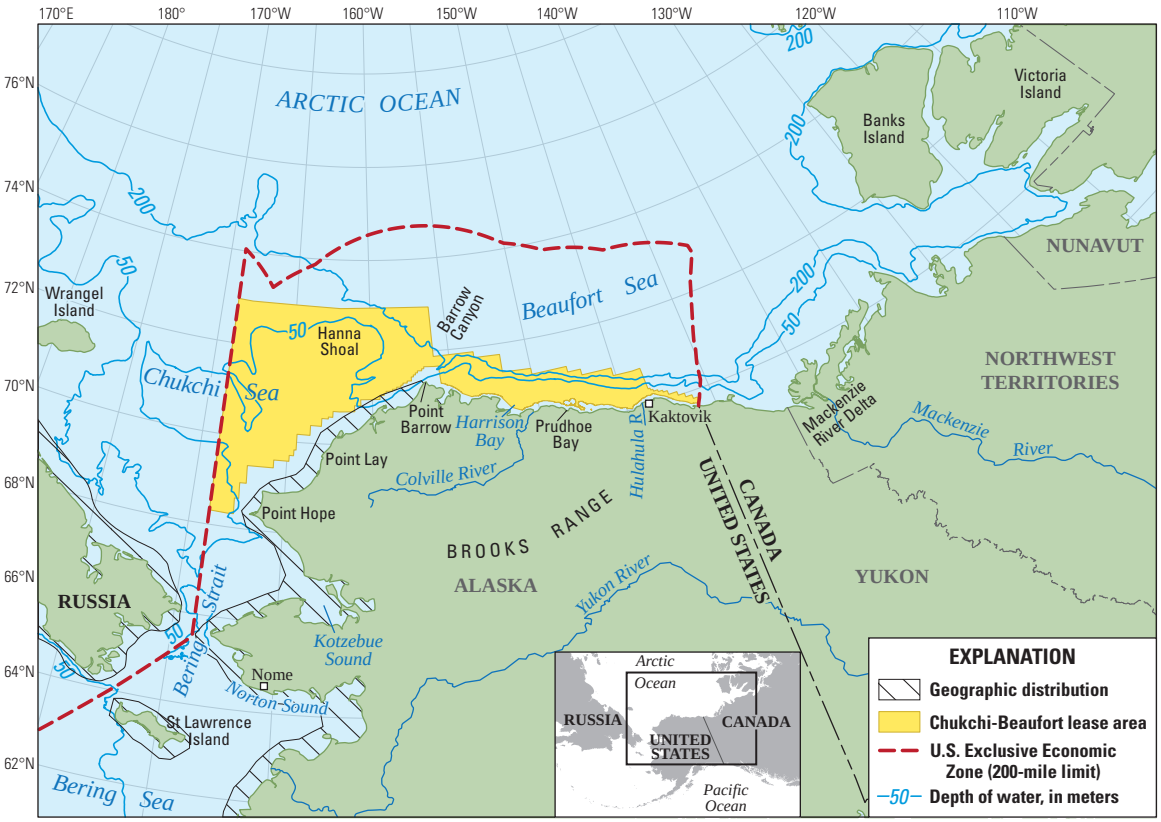
Ecological Role: Unknown but likely minimal, especially in the U.S. Beaufort Sea.

Physical Description/Attributes: Olive-brown or gray-brown with white or yellow markings. Lower sides have a series of light spots, the belly is white, the underside of head dark, and all fins are spotted and barred. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 475) [1]. Swim bladder: Absent [1]. Antifreeze glycoproteins in blood serum: Unknown.

Ranges: *U.S. Chukchi Sea to western U.S. Beaufort Sea off Point Barrow, Alaska, at about 71°22'N, 156°19'W* [2]. Elsewhere in Alaska, in eastern Bering Sea south to Herendeen Bay [1]. Worldwide, from Sea of Japan at Peter the Great Bay to Sea of Okhotsk and western Bering Sea [1, 3–5].

Relative Abundance: *Common in eastern U.S. Chukchi Sea* [7] *and rare in U.S. Beaufort Sea* [1, 2]. Common in Sea of Japan, Sea of Okhotsk, and parts of Bering Sea [3–5].

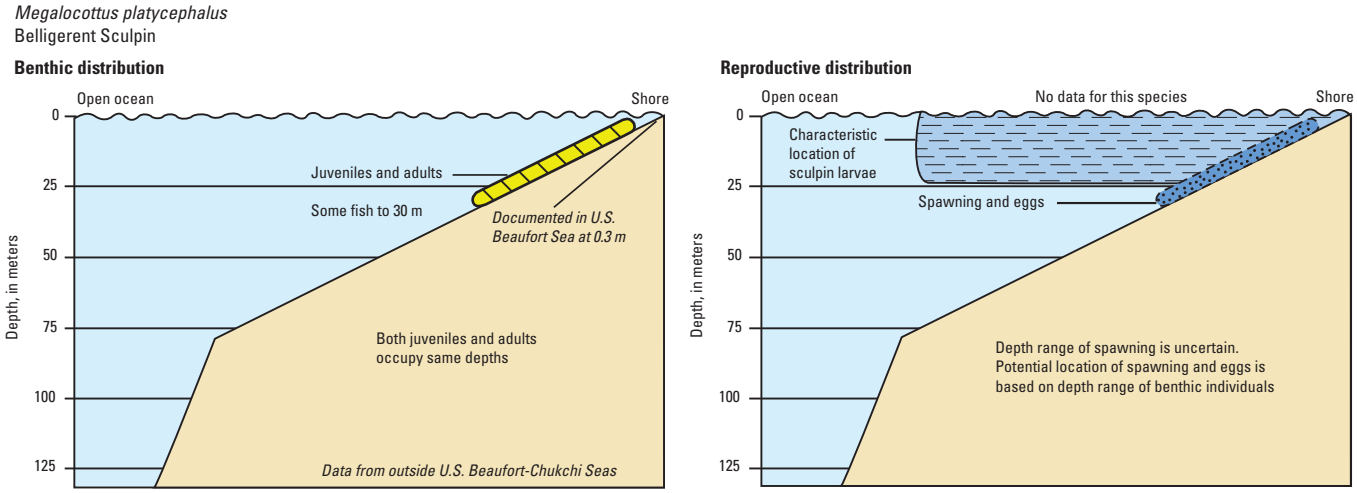
Belligerent Sculpin
Megalocottus platycephalus



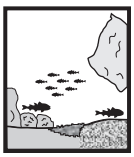
Base modified from USGS and other digital data. U.S.-Russia Maritime Boundary follows the EEZ/200-mile limit line, western edge. Coordinate reference system: projection, Lambert Azimuthal Equal Area; latitude of origin, 75.0°; horizontal datum, North American Datum of 1983.

Geographic distribution of Belligerent Sculpin (*Megalocottus platycephalus*) within Arctic Outer Continental Shelf Planning Areas [6] based on review of published literature and specimens from historical and recent collections [1, 2, 7].

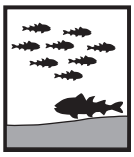
Depth Range: *Documented in U.S. Beaufort Sea at 0.3 m* [2]. Juveniles and adults are found from shallow subtidal to 40 m [1, 7, 9].



Benthic and reproductive distribution of Belligerent Sculpin (*Megalocottus platycephalus*).



Habitats and Life History
Eggs—Size: Unknown. Time to hatching: Unknown. Habitat: Benthic [9].
Larvae—Size at hatching: Unknown. Size at juvenile transformation: Unknown. Days to juvenile transformation: Unknown. Habitat: Pelagic [9].
Juveniles—Age and size: Unknown. Habitat: Benthic, shallow nearshore waters [9].
Adults—Age and size at first maturity: Unknown. Maximum age: Unknown. Maximum size: 42 cm TL [5]. Habitat: Benthic, shallow coastal waters, estuaries, and occasionally lower parts of rivers [3, 9].
Substrate—Unknown.
Physical/chemical—Temperature: 2.6–12.6 °C [7]. Salinity: Brackish to marine waters [9].

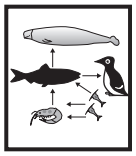


Behavior
Diel—Unknown. **Seasonal**—Along western Kamchatka Peninsula (Russia) coast, lives in coastal waters in winter and spring and ascends well up estuaries and short distances up rivers in summer and fall [5].
Reproductive—Unknown.
Schooling—Unknown.
Feeding—Unknown.

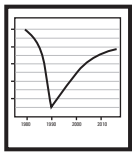
Populations or Stocks
There have been no studies.

Reproduction
Mode—Separate sexes; oviparous [10].
Spawning season—Unknown.
Fecundity—Unknown.

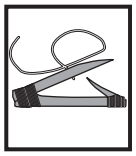
Food and Feeding
Food items—Off western Kamchatka Peninsula, smaller fish feed on algae, and crustaceans such as copepods, cumaceans, amphipods, and mysids. Larger fish feed on similar prey as well as small fishes [11].
Trophic level—4.08 standard error 0.70 [12].



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

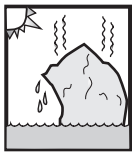


Resilience
Low, minimum population doubling time: 4.5–14 years (assuming fecundity = 10–100) [12].

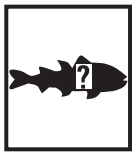


Traditional and Cultural Importance
Historically, an important subsistence species in northeastern Bering Sea and *U.S. Chukchi Sea* [13, 14].

Commercial Fisheries
Currently, Belligerent Sculpin are not commercially harvested.



Potential Effects of Climate Change
A predominantly Boreal Pacific species [2] that appears to be common in parts of the Bering Sea and uncommon in the U.S. Chukchi Sea. Belligerent Sculpin would be expected to increase in abundance in the U.S. Chukchi Sea and potentially the Beaufort Sea as waters warm.



Areas for Future Research [B]
Little is known about the biology and ecology of this species from the 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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Brightbelly Sculpin (*Microcottus sellaris*)
(Gilbert, 1896)

Family Cottidae

Brightbelly Sculpin (*Microcottus sellaris*). Photograph by Doyne W. Kessler, National Marine Fisheries Service.

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

Ecological Role: Unknown in benthic ecosystems over the continental shelf.

Physical Description/Attributes: Purplish body spotted and mottled with either black and white or with red or black. Body has two or more white bars and bright yellow belly. Pelvic fins have black or red spots along rays. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 483) [1]. Swim bladder: Absent [1]. Antifreeze glycoproteins in blood serum: Unknown.

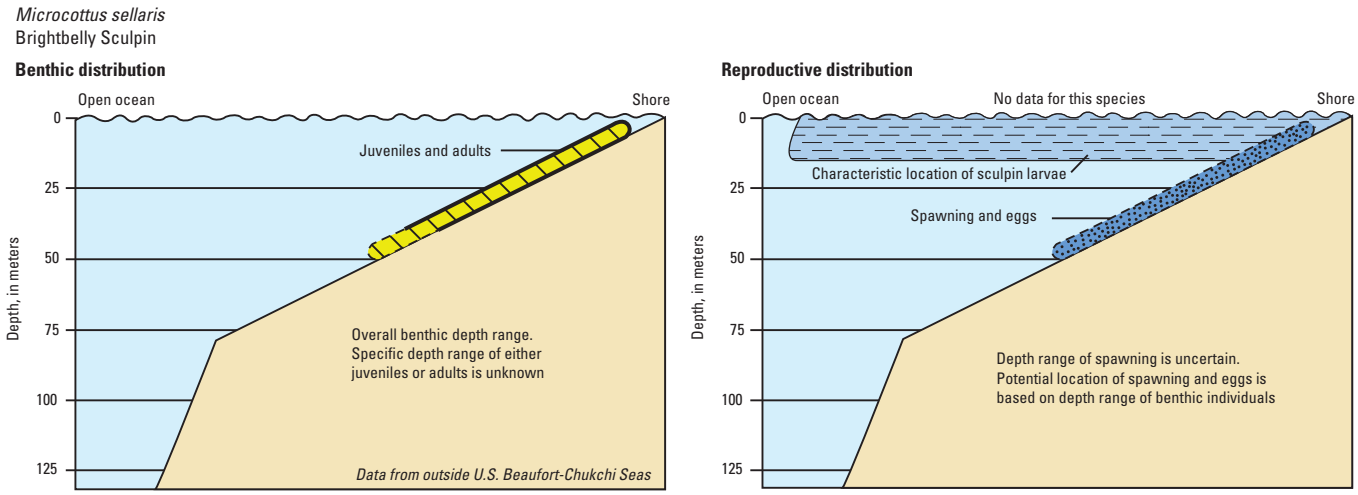
Ranges: *Southern U.S. Chukchi Sea* [2–4]. Elsewhere in Alaska, to southern Bering Sea and Commander–Aleutian Islands chain. Worldwide: From Gulf of Anadyr southward to the northern Sea of Japan, southern Okhotsk Sea, and Kuril Islands, Russia [1].

Relative Abundance: *Rare in U.S. Chukchi Sea* [2–4]; absent from the U.S Beaufort Sea. Common as far north as Norton Sound, eastern Bering Sea and southward to Sea of Japan and Kamchatka Peninsula, Russia [6–8].

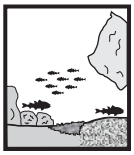
Base modified from USGS and other digital data. U.S.-Russia Maritime Boundary follows the EEZ/200-mile limit line, western edge. Coordinate reference system: projection, Lambert Azimuthal Equal Area; latitude of origin, 75.0°; horizontal datum, North American Datum of 1983.

Geographic distribution of Brightbelly Sculpin (*Microcottus sellaris*) within Arctic Outer Continental Shelf Planning Areas [5] based on review of published literature and specimens from historical and recent collections [1, 3, 4].

Depth Range: Coastal, shallow waters down to 50 m, most often from shallow subtidal to about 40 m [1, 6, 9–11]. Some juveniles are found in nearshore waters [6].

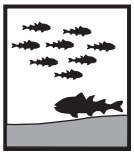


Benthic and reproductive distribution of Brightbelly Sculpin (*Microcottus sellaris*).



Habitats and Life History

Eggs—Size: Unknown. Time to hatching: Unknown. Habitat: Likely benthic, based on other members of this family [1, 9].
Larvae—Size at hatching: Unknown. Size at juvenile transformation: Unknown. Days to juvenile transformation: Unknown. Habitat: Likely pelagic, based on other members of this family [1].
Juveniles—Age and size: Unknown. Habitat: Likely benthic, based on other members of this family [1, 9]. Some juveniles are found in nearshore eelgrass beds [6].
Adults—Age and size at first maturity: Unknown. Maximum age: Unknown. Maximum size: 17 cm TL [15]. Habitat: Likely benthic, based on other members of this family [1, 9].
Substrate—Unknown.
Physical/chemical—Temperature: 2–10 °C in summer off western Kamchatka Peninsula, primarily 6–8 °C [7]. Salinity: Marine and estuarine fish [9].



Behavior

Diel—Unknown.
Seasonal—Unknown.
Reproductive—Unknown.
Schooling—Unknown.
Feeding—At night may move off bottom to feed [6].

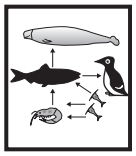
Populations or Stocks

There have been no studies.

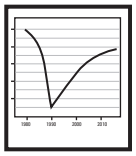
Reproduction

Mode—Separate sexes; oviparous [12].
Spawning season—Unknown.
Fecundity—Unknown.

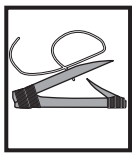
Food and Feeding
Food items—Juveniles living in eelgrass beds in eastern Bering Sea feed on polychaetes, amphipods and other crustaceans, snails, eelgrass, and fishes [6, 13].
Trophic level—3.4 standard error 0.53 [14].



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

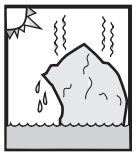


Resilience
Medium, minimum population doubling time: 1.4–4.4 years (Preliminary *K* or Fecundity) [14].

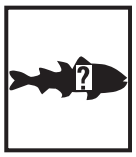


Traditional and Cultural Importance
None reported.

Commercial Fisheries
Currently, Brightbelly Scuplin are not commercially harvested.



Potential Effects of Climate Change
As a predominantly Boreal Pacific species that appears to be common in the eastern Bering Sea and relatively rare in the Chukchi Sea, Brightbelly Sculpin could be expected to increase in abundance in the U.S. Chukchi Sea and perhaps to expand their distribution into the Beaufort Sea as waters warm.



Areas for Future Research [B]
Little is known about the biology and ecology of this species from the 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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Plain Sculpin (*Myoxocephalus jaok*)
(Cuvier, 1829)

Family Cottidae

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

Ecological Role: Plain Sculpin have been only rarely observed. There ecological significance is suspected to be of minor importance in nearshore and shelf habitats.

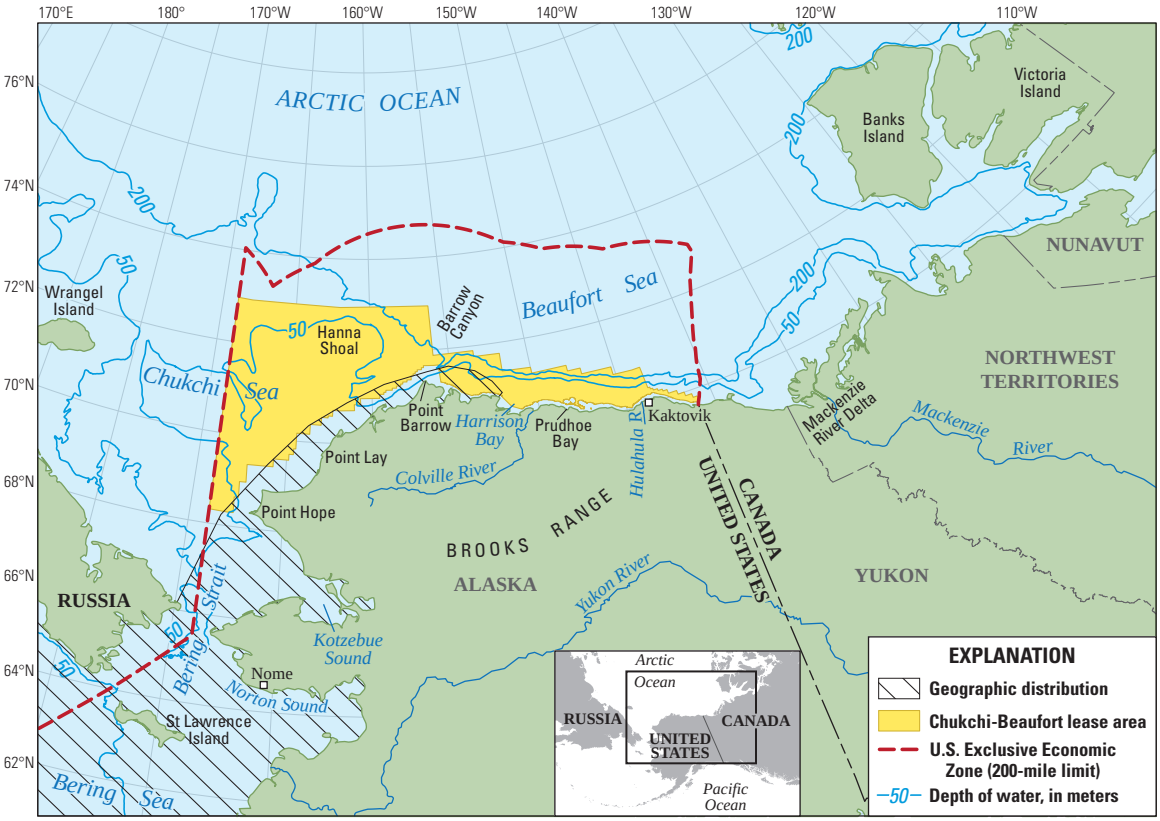
Physical Description/Attributes: Gray-brown body covered in small black spots. Lower sides have white spots. Fins are barred and spotted. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 481) [1]. Swim bladder: Absent [1]. Antifreeze glycoproteins in blood serum: Unknown.

Plain Sculpin (*Myoxocephalus jaok*) 133 mm, northeastern Chukchi Sea, 2007. Photograph by C.W. Mecklenburg, Point Stephens Research.

Ranges: *U.S. Chukchi Sea and western Beaufort Sea eastward to at least 71°N, 153°W* [1, 2]. Elsewhere in Alaska, throughout Bering Sea to eastern Gulf of Alaska at Limestone Inlet [1] and Glacier Bay [3]. Worldwide, from Sea of Japan off North Korea to Sea of Okhotsk [1].

Relative Abundance: *Uncommon in U.S. Chukchi Sea and western Beaufort Sea* [2, 5]. Common throughout eastern Bering Sea as far north as Norton Sound and southwards to about Kodiak Island, Alaska, and westwards to Sakhalin Island (Russia), Sea of Okhotsk [6–10].

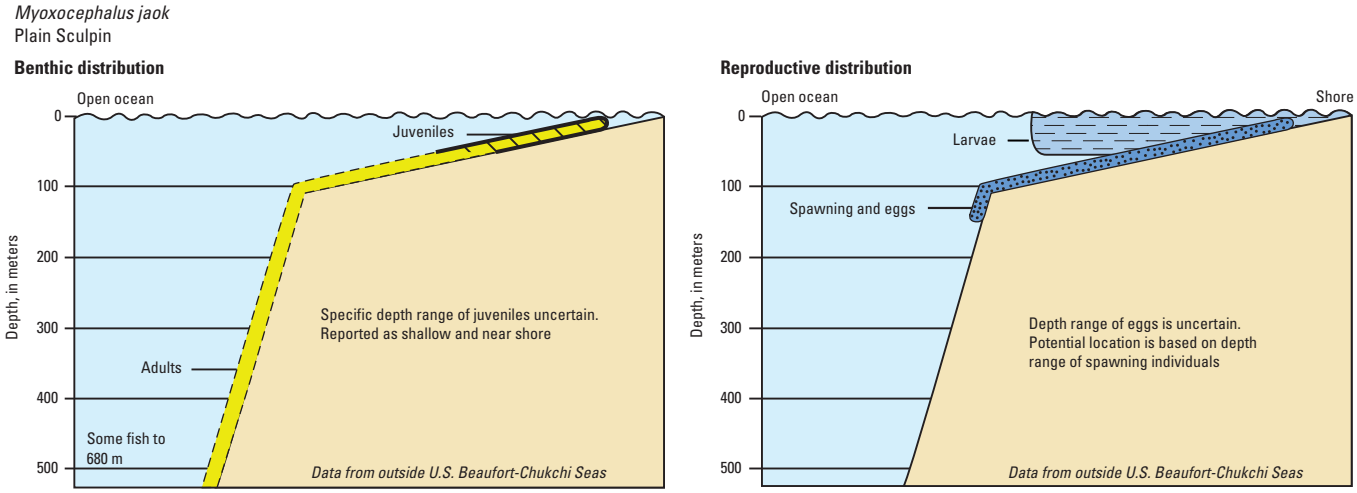
Plain Sculpin
Myoxocephalus jaok



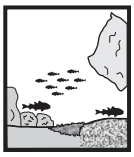
Base modified from USGS and other digital data. U.S.-Russia Maritime Boundary follows the EEZ/200-mile limit line, western edge. Coordinate reference system: projection, Lambert Azimuthal Equal Area; latitude of origin, 75.0°; horizontal datum, North American Datum of 1983.

Geographic distribution of Plain Sculpin (*Myoxocephalus jaok*), within Arctic Outer Continental Shelf Planning Areas [4] based on review of published literature and specimens from historical and recent collections [1, 2, 5].

Depth Range: Intertidal to 680 m, mainly less than depth of 50 m off North America [6] and deeper than 5 m in western Pacific Ocean [11]. Larvae live over coastal and continental shelf waters [12]. Juveniles are in shallow nearshore waters [11, 13]. Spawning has been noted at nearshore at 6–8 m and on mid-continental shelf at 80–130 m [14].

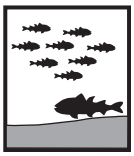


Benthic and reproductive distribution of Plain Sculpin (*Myoxocephalus jaok*).



Habitats and Life History

Eggs—Size: 1.9–2.4 mm [14, 15]. Time to hatching: Unknown. Habitat: Benthic and adhesive [14].
Larvae—Size at hatching: Unknown. Size at juvenile transformation: 1.3–2.0 cm SL [13, 16]. Days to juvenile transformation: About two months in Peter the Great Bay [15]. Habitat: Pelagic [12].
Juveniles—Age and size: Unknown. Habitat: Benthic [1, 6].
Adults—Age and size at first maturity: Few males mature at 3 years and most by 6 years. Females mature later, some as early as 5 years and most by 8 years [14, 15]. Maximum age: At least 15 years in Sea of Japan and western Pacific Ocean. Females may live longer than males [14, 15]. Maximum size: 70 cm TL [17]. Females grow faster than males [14, 15]. Habitat: Benthic [1, 6].
Substrate—Sand and mud bottoms [1].
Physical/chemical—Temperature: -1.9–13.1 °C [2]. Off Kamchatka Peninsula, most common at 2–4 °C [17]. Salinity: Marine waters [18–20].



Behavior

Diel—Unknown.
Seasonal—Young-of-the-year settle into shallow nearshore waters as early as May [13]. Some adults occupy shallower shelf waters in summer and retreat to continental slope during winter [17, 21].
Reproductive—Females lay eggs in shallow waters on plants and mussel clusters. Males guard nests until the ova hatch [14]. Schooling: Unknown.
Feeding—Off Kamchatka Peninsula, fish feed most heavily during summer months [22].

Populations or Stocks

There have been no studies.

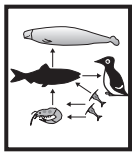
Reproduction

Mode—Separate sexes; oviparous [23].
Spawning season—December–March [14, 15, 24].
Fecundity—From 25,411–147,029 eggs, however it is unclear if all eggs are deposited at one time [14].

Food and Feeding

Food items—A wide range of benthic and water column prey. Fishes and crabs often are most important prey, but in eastern Bering Sea, shrimps, hermit crabs, brittle stars, polychaetes, clams, squids, copepods, mysids, gammarid amphipods, and euphausiids also are consumed [22, 25, 26].

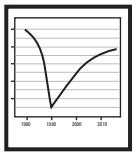
Trophic level—4.2 standard error 0.73 [27].



Biological Interactions

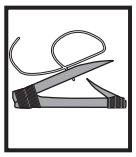
Predators—Mostly unknown. Great Sculpins [22] and probably river otters [28].

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



Resilience

Low, minimum population doubling time: 4.5–14 years (assuming fecundity = 10–100) [27].

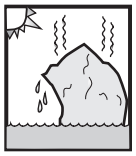


Traditional and Cultural Importance

Historically, this species was caught as a food fish in the northeastern Bering Sea and southeastern U.S. Chukchi Sea [29]. Like other nearshore species, they were taken mainly by elderly men and women who were not able to go great distances to procure other food [30].

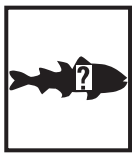
Commercial Fisheries

Currently, Plain Sculpin are not commercially harvested.



Potential Effects of Climate Change

A predominantly Boreal Pacific species that appears to be common in the eastern Bering Sea but uncommon in the Chukchi Sea. Plain Sculpin could be expected to increase in abundance in the Chukchi Sea and perhaps to expand their range into the Beaufort Sea.



Areas for Future Research [B]

Little is known about the biology and ecology of this species from the 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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Great Sculpin (*Myoxocephalus polyacanthocephalus*)
(Pallas, 1814)

Family Cottidae

Great Sculpin (*Myoxocephalus polyacanthocephalus*) 146 mm, Semidi Islands, western Gulf of Alaska, 2007. Photograph by C.W. Mecklenburg, Point Stephens Research.

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

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

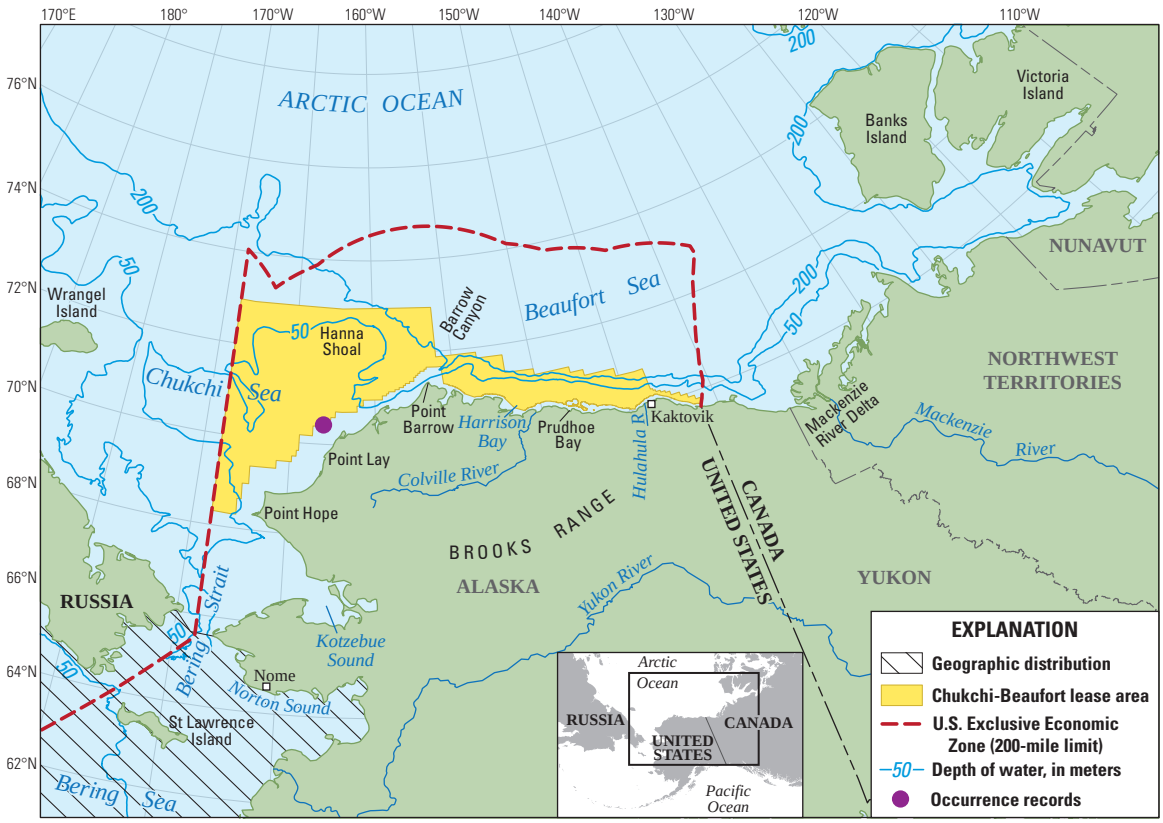
Ecological Role: Minor role. Great Sculpin are rare within the U.S. Chukchi Sea and absent from the Beaufort Sea.

Physical Description/Attributes: Brown or gray with three darker saddles. Belly and lower sides have small white spots, and fins are barred and spotted. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 482) [1]. Swim bladder absent [1]. Antifreeze glycoproteins in blood serum: Unknown. Unlike that of Arctic and shorthorn sculpins, blood serum is clear, rather than blue or green [2].

Ranges: *One record from northeastern Chukchi Sea near Icy Cape at 70°20'N, 163°06'W* [3]. Elsewhere in Alaska, throughout Bering Sea, Aleutian Islands and entire southeastern coast. Worldwide, in western Pacific Ocean, Gulf of Andyr to sea of Okhotsk Sea and eastern Sea of Japan and in eastern Pacific Ocean to southern Puget Sound, Washington [4–7].

Relative Abundance: *Rare in eastern U.S. Chukchi Sea* [3, 9, 10]. Elsewhere in Alaska, uncommon in northern most Bering Sea [10, 11] and common along Aleutian Islands, in eastern Bering Sea, and to at least southeastern Alaska [6, 7]. Worldwide, common in Sea of Japan eastwards along eastern Kuril Island and Kamchatka Peninsula, Russia [4, 5].

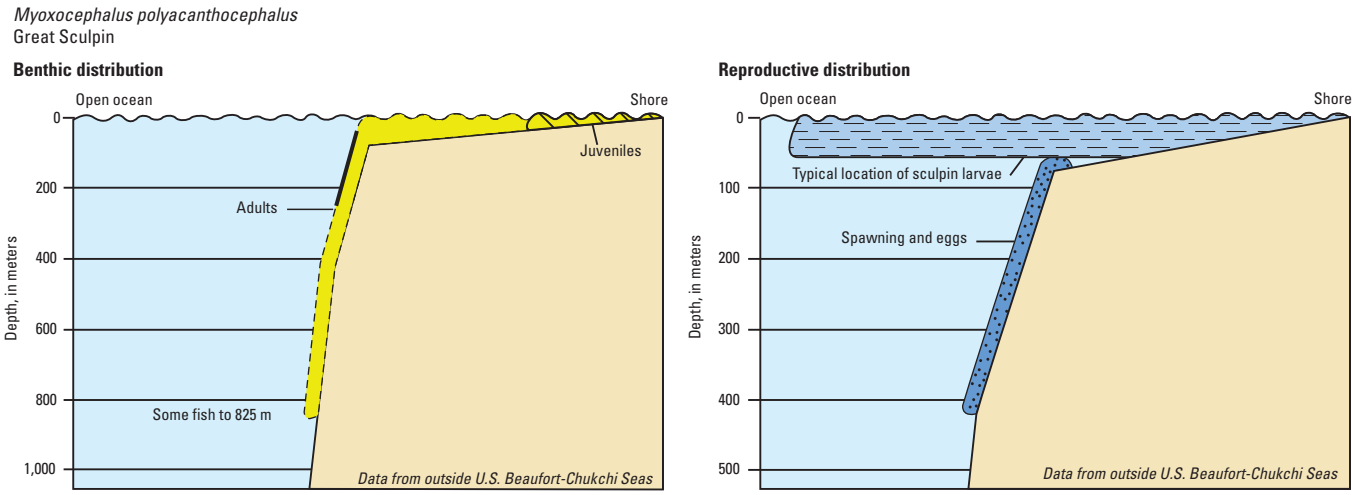
Great Sculpin
Myoxocephalus polyacanthocephalus



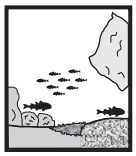
Base modified from USGS and other digital data. U.S.-Russia Maritime Boundary follows the EEZ/200-mile limit line, western edge. Coordinate reference system: projection, Lambert Azimuthal Equal Area; latitude of origin, 75.0°; horizontal datum, North American Datum of 1983.

Geographic distribution of Great Sculpin (*Myoxocephalus polyacanthocephalus*) within Arctic Outer Continental Shelf Planning Areas [8] based on review of published literature and specimens from historical and recent collections [1, 3, 9].

Depth Range: Intertidal to 825 m, primarily 20–250 m [12–17]. Adults occasionally taken in subtidal nearshore waters [18]. Larvae are found over coastal and continental shelf waters [19]. Juveniles usually 20 m or less [7, 20]. Spawning occurs on lower continental shelf and upper continental slope [4, 21]. Found spawning on slope at depths of 415 m off Sakhalin Island, Russia [21].

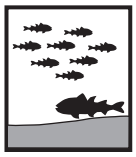


Benthic and reproductive distribution of Great Sculpin (*Myoxocephalus polyacanthocephalus*).



Habitats and Life History

Eggs—Size: Unknown. Time to hatching: Unknown. Habitat: Benthic and adhesive [4].
Larvae—Size at hatching: As small as 1.1 cm SL [22]. Size at juvenile transformation: Unknown. Days to juvenile transformation: Unknown. Habitat: Pelagic [19, 23].
Juveniles—Age and size: Unknown. Habitat: Benthic, neritic [20, 24], complex habitats such as rocks, cobbles, eelgrass, and other aquatic plants, and over soft sea floors [5–7, 20, 25, 26].
Adults—Age and size at first maturity: In Sea of Okhotsk, males first mature at 5 years (33–34 cm TL), fifty percent at 6 years (40 cm TL), and all at 8 years (50 cm TL). Females mature when older and larger, first at 7 years (49–50 cm), fifty percent at 8 years (55 cm) and all at 9 years (65 cm TL). Maximum age: 16 years, off North America [27]. Maximum size: 76 cm TL [1] and more than 9 kg [12, 28]. Habitat: Benthic, neritic to oceanic [12–14, 16, 17]. Complex habitats, such as rocks, cobbles, eelgrass, and other aquatic plants as well as soft sea floors [5–7, 20, 25, 26].
Substrate—Rocks, cobbles, eelgrass, other aquatic plants and soft sea floors [5–7, 20, 25, 26].
Physical/chemical—Temperature: -0.5–12 °C, most abundant in 8 °C or less [4, 7, 12, 29, 30]. In Sea of Okhotsk spawning occurs between 0.8 and 1.9 °C [4, 21]. Salinity: Marine, or slightly estuarine waters [4, 7, 12, 29, 30].



Behavior

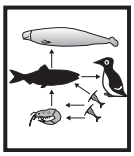
Diel—Unknown.
Seasonal—Beginning in May, young-of-the-year recruit from plankton to intertidal and shallow subtidal waters [23, 31]. In western Pacific Ocean and Sea of Japan, adults migrate into deeper waters in winter [15, 21].
Reproductive—Sea of Okhotsk fish spawn over cobble sea floors [4, 21].
Schooling—Little is known although adults have been noted forming dense aggregations in Sea of Okhotsk [4].
Feeding behavior—In western Pacific Ocean, feeding is heavier during summer [28, 29].

Populations or Stocks

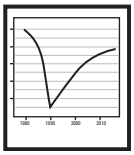
There have been no studies.

Reproduction
Mode—Unknown.
Spawning season—January–February in Sea of Okhotsk [4].
Fecundity—48,000–423,000 adhesive and yellowish-orange to red eggs [4, 21].

Food and Feeding
Food items—In eastern Bering Sea, a wide range of benthic and epibenthic prey. Fishes (for example, Capelin, Pacific Cod, Walleye Pollock, snailfishes, and flatfishes) and crabs are most important, followed by polychaetes, clams, octopi, mysids, gammarid and caprellid amphipods, isopods, euphausiids, shrimps, hermit crabs, brittle stars, and echiuroids [31–33]. Under certain circumstances, adults prey on eggs of conspecifics [28]. Smaller fish feed primarily on invertebrates and larger individuals on fishes [29, 34, 35].
Trophic level—4.1 standard error 0.67 [36].



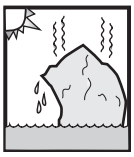
Biological Interactions
Predators—In northeastern Pacific Ocean and Bering Sea, a wide range including other Great Sculpin, Pacific Cod, Pacific Halibut, Pink Salmon, Red Irish Lord, Rock Greenling, Walleye Pollock, Pigeon Guillemot, mink, harbor seals, and Steller sea lions [26, 35, 37–41].
Competitors—Presumably a wide range of other zoobenthic feeders such as Arctic Cod, Walleye Pollock, poachers, eelpouts, and other sculpins.



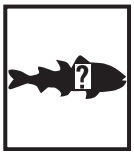
Resilience
Low, minimum population doubling time: 4.5–14 years (t_m=6–8; t_{max}=9–13; K=0.08–0.21; Fecundity = 2,00–10,000) [36].

Traditional and Cultural Importance
Historically, Great Sculpin were an important subsistence fish in Alaskan waters [42]. Currently, they are an unmarketed bycatch in Russian trawl fisheries [43].

Commercial Fisheries
Currently, Plain Sculpin are not commercially harvested.



Potential Effects of Climate Change
A Boreal Pacific species [9], Great Sculpin would be expected to increase in abundance in the U.S. Chukchi Sea and possibly expand their range into the Beaufort Sea.



Areas for Future Research [B]
Little is known about the biology and ecology of this species from the 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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Fourhorn Sculpin (*Myoxocephalus quadricornis*)
(Linnaeus, 1758)

Family Cottidae

Fourhorn Sculpin (*Myoxocephalus quadricornis*) Photograph by Doyne W. Kessler, National Marine Fisheries Service.

Colloquial Names: Iñupiat: Kanaiok [1]; Kanayuq [2].

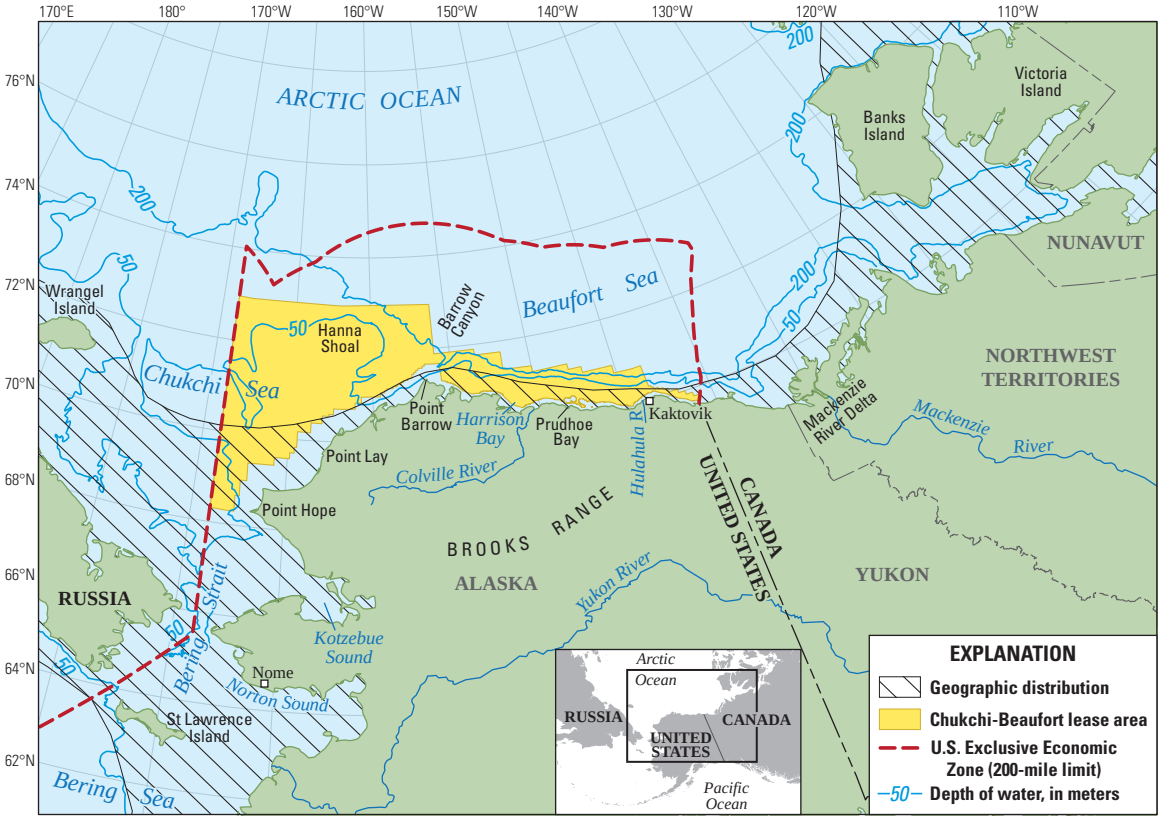
Ecological Role: This species is ubiquitous in the shallow nearshore waters of the U.S. Beaufort and Chukchi Seas. Found in the nearshore throughout the year, it is consumed by a wide variety of fishes, birds, and mammals.

Physical Description/Attributes: Dark gray on backs and sides and lighter on belly. Saddles on the back and bars on the fins. Elongate, tapering body with dorsally compressed head. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 477) [3]. Swim bladder: Absent [3]. Antifreeze glycoproteins in blood serum: Unknown.

Ranges: *In shallow waters of the U.S. Chukchi and Beaufort Seas.* Elsewhere, Arctic; Circumpolar; southward to Gulf of Anadyr, St. Lawrence Island, and northern Bristol Bay, Bering Sea, and to northern Greenland and Baltic Sea in the Atlantic [4].

Relative Abundance: *Common throughout shallow waters of U.S. Beaufort Sea* [7–9] *and Chukchi Sea to Point Lay* [10, 11]. *Abundance south of Point Lay is unknown.* Extremely abundant in shallow waters in Canadian Beaufort Sea eastwards to Tuktoyaktuk Peninsula, Canada [9, 12, 13].

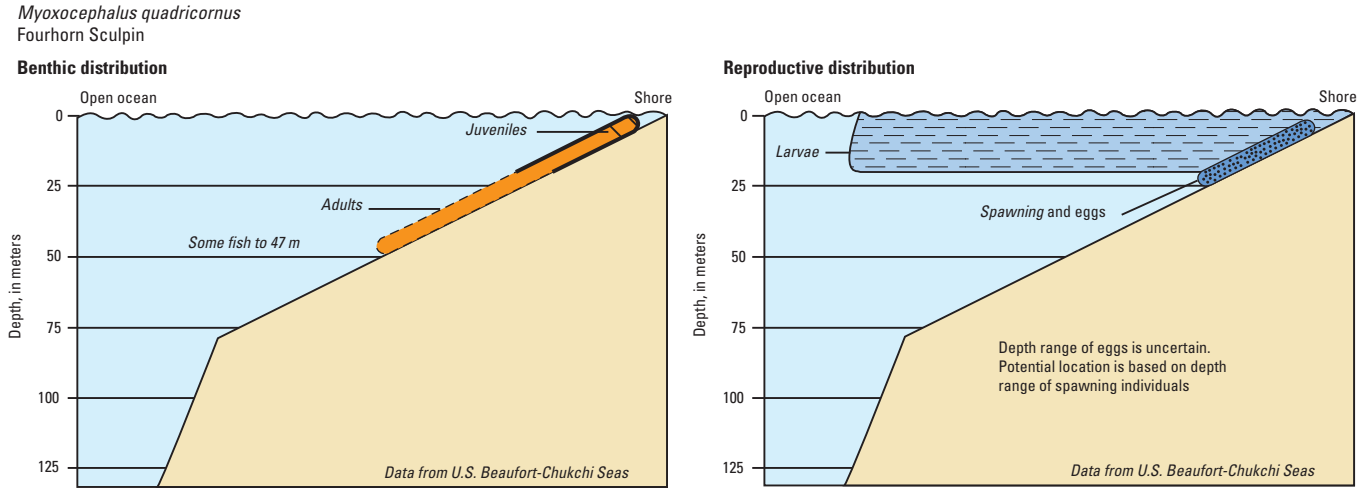
Fourhorn Sculpin
Myoxocephalus quadricornis



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 Fourhorn Sculpin (*Myoxocephalus quadricornis*) within Arctic Outer Continental Shelf Planning Areas [5] based on review of published literature and specimens from historical and recent collections [3, 4, 6].

Depth Range: *Intertidal to 47 m, mainly 15–20 m or less* [10, 14]. Elsewhere, in Baltic Sea common to at least 40 m [15]. *Spawning occurs nearshore as shallow as 4 m* [16–18]. In northeast Pacific Ocean, larvae are pelagic in coastal and continental shelf waters [19]. *Juveniles are found in very shallow waters, often 1 m or less* [16].



Benthic and reproductive distribution of Fourhorn Sculpin (*Myoxocephalus quadricornis*).

Habitats and Life History

Eggs—Size: 1.5–2.9 mm [15, 20, 21]. Color can be green, yellow, or brown according to type of prey eaten by females [22]. Time to hatching: Baltic Sea eggs hatched in 97 days at 1.5 °C and 55 days at 4.7 °C, and no eggs hatched at 10.5 °C [23]. Habitat: Benthic and adhesive [15, 20, 21].

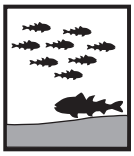
Larvae—Size at hatching: Unknown. Size at juvenile transformation: *10–12 mm FL* [16, 17, 24–28]. Days to juvenile transformation: Unknown. Habitat: Pelagic in coastal and continental shelf waters [19].

Juveniles—Age and size: 10–12 mm to 100–250 mm FL [12, 16, 17, 24–30]. Habitat: Same as adults.

Adults—Age and size at first maturity: Varies with location. *In Simpson Lagoon (near Colville River), males matured between 2–4 years and females between 4–6 years* [16]. On Yukon Coast a few of both sexes were mature at 5 years, all males at 7 years, and all females at 10 years [29]. Generally, few fish mature at 100 mm FL and all by 250 mm FL [12, 16, 17, 25, 29, 30]. Growth rates are variable between locations and females tend to grow larger at age than males [12, 18, 29]. A comparison of growth rates at two Baltic Sea locations indicated that growth was faster at higher ambient temperatures [31]. Maximum age: 16 years [17] and females may live longer [12, 18, 29]. Maximum size: 36.5 cm TL [3]. Habitat: *Benthic habitats in protected, nearshore waters of river mouths, bay and inlets, and along open coasts* [7, 29]. Occasionally, travels upstream in rivers and occupies lakes; reported in Mackenzie River as far upstream as 193 km, in Meade River as far upstream as 129 to 145 km [14] and in deep, cold Scandinavian lakes [32]. Eelgrass [33].

Substrate—Mud sea floors [23, 34, 35].

Physical/chemical—*In U.S. Beaufort Sea, most abundant in colder, more saline marine waters* [36, 37]. Temperature: *In Alaskan and Canadian waters fish have been found at water temperatures between -2.0 and 15 °C* [14, 38]. *Spawning occurs often at temperatures of less than 0 °C* [16–18]. In Baltic Sea, upper lethal temperatures are between 17.5 to 25.5 °C [39]. Salinity: *Fresh waters to 32 ppt* [16, 27]. In a saline lake on Cornwallis Island, Canadian Arctic, fish survive in hypersaline conditions of as much as 36 ppt [40].



Behavior

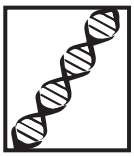
Diel—*Only limited coastal movements occur aside from seasonal, ice-related, inshore-offshore excursions* [16, 41, 42]. At night, small individuals may rise up into water column to feed [43].

Seasonal—*In U.S. Beaufort Sea, fish over winter along shallow, bottom ice-free coastlines* [12, 13, 16, 18, 25, 44] *and river deltas* (for example, Colville and Sagavanirktok) [13, 45, 46]. *In June and early July, after inshore bottom ice melts, migrations occur from just offshore into shallow waters* [16, 28]. *Young-of-the-year recruit to very shallow waters from June to August* [16, 17, 24–28].

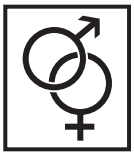
Reproductive—*Females spawn annually* [16] and may spawn more than one batch per season [30]. In Baltic Sea, males become territorial a few months before spawning and prepare nests by digging holes in mud sea floors. Females lay eggs in these depressions and males guard eggs until they hatch by lying on or next to eggs and fanning them with pectoral fins. Along with raising and opening fins, guarding males also make warning sounds and bite intruders. In aquaria, harassed males will move eggs to another location by pushing them, tucking them into the angle between head and pectoral fin, or taking eggs into their mouths [23, 34, 35].

Schooling—Probably does not school.

Feeding—Smaller fish prey primarily on invertebrates, whereas larger ones add fishes to their diets [29].



Populations or Stocks: There have been no studies, although genetic research in the Canadian Arctic suggests little population structure in this region [47].



Reproduction

Mode—Though described as having external fertilization, a number of females containing fertilized eggs have been found [23].

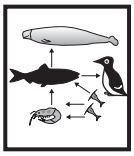
Spawning season—*January–March in U.S. Beaufort Sea*, [12, 17, 18] *and occasionally during summer months* [30].

Fecundity—792–6,150 [15, 48] or as much as 18,000 eggs [49].

Food and Feeding

Food items—*Benthic and epibenthic organisms. Dominant prey are crustaceans, primarily isopods and amphipods, and fishes (for example, Fourhorn Sculpin, Saffron Cod, and Arctic Cod). Other prey include polychaetes, insects, ascidians, fish eggs, clams, plant material, copepods, and shrimps* [10, 11, 13, 17, 50].

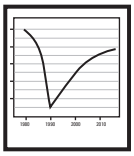
Trophic level—3.7 standard error 0.59 [51].



Biological Interactions

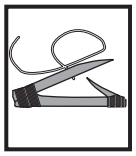
Predators—A wide range of fishes, such as Arctic Cisco, Arctic Sculpin, Dolly Varden, Fourhorn Sculpin, Pacific Herring, Arctic Smelt, Saffron Cod, Shorthorn Sculpin, various eelpouts, as well as grebes, herons, loons, mergansers, Mew Gulls, Thick-billed Murres, ringed and probably bearded seals, and polar bears [10, 18, 27, 29, 40, 52–55].

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



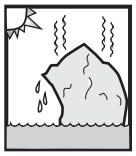
Resilience

Low, minimum population doubling time: 4.5–14 years (t_m=3–5; t_{max}=14; Fecundity=792) [51].

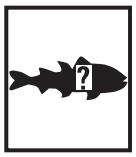


Traditional and Cultural Importance
Generally, although they are widely taken as bycatch in a number of Canadian Arctic subsistence fisheries, Fourhorn Sculpin only are occasionally consumed [11, 56, 57]. In the past, particularly during times of poor fishing, they were more often targeted and eaten [1, 58]. Hudson Bay Inuits reportedly catch and consume in moderate numbers [59].

Commercial Fisheries
Currently, Fourhorn Sculpin are not commercially harvested.



Potential Effects of Climate Change
It is unclear what effects climate change will have on this species. This species appears to be somewhat eurythermal, implying that it would not be negatively affected by warming temperatures. However, its apparent rarity south of the Bering Strait suggests (1) physiological adaptation to colder water or (2) a competitive advantage for cold-temperate species, or both. If these assumptions are true, climate change effects might include a northerly shift in the distribution of the species and increased interactions with other marine species.



Areas for Future Research [A]
The Fourhorn Sculpin is one of the more dominant species in the U.S. Beaufort Sea nearshore , as it is relatively well-studied in coastal monitoring programs. It is a potential indicator species and, as such, information 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) seasonal and ontogenetic movements, and (5) population dynamics.

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Arctic Sculpin (*Myoxocephalus scorpioides*)
(Fabricius, 1780)

Family Cottidae

Colloquial Name: Iñupiat: *Tivaqiq* (Coronation Gulf) [1].

Ecological Role: Largely unknown. However, Arctic Sculpin are unlikely to represent a significant prey resource to other fish, birds, or mammals.

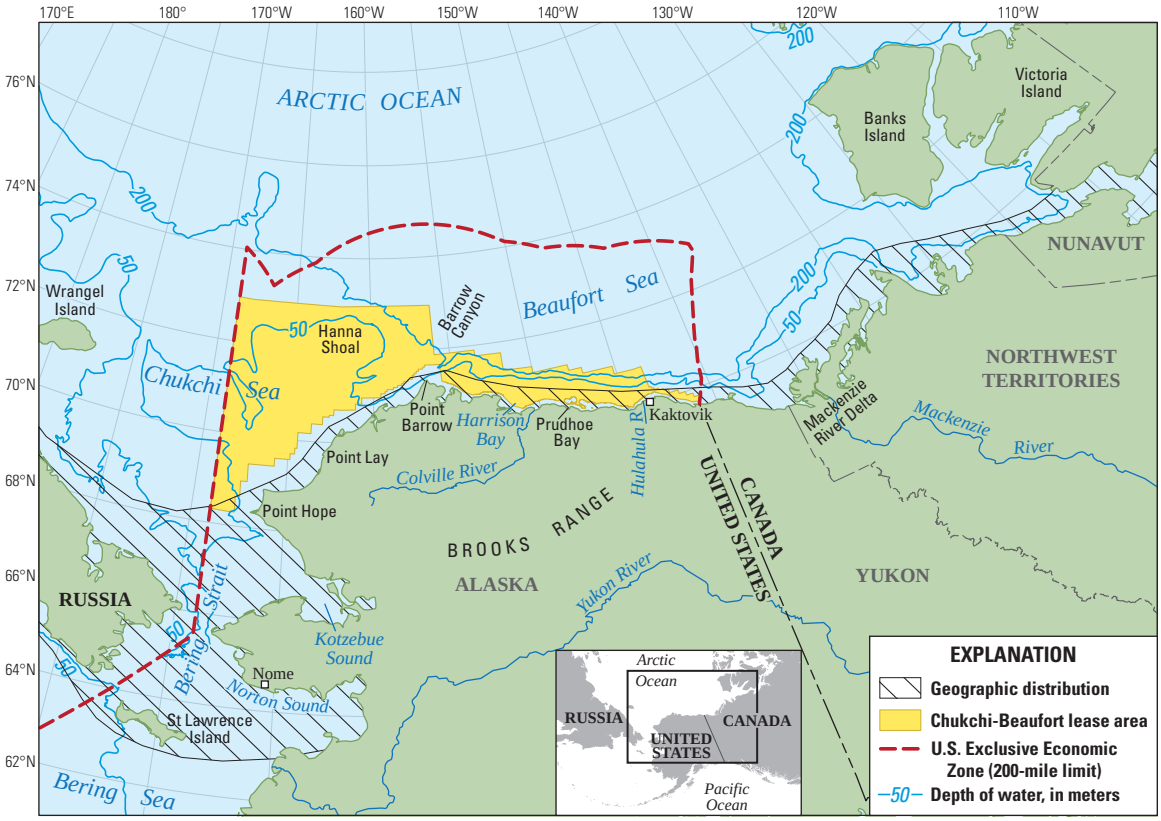
Physical Description/Attributes: Purplish-blue or blackish body with dark bands, white mottling and spots, and with barred and spotted fins. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 479) [2]. Swim bladder: Absent [2]. Antifreeze glycoproteins in blood serum: Unknown. Blood serum is green to blue-green in color, likely caused by biliverdin build-up [3].

Arctic Sculpin (*Myoxocephalus scorpioides*). Photograph by Andrey Vinnikov, Chukotka Branch, Pacific Research Institute of Fisheries and Oceanography.

Range: *Along coasts of U.S. Chukchi and Beaufort Seas.* Elsewhere in Alaska, in Bering Sea south to Norton Sound and St. Lawrence Island. Worldwide, in western Bering Sea south to Gulf of Anadyr; from East Siberian Sea and along Arctic Canadian coast eastward to Greenland and Gulf of St. Lawrence in the Atlantic [4–7].

Relative Abundance: *Uncommon in U.S. Chukchi and Beaufort Seas* [4].Reported as common in Canadian Arctic Ocean but likely misidentified, confused with the more numerous *M. scorpius* [4].

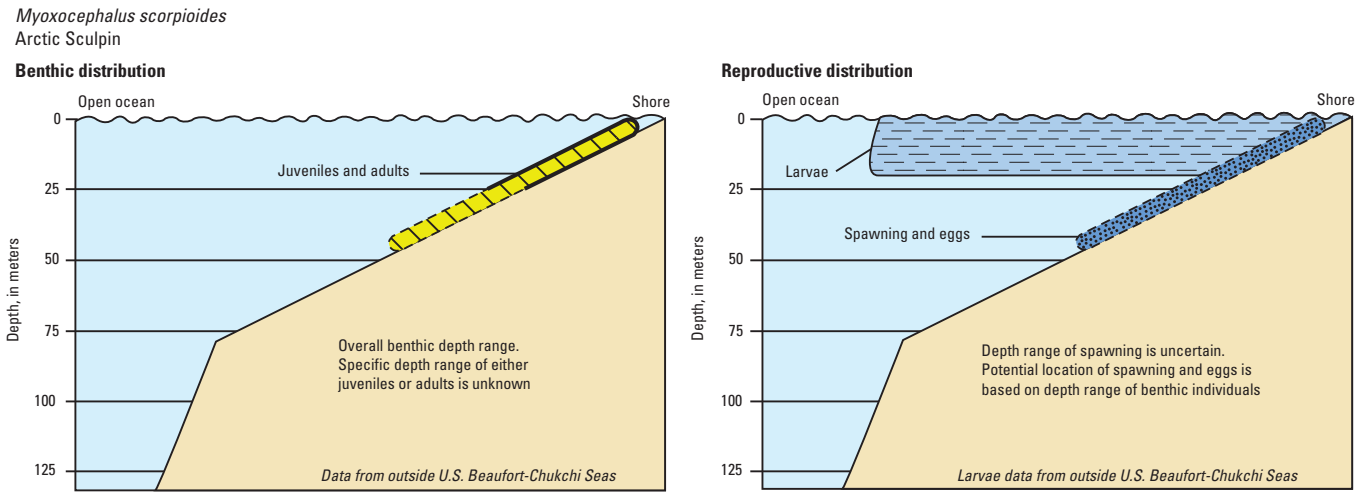
Arctic Sculpin
Myoxocephalus scorpioides



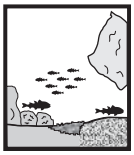
Base modified from USGS and other digital data. U.S.-Russia Maritime Boundary follows the EEZ/200-mile limit line, western edge. Coordinate reference system: projection, Lambert Azimuthal Equal Area; latitude of origin, 75.0°; horizontal datum, North American Datum of 1983.

Geographic distribution of Arctic Sculpin (*Myoxocephalus scorpioides*) within Arctic Outer Continental Shelf Planning Areas [8] based on review of published literature and specimens from historical and recent collections [4, 9].

Depth Range: Shallow nearshore to depth of 40 m off Alaska [2, 21] and to 40 m elsewhere [10]. Larval *Myoxocephalus* spp. live in coastal and continental shelf waters [11].

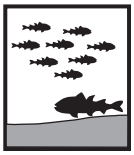


Benthic and reproductive distribution of Arctic Sculpin (*Myoxocephalus scorpioides*).



Habitats and Life History

Eggs—Size: Unknown. Time to hatching: Unknown. Habitat: Likely benthic, based on other members of this family [2].
Larvae—Size at hatching: Unknown. Size at juvenile transformation: Unknown. Days to juvenile transformation: Unknown. Habitat: Pelagic [11].
Juveniles—Age and size: Unknown. Habitat: Benthic [12].
Adults—Age and size at first maturity: Unknown. Maximum age: Unknown. Maximum size: 23.8 cm TL [2]. Habitat: Benthic [11, 12].
Substrate—Rock and algae [13].
Physical/chemical—Temperature: Below 0 to 8 °C or higher [14]. Salinity: Marine and estuarine waters as low as 6 ppt [7, 14–17].



Behavior

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

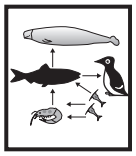
Populations or Stocks

There have been no studies.

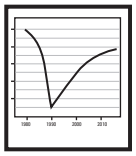
Reproduction

Mode—Unknown.
Spawning season—Autumn, in Russian Arctic Ocean [14].
Fecundity—Unknown.

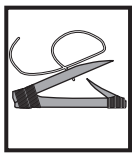
Food and Feeding
Food items—Amphipods [12, 14].
Trophic level—3.39 standard error 0.52 [18].



Biological Interactions
Predators—Black Guillemots and possibly bearded seals in Canadian Arctic Ocean [19, 20].
Competitors—Presumably a wide range of other zoobenthic feeders such as Arctic Cod, Walleye Pollock, poachers, eelpouts, and other sculpins.

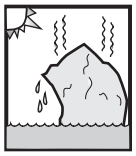


Resilience
Medium, minimum population doubling time: 1.4–4.4 years (Preliminary *K* or Fecundity) [18].

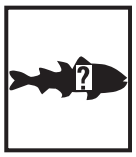


Traditional and Cultural Importance
None reported. Not commonly caught and retained in subsistence fisheries [12].

Commercial Fisheries
Currently, Arctic Scuplin are not commercially harvested.



Potential Effects of Climate Change
The Arctic Sculpin is an endemic species that lives in shallow waters close to shore. A distributional shift to the north, in this case contraction from the northern Bering Sea, and increased species abundance in coastal waters are likely outcomes of climate warming.



Areas for Future Research [B]
Little is known about the biology and ecology of this species from the 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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Shorthorn Sculpin (*Myoxocephalus scorpius*)

(Linnaeus, 1758)

Family Cottidae

Shorthorn Sculpin (*Myoxocephalus scorpius*) 237 mm, Bering Strait, 2006. Photograph by C.W. Mecklenburg, Point Stephens Research.

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

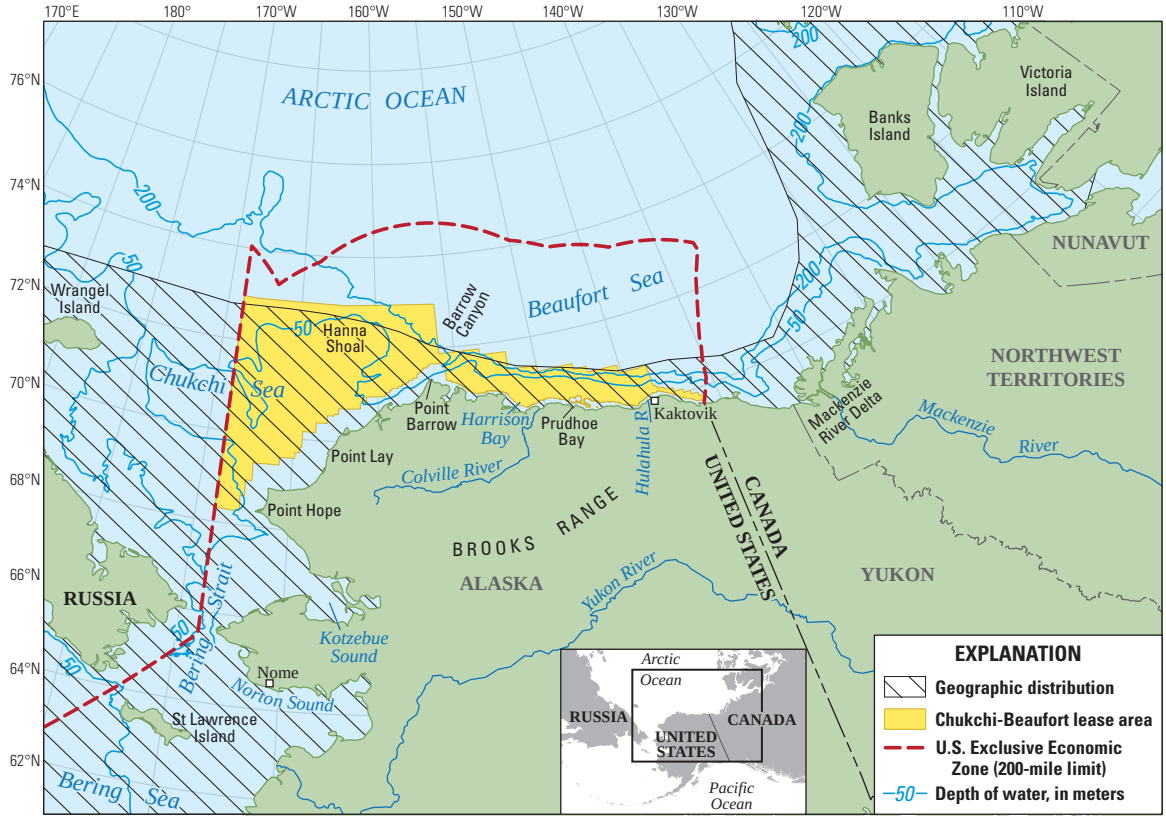
Ecological Role: Shorthorn Sculpin is one of the most common benthic species in the shallower waters of the U.S. Chukchi Sea and is common in the Beaufort Sea. Although research is lacking, available information implies that this species is likely of moderate ecological importance as prey for some marine mammals and sea birds.

Physical Description/Attributes: Body variably colored from black to greenish brown to pale olive with yellow and orange tinges and dark mottling. Belly is white, red (particularly in males), yellow, orange, or brown. Fins are brown, green, or yellow, with paler spots and bars [1–3]. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 478) [3]. Swim bladder: Absent [3]. Antifreeze glycoproteins in blood serum: Present [4, 5]. Blood serum is colored blue-green, likely due to biliverdin build-up [6].

Ranges: *U.S. Chukchi and Beaufort Seas*. Elsewhere in Alaska, southward through Bering Sea and Commander–Aleutian Islands chain and all southeastern Gulf of Alaska. Worldwide, circumpolar; southward to Gulf of Maine, Bay of Biscay, southwestern Kamchatka Peninsula, Russia, and northern British Columbia, Canada [7].

Relative Abundance: *Common throughout much of the Chukchi Sea [10] (to at least 71°55'N, 175°18'W [11], and in U.S. Beaufort Sea* [12–14]. Common in eastern Bering Sea and Norton Sound [15, 16] along with James Bay, Hudson Bay, and Hudson Strait, Canada [17].

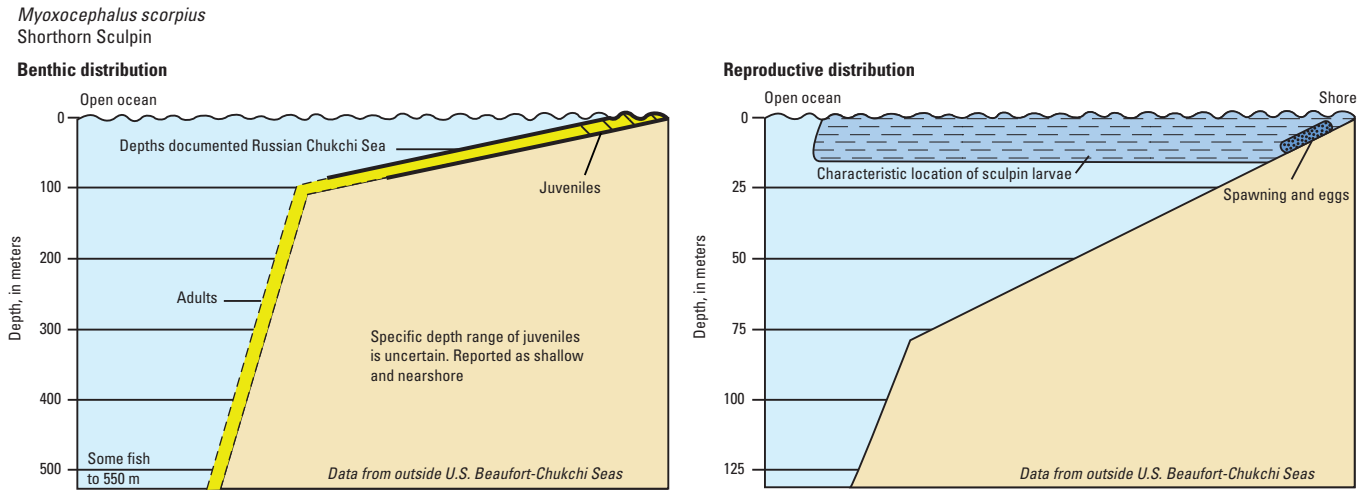
Shorthorn Sculpin
Myoxocephalus scorpius



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 Shorthorn Sculpin (*Myoxocephalus scorpius*) within Arctic Outer Continental Shelf Planning Areas [8] based on review of published literature and specimens from historical and recent collections [3, 7, 9].

Depth Range: In Russian Chukchi Sea to at least 84 m [10, 11, 13]. Overall, intertidal (juveniles) [18] to 550 m, mainly less than 70 m [3]. Off Newfoundland, adults have been observed at less than 3 m [19]. Spawning occurs between 3 and 11 m [2, 20]. Larval *Myoxocephalus* spp. live in coastal and continental shelf waters [21].



Benthic and reproductive distribution of Shorthorn Sculpin (*Myoxocephalus scorpius*).

Habitats and Life History

Eggs—Size: 1.8–2.5 mm [22]. Time to hatching: 7–8 weeks at 3.3 °C [23] and less than 3 months at -1.5–0 °C [2, 20]. Habitat: Benthic and adhesive, in crevices of boulders and other rocky formations [2, 20].

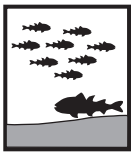
Larvae—Size at hatching: 6.0–8.8 mm [23]. Size at juvenile transformation: 1.0–2.0 cm TL, [24, 25]. Days to juvenile transformation: Unknown. Habitat: Pelagic, in coastal and continental shelf waters [21].

Juveniles—Age and size: 1–2 to 21–39 cm TL [24, 25]. Age unknown. Habitat: Young juveniles are pelagic and neritic [21], and older juveniles are benthic and neritic [3].

Adults—Age and size at first maturity: Off Newfoundland, a few of both sexes mature at 3 years (21 cm TL), all males at 6 years (30 cm TL); 60 percent of females at 6 years (34–35 cm TL), and all by 8 years (39 cm TL). Females grow larger than males and males mature at a slightly younger age and smaller size [2, 19, 20]. In European waters, males mature at 1 year (8–14 cm TL) and all females at 3 years (20 cm) [26]. In Russian Arctic Ocean, both sexes mature at 2–4 years and 15 cm TL (males) and 20 cm (females) long TL [25]. Egg development within female may take as long as 2.5 years in Newfoundland waters [20] and 1 year in European waters [27]. Generally, Newfoundland fish live much longer, grow more slowly, and mature later in life than do those across the Atlantic Ocean [19, 20, 28]. Based on Baltic Sea research, fish on both sides of the Atlantic Ocean appear to weigh about the same at length with females heavier at length than males [27]. Maximum age: 15 years [2] (rarely more than 6 years in Europe) [26]. Maximum size: 60 cm TL [3] and 1.1 kg [29]. Habitat: Benthic, mainly shallow shelf waters [3, 25, 30].

Substrate—A wide range, including sand, mud, boulder, cobble, and algal beds [2, 11, 12, 31].

Physical/chemical—Temperature: -1.8–18.9 °C [11, 32], most commonly less than 0 °C [25]. Salinity: From 5 ppt to full sea water [25, 32, 33].



Behavior

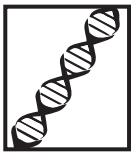
Diel—Off Newfoundland, juveniles move into shallower waters (less than 1–2 m) at night. [34].

Seasonal—Young-of-the-year recruit to shallow, often estuarine, waters [1] *and some stay nearshore year round* [13]. Off Newfoundland, seasonal inshore-offshore movements of juveniles (shallow in summer and deeper depths in winter) have been reported [20].

Reproductive—Spawning occurs in shallow waters. Adhesive eggs are laid in crevices of boulders and other rocky formations. Nests are 1–4 m apart and may contain clutches of more than one female. Males aggressively guard eggs until hatching. After spawning, females move into deep waters (likely deeper than 100 m) and return in April and May after eggs hatch [2, 20].

Schooling—Unknown.

Feeding—Semi-sedentary, lies in wait for prey [7]. When drifting ice darkens the waters, diets shifts from drabber benthic prey to brightly colored midwater amphipods [35]. Females feed less just before and after spawning [2].



Populations or Stocks

There have been no studies.

Reproduction

Mode—Unknown.

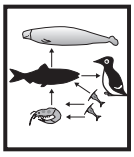
Spawning season—November and December in Newfoundland [2, 20] and as late as March in Europe [23].

Fecundity—4,205–60,976 (as few as 1,200 in Norway) [23], pink, orange, or red colored eggs [20, 23].

Food and Feeding

Food items—A diverse array of vertebrate and invertebrate prey. In Newfoundland, the Canadian Arctic Ocean, eastern and western Bering Sea, and Norway, fishes and crabs are often most important in the diet, although many other crustaceans (for example, isopods, amphipods, and shrimps), polychaetes, snails, sea urchins, brittle stars, and sea cucumbers also are consumed [2, 23, 35–37].

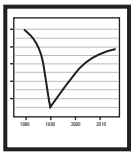
Trophic level—3.9 standard error 0.40 [38].



Biological Interactions

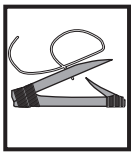
Predators—*Ringed seals in U.S. Chukchi Sea* [39]. Black Guillemots, Thick-billed Murres, and bearded seals in Canadian Arctic Ocean [40–42]. River otters in southeastern Alaska [43].

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



Resilience

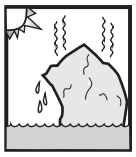
Medium, minimum population doubling time: 1.4–4.4 years (t_m=2; Fecundity=2,742) [38].



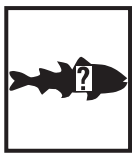
Traditional and Cultural Importance

Seem to have relatively little importance in the U.S. Chukchi and Beaufort Seas. Historically, this was a fairly important species to the Inuits of the Canadian Arctic where it is frequently used as food if other sources are in short supply and used as dog-feed [1].

Commercial Fisheries
Currently, Shorthorn Sculpin are not commercially harvested.



Potential Effects of Climate Change
The Shorthorn Sculpin reproduces and is common in Arctic and Boreal waters [7] and the possible effects of warming on its distribution are difficult to predict. This species has already reestablished the circumpolar distribution it had in pre-Wisconsinan glacial and Bering Land Bridge times [7].



Areas for Future Research [B]
Although there has been substantial life history work conducted off Newfoundland [2, 19, 20] and in European waters [23, 26, 27] 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. The distribution of the species in regional habitats suggests its potential suitability as an indicator species for monitoring changes associated with global warming.

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Hairhead Sculpin (*Trichocottus brashnikovi*)

Soldatov & Pavlenko, 1915

Family Cottidae

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. However, Hairhead Sculpin are unlikely to represent a significant prey resource to higher level organisms except for the possibility of greater importance in the southeastern Chukchi Sea.

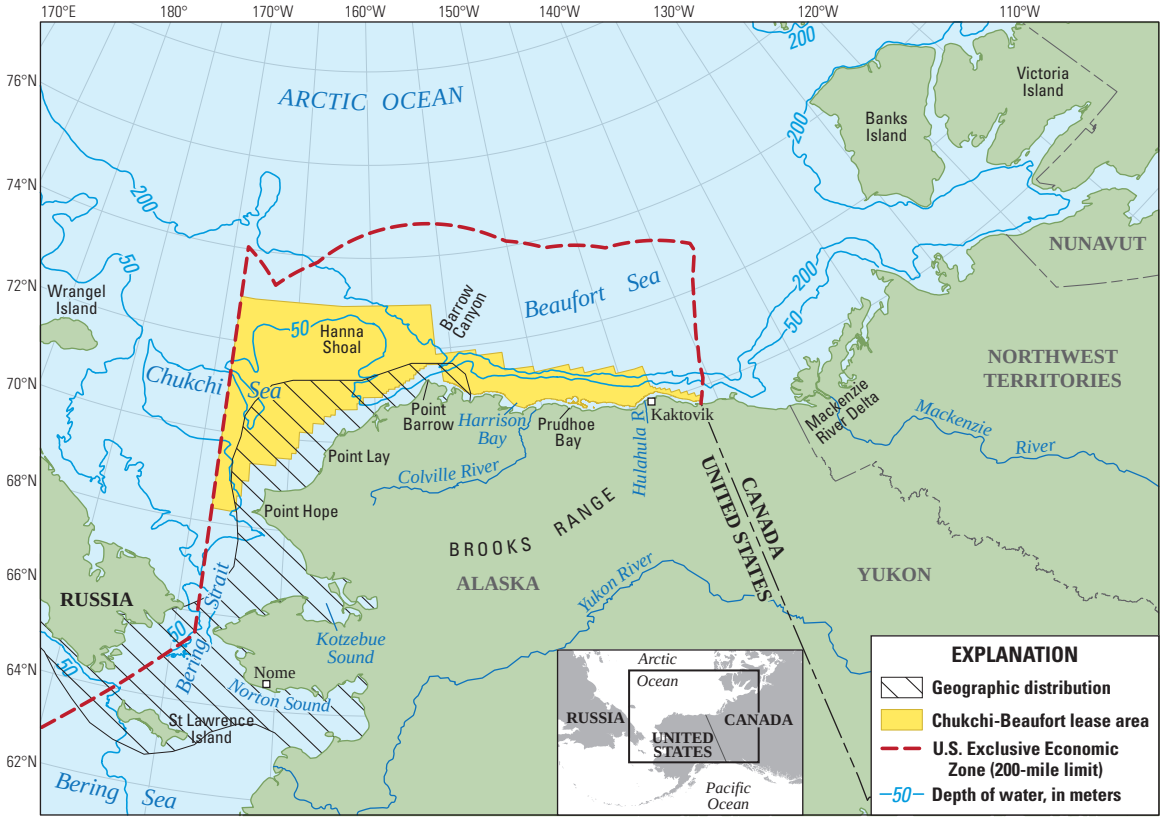
Hairhead Sculpin (*Trichocottus brashnikovi*) 164 mm TL, northeastern Bering Sea, 2006. Photograph by C.W. Mecklenburg, Point Stephens Research.

Physical Description/Attributes: Head and body mottled reddish and blackish brown with vague dark saddles; numerous white spots make pattern indistinct; white underside, and white band around caudal peduncle [1]. Swim bladder: Absent [2]. Antifreeze glycoproteins in blood serum: Unknown.

Range: *U.S. Chukchi Sea [3] and U.S. Beaufort Sea eastward at least to 72°N, 155°W, northeast of Dease Inlet* [1]. Elsewhere in Alaska, in northeastern Bering Sea from Seward Peninsula south to St Lawrence Island. Worldwide, from western Bering Sea off Cape Navarin, Russia, south to Sea of Okhotsk and northern Sea of Japan [2].

Relative Abundance: *Common, although perhaps not abundant, in U.S. Chukchi Sea and present but uncommon in U.S. Beaufort Sea* [1, 3].

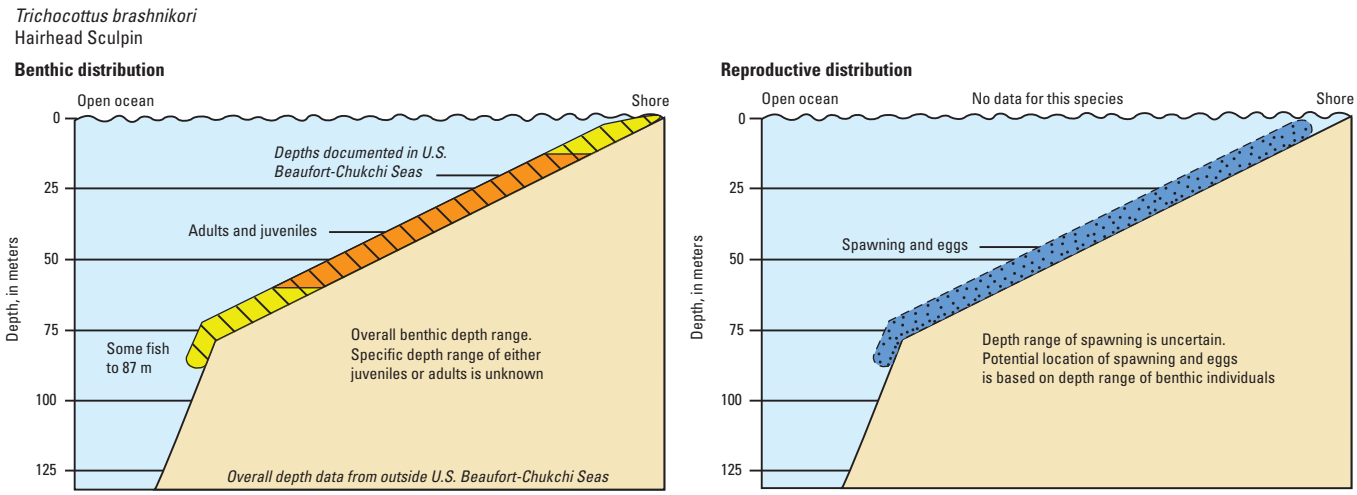
Hairhead Sculpin
Trichocottus brashnikovi



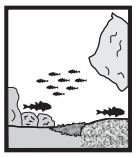
Base modified from USGS and other digital data. U.S.-Russia Maritime Boundary follows the EEZ/200-mile limit line, western edge. Coordinate reference system: projection, Lambert Azimuthal Equal Area; latitude of origin, 75.0°; horizontal datum, North American Datum of 1983.

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

Depth Range: 7–87 m [2]. *Documented in U.S. Chukchi and Beaufort Seas at 13–60 m* [1, 3].



Benthic and reproductive distribution of Hairhead Sculpin (*Trichocottus brashnikovi*).



Habitats and Life History

Eggs—Size: Unknown. Time to hatching: Unknown. Habitat: Likely benthic, based other members of this family [2].

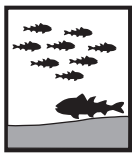
Larvae—Size at hatching: Unknown. Size at juvenile transformation: Unknown. Days to juvenile transformation: Unknown. Habitat: Likely pelagic, based other members of this family [2].

Juveniles—Age and size: Unknown. Habitat: Benthic [2].

Adults—Age and size at first maturity: Unknown. Maximum age: Unknown. Maximum size: 22.5 cm [2]. Habitat: Benthic [2].

Substrate—Sandy bottoms [2].

Physical/chemical—Temperature: -1.2–6.5 °C [1]. Salinity: Marine [2].



Behavior

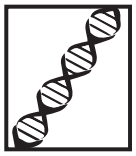
Diel—Unknown.

Seasonal—Unknown.

Reproductive—Unknown.

Schooling—Unknown.

Feeding—Unknown.



Populations or Stocks

There have been no studies.

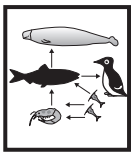
Reproduction

Mode—Unknown.

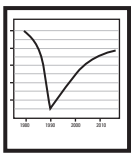
Spawning season—Unknown.

Fecundity—Unknown.

Food and Feeding
Food items—Unknown.
Trophic level—3.45 standard error 0.48 [5].



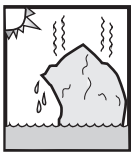
Biological Interactions
Predators—Unknown.
Competitors—Presumably a wide range of other zoobenthic feeders such as Arctic Cod, Walleye Pollock, other sculpins, poachers, and eelpouts.



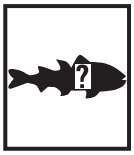
Resilience
Medium, minimum population doubling time: 1.4–4.4 years (Preliminary *K* or Fecundity) [5].

Traditional and Cultural Importance
None reported.

Commercial Fisheries
Currently, Hairhead Sculpin are not commercially harvested.



Potential Effects of Climate Change
As a Boreal Pacific species, a northerly shift in distribution and increased abundance are probable expectations of warming. The effects of increased abundance on biological interactions, especially competition with similar species, presently cannot be assessed.



Areas for Future Research [B]
Little is known about the biology and ecology of this species from the 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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Bigeye Sculpin (*Triglops nybelini*)

Jensen, 1944

Family Cottidae

Bigeye Sculpin (*Triglops nybelini*) 105 mm, Chukchi Borderland, 2009. Photograph by C.W. Mecklenburg, Point Stephens Research.

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

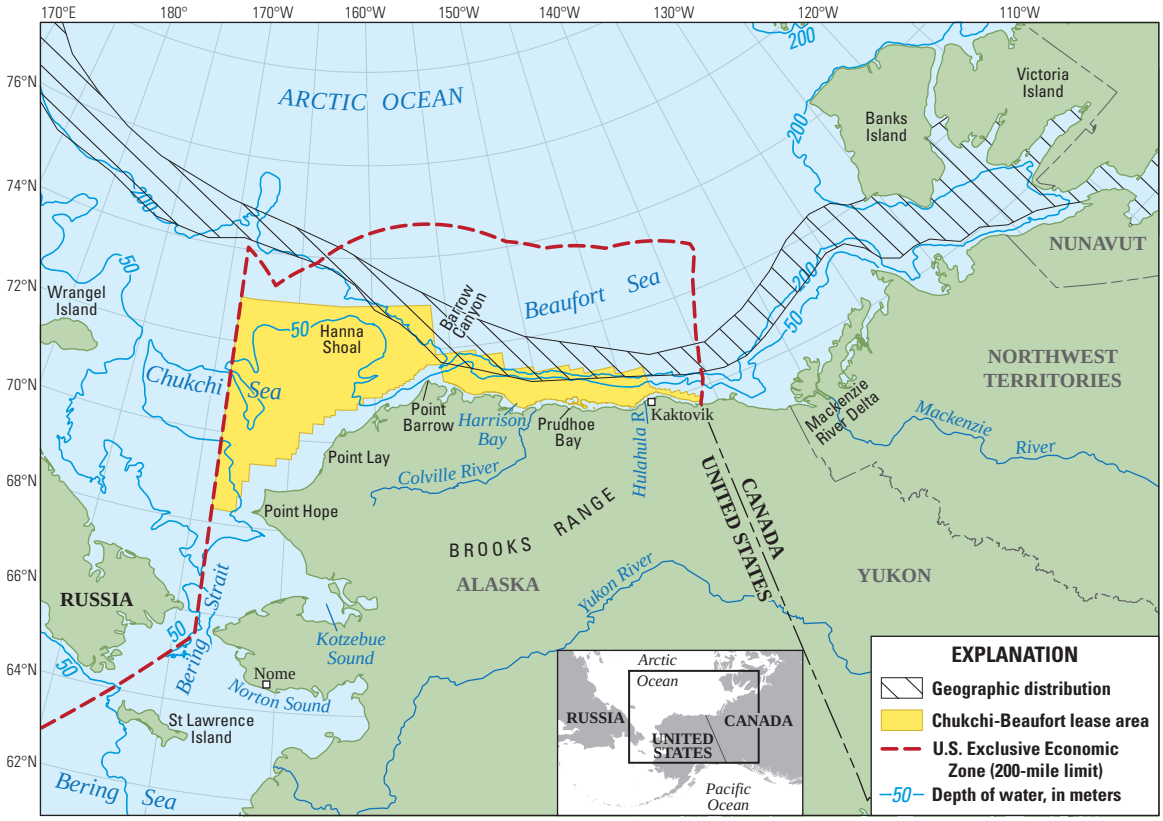
Ecological Role: Largely unknown. However, the Bigeye Sculpin is an uncommon species and is unlikely to represent a significant prey resource to higher level organisms

Physical Description/Attributes: Dark brown back without dark saddles, cream-colored belly and broken or complete black lines along sides. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 426) [1]. Swim bladder: Absent [1]. Antifreeze glycoproteins in blood serum: Unknown.

Ranges: *U.S. Chukchi Sea slope and U.S. Beaufort Sea slope eastward to 149°W* [2]. Practically circumpolar in Arctic Ocean [3].

Relative Abundance: *Unknown, likely uncommon, especially at depths shallower than 200 m.*

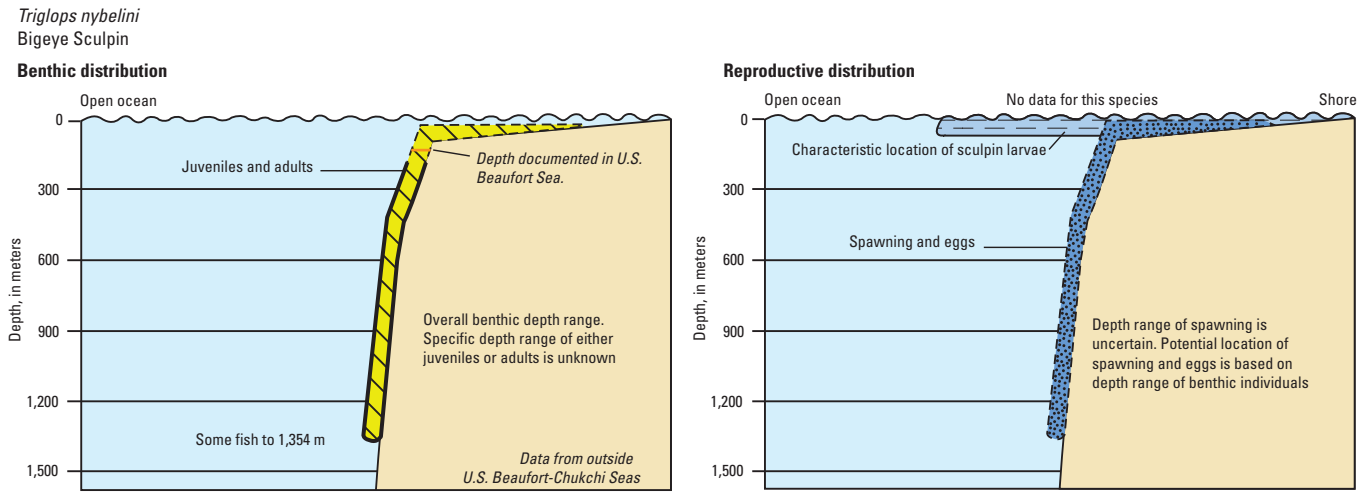
Bigeye Sculpin
Triglops nybelini



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 Bigeye Sculpin (*Triglops nybelini*) within Arctic Outer Continental Shelf Planning Areas [4] based on review of published literature and specimens from historical and recent collections [1-3].

Depth Range: 9–1,354 m, usually deeper than 200 m [1, 3]. *As shallow as 101 m in U.S. Beaufort Sea* [2].



Benthic and reproductive distribution of Bigeye Sculpin (*Triglops nybelini*).

Habitats and Life History

Eggs—Size: 3 mm, almost ripe eggs in Kara Sea [5]. Time to hatching: Unknown. Habitat: Likely benthic, based on other members of this family [1, 5].

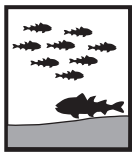
Larvae—Size at hatching: Unknown. Size at juvenile transformation: Unknown. Days to juvenile transformation: Unknown. Habitat: Likely pelagic, based on other members of this family [1, 5]. [1].

Juveniles—Age and size: Unknown. Habitat: Likely benthic, based on other members of this family [1, 5].

Adults—Age and size at first maturity: Starting at 3–4 years, at latest by 7 years, and 14 cm in the Barents Sea. [6]. Maximum age: Unknown. Maximum size: 17 cm TL [1]. Habitat: Likely benthic, based on other members of this family [1, 5].

Substrate—Soft sea floors [5, 7].

Physical/chemical—Temperature: -1.8 to -0.1 °C, in Russian Arctic Ocean [5]. Salinity: Marine [5, 7], prefers less than 34 ppt [6].



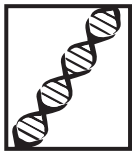
Behavior

Diel—Unknown. Seasonal—Unknown.

Reproductive—Unknown.

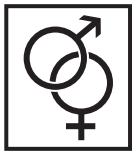
Schooling—Unknown.

Feeding—Unknown.



Populations or Stocks

There have been no studies.



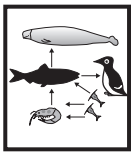
Reproduction

Mode—Unknown.

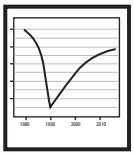
Spawning season—Probably summer and early autumn, off Europe and Asia [5, 6].

Fecundity—600–100 eggs [6]. Mature females contain more than one size class of eggs. In Kara Sea two females contained 307 and 600 eggs of the largest class size [5].

Food and Feeding
Food items—In Russian Arctic Ocean, zooplanktors such as euphausiids and calanoid copepods [5] and fish [6].
Trophic level—3.29 standard error 0.41 [8].



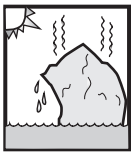
Biological Interactions
Predators—In Hudson Bay, Thick-billed Murres and Black Guillemots [9].
Competitors—Presumably a wide range of other zoobenthic feeders such as Arctic Cod, Walleye Pollock, poachers, eelpouts, and other sculpins.



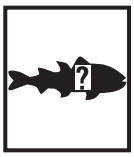
Resilience
Medium, minimum population doubling time: 1.4–4.4 years (Preliminary *K* or Fecundity) [8].

Traditional and Cultural Importance
None reported.

Commercial Fisheries
Currently, Bigeye Sculpin are not commercially harvested.



Potential Effects of Climate Change
The Bigeye Sculpin is an endemic Arctic species [3]. A northerly shift in its distribution to colder and deeper offshore waters may be an outcome of climate warming.



Areas for Future Research [B]
Little is known about the biology and ecology of this species from the 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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Ribbed Sculpin (*Triglops pingelii*)
(Reinhardt, 1837)

Family Cottidae

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

Ecological Role: Largely unknown. However, the Ribbed Sculpin is unlikely to represent a significant prey resource to higher level organisms and does not play a significant role in regional food webs.

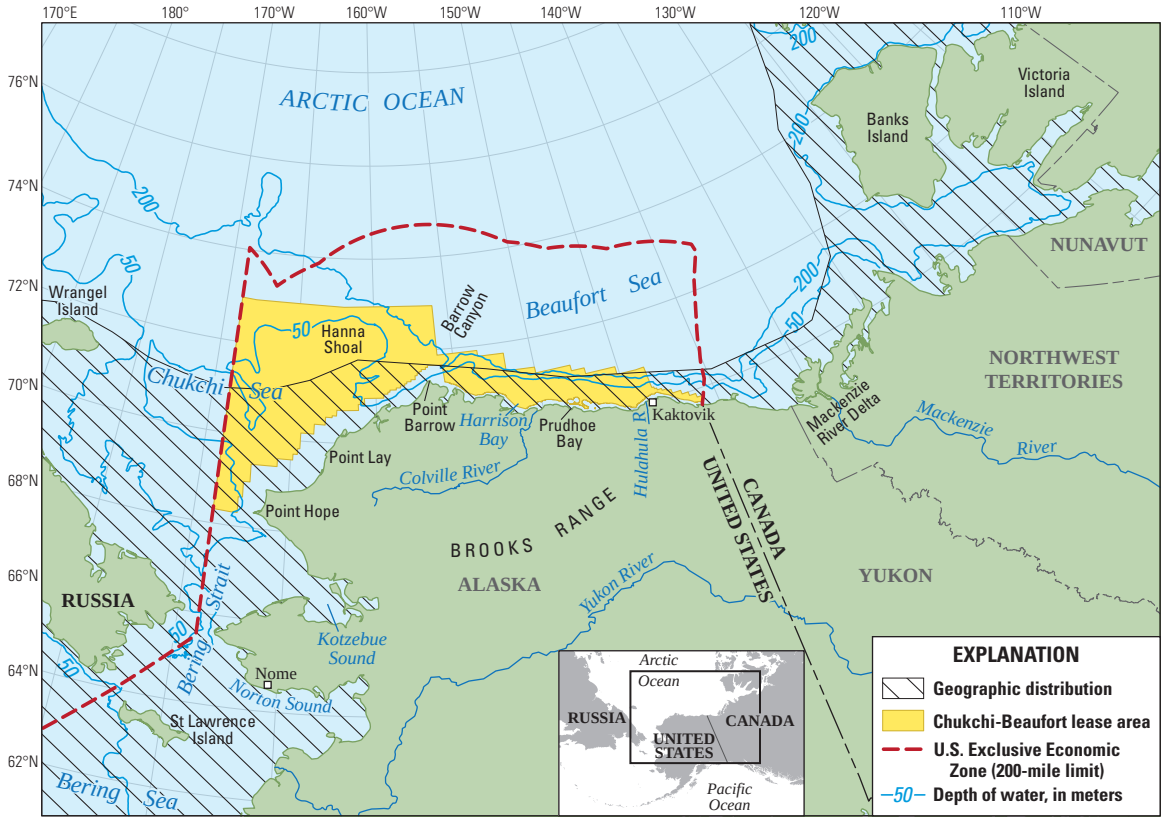
Ribbed Sculpin (*Triglops pingelii*) 145 mm, U.S. Chukchi Sea. Photograph by C.W. Mecklenburg, Point Stephens Research.

Physical Description/Attributes: Olive brown-back with vague blackish saddles, white belly, and dark spots or streaks on sides below lateral line. In males the dark streaks form a broken or continuous stripe. For specific diagnostic characteristics, see, *Fishes of Alaska* (Mecklenburg and others, 2002, p. 428) [1] Swim bladder: Absent [1]. Antifreeze glycoproteins in blood serum: Unknown.

Range: *U.S. Beaufort and Chukchi Seas.* Elsewhere in Sea of Okhotsk, Bering Sea and Commander–Aleutian Islands chain and entire southeast coast [4]. Worldwide, circumpolar in Arctic Ocean; south to Sea of Japan, Puget Sound, Strait of Belle Isle, southern Greenland, Jan Mayen Island, Norway, and White Sea [2].

Relative Abundance: *Common in U.S. Chukchi Sea* [1, 4–8] *but uncommon in U.S. Beaufort Sea.* Elsewhere, common in Canadian Beaufort Sea off Herschel Island [9] and from off western Kamchatka Peninsula, Russia, along Aleutian Islands, in central and eastern Bering Sea, and eastward to Kodiak Island region [10–12].

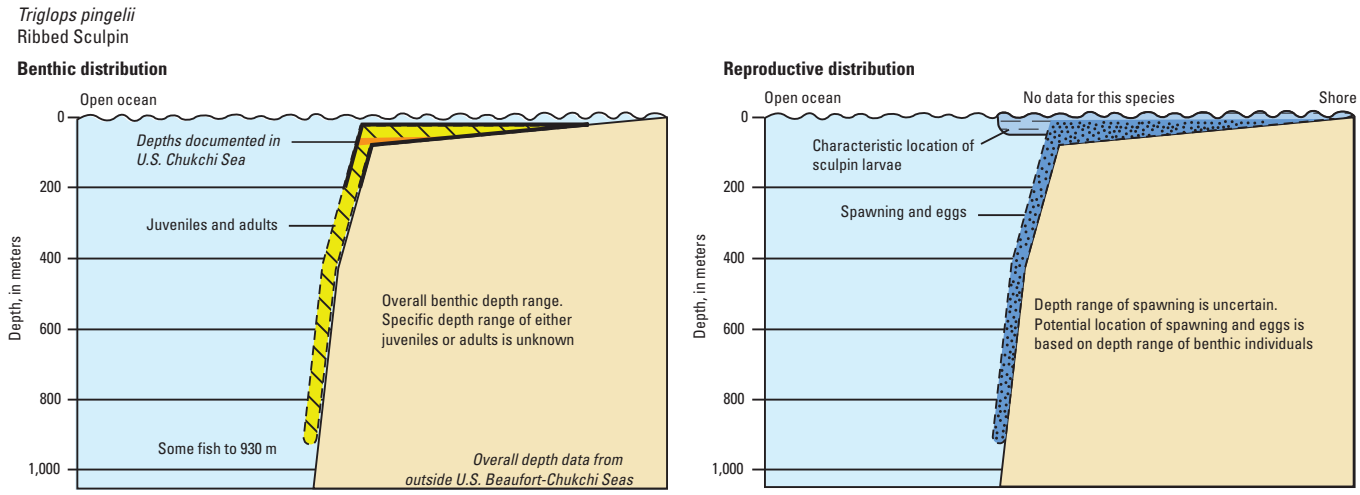
Ribbed Sculpin
Triglops pingelii



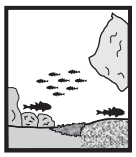
Base modified from USGS and other digital data. U.S.-Russia Maritime Boundary follows the EEZ/200-mile limit line, western edge. Coordinate reference system: projection, Lambert Azimuthal Equal Area; latitude of origin, 75.0°; horizontal datum, North American Datum of 1983.

Geographic distribution of Ribbed Sculpin (*Triglops pingelii*) 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. Chukchi Sea at 30–48 m* [8]. Elsewhere, 4–930 m [13], typically less than 200 m [2].

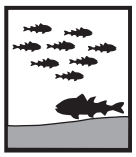


Benthic and reproductive distribution of Ribbed Sculpin (*Triglops pingelii*).



Habitats and Life History

Eggs—Size: 2–3 mm, red in color [14–16]. Time to hatching: Unknown. Habitat: Benthic [14, 15].
Larvae—Size at hatching: Unknown. Size at juvenile transformation: *35 mm TL* [6]. Days to juvenile transformation: Unknown. Habitat: *Pelagic* [6].
Juveniles—Age and size: Unknown. Habitat: Benthic to epibenthic [11, 17].
Adults—Age and size at first maturity: 3–5 years at 7–9 cm [16]. Maximum age: 9 years [16]. Maximum size: 20.2 cm SL, about 23.3 cm TL; reported but not verifiable to 24.2 cm [1]. Females grow larger and are heavier at length [18]. Habitat: Benthic to epibenthic [11, 17].
Substrate—Soft sea floors and rocky bottoms [8, 17, 19].
Physical/chemical—Temperature: -1.5–10.5 °C [1, 8, 17, 19]. Salinity: Mainly marine [8, 15], also taken in brackish waters [20].

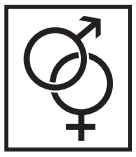


Behavior

Diel—Juveniles and adults have been captured in midwaters at night [17].
Seasonal—Unknown.
Reproductive—Unknown.
Schooling—Unknown.
Feeding—Fish have been observed feeding as much as 1 m above the bottom [19].

Populations or Stocks

There have been no studies.



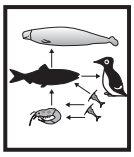
Reproduction

Mode—Unknown.
Spawning season—In autumn off Kodiak Island, Alaska [21, 22].
Fecundity—About 300–450 eggs [16].

Food and Feeding

Food items—In southeastern Beaufort Sea and northwest Atlantic Ocean, primarily planktonic or epibenthic organisms such as amphipods, mysids, copepods, larval ascidians, euphausiids, and arrow worms [23].

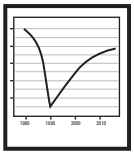
Trophic level—3.41 standard error 0.51 [24].



Biological Interactions

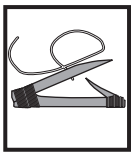
Predators—Ringed seals and probably bearded seals in Canadian Arctic Ocean [25–27] as well as Thick-billed Murres during summer [28]. Great and Plain sculpins, Pacific Cod, Pacific Halibut, Pigeon Guillemots, Tufted Puffins, and Thick-billed Murres in Bering Sea, Gulf of Alaska, and off British Columbia, Canada and Kamchatka Peninsula, Russia [29–34].

Competitors—Presumably a wide range of other zoobenthos 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) [24].

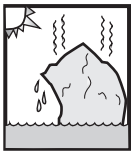


Traditional and Cultural Importance

None reported.

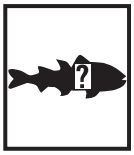
Commercial Fisheries

Currently, Ribbed Scuplin are not commercially harvested.



Potential Effects of Climate Change

The Ribbed Sculpin reproduces in Arctic and Boreal waters [2], so it is difficult to predict how climate warming might affect its distribution or abundance. A trend of increasing abundance with latitudinal change is hypothesized.



Areas for Future Research [B]

Little is known about the biology and ecology of this species from the 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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Crested Sculpin to Leatherfin Lumpsucker

Crested Sculpin (*Blepsias bilobus*)

Cuvier, 1829

Family Hemitripteridae

Note: *Except for the 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: Unknown, but given what is known about the species distribution and abundance, likely to be minor with respect to marine ecosystem function in the Chukchi Sea.

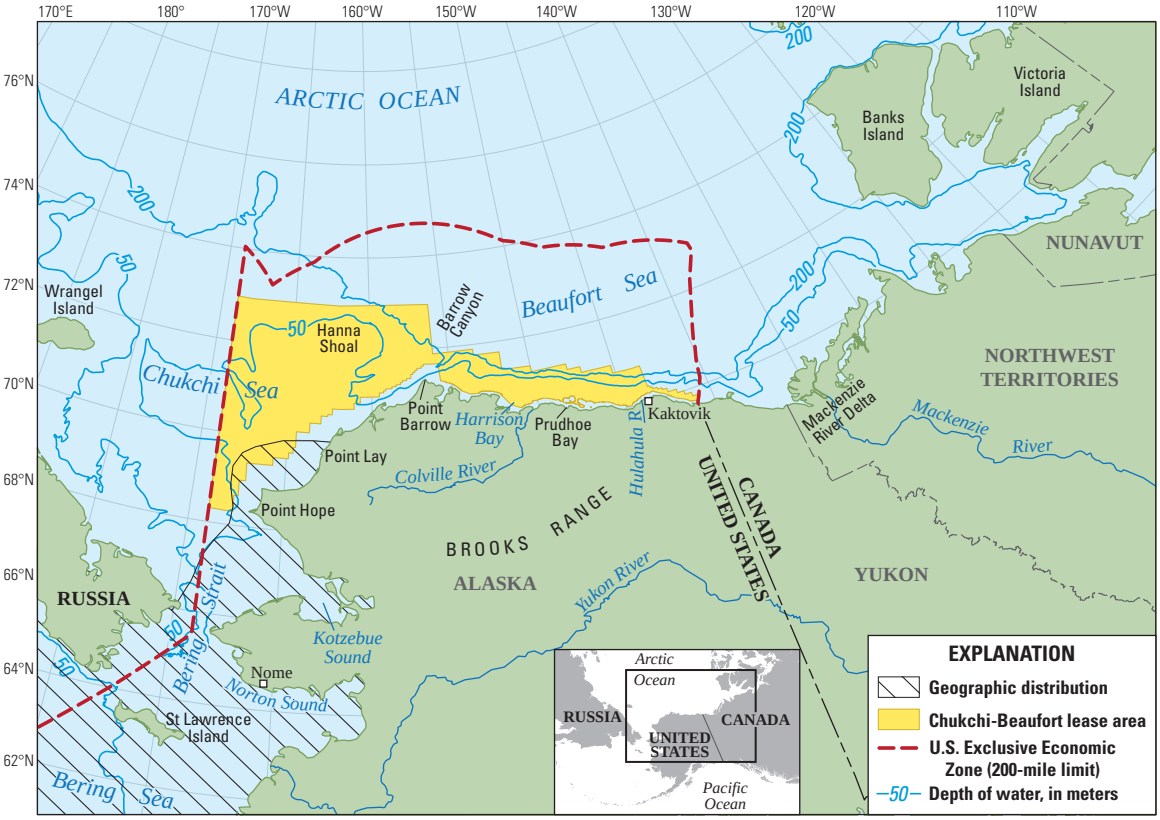
Physical Description/Attributes: Compressed body densely covered in prickles; orange-brown to olive green with darker blotches dorsally, or white with olive to black mottling. For specific diagnostic characteristics, see *Fishes of Alaska* (Meckenburg and others, 2002, p. 509) [1]. Swim bladder: Absent [2]. Antifreeze glycoproteins in blood serum: Unknown.

Crested Sculpin (*Blepsias bilobus*), 128 mm TL, eastern Chukchi Sea, 2007. Photograph by C.W. Mecklenburg, Point Stephens Research.

Range: *U.S. Chukchi Sea* [3]. Elsewhere in Alaska, Bering Sea, and Aleutian Islands from Amchitka Island along coasts to southern British Columbia near Port Hardy. Worldwide, Seas of Okhotsk and Japan [3].

Relative Abundance: *Uncommon in U.S. Chukchi Sea.* [6]. Elsewhere, common in Sea of Japan and eastern Bering Sea north to about St. Lawrence Island [3, 7, 8].

Crested Sculpin
Blepsias bilobus

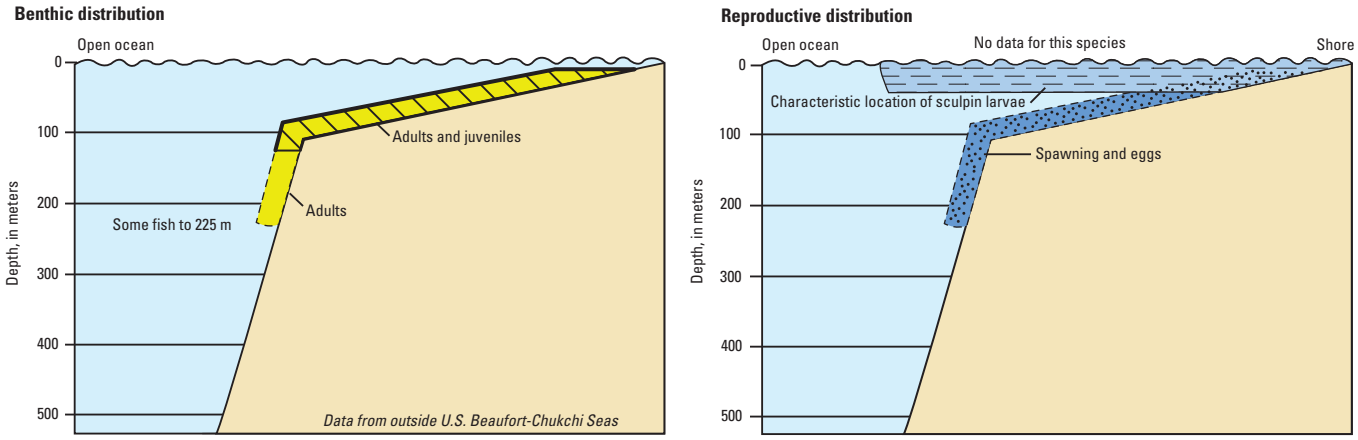


Base modified from USGS and other digital data. U.S.-Russia Maritime Boundary follows the EEZ/200-mile limit line, western edge. Coordinate reference system: projection, Lambert Azimuthal Equal Area; latitude of origin, 75.0°; horizontal datum, North American Datum of 1983.

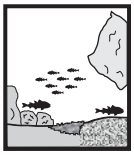
Geographic distribution of Crested Sculpin (*Blepsias bilobus*) within Arctic Outer Continental Shelf Planning Areas [4] based on review of published literature and specimens from historical and recent collections [3, 5].

Depth Range: 4–250 m [9, 15], typically less than 120 m [1]. Juveniles collected at the shallower depths and near the surface [9].

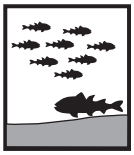
Blepsias bilobus
Crested Sculpin



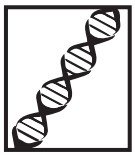
Benthic and reproductive distribution of Crested Sculpin (*Blepsias bilobus*).



Habitats and Life History
Eggs—Size: Unknown. Time to hatching: Unknown. Habitat: Likely benthic [10].
Larvae—Size at hatching: Unknown. Size at juvenile transformation: Unknown. Days to juvenile transformation: Unknown. Habitat: Pelagic [10].
Juveniles—Age and size: Unknown. Habitat: Benthic, nearshore to upper slope [1]; over bare bottoms, bedrock, and among kelp and eelgrass [11].
Adults—Age and size at first maturity: Unknown. Maximum age: Unknown. Maximum size: 27 cm TL [1]. Habitat: Benthic [1–3], nearshore to upper slope [1]; over bare bottoms, bedrock, and among kelp and eelgrass [11]
Substrate—At least bedrock [11].
Physical/chemical—Temperature: -1.4–11.4 °C [15]. Salinity: Marine.



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



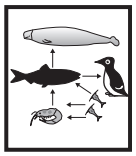
Populations or Stocks
There have been no studies.

Reproduction
Mode—Probably oviparous [10].
Spawning season—Unknown.
Fecundity—Unknown.

Food and Feeding

Food items—Amphipods and Walleye Pollock *(Gadus chalcogrammus*) in Russia [13]. Small invertebrates in general for members of the Hemitripteridae family [2].

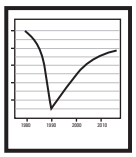
Trophic level—4.13 standard error ±0.74 [13].



Biological Interactions

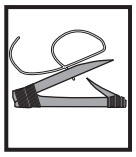
Predators—Great Sculpin [14].

Competitors—Likely other sculpins, as well as flatfishes, gadids, and eelpouts.



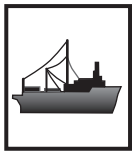
Resilience

Unknown.



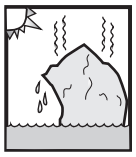
Traditional and Cultural Importance

None reported.



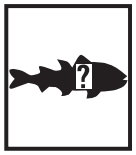
Commercial Fisheries

Currently, Crested Sculpin are not commercially harvested.



Potential Effects of Climate Change

This Boreal Pacific species could be expected to increase in abundance and become more widespread in the Chukchi Sea, and perhaps to expand its distribution to the Beaufort Sea.



Areas for Future Research [B]

Little is known about the ecology and life history of this species. 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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Johnson, S.W., Neff, A.D., and Thedinga, J.F., 2005, An atlas on the distribution and habitat of common fishes in shallow nearshore waters of southeastern Alaska: Alaska Fisheries Science Center, Technical Memorandum NMFS-AFSC-157, 98 p. [11]

Love, M.S., Mecklenburg, C.W., Mecklenburg, T.A., and Thorsteinson, L.K., 2005, Resource inventory of marine and estuarine fishes of the West Coast and Alaska—A checklist of North Pacific and Arctic Ocean species from Baja California to the Alaska-Yukon border: Seattle, Washington, U.S. Department of the Interior, U.S. Geological Survey, Biological Resources Division, OCS Study MMS 2005-030 and USGS/NBII 2005-001, 276 p. [9]

Mecklenburg, C.W., 2003, Family Hemitripteridae Gill 1872—Sea ravens or sailfin sculpins: California Academy of Sciences Annotated Checklists of Fishes no. 5, 6 p. [2]

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. [3]

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Eyeshade Sculpin (*Nautichthys pribilovius*)
(Jordan & Gilbert, 1898)

Family Hemitripteridae

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

Ecological Role: Unlikely to be of significant importance in regional foods webs.

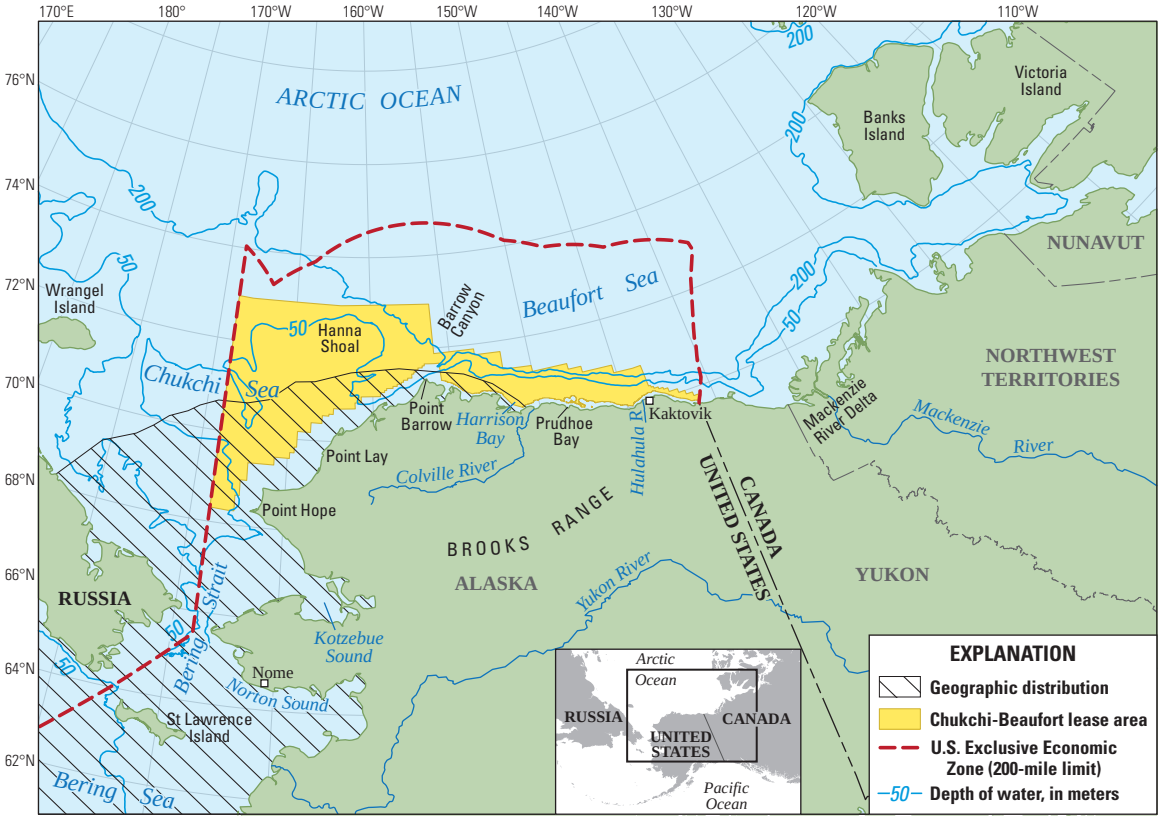
Physical Description/Attributes: Brown to gray-brown body with vague dark blotches and covered with prickles that extend onto dorsal and pectoral fins; black bar from eye diagonally downward on cheek. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 512) [1]. Swim bladder: Absent [2]. Antifreeze glycoproteins in blood serum: Unknown.

Eyeshade Sculpin (*Nautichthys pribilovius*), 109 mm TL, Bering Strait, 2007. Photograph by C.W. Mecklenburg, Point Stephens Research.

Range: *U.S. Chukchi Sea and western U.S. Beaufort Sea* [3, 4]. Elsewhere in Alaska, in Bering Sea and Aleutian Islands from Attu Island to southeastern Alaska at Steamer Bay. Worldwide, Gulf of Anadyr to Commander Islands and to Seas of Okhotsk and Japan [1, 3].

Relative Abundance: *Common in eastern Chukchi Sea* [4, 7] *and more common in Bering Strait and southeastern Chukchi Sea* [6] and eastern Bering Sea [8] but rare in Sea of Japan [9] and U.S. Beaufort Sea.

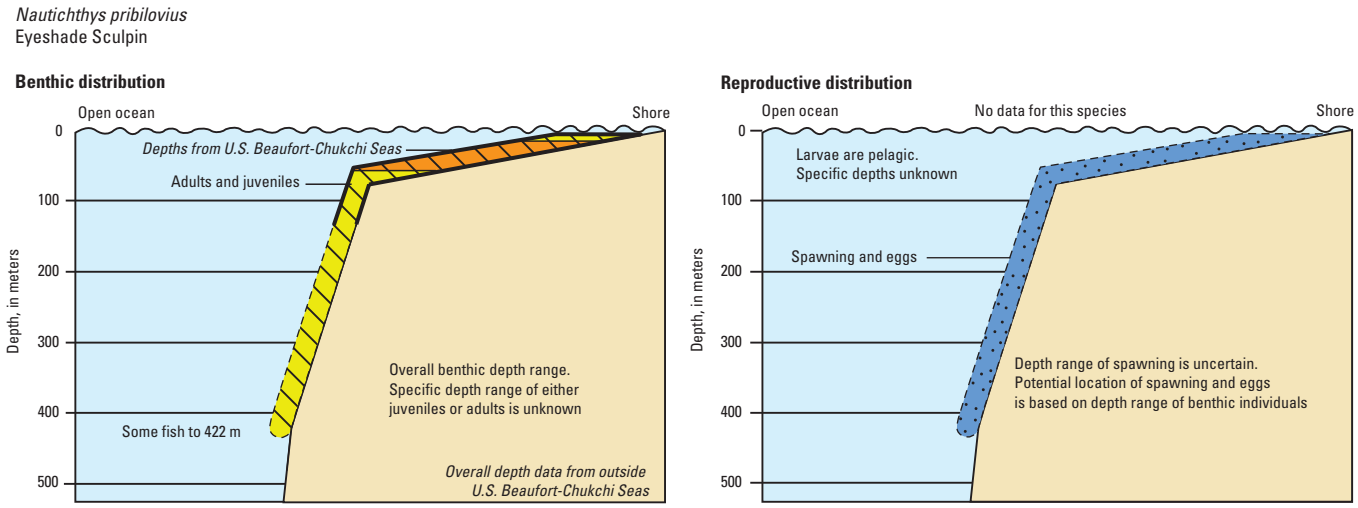
Eyeshade Sculpin
Nautichthys pribilovius



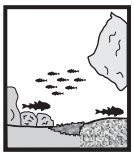
Base modified from USGS and other digital data. U.S.-Russia Maritime Boundary follows the EEZ/200-mile limit line, western edge. Coordinate reference system: projection, Lambert Azimuthal Equal Area; latitude of origin, 75.0°; horizontal datum, North American Datum of 1983.

Geographic distribution of Eyeshade Sculpin (*Nautichthys pribilovius*) within Arctic Outer Continental Shelf Planning Areas [5] based on review of published literature and specimens from historical and recent collections [1, 3, 4, 6].

Depth Range: 11 m [4] to 422 m, typically less than 135 m in Bering Sea and Gulf of Alaska [1]. *Documented at depths of 11–53 m* [4] *in the U.S. Chukchi Sea and 24–53 m in the U.S. Beaufort Sea* [4].



Benthic and reproductive distribution of Eyeshade Sculpin (*Nautichthys pribilovius*).



Habitats and Life History

Eggs—Size: 2.5–2.7 mm [10]. Time to hatching: Unknown. Habitat: Likely benthic based on life history of the Sailfin Sculpin (*Nautichthys oculofasciatus*) [11].

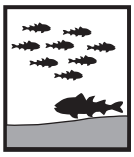
Larvae—Size at hatching: Unknown. Size at juvenile transformation: Unknown. Days to juvenile transformation: Unknown. Habitat: Likely pelagic based on life history of Sailfin Sculpin [11].

Juveniles—Age and size: Unknown. Habitat: Benthic [1].

Adults—Age and size at first maturity: Unknown. Maximum Age: Unknown. Maximum size: As long as 10.9 cm TL [1]. Habitat: Benthic [1].

Substrate—*Shell hash, gravel, sand, mud and rock in U.S. Chukchi Sea* [6].

Physical/chemical—Temperature: *-1.7–11.4 °C* [4, 6, 12]. Prefers temperatures greater than 0 °C [10]. Salinity: Marine to slightly estuarine [13].



Behavior

Diel—Unknown.

Seasonal—Unknown.

Reproductive—Unknown.

Schooling—Unknown.

Feeding—Unknown.

Populations or Stocks

There have been no studies.

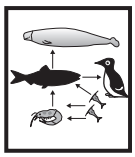
Reproduction

Mode—Oviparous [10].

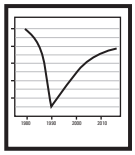
Spawning season—Unknown.

Fecundity—50 eggs [10].

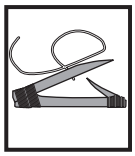
Food and Feeding
Food items—Unknown. Small invertebrates in general for members of the Hemitripteridae family [2].
Trophic level—3.62 standard error 0.65 [14].



Biological Interactions
Predators—Unknown.
Competitors—Unknown.

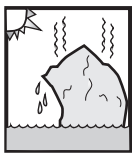


Resilience
Unknown. No data.

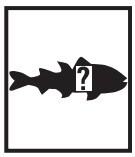


Traditional and Cultural Importance
None reported.

Commercial Fisheries
Currently, Eyeshade Sculpin are not commercially harvested.



Potential Effects of Climate Change
A predominantly Boreal Pacific species [3], Eyeshade Sculpin are apt to become more abundant in the Chukchi and Beaufort Seas as water temperatures increase. A range expansion in the Beaufort Sea also is likely.



Areas for Future Research [B]
Little is known about the biology and ecology of this species from the region. Research needs include: (1) depth and location of pelagic larvae, (2) depth, location, and timing of young-of-the-year Demersal 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., Stein, D.L., Sheiko, B.A., Chernova, N.V., Mecklenburg, T.A., and Holladay, B.A., 2007, Russian–American long-term census of the Arctic—Benthic fishes trawled in the Chukchi Sea and Bering Strait, August 2004: Northwestern Naturalist, v. 88, no. 3, p. 168–187. [6]

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Polar Sculpin (*Cottunculus microps*)

Collett, 1875

Family Psychrolutidae

Polar Sculpin (*Cottunculus microps*) 135 mm TL, Chukchi Borderland, 2009. Photograph by C.W. Mecklenburg, Point Stephens Research.

Note on taxonomy: *Based on recent taxonomic revision Cottunculus sadko (Essipov, 1937) is treated as a synonym of C. microps* [1, 2]. *Data on fish originally identified as* C. sadko *are included here.*

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

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

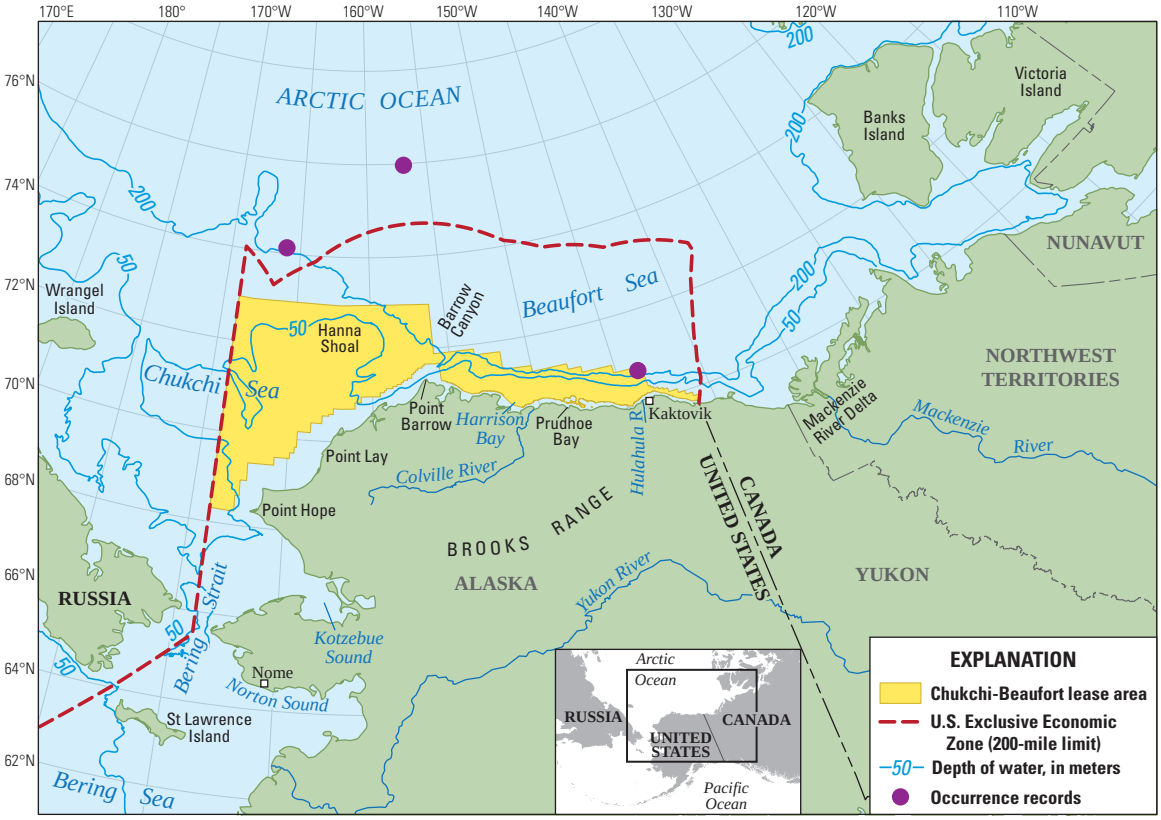
Ecological Role: Minor in the U.S. Beaufort Sea.

Physical Description/Attributes: Tadpole shaped body with moveable skin over a clear, gelatinous layer. Body is greyish with three vague, dark bands. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 518 [as *C. sadko*]) [3]. Swim bladder: Absent [3]. Antifreeze glycoproteins in blood serum: Unknown.

Range: *One record from continental slope off U.S. Beaufort Sea.* One record outside the U.S. 200-mile limit north of the eastern Chukchi Sea. North to about 82°N [4]; circumpolar; Kara Sea slope in Voronin Trough, Laptev Sea slope off Bolshevik Island, Faroe Trough, Nansen Rise off Spitsbergen, western Barents Sea, slope off Franz Josef Land; and south to Gulf of St. Lawrence and New Jersey, English Channel, and North Sea [4].

Relative Abundance: *Rare in U.S. Beaufort Sea* [4]. Common eastward from Hudson Strait and Baffin Bay to Greenland and the Barents Sea [1, 7, 8].

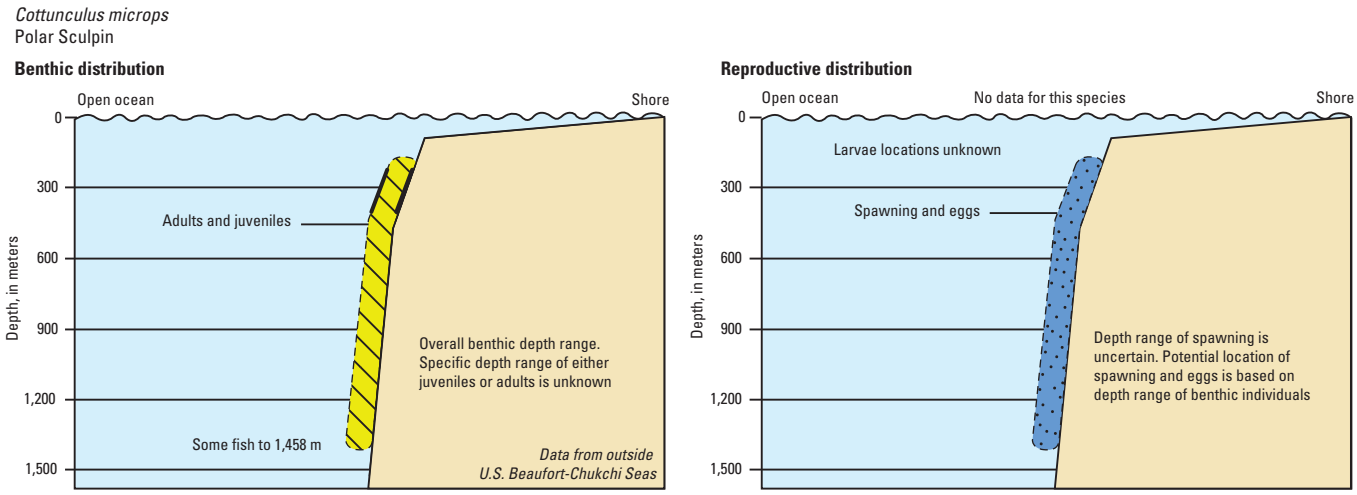
Polar Sculpin
Cottunculus microps



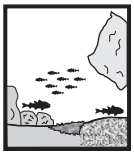
Base modified from USGS and other digital data. U.S.-Russia Maritime Boundary follows the EEZ/200-mile limit line, western edge. Coordinate reference system: projection, Lambert Azimuthal Equal Area; latitude of origin, 75.0°; horizontal datum, North American Datum of 1983.

Geographic distribution of Polar Sculpin (*Cottunculus microps*) within Arctic Outer Continental Shelf Planning Areas [5] in the study area based on review of published literature and specimens from historical and recent collections [4, 6].

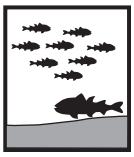
Depth Range: Upper continental slopes at 159–2,476 m [6], mainly 170–400 m in Barents Sea [1].



Benthic and reproductive distribution of Polar Sculpin (*Cottunculus microps*).



Habitats and Life History
Eggs—Size: 3–5 mm [1]. Time to hatching: Unknown. Habitat: Benthic [9].
Larvae—Size at hatching: Size at juvenile transformation: Days to juvenile transformation: Habitat: Unknown.
Juveniles—Age and size: Unknown. Habitat: Benthic, deep troughs, and upper parts of continental slope [3].
Adults—Age and size at first maturity: Unknown. Maximum age: 8–10 years [1]. Maximum size: As long as 33 cm TL (mainly 6–16 cm) and 0.7 kg [1]. Habitat: Benthic, deep troughs, and upper parts of continental slope [3].
Substrate—Mud, soft bottoms [1, 3].
Physical/chemical—Temperature: -0.4–1.9 °C in Baffin Bay [10]. Typically temperatures greater than 0 °C [1]. Salinity: Prefers high salinity (34.5–35 ppt) [1].

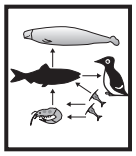


Behavior
Diel—Unknown.
Seasonal—Unknown.
Reproductive—Adults of this family typically guard their eggs [7].
Schooling—Unknown. **Feeding**—Unknown.

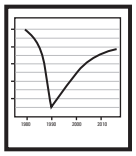
Populations or Stocks
There have been no studies.

Reproduction
Mode—Oviparous [7].
Spawning season—Summer–autumn in Barents Sea [1].
Fecundity—125–435 eggs [1].

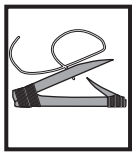
Food and Feeding
Food items—Benthic invertebrates such as pantopods, amphipods, gammarids, polychaetes, mysids, mollusks, etc. [1, 11].
Trophic level—3.41 standard error 0.39 [12].



Biological Interactions
Predators—Greenland halibut in Barents Sea [13].
Competitors—Juveniles would likely be consumed by a range of benthic feeders, such as flatfishes, cods, sculpins, and poachers.

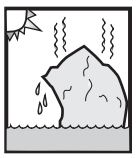


Resilience
Low, minimum population doubling time: 4.5–14 years (Fecundity = 66) [12].

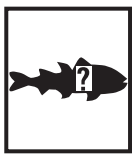


Traditional and Cultural Importance
None reported.

Commercial Fisheries
Currently, Polar Sculpin are not commercially harvested.



Potential Effects of Climate Change
Unknown.



Areas for Future Research [B]
Little is known about the ecology and life history of this species. 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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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. [4]

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

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Smoothcheek Sculpin (*Eurymen gyrinus*)

Gilbert & Burke, 1912

Family Psychrolutidae

Smoothcheek Sculpin (*Eurymen gyrinus*), 111 mm TL, northern Bering Sea, 2007. Photograph by C.W. Mecklenburg, Point Stephens Research.

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

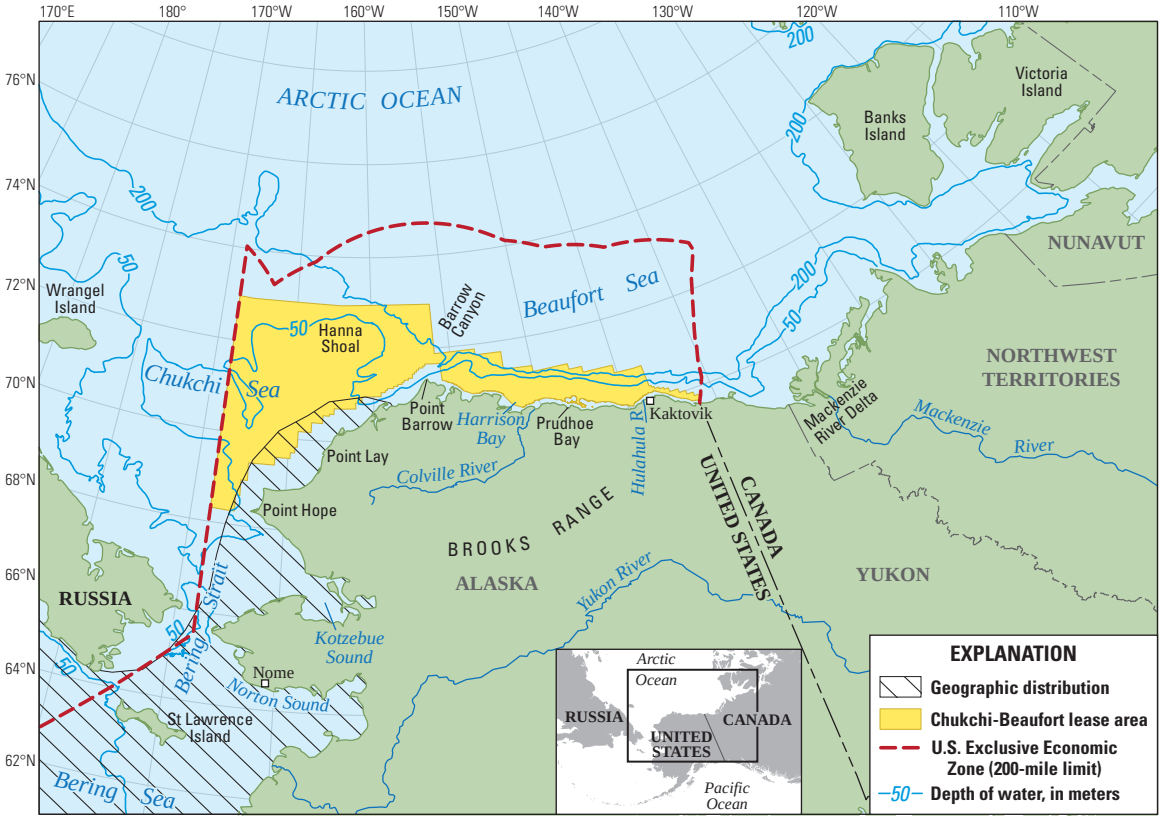
Ecological Role: Scarcity within U.S. Chukchi Sea waters and absence from the U.S. Beaufort Sea suggests a minor ecological role.

Physical Description/Attributes: Tadpole-shaped body with moveable skin over a clear, gelatinous layer. Color is highly variable according to habitat [1]. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 517) [1]. Swim bladder: Absent [1]. Antifreeze glycoproteins in blood serum: Unknown.

Range: *U.S. Chukchi Sea to 70°26'N, 164°38'W* [2]. Elsewhere in Alaska, Bering Sea south to Aleutian Islands and to western Gulf of Alaska at Kodiak Island. Worldwide, Seas of Japan and Okhotsk and Pacific coast of Honshu, and off Japan to Commander Islands [1].

Relative Abundance: *Rare in U.S. Chukchi Sea and absent from U.S. Beaufort Sea* [1, 2, 4]; typically caught in shallow waters, but rarely sampled by research investigations. Rare in Sea of Japan [5].

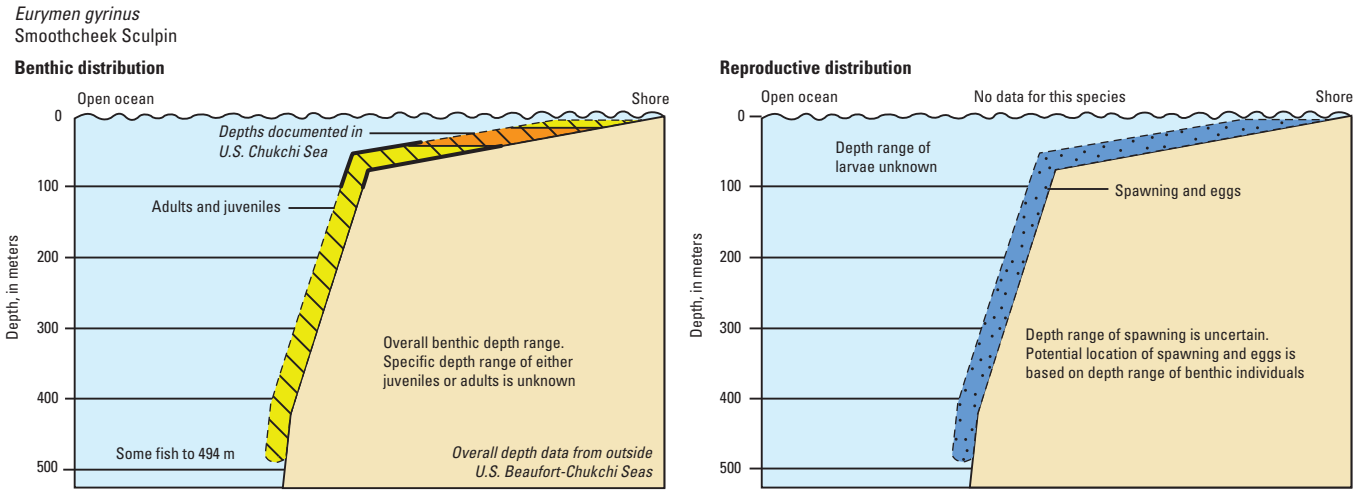
Smoothcheek Sculpin
Eurymen gyrinus



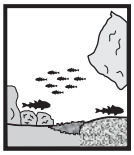
Base modified from USGS and other digital data. U.S.-Russia Maritime Boundary follows the EEZ/200-mile limit line, western edge. Coordinate reference system: projection, Lambert Azimuthal Equal Area; latitude of origin, 75.0°; horizontal datum, North American Datum of 1983.

Geographic distribution of Smoothcheek Sculpin (*Eurymen gyrinus*) 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: 2–174 m [2, 6], typically 40–100 m in the Pacific Ocean off the northern Kuril Islands, Russia [7]. *Found at depths of 17–44 m in the U.S. Chukchi Sea* [2].

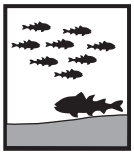


Benthic and reproductive distribution of Smoothcheek Sculpin (*Eurymen gyrinus*).



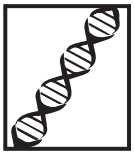
Habitats and Life History

Eggs—Size: Unknown. Time to hatching: Unknown. Habitat: Likely benthic, like the more well-known members of the family Psychrolutidae [8].
Larvae—Size at hatching: Unknown. Size at juvenile transformation: Unknown. Days to juvenile transformation: Unknown. Habitat: Unknown.
Juveniles—Age and size: Unknown. Habitat: Benthic [1]. Adults: Age and size at first maturity: Unknown. Maximum age: Unknown. Maximum size: As long as 38.8 cm TL [1]. Habitat: Benthic [1].
Substrate—Unknown.
Physical/chemical—Temperature: Unknown. Salinity: Marine [1].



Behavior

Diel—Unknown.
Seasonal—Unknown.
Reproductive—Adults of this family typically guard their eggs [8].
Schooling—Unknown.
Feeding—Unknown.



Populations or Stocks

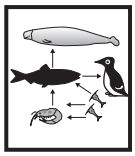
There have been no studies.

Reproduction

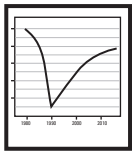
Mode—Oviparous [8].
Spawning season—Unknown.
Fecundity—Unknown.

Food and Feeding

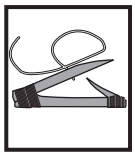
Food items—Unknown.
Trophic level—3.41 standard error 0.46 [9].



Biological Interactions
Predators—Unknown.
Competitors—Unknown.

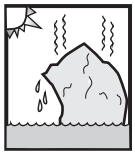


Resilience
Low, minimum population doubling time: 4.5–14 years (Preliminary *K* or Fecundity) [9].

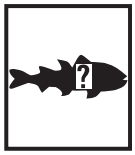


Traditional and Cultural Importance
None reported.

Commercial Fisheries
Currently, Smoothcheek Sculpin are not commercially harvested.



Potential Effects of Climate Change
It is likely that warming Arctic waters would allow this species to penetrate farther into the U.S. Chukchi Sea and perhaps 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 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.

References Cited

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Alligatorfish (*Aspidophoroides monopterygius*)
(Bloch, 1786)

Family Agonidae

Alligatorfish (*Aspidophoroides monopterygius*), 84 mm TL, Chukchi Sea, 2007. 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*.

Note on taxonomy: *The Alaskan population was described and named as a distinct species, Aspidophoroides bartoni (Gilbert, 1896), to which the common name Aleutian Alligatorfish has been applied* [1]. *Recent genetic and morphological data confirm that they are the same species* [1, 2].

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

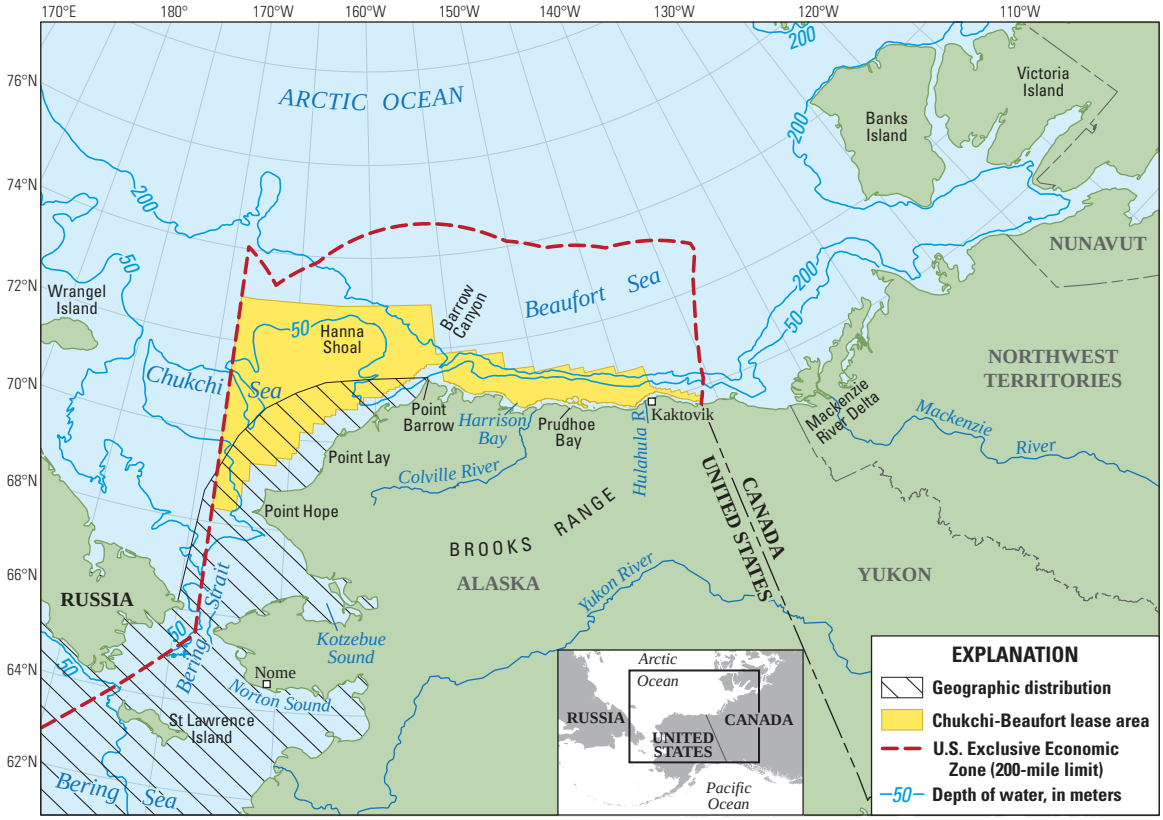
Ecological Role: Current information about the occurrence of this fish is limited in the U.S. Chukchi and Beaufort Seas. It is unlikely to represent a significant prey resource in regional food webs.

Physical Description/Attributes: Brownish to olive green with a slender body covered with bony plates; faint dark bands on sides and back; and a white belly. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 553) [1]. Swim bladder absent [3]. Antifreeze glycoproteins in blood serum: Unknown.

Range: *U.S. Chukchi Sea northward to Point Barrow and Beaufort Sea eastward to about 71°N, 151°W* [2, 4]. Elsewhere in Alaska, in Bering Sea and Aleutian Islands, to Prince William Sound and Gulf of Alaska [1]. Worldwide, in western Pacific from Sea of Japan and Sea of Okhotsk to Gulf of Anadyr, and western Atlantic Ocean from northwestern Greenland to New Jersey [1, 2].

Relative Abundance: *Common in U.S. Chukchi Sea* [2, 4, 6, 7]. In Alaska, common in eastern Bering Sea, and along the western end of the Alaska Peninsula [8–10].Worldwide, common in nearshore waters off Kamchatka, Russia [11].

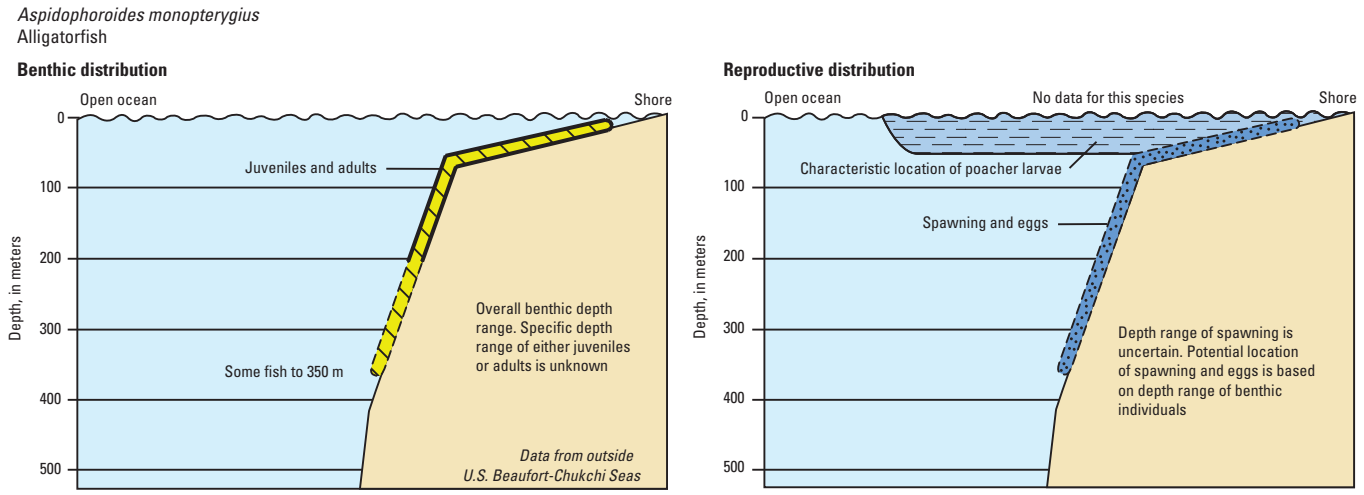
Alligatorfish
Aspidophoroides monopterygius



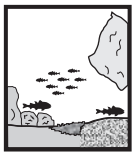
Base modified from USGS and other digital data. U.S.-Russia Maritime Boundary follows the EEZ/200-mile limit line, western edge. Coordinate reference system: projection, Lambert Azimuthal Equal Area; latitude of origin, 75.0°; horizontal datum, North American Datum of 1983.

Geographic distribution of Alligatorfish (*Aspidophoroides monopterygius*) within Arctic Outer Continental Shelf Planning Areas [5] based on review of published literature and specimens from historical and recent collections [1, 2, 4].

Depth Range: Overall range is 8–337 m, but almost entirely less than 200 m [1]. Depth range of larvae is unknown. In general, poacher larvae are abundant in near-surface waters, and over continental shelf and upper slope [12–14]. Depth range of juveniles is unknown.



Benthic reproductive distribution of Alligatorfish (*Aspidophoroides monopterygius*).



Habitats and Life History

Eggs—Size: Unknown. Time to hatching: Unknown. Habitat: Demersal and adhesive (probably on sand and mud) [3].

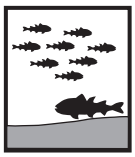
Larvae—Size at hatching: Unknown. Size at juvenile transformation: 29.0 mm in western North Atlantic [15]. Days to juvenile transformation: Unknown. Habitat: Pelagic although distance from shore and depth in water column are unknown for this species; in general poacher larvae are abundant in near-surface waters, over continental shelf and shallow slope waters [12–14].

Juveniles—Age and size: Unknown. Habitat: Demersal [1, 3, 16], although fish to at least 4.1 cm TL are occasionally found in midwaters [17].

Adults—Age and size at first maturity: Unknown. Maximum age: At least 6 years. Females grow larger and may have a slightly longer life span [18]. Maximum size: 17.8 cm TL [1]. Habitat: Demersal [3, 16].

Substrate—Juveniles and adults live on sand and mud [1, 19].

Physical/chemical—Temperature: Between at least -1.7–12.2 °C. [19, 20]. Salinity: All life stages live in marine waters. [19–21].



Behavior

Diel—Unidentified poacher larvae have migrated into slightly deeper waters at night in southeastern Alaska [13].

Seasonal—Off Kamchatka, found in relatively shallow waters during summer and during winters in deeper waters on the edge of the continental shelf [11].

Reproductive—Unknown.

Schooling—Unlikely. Other poacher species are solitary [16, 22].

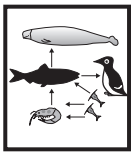
Feeding—Unknown.

Populations or Stocks

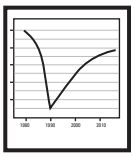
There have been no studies.

Reproduction
Mode—Separate sexes, oviparous [23].
Spawning season—Poorly known. November to January in Atlantic Ocean [24].
Fecundity—Poorly known. One "medium-sized" Alligatorfish in Atlantic Ocean specimen contained about 600 eggs [19].

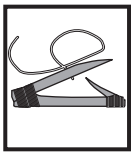
Food and Feeding
Food items—Benthic individuals eat mostly zoobenthos, including crustaceans (for example, amphipods, isopods, cumaceans) and polychaetes [25, 26], although midwater animals such as pteropods are also consumed [26]. Food habits of larvae are unknown.
Trophic level—3.5 (standard error 0.43) [27].



Biological Interactions
Predators—Cannibalism has not been reported. Bering Sea, Kamchatka Peninsula and northern Kuril Island, Russia, predators include Flathead Sole, Great Sculpin, Plain Sculpin, Pacific Cod, Pacific halibut, and Sablefish [28–34]. Of these species, only great and plain sculpins and Pacific Halibut inhabit the U.S. Chukchi Sea, and Great Sculpin and Pacific Halibut are rarely found there.
Competitors—Presumably other zoobenthic feeders such as Arctic Cod, Walleye Pollock, other poachers, eelpouts, and sculpins.

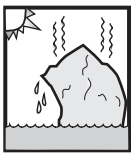


Resilience
Medium, minimum population doubling time is 1.4–4.4 years (Preliminary *K* or Fecundity) [27].

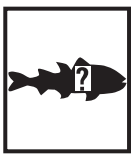


Traditional and Cultural Importance
None reported.

Commercial Fisheries
Currently, Alligatorfish are not commercially harvested.



Potential Effects of Climate Change
Alligatorfish are common in marine waters of Arctic Alaska in temperatures 1.1–2.5 °C. Warming could lead to increased patterns of abundance and that could lead to increased competition with other fishes that feed on small benthic organisms. This would potentially, include Arctic Cod, Walleye Pollock, other poachers, and sculpins.



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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Arctic Alligatorfish (*Aspidophoroides olrikii*)

Lütken, 1877

Family Agonidae

Arctic Alligatorfish (*Aspidophoroides olrikii*), 61 mm TL, Chukchi Sea, 2004. Photograph by B.A. Sheiko and C.W. Mecklenburg, Russian Academy of Sciences and Point Stephens Research.

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

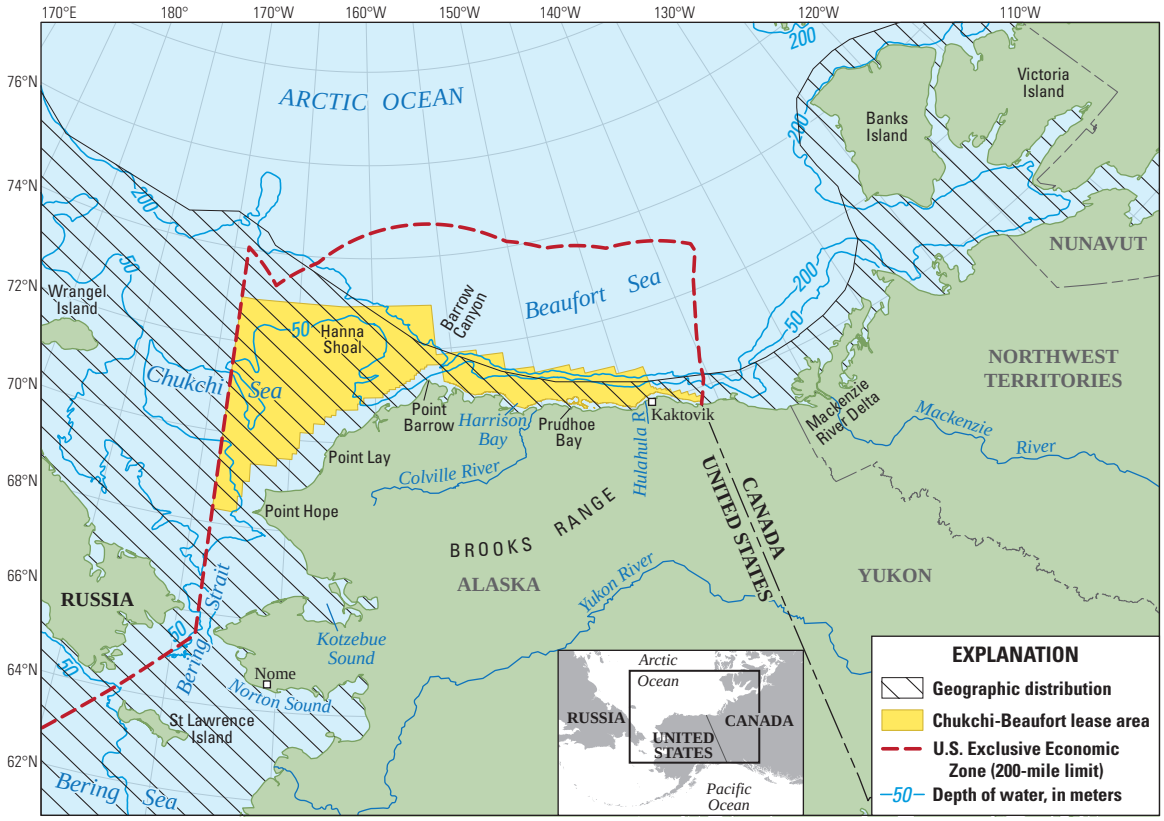
Ecological Role: Largely unknown. Species information regarding biology and ecology is not available. Although this species appears to be common in the U.S. Chukchi and Beaufort Seas, it does not school and its biomass is likely to be relatively low. Thus, this species is unlikely to represent a significant prey resource to birds, mammals, and larger fishes.

Physical Description/Attributes: Brownish to olive green on back and sides and white on belly. Caudal fin has a white margin and center [1]. Males have a chalky white blotch on dorsal fin [2]. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 552) [1]. Swim bladder: Absent [3]. Antifreeze glycoproteins in blood serum: Unknown.

Range: *In U.S. Beaufort Sea and northward to at least 71°55'N, 175°18'W in U.S. Chukchi Sea* [4]. Elsewhere in Alaska, south through the Bering Sea to northern Gulf of Alaska in Prince William Sound [5]. Worldwide, practically circumpolar in Arctic Ocean, from southern Barents Sea and White Sea eastward to west Greenland but not Canadian high Arctic archipelago; south in western Atlantic Ocean to Newfoundland [1, 2, 4, 5].

Relative Abundance: *Common throughout U.S. Chukchi Sea and U.S. Beaufort Seas* [1, 2, 4, 7, 8]. Reports of presence between Herschel Island and Franklin Bay, Canada [9–11] and numerous unpublished museum specimens from Alaska eastward to Hudson Bay indicate this species is common in Arctic Canadian waters [2].

Arctic Alligatorfish
Aspidophoroides olrikii

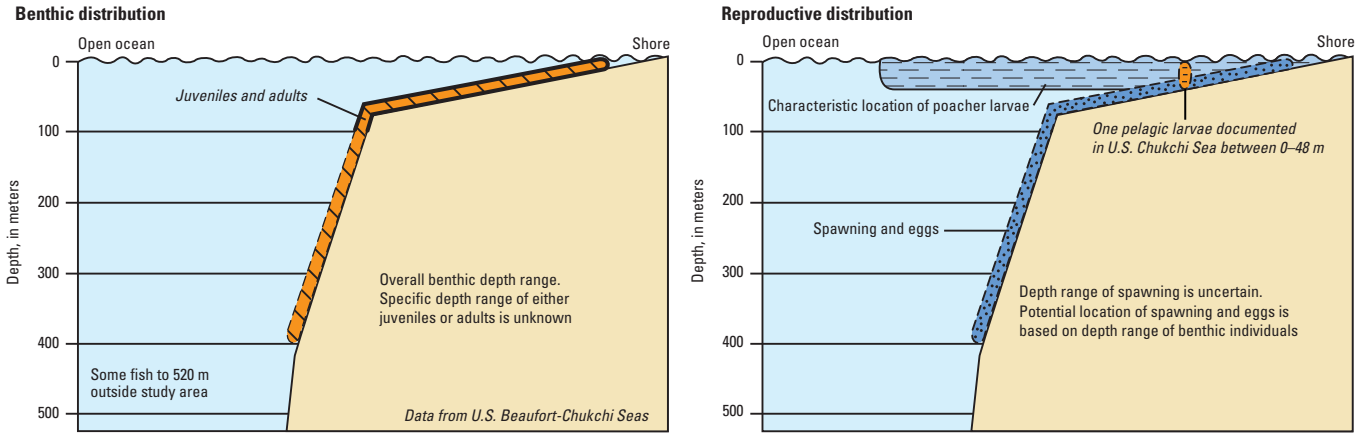


Base modified from USGS and other digital data. U.S.-Russia Maritime Boundary follows the EEZ/200-mile limit line, western edge. Coordinate reference system: projection, Lambert Azimuthal Equal Area; latitude of origin, 75.0°; horizontal datum, North American Datum of 1983.

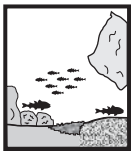
Geographic distribution of Arctic Alligatorfish (*Aspidophoroides olrikii*) within Arctic Outer Continental Shelf Planning Areas [6] based on review of published literature and specimens from historical and recent collections [1, 2, 5].

Depth Range: *As deep as 400 m in U.S. Chukchi and Beaufort Seas* [7], *usually less than 100 m* [1, 4, 5, 8, 12]. Elsewhere, overall depth range is 3–520 m [2]. Depth range of pelagic juveniles and larvae is poorly known. *One pelagic larva documented between 48 m and surface in the U.S. Chukchi Sea* [13]. Off Oregon and California, poacher larvae are abundant in near-surface waters, over the continental shelf and upper slope waters [14–16].

Aspidophoroides olrikii
Arctic Alligatorfish



Benthic and reproductive distribution of Arctic Alligatorfish (*Aspidophoroides olrikii*).



Habitats and Life History

Eggs—Size: 0.75–1.5 mm [17]. Time to hatching: Unknown. Habitat: Demersal and adhesive (probably on sand and mud) [3].

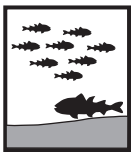
Larvae—Size at hatching: Unknown. Size at juvenile transformation: 2.5–6.2 cm TL [7, 12, 18]. Days to juvenile transformation: 2–3 months [3]. Habitat: Pelagic although distance from shore and depth in water column are unknown for this species, in general poacher larvae are abundant in near-surface waters, over continental shelf and shallow slope waters [14–16].

Juveniles—Age and size: Unknown. Habitat: Demersal [3, 19].

Adults—Age and size at first maturity: Age unknown. About 62 mm off Russia [12]. Maximum age: Unknown. Maximum size: 10 cm TL [2]. Habitat: Demersal [1, 3, 19].

Substrate—Sand and mud bottoms; also lives around rocks [4, 12, 20].

Physical/chemical—Temperature: Juveniles and adults at least -1.8–7.9 °C [2, 21–23], prefers around 0 °C [24]. Salinity: Marine and estuarine waters as brackish as 20 ppt [12, 25], prefers 33–35 ppt [24].



Behavior

Diel—Unidentified poacher larvae have migrated into slightly deeper waters at night in southeastern Alaska [15].

Seasonal—Unknown.

Reproductive—Unknown.

Schooling—Unlikely. Other poacher species are solitary [19, 26].

Feeding—Unknown.

Populations or Stocks

There have been no studies.

Reproduction

Mode—Separate sexes, oviparous [27].

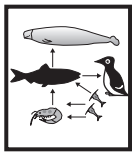
Spawning season—Unknown.

Fecundity—At least 110–260 eggs [7, 12].

Food and Feeding

Food items—*A few fish examined in the U.S. Chukchi and Beaufort seas had eaten gammarid amphipods, polychaetes, and clam siphons* [7, 28], whereas fish in the Russian Arctic consumed amphipods, isopods, ostracods, and nemerteans [12]. Food habits of larvae are unknown.

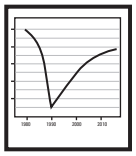
Trophic level—3.3 standard error 0.49 [29].



Biological Interactions

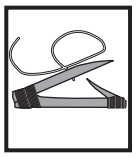
Predators—Unknown.

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



Resilience

Medium, minimum population doubling time: 1.4–4.4 years (assuming t_m=2–4; Fecundity <2,000) [21]

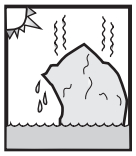


Traditional and Cultural Importance

None reported.

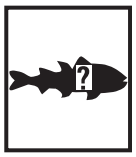
Commercial Fisheries

Currently, Arctic Alligatorfish are not commercially harvested.



Potential Effects of Climate Change

This is a predominantly Arctic species; thus, the distribution of Arctic Alligatorfish would be expected to shift northwards with warming temperatures.



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 movement,; (6) population studies, (7) prey, and (8) predators.

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Fourhorn Poacher (*Hypsagonus quadricornis*)

(Valenciennes, 1829)

Family Agonidae

Fourhorn Poacher (*Hypsagonus quadricornis*), 103 mm TL, Bering Strait, 2007. Photograph by C.W. Mecklenburg, Point Stephens Research.

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

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

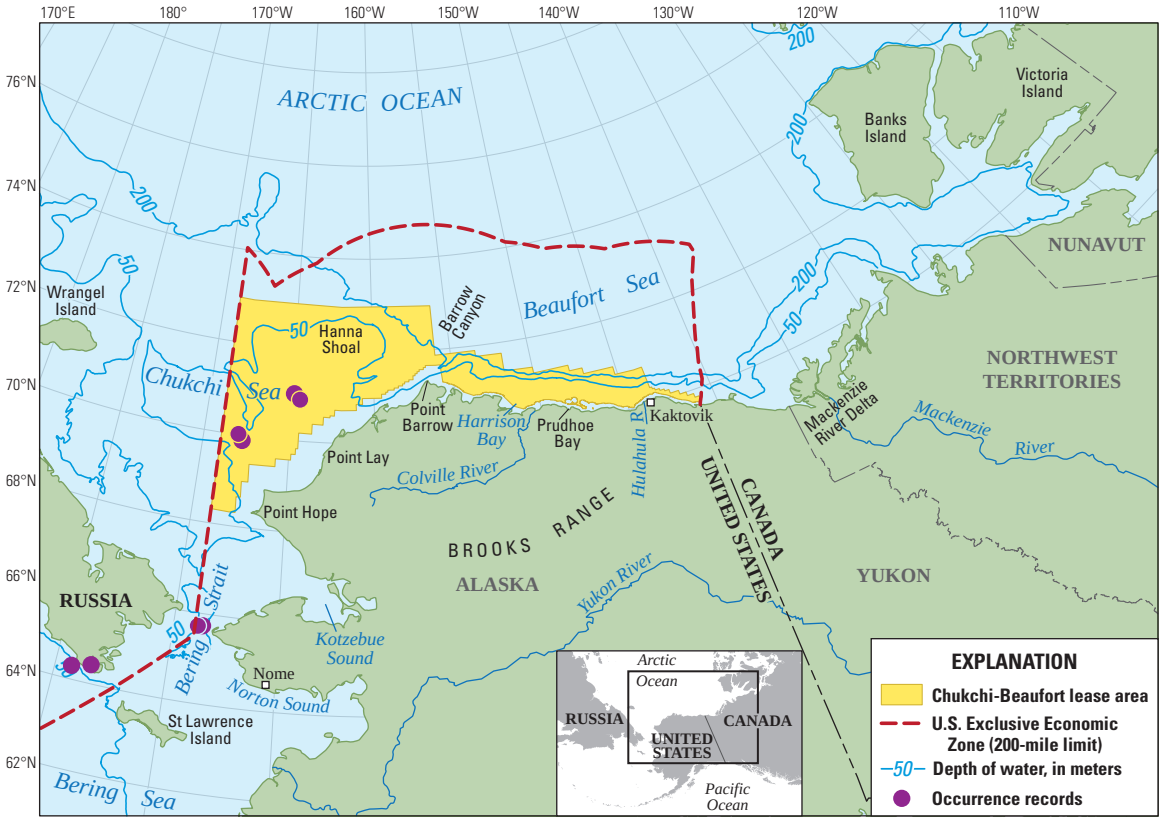
Ecological Role: Current information about the occurrence of this fish is limited in the U.S. Chukchi Sea. Its rare occurrence suggests it is not important in local or regional food webs.

Physical Description/Attributes: Reddish brown and bony-plated with cryptic coloration of white, yellow, red, and brown bands and blotches, and a dark vertical band along margin of caudal fin. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 531) [1]. Swim bladder: Absent [2]. Antifreeze glycoproteins in blood serum: Unknown.

Range: *From Bering Strait to northeastern Chukchi Sea west of Point Lay* [3]. *Found in the U.S. Chukchi Sea for the first time in 2007 in a region, which had been extensively sampled, this boreal species could be new to the Arctic* [3, 4]. Elsewhere, from Commander–Aleutian Islands chain and southern Bering Sea southward to Puget Sound, Washington, and to Sea of Okhotsk and northern Sea of Japan [1, 3–7].

Relative Abundance: *Rare in U.S. Chukchi Sea* [3]. Elsewhere in Alaska, rare north of 57°N in Bering Sea [3]. Common around the Aleutian Islands, Pribilof Islands, and eastward to Cook Inlet, Gulf of Alaska, southward to Puget Sound, Washington, and around the Kuril Islands and Kamchatka Peninsula, Russia.

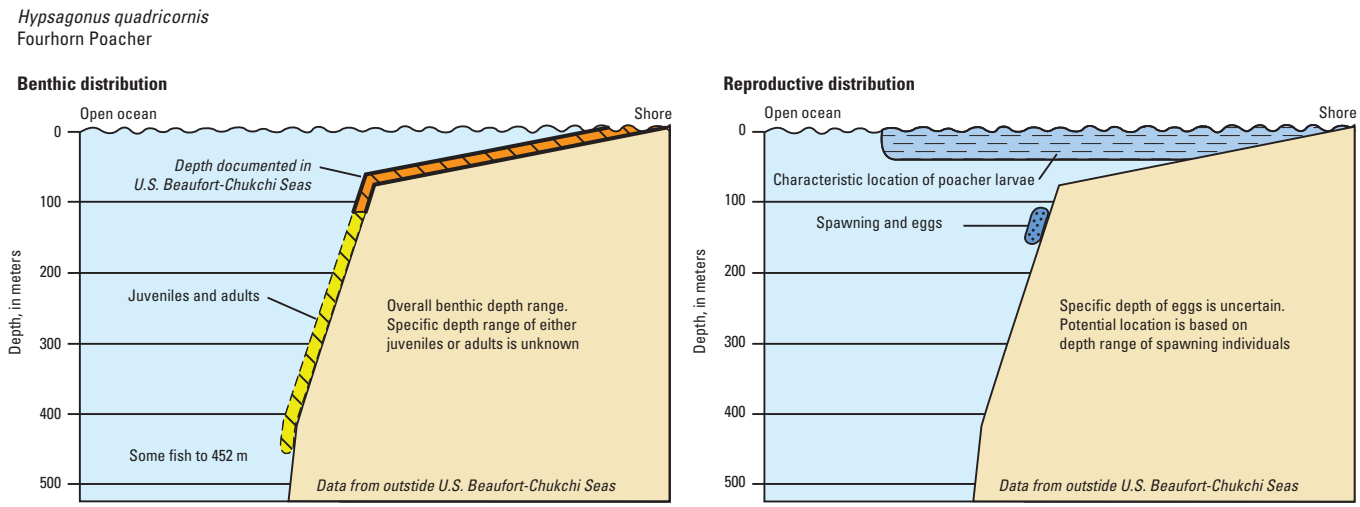
Fourhorn Poacher
Hypsagonus quadricornis



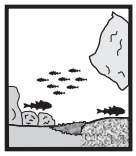
Base modified from USGS and other digital data. U.S.-Russia Maritime Boundary follows the EEZ/200-mile limit line, western edge. Coordinate reference system: projection, Lambert Azimuthal Equal Area; latitude of origin, 75.0°; horizontal datum, North American Datum of 1983.

Geographic distribution of Fourhorn Poacher (*Hypsagonus quadricornis*) within Arctic Outer Continental Shelf Planning Areas [8] based on review of published literature and specimens from historical and recent collections [3, 4].

Depth Range: From intertidal zone to 452 m [1], but most abundant at less than 200 m [1, 5, 9, 10]. *Occurs at depths less than 110 m in northern Bering Sea and U.S. Chukchi Sea* [4]. In the Pacific Ocean off the northern Kuril Islands, spawning occurs at depths of 110–150 m [10]. Depth range of juveniles is unknown. Depth range of larvae is unknown. In general, poacher larvae are abundant in near-surface waters, over continental shelf and upper slope [11–13].

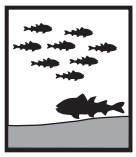


Benthic and reproductive distribution of Fourhorn Poacher (*Hypsagonus quadricornis*).



Habitats and Life History

Eggs—Size: 1.5–3.1 mm [10]. Time to hatching: Unknown. Habitat: Demersal and adhesive [2].
Larvae—Size at hatching: 6.4 mm [14]. Size at juvenile transformation: 14 mm [14]. Days to juvenile transformation: Unknown. Habitat: Pelagic [2]. In general, poacher larvae are abundant in near-surface waters, over continental shelf and shallow slope waters [11–13].
Juveniles—Age and size: Unknown. Habitat: Demersal and live over both high and low relief sea floors [2, 7, 10, 15].
Adults—Age and size at first maturity: Off the Kuril Islands, most fish mature by 3 years at 6.5 to 7.5 cm TL, although some males may mature a year earlier [10]. Males and females grow to same length and have similar life spans [10]. Maximum age: At least 7 years old. Maximum size: 12.0 cm TL [10]. Habitat: Demersal and live over both high and low relief sea floors [2, 7, 10, 15].
Substrate—On silty, rocky sand, gravel, and pebble bottoms [1, 4].
Physical/chemical—Temperature: -1.2 °C [4] to 10 °C**.** Salinity: Marine (or occasionally estuarine [7, 15].

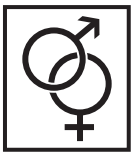


Behavior

Diel—Unidentified poacher larvae have migrated into slightly deeper waters at night in southeastern Alaska [12].
Seasonal—Off Kamchatka, found in relatively shallow waters during summer; winters deeper on the edge of the continental shelf [5].
Reproductive—Unknown.
Schooling—Unlikely. Other poacher species are solitary [16, 17].
Feeding—Can use pectoral fins to lift up rocks and shells to look for prey [14].

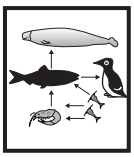
Populations or Stocks

There have been no studies.

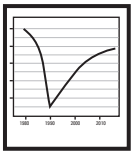


Reproduction
Mode—Separate sexes, oviparous. Fertilization is external [2].
Spawning season—Poorly known. Spawning occurs at least during July and August [10].
Fecundity—Poorly known. 57–921 eggs, spawned in a single batch [10].

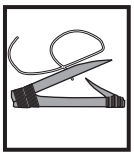
Food and Feeding
Food items—In general, poachers feed on crustaceans and polychaetes [2]. Off the Kuril Islands, polychaetes, gammarid, and caprellid amphipods are the most important foods. However, in fishes over 10 cm (4.0 in.) long, shrimps, limpets, and small fishes (mainly sculpins) are of increasing importance [10]. Food habits of larvae are unknown.
Trophic level—3.19 (standard error: 0.37) [18].



Biological Interactions
Predators—Cannibalism has not been reported. Predators include Pacific Cod and Whiteblotched Skates [19, 20].
Competitors—Presumably other zoobenthos feeders such as Arctic Cod, Walleye Pollock, other poachers, eelpouts, and sculpins.

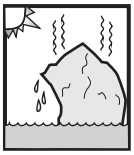


Resilience
High, minimum population doubling time: less than 15 months (Preliminary *K* or Fecundity) [18].

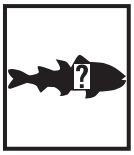


Traditional and Cultural Importance
None reported.

Commercial Fisheries
Currently, Fourhorn Poacher are not commercially harvested.



Potential Effects of Climate Change
Fourhorn Poacher are found primarily in the southeastern Chukchi Sea. Warming, associated with climate change, could increase this species abundance in conjunction with a range extension to the north. Potential effects include changes in competition with other marine fishes that feed on small benthic organisms, including Arctic Cod, Walleye Pollock, other poachers, flatfishes, and sculpins.



Areas for Future Research [B]
Little is known about the ecology and life history of this species in the Chukchi Sea. 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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Atlantic Poacher (*Leptagonus decagonus*)
(Bloch & Schneider, 1801)

Family Agonidae

Atlantic Poacher (*Leptagonus decagonus*), 150 mm TL, off northeastern Sakhalin Island, Russia, Sea of Okhotsk, 2003. Photograph by B.A. Sheiko, Russian Academy of Sciences.

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

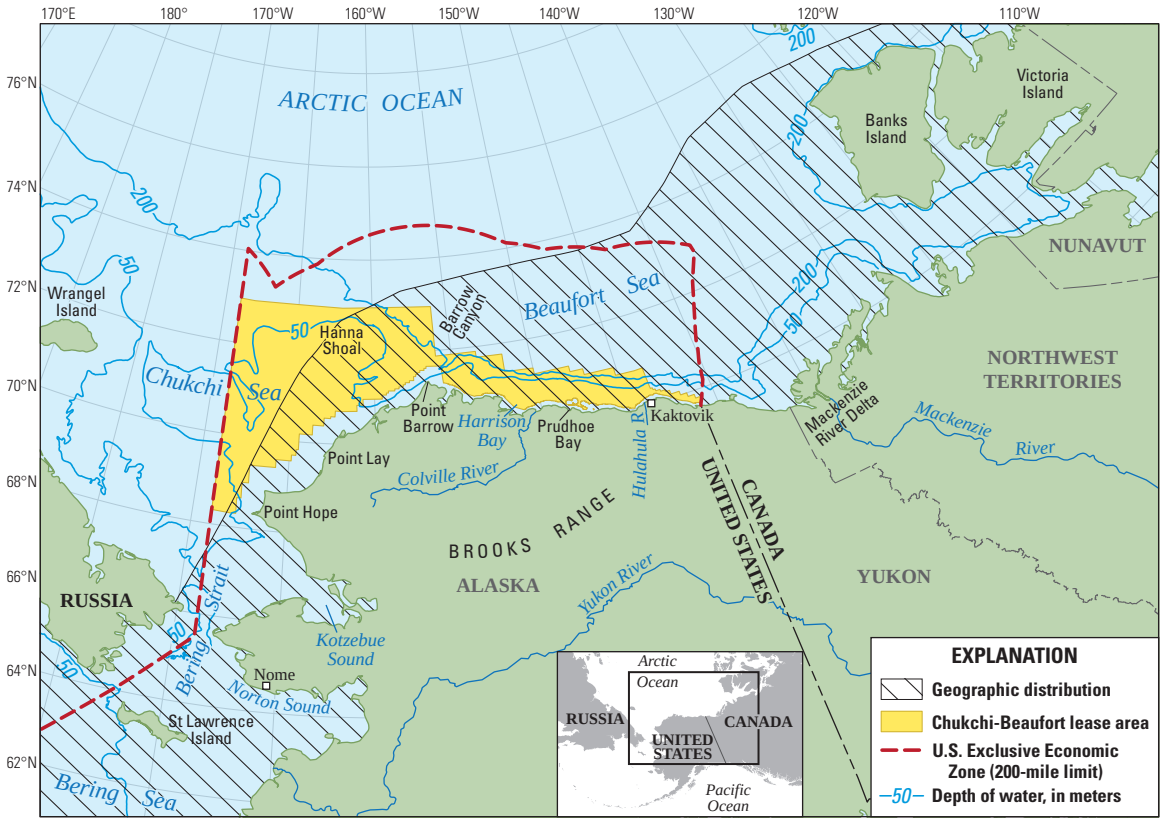
Ecological Role: Current information about occurrence is limited in the U.S. Chukchi and Beaufort Seas. The Atlantic Poacher is unlikely to represent a significant prey resource to higher-level organisms or role in regional food webs.

Physical Description/Attributes: A yellowish gray fish with vague grayish brown bands and patches. Pectoral and caudal fins are brownish black toward tips. For species diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 537) [1]. Swim bladder: Absent [2]. Antifreeze glycoproteins in blood serum: Unknown.

Range: *U.S. Chukchi and Beaufort Seas* [1, 3]. Elsewhere in Alaska, south to Bristol Bay in Bering Sea. Worldwide, nearly circumpolar from Laptev Sea east to western North Atlantic; in Atlantic Ocean to Newfoundland; and in Pacific Ocean there is an isolated population in Sea of Okhotsk [1, 4, 5].

Relative Abundance: *Uncommon in U.S. Chukchi and Beaufort Seas* [1, 3]. Elsewhere, common at least in western Barents Sea [8] and rare around much of Greenland [9].

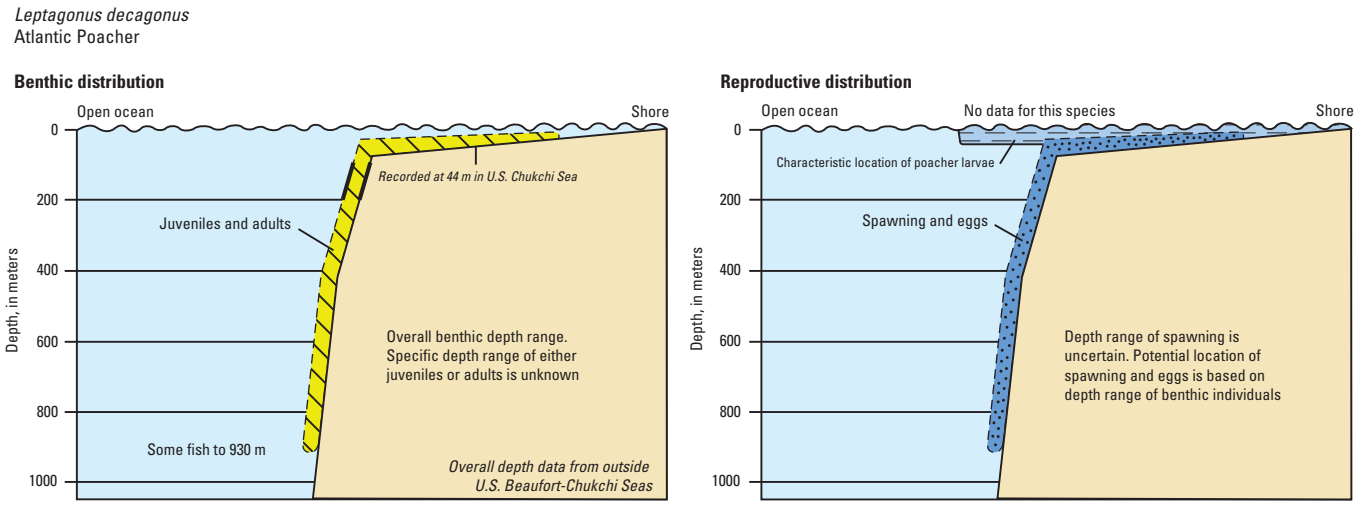
Atlantic Poacher
Leptagonus decagonus



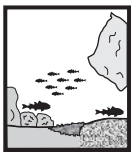
Base modified from USGS and other digital data. U.S.-Russia Maritime Boundary follows the EEZ/200-mile limit line, western edge. Coordinate reference system: projection, Lambert Azimuthal Equal Area; latitude of origin, 75.0°; horizontal datum, North American Datum of 1983.

Geographic distribution of Atlantic Poacher (*Leptagonus decagonus*) within Arctic Outer Continental Shelf Planning Areas [6] based on review of published literature and specimens from historical and recent collections [1, 3, 7].

Depth Range: Overall range is 24–930 m, but usually between 100–200 m [1, 3]. *Documented in U.S. Chukchi Sea at 44–59 m* [1, 5]. Depth range of juveniles is unknown. Depth range of larvae is unknown. In general, abundant in near-surface waters, over continental shelf and shallow slope waters [10–12].



Benthic and reproductive distribution of Atlantic Poacher (*Leptagonus decagonus*).



Habitats and Life History

Eggs—Size: 1.5–2.0 mm [13]. Time to hatching: Unknown. Habitat: Demersal and adhesive (probably on sand and mud) [2].

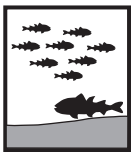
Larvae—Size at hatching: Unknown. Size at juvenile transformation: About 28 mm TL [14]. Days to juvenile transformation: 2–3 months for poachers in general [2]. Habitat: Pelagic [2], although distance from shore and depth in water column are unknown for this species, in general poacher larvae are abundant in near-surface waters, over continental shelf and shallow slope waters [10–12].

Juveniles—Age and size: Unknown. Habitat: Demersal [1, 5].

Adults—Age and size at first maturity: Unknown. Maximum age: Unknown. Maximum size: 22.6 cm TL [1, 15]. Habitat: Demersal [1, 5].

Substrate—Both juveniles and adults live on sand and mud [1, 5].

Physical/chemical—Temperature: Documented -1.7–7.4 °C [5, 13–15]. Salinity: Mainly marine but occasionally found at 27.4 ppt [1, 5]. *In U.S. Chukchi Sea, recorded at 32.58 psu* [5].



Behavior

Diel—Unidentified poacher larvae migrated into slightly deeper waters at night in southeastern Alaska [11].

Seasonal—Unknown.

Reproductive—Unknown.

Schooling—Unlikely. Other poacher species are solitary [16, 17].

Feeding—Unknown.

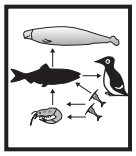
Feeding Behavior—Unknown.

Populations or Stocks

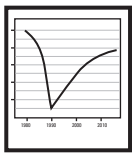
There have been no studies.

Reproduction
Mode—Separate sexes, oviparous. Fertilization is external [2].
Spawning season—Poorly known. At least from May to July [13].
Fecundity—Poorly known. 480–1,750 eggs [13].

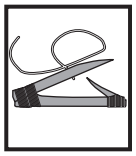
Food and Feeding
Food items—Food habits of larvae are unknown. Adults and juveniles feed on water column crustaceans (such as, copepods), benthic crustaceans, and polychaetes [13].
Trophic level—3.21 standard error 0.36. Based on food items [18].



Biological Interactions
Predators—Cannibalism has not been reported and is unlikely. Predators are poorly known. In the Canadian Arctic, they are occasionally eaten by bearded seals [19].
Competitors—Presumably other zoobenthic feeders such as Arctic Cod, Walleye Pollock, other poachers, eelpouts, flatfish, and sculpins.

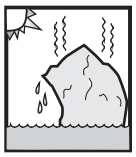


Resilience
Medium, minimum population doubling time: 1.4–4.4 years (Fecundity = 1,088) [18].

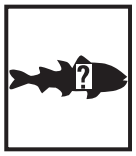


Traditional and Cultural Importance
None reported.

Commercial Fisheries
Currently, Atlantic Poacher are not commercially harvested.



Potential Effects of Climate Change
This species is widely distributed in the Chukchi and Beaufort Seas, as well as southward to the eastern Bering Sea and eastward to the North Atlantic. Climate effects will likely result in changes in abundance and competition with other marine fishes.



Areas for Future Research [B]
Little is known about the ecology and life history from the 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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Bering Poacher (*Occella dodecaedron*)

(Tilesius, 1813)

Family Agonidae

Bering Poacher (*Occella dodecaedron*), 107 mm TL, Norton Sound, Bering Sea, 2002. Photograph by C.W. Mecklenburg, Point Stephens Research.

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

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

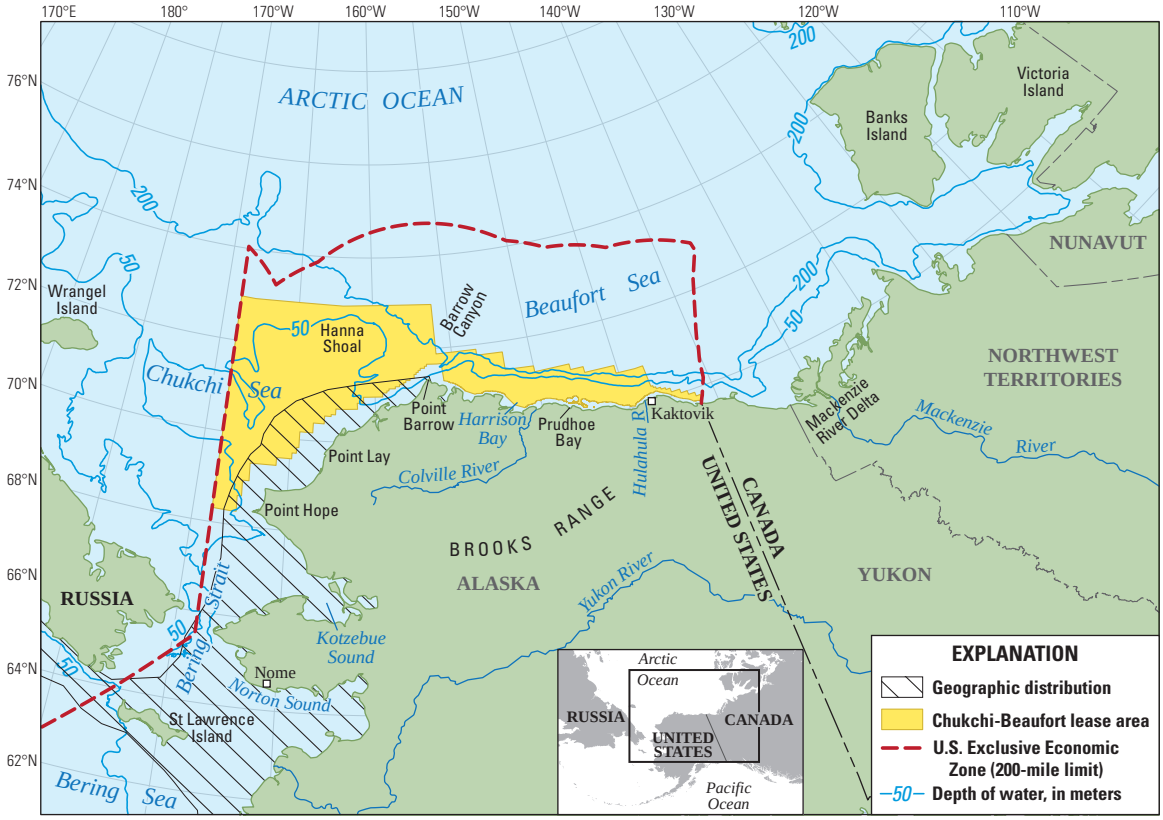
Ecological Role: Current information about this species occurrence in the U.S. Chukchi and Beaufort Seas is very limited. The Bering Poacher is unlikely to represent a significant prey resource to other fish or higher trophic level organisms.

Physical Description/Attributes: Brownish olive on the back and sides, and light tan or ivory white on the underside. Males have orange pectoral fins and those of females are translucent; pelvic fin membranes in males are black and in females are white [1]. For specific diagnostic characteristics, see *Fishes of Alaska* (Mecklenburg and others, 2002, p. 536) [2]. Swim bladder: Absent [3]. Antifreeze glycoproteins in blood serum: Unknown.

Range: *Eastern Chukchi Sea* [4]. Elsewhere in Alaska, from Port Clarence (northeastern Bering Sea near Bering Strait) [4] to western Gulf of Alaska [2]. Worldwide, Sea of Japan northward from Peter the Great Bay, Sea of Okhotsk, and Kuril Islands to Pacific Ocean off Kamchatka Peninsula, Russia, and western Bering Sea at Gulf of Anadyr [2].

Relative Abundance: *Rare in U.S. Chukchi Sea* [2, 4, 6, 7]. Elsewhere in Alaska, common in southeastern [8, 9] but rare in northern Bering Sea [4]. There appears to be a northward shift in the southeastern Bering Sea [10].Worldwide, common at least in Sea of Japan [11] and around Kamchatka Peninsula, Russia [12].

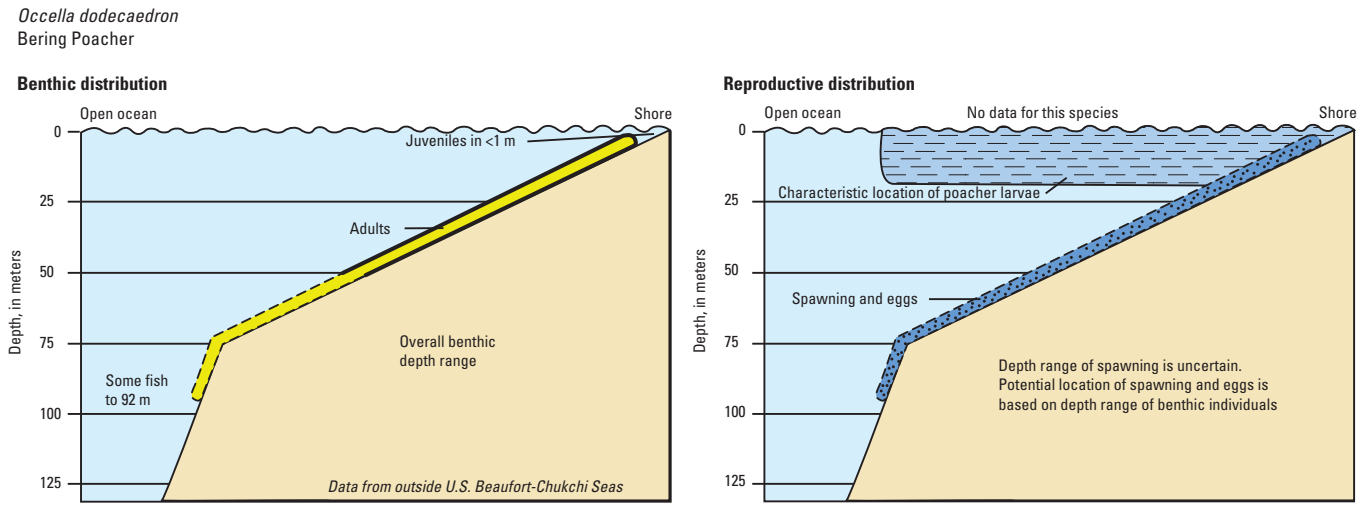
Bering Poacher
Occella dodecaedron



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 Bering Poacher (*Occella dodecaedron*) within Arctic Outer Continental Shelf Planning Areas [5] based on review of published literature and specimens from historical and recent collections [4, 6].

Depth Range: Overall range is 5–92 m, mainly less than 50 m [12–14]. A record from 375 m [13] is likely in error. Juveniles may live in less than 1 m [15]. Depth range of larvae unknown. In general, poacher larvae are abundant in near-surface waters, over continental shelf and shallow slope waters [16–18].



Benthic and reproductive distribution of Bering Poacher (*Occella dodecaedron*).

Habitats and Life History

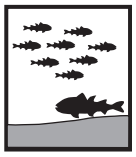
Eggs—Size: Unknown. Time to hatching: Unknown. Habitat: Benthic and adhesive (probably on sand and mud) [3].

Larvae—Size at hatching: Unknown. Size at juvenile transformation: Unknown. Days to juvenile transformation: 2–3 months [3]. Habitat: Pelagic, although distance from shore and depth in water column are unknown for this species, in general, poacher larvae are abundant in near-surface waters, over continental shelf and shallow slope waters [16–18].

Juveniles—Age and size: Unknown. Habitat: Benthic [3, 19].

Adults—Age and size at first maturity: Unknown. Maximum age: At least 9 years. Females are larger at age than males [1]. Maximum size: As long as 23 cm TL [20]. Habitat: Benthic [3, 19]. Substrate: Both juveniles and adults live on sand and mud [21].

Physical/chemical—Temperature: -1.5–15 °C [6, 12, 22]. In southeastern Bering Sea, mainly 2.2–5.5 °C [22]. Salinity: All life stages live in marine waters [12, 22] and occasionally estuaries [6].



Behavior

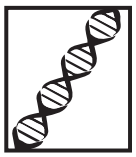
Diel—Unidentified poacher larvae have migrated into slightly deeper waters at night in southeastern Alaska [17].

Seasonal—Off Kamchatka Peninsula, Russia, found in relatively shallow waters during the summer; during winters found deeper on the edge of the continental shelf [12].

Reproductive—Unknown for this family [3].

Schooling—Unlikely. Other poacher species are solitary [19, 23].

Feeding—Unknown.

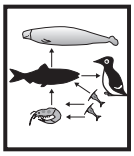


Populations or Stocks

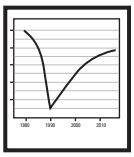
There have been no studies.

Reproduction
Mode—Separate sexes, oviparous. Fertilization is external [3].
Spawning season—Poorly known. Spawning occurs in the spring [1, 21].
Fecundity—400–4,575 eggs [1, 21].

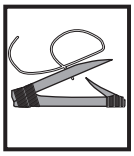
Food and Feeding
Food items—In eastern Bering Sea, off Kamchatka Peninsula, Russia, and in Sea of Japan, small epibenthic crustaceans (for example, mysids, amphipods, isopods, and shrimps) and polychaetes [1, 20, 24]. Food habits of larvae are unknown.
Trophic level—4.0 [10].



Biological Interactions
Predators—Pacific Cod and Plain Sculpin in eastern Bering Sea and off Kamchatka Peninsula, Russia. Cannibalism has not been reported and is unlikely [25, 26].
Competitors—Presumably a wide range of other zoobenthic feeders such as Arctic Cod, Walleye Pollock, other poachers, eelpouts, and sculpins.

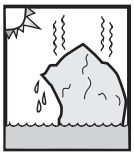


Resilience
Medium, minimum population doubling time: 1.4–4.4 years (Preliminary *K* or Fecundity) [27].

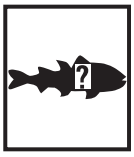


Traditional and Cultural Importance
None reported.

Commercial Fisheries
Currently, Bering Poacher are not commercially harvested.



Potential Effects of Climate Change
Bering Poacher is a Boreal Pacific species [4] and may be expected to expand its distribution northward and become more abundant in the Chukchi Sea as the climate continues to warm. It already appears to be moving northward in the eastern Bering Sea, perhaps in response to warming water temperatures [10]. This may increase competition with other fishes that feed on small benthic organisms, including Arctic Cod, Walleye Pollock, other poachers, and sculpins.



Areas for Future Research [B]
Little is known about the biology and ecology of this species. 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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Tubenose Poacher (*Pallasina barbata*)
(Steindachner, 1876)

Family Agonidae

Tubenose Poacher (*Pallasina barbata*), 138 mm TL, eastern Chukchi Sea, 2007. Photograph by C.W. Mecklenburg, Point Stephens Research.

Note on taxonomy: *The eastern Pacific form is treated by Russian authors as a separate species*, Pallasina aix *(Starks, 1896), although other taxonomists have given evidence for it being the same as* P. barbata [1].

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

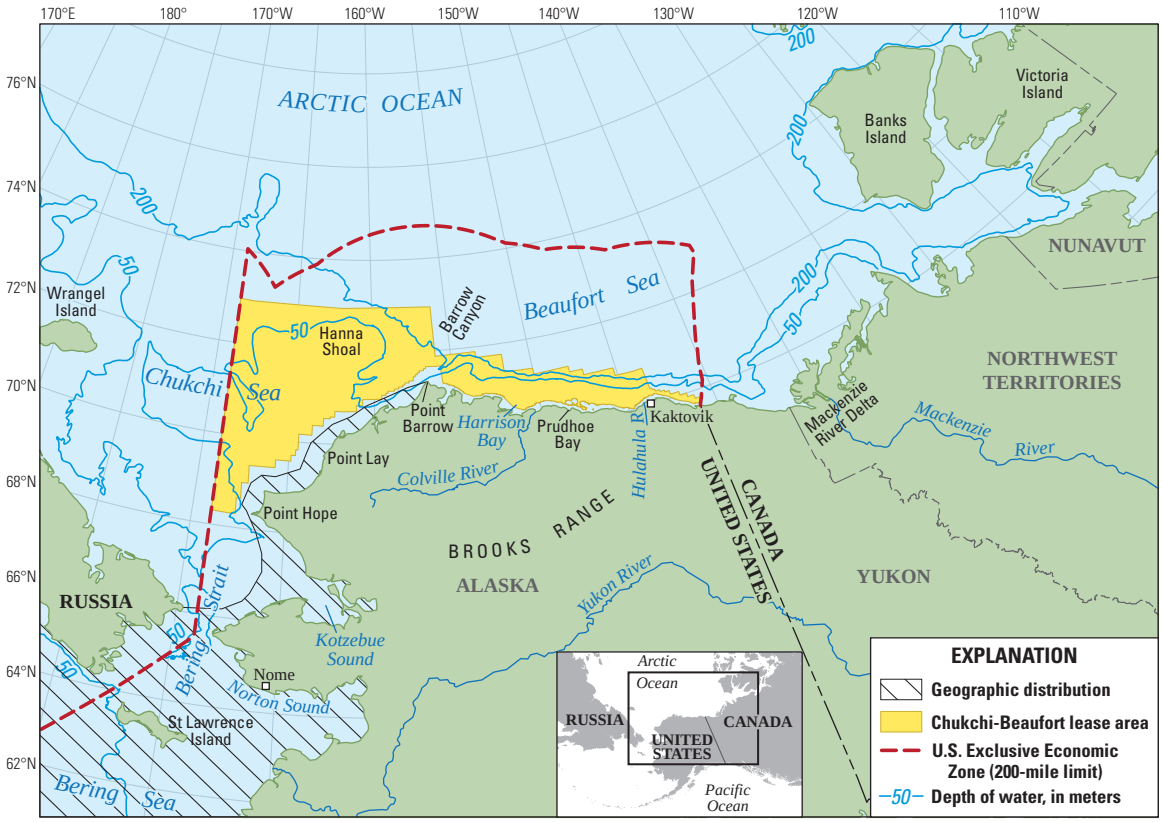
Ecological Role: Largely unknown. Current information about the occurrence of this fish in the U.S. Chukchi and Beaufort Seas is limited. The Tubenose Poacher is unlikely to represent a significant prey resource for many higher level organisms.

Physical Description/Attributes: An elongate, slender fish with gray to brownish back and sides and white underside. For specific diagnostic characteristics, see *Fishes of Alaska*, (Mecklenburg and others, 2002, p. 533) [1]. Swim bladder: Absent [2]. Antifreeze glycoproteins in blood serum: Unknown.

Range: *U.S. Chukchi Sea as far northward to Point Barrow, Alaska* [3]. Elsewhere in Alaska, along coast southward from Bering Strait [1]. Worldwide, from Sea of Japan off Korea, to Sea of Okhotsk, and Pacific Ocean off Kuril Islands south to Bodega Bay, central California [1, 4–8].

Relative Abundance: *Rare in U.S. Chukchi Sea* [3, 10, 11]. Elsewhere in Alaska, common in Bering Sea from Norton Sound southwards [10]. Worldwide, common in Pacific Ocean from Sea of Japan and Sea of Okhotsk, and southwards to Puget Sound [4–8].

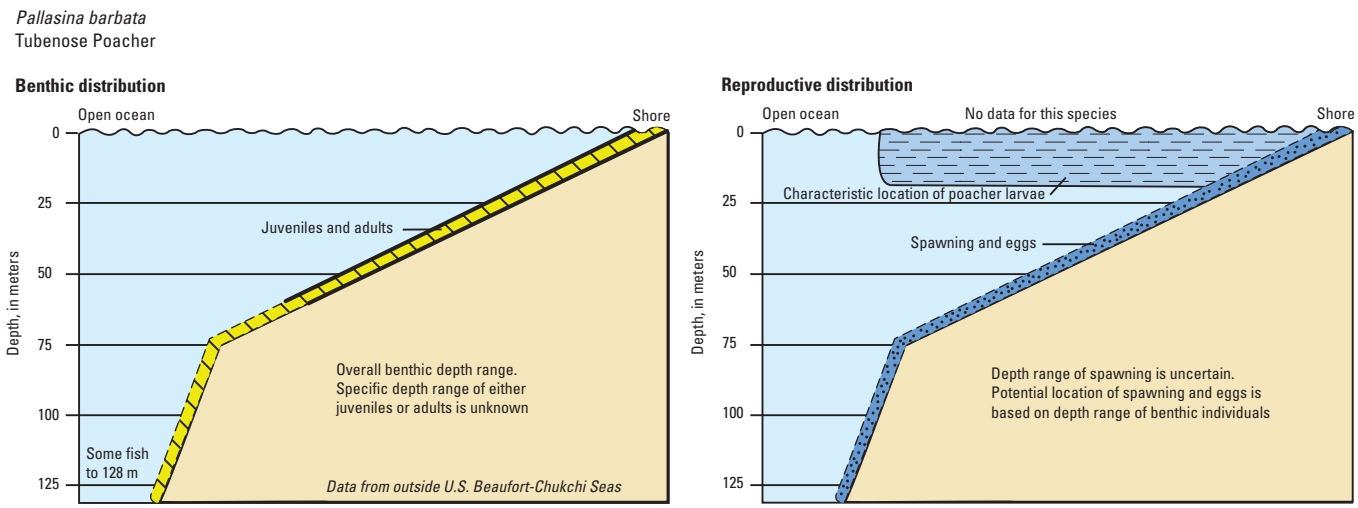
Tubenose Poacher
Pallasina barbata



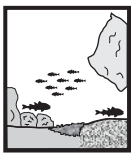
Base modified from USGS and other digital data. U.S.-Russia Maritime Boundary follows the EEZ/200-mile limit line, western edge. Coordinate reference system: projection, Lambert Azimuthal Equal Area; latitude of origin, 75.0°; horizontal datum, North American Datum of 1983.

Geographic distribution of Tubenose Poacher (*Pallasina barbata*) within Arctic Outer Continental Shelf Planning Areas [9] based on review of published literature and specimens from historical and recent collections [1, 3, 10].

Depth Range: Intertidal zone, including tide pools, to 128 m [10]. Most abundant in shallow nearshore waters down to 60 m [4, 8, 10, 12–14]. Depth range of juveniles is unknown. Depth range of larvae is unknown. In general, poacher larvae are abundant in near-surface waters, over continental shelf and upper slope [15–17]. Overall spawning depth is unknown but has been observed in shallow, nearshore waters [12, 13].



Benthic and reproductive distribution of Tubenose Poacher (*Pallasina barbata*).



Habitats and Life History

Eggs—Size: Unknown. Time to hatching: Unknown, though larvae have been caught in Barkley Sound, British Columbia, in April [18]. Habitat: Benthic and adhesive (probably on sand and mud) [2].

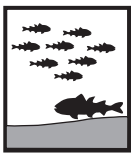
Larvae—Size at hatching: Unknown. Size at juvenile transformation: 2–3 cm TL [4, 18, 19]. Days to juvenile transformation: 2–3 months [2]. Habitat: Pelagic, although distance from shore and depth in water column are unknown for this species, in general poacher larvae are abundant in near-surface waters, over continental shelf and shallow slope waters [15–17].

Juveniles—Age: Unknown. Size: 2–3 cm TL [4, 18, 19] to 9 cm TL [13]. Habitat: Demersal and shallow (often intertidal) [4, 10, 18, 19].

Adults—Age and size at first maturity: Age unknown. May mature at about 9 cm TL [13]. Maximum age: At least 5 years [20]. Maximum size: 20.8 cm TL [1]. Habitat: Benthic and shallow (often intertidal) [1, 4, 10, 18, 19]. Generally, a structure-oriented fish [12, 21]. Common in eelgrass beds, although they also inhabit kelp stands, rocky outcrops, and shell hash sea floors [8, 11–13].

Substrate—Shell hash, sand and gravel bottoms [1, 11].

Physical/chemical—Temperature: Documented off Kamchatka Peninsula, Russia, at 0–12 °C [14], and in Bering Strait at 10.5 °C [11]. Salinity: Marine and estuarine [14], found at 30.62 salinity units in U.S. Bering Strait [11].



Behavior

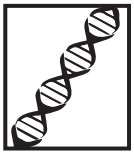
Diel—Unidentified poacher larvae migrated into slightly deeper waters at night in southeastern Alaska [16].

Seasonal—Off Kamchatka Peninsula, Russia, found in relatively shallow waters during summer and during winter in deeper waters on the edge of continental shelf [14].

Reproductive—During summer months, adults move into shallow waters to spawn [12, 13].

Schooling—Unlikely. Other poacher species are solitary [22, 23].

Feeding—Unknown.



Populations or Stocks

There have been no studies.