

Environmental Studies Program: Ongoing Study

Title	Utilization of the Under-ice Habitat by Arctic Cod in the Western Arctic Ocean: A Multidisciplinary Collaborative Study (AK-19-02-03)
Administered by	Alaska Regional Office
BOEM Contact(s)	Sean Burrell (sean.burrell@boem.gov)
Procurement Type(s)	Cooperative Agreement
Conducting Organizations(s)	CMI, UAF
Total BOEM Cost	\$258,539 plus Joint Funding (\$258,539)
Performance Period	FY 2019-2023
Final Report Due	January 2023
Date Revised	September 15, 2022
PICOC Summary	
<i><u>Problem</u></i>	Limited information exists on the under-ice distribution and habitat of Arctic cod. The association with sea ice is assumed to be a critical part of the life history for Arctic cod. This information will inform effective management of development activities, assessment of development impacts, and mitigation measures.
<i><u>Intervention</u></i>	Conduct surveys of Arctic cod under-ice using a Surface and Under-Ice Trawl (SUIT) during the late fall and early winter in the western Arctic Ocean.
<i><u>Comparison</u></i>	Current baseline understanding of the distribution and habitat association of Arctic cod in the Alaskan Arctic compared to information gained from this study.
<i><u>Outcome</u></i>	A better understanding of the under-ice associations of Arctic cod life history and key under-ice habitat locations in the western Arctic Ocean.
<i><u>Context</u></i>	Chukchi and Beaufort Seas

BOEM Information Need(s): Information on under-ice fauna, particularly the use of under-ice habitat by Arctic cod, has been a priority for BOEM for several years. A current BOEM study includes developing a description of Essential Fish Habitat (EFH) for Arctic cod (AK-19-07). This project will provide information to help refine the EFH description and is a first step toward a comprehensive winter spawning survey for Arctic cod. Information on the use of sea ice by Arctic cod is especially important for analyses of the potential impacts of spilled oil that may become trapped and held under ice. The information obtained through this project will aid in understanding how this critical environment may be potentially affected by oil and gas exploration and extraction, or by renewable energy development, on the Outer Continental Shelf of the Chukchi and Beaufort seas.

Background: Arctic cod (*Boreogadus saida*) are the most abundant and widely distributed forage fish in the Arctic Ocean and surrounding seas, including the Pacific Arctic (De Robertis et al. 2017). Because of their high abundance and energy density, they are an important prey resource for many seabirds (Matley et al. 2012) and marine mammals (Loseto et al. 2009). Adult Arctic cod have a benthic-pelagic lifestyle and can reach high biomasses in some Arctic shelf and slope regions. Spawning takes place under the ice in late fall to early winter (Borkin et al. 1987). The eggs float to the underside of the ice

and hatch approximately 60-85 days after spawning at sub-zero temperatures (Sakurai et al. 1998). Developing eggs and larvae are closely associated with sea ice and may be particularly susceptible to changing ice conditions.

Until very recently, estimates of the abundance of Arctic cod under sea ice, based on observations by divers and from ice-hole catches, were believed to be low compared to large schools in the pelagic realm (Melnikov and Chernova 2013). However, sampling of the upper 2 m of the water column under the ice with a "Surface and Under-Ice Trawl" (SUIT, Flores et al. 2012) demonstrated that Arctic cod were ubiquitous at the ice-water interface during summer in the Eurasian Basin of the Arctic Ocean (David et al. 2016). The extent to which Arctic cod use under-ice habitat in the Pacific Arctic is unknown, however. Aggregations of different age classes have been documented in various shelf and slope areas of the Chukchi and Beaufort seas across the open water season, but it is uncertain where these Arctic cod overwinter. It is likely that at least some of these Arctic cod become associated with sea ice after its formation in late fall and early winter.

Objectives: This study is a component of the international Go-West expedition, which will examine the entrainment of young Arctic cod into the sea-ice habitat in the Chukchi and Beaufort seas during the fall and evaluate sea-ice association as an important survival strategy, which may have positive effects on recruitment to the adult population the following summer. Specific objectives of this project include:

- Identify sea-ice habitats favorable for Arctic cod in terms of physical properties, ice algal biomass and prey composition.
- Test for the presence of scattering layers in the underlying water column.
- Assess the pre-winter condition of Arctic cod.
- Assess the under-ice composition and abundance of zooplankton in late fall.
- Using genetics, assess the connectivity between central Arctic under-ice populations and shelf-based spawning populations of Arctic cod.

Methods: Researchers will sample Arctic cod, sympagic fauna, sea-ice habitat properties, and hydroacoustics profiles of zooplankton and fish in the western Beaufort Sea when sea-ice formation and potential entrainment of juvenile Arctic cod are in progress. The target area will be flexibly adapted to the position of the ice edge to allow sampling across the marginal ice zone, where sea-ice formation is taking place during fall and facilitate observation of entrainment of Arctic cod. Sampling is expected to occur over deep water offshore of the narrow Beaufort Sea shelf, but may be moved westward or onto the Chukchi shelf if freeze-up occurs early.

Researchers will sample at least 12 stations along several transects from the marginal ice zone into the consolidated ice pack. At each station they will obtain temperature and salinity profiles and collect water samples to a maximum depth of 600 m, sample plankton in the upper 100 m of the water column using a vertical Bongo haul, deploy the SUIT, and obtain echograms using an EK80 echo sounder. In light ice conditions researchers will also deploy a pelagic net at selected depths if scattering layers are present. The SUIT will be used to estimate the abundance and size composition of Arctic cod, as well as the abundance and community composition of other ice-associated fauna in the upper 2 m of the water column both under ice and in open waters well beside the cruise track of its towing vessel. Additional sensors will collect data on sea ice and water column properties (e.g., temperature, salinity, chlorophyll a, ice thickness), as well as the speed and inflow angle of the water entering the net. An under-water video

camera will be used to visually assess sea ice structure and catch efficiency of the net. Hyper-spectral probes (RAMSES, TriOS) will monitor the spectral light transmission during trawling to allow estimating the amount of ice algal biomass along the sampling path (Lange et al. 2016). The trophic significance of ice algae in the Arctic pelagic food web will be investigated with molecular and isotopic biomarkers.

Specific Research Question(s):

1. Where do Arctic cod in the Pacific Arctic overwinter?
2. What is the extent of under-ice habitat use by Arctic cod in the Pacific Arctic?

Current Status: Awaiting Draft Final Report.

Publications Completed: None

Affiliated WWW Sites:

<http://www.boem.gov/akstudies/>

<https://marinecadastre.gov/espis/#/search/study/100247>

<https://www.uaf.edu/cfos/research/cmi/>

References:

- Borkin, L.V., Ozhigin, V.K., and Shleinik, V.N. 1987. Effect of oceanographical factors on the abundance of the Barents Sea polar cod year classes. In *The Effect of Oceanographic Conditions on Distribution and Population Dynamics of Commercial Fish Stocks in the Barents Sea*. Edited by H. Loeng. pp. 169-180.
- David, C., Lange, B., Krumpen, T., Schaafsma, F., van Franeker, J.A., and Flores, H. 2016. Underice distribution of polar cod *Boreogadus saida* in the central Arctic Ocean and their association with sea-ice habitat properties. *Polar Biol.* 39(6): 981-994.
- De Robertis, A., Taylor, K., Wilson, C.D., and Farley, E.V. 2017. Abundance and Distribution of Arctic cod (*Boreogadus saida*) and other Pelagic Fishes over the U.S. Continental Shelf of the Northern Bering and Chukchi Seas. *Deep Sea Research Part II: Topical Studies in Oceanography* 135: 51-65.
- Flores, H., van Franeker, J.A., Siegel, V., Haraldsson, M., Strass, V., Meesters, E.H., Bathmann, U., and Wolff, W.J. 2012. The Association of Antarctic Krill *Euphausia superba* with the Under-Ice Habitat. *PLOS ONE* 7(2): e31775.
- Lange, B.A., Katlein, C., Nicolaus, M., Peeken, I., and Flores, H. 2016. Sea ice algae chlorophyll a concentrations derived from under-ice spectral radiation profiling platforms. *Journal of Geophysical Research: Oceans* 121(12): 8511-8534.
- Loseto, L.L., Stern, G.A., Connelly, T.L., Deibel, D., Gemmill, B., Prokopowicz, A., Fortier, L., and Ferguson, S.H. 2009. Summer diet of beluga whales inferred by fatty acid analysis of the eastern Beaufort Sea food web. *J. Exp. Mar. Biol. Ecol.* 374(1): 12-18.
- Matley, J.K., Crawford, R.E., and Dick, T.A. 2012. Summer foraging behaviour of shallow-diving seabirds and distribution of their prey, Arctic cod (*Boreogadus saida*), in the Canadian Arctic. *Polar Res.* 31(1): 15894.

- Melnikov, I.A., and Chernova, N.V. 2013. Characteristics of under-ice swarming of polar cod *Boreogadus saida* (Gadidae) in the Central Arctic Ocean. *Journal of Ichthyology* 53(1): 7-15.
- Sakurai, Y., Ishii, K., Nakatani, T., Yamaguchi, H., Anma, G., and Jin, M. 1998. Reproductive Characteristics and Effects of Temperature and Salinity on the Development and Survival of Eggs and Larvae of Arctic Cod (*Boreogadus saida*). *Mem. Fac. Fish. Hokkaido Univ.* 45(1): 77-89.