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Environmental drivers of benthic fish distribution in and around Barrow Canyon in the northeastern Chukchi Sea and western Beaufort Sea

Elizabeth Logerwell[a,*], Kimberly Rand[a], Seth Danielson[b], Leandra Sousa[c]

[a] Alaska Fisheries Science Center, National Marine Fisheries Service, 7600 Sand Point Way NE, Seattle, WA 98115, USA
[b] School of Fisheries and Ocean Sciences, University of Alaska, 905 N. Koyukuk Drive, Fairbanks, AK 99775, USA
[c] Department of Wildlife Management, North Slope Borough, 1274 Agvik Street, Barrow, AK 99723, USA

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ABSTRACT

We investigate the relationships between Arctic fish and their environment with the goal of illustrating mechanisms of climate change impacts. A multidisciplinary research survey was conducted to characterize fish distribution and oceanographic processes in and around Barrow Canyon in the northeastern Chukchi Sea in summer 2013. Benthic fish were sampled with standard bottom trawl survey methods. Oceanographic data were collected at each trawl station. The density of Arctic cod (*Boreogadus saida*), the most abundant species, was related to bottom depth, salinity and temperature. Arctic cod were more abundant in deep, cold and highly saline water in Barrow Canyon, which was likely advected from the Chukchi Shelf or from the Arctic Basin. We hypothesize that Arctic cod occupied Barrow Canyon to take advantage of energy-rich copepods transported in these water masses. Arctic cod were similarly more abundant in deep, cold and high salinity water in the Beaufort Sea, documented by a comparable multidisciplinary survey conducted in 2008. These linkages between oceanographic variables and benthic fish distribution and abundance suggest that advection, sea-ice dynamics and pelagic-benthic coupling are important for the ecology of benthic Arctic fishes. These processes have been and will likely continue to be impacted by climate change. Our results improve the understanding of the mechanistic linkages between climate change and benthic Arctic fish ecology.

1. Introduction

Arctic marine ecosystems are thought to be particularly impacted by climate change. Potential stressors include ocean warming (Overland et al., 2014), loss of sea ice (Frey et al., 2014) and ocean acidification (Mathis et al., 2014). An elementary prediction is that the range of mobile Arctic marine taxa will shift northwards with rising ocean temperatures (Cheung et al., 2009). However, spatial and temporal dynamics of seasonal ocean production, the complexities of ocean current systems and the relationships between ocean dynamics and organisms' ecology indicate that such predictions may not apply to all taxa (Hollowed et al., 2013). Our overall goal is to relate spatial variability in the distribution and abundance of Arctic marine fauna to oceanographic variables that are potentially affected by climate change. In this way, we aim to illustrate potential mechanisms linking climate change to Arctic marine communities.

The Chukchi Sea is a shallow continental shelf covered by sea ice for 5–7 months a year. Bering Strait defines the southern boundary of the Chukchi Sea and is the passageway for Pacific Water to enter the Arctic (Moore and Stabeno, 2015; Woodgate et al., 2015). Transport in the eastern Chukchi Sea during the summer occurs in two pathways: the Alaskan Coastal Current, which flows north along the Alaska Coast, and a Central Channel Current, which flows north through the Central Channel and around Hanna Shoal (Fig. 1). The two currents separate at Point Hope and then merge again in Barrow Canyon, a focal area for advection of Pacific water towards the open Arctic (Pickart et al., 2005). These two currents are known as the "Bering to Barrow Current System" (Gong and Pickart, 2015). Primary production begins annually in a spring bloom once sufficient light reaches the photic zone of nutrient-rich Pacific waters (Carmack, 2006), which can occur with ice retreat and beneath first-year ice (Arrigo et al., 2012). Zooplankton grazing pressure is relatively low, such that much of the organic carbon is exported to the seafloor where it supports a rich benthic community (Grebmeier et al., 2006a).

High benthic productivity on Pacific Arctic shelves supports predators such as Pacific walrus (*Odobenus rosmarus divergens*), gray whales (*Eschrichtius robustus*), bearded seals (*Erignathus barbatus*) and spectacled eiders (*Somateria fischeri*). Arctic cod (*Boreogadus saida*) occupy benthic and pelagic habitats and are the dominant fish in much of the Pacific Arctic (Logerwell et al., 2015). Arctic cod is a key prey item for

* Corresponding author.
E-mail address: Libby.Logerwell@noaa.gov (E. Logerwell).

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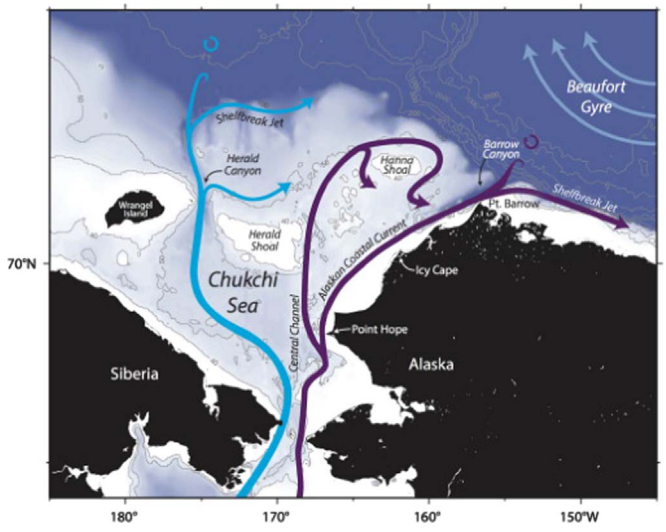

Fig. 1. Bathymetric map of the Chukchi Sea and geographical place names. The prominent topographic features are Bering Strait to the south, Barrow Canyon to the east, Herald Canyon to the west, and two shoal regions with the Central Channel between them. The purple arrows represent the "Bering to Barrow Current System" in the eastern Chukchi Sea, and the blue arrows denote flow pathways in the western Chukchi Sea. Reprinted with permission from Gong and Pickart (2015).

beluga whales (*Delphinapterus leucas*), ringed seals (*Pusa hispida*), bearded seals, harp seals (*Pagophilus groenlandicus*), black guillemot (*Cepphus grylle*) and thick-billed murres (*Uria lomvia*) (Bradstreet and Cross, 1982; Bradstreet, 1976; Bradstreet et al., 1986; Huntington et al., 1999). Alaska Arctic communities on the Chukchi Sea coast rely on many of these marine mammal species for subsistence use (Hovelsrud et al., 2008; Huntington et al., 1999). Thus, understanding the potential impacts of climate change on Arctic cod and other benthic fish is important for understanding the potential impacts of climate change on Arctic ecosystems and human communities.

Compared to other Arctic and high-latitude regions, such as the Bering Sea and Barents Sea (Lomas and Stabeno, 2014; Wiebe et al., 2012), little is known about the environmental drivers of benthic fish distribution and productivity in the Chukchi Sea. A few recent studies of demersal fish in the offshore northeast and in the south to north-central Chukchi Sea have shown that water mass characteristics affect benthic fish species assemblages and fish density (Day et al., 2013; Norcross et al., 2010; Sigler et al., in press). No studies have been published to date on the benthic fish community of the northeastern Chukchi Sea in and around Barrow Canyon, an important area for foraging seabirds (Kuletz et al., 2015), bowhead whales *Balaena mysticetus* (Citta et al., 2015) and beluga whales *Delphinapterus leucas* (Stafford et al., 2013). Intermittent baseline studies were conducted in the Chukchi Sea in the late 1970s and early 1980s (Frost and Lowry, 1983; Frost et al., 1978), and recent multidisciplinary research efforts have increased in this region in order to help mitigate impacts of human activity in the Arctic outer continental shelf (Day et al., 2013). However, most of these studies have not included the nearshore marine environment which is critical to the subsistence activities of local arctic communities and an integral part of the Chukchi Sea ecosystem.

The SHELFZ (**S**helf **H**abitat and **E**co**L**ogy of **F**ish and **Z**ooplankton) project is a multidisciplinary research effort seeking to characterize fish and zooplankton distributions and understand the connections between nearshore and offshore habitats in the Chukchi Sea. In this study, nearshore (< 20 m isobath) and offshore (> 20 m isobath) data were concurrently collected for fish, zooplankton, fisheries acoustics and water mass properties along Alaska's Chukchi Sea coast. In this paper, we examine the relationships between benthic fish distribution and the oceanographic and benthic characteristics of their habitat in the offshore SHELFZ study area (> 20 m isobath). A similar benthic fish survey was conducted in 2008 in the western Beaufort Sea using the same oceanographic sampling and trawl gear (Logerwell et al., 2011). This provides a unique opportunity to compare patterns in benthic fish habitat use and to examine the connectivity between the northeastern Chukchi Sea and western Beaufort Sea in and around Barrow Canyon.

Ocean water column properties such as temperature and salinity are indicators of water masses which have different origins, transport pathways and potential productivity (Weingartner, 2008). We expect the distribution of benthic fish to track the spatial extent of water masses that provide favorable living and feeding conditions. For example, cold and high salinity water in the northeast Chukchi Sea and western Beaufort Sea is an indicator of winter-transformed Bering Sea water advected through Bering Strait and across the Chukchi Shelf (Gong and Pickart, 2015; Pickart et al., 2005). This water is typically rich in dissolved and particulate organic carbon and could thus be high in secondary productivity and provide good foraging conditions for fish (Mathis et al., 2007; Pickart et al., 2005). We also expect benthic fish distributions to respond to surface water properties and water column stratification because these parameters can limit or enhance pelagic productivity and thus pelagic inputs to the benthos (Grebmeier et al., 2006a).

2. Methods

2.1. Field methods

The survey was conducted from 17 August to 5 September 2013 in the northeastern Chukchi Sea. The survey area was located between the village of Wainwright and the city of Barrow, 132 km along the coast and extending from the coast to approximately 75 km offshore. Barrow Canyon (indicated by depths greater than 100 m) extends through the center of the survey area (Fig. 2).

The 43.5-m (143-foot) fishing vessel FV *Alaska Knight* was chartered for the survey. Benthic fish and invertebrates were surveyed using bottom trawls deployed in concordance with standards set by the Alaska Fisheries Science Center's (AFSC) Resource Assessment and Conservation Engineering (RACE) Division (Stauffer, 2004). The net used for the bottom trawls was an 83–112 Eastern otter trawl built to standards detailed in Stauffer (2004), with a 25.3-m (83 ft) headrope and a 34.1-m (112 ft) footrope. A total of 29 bottom trawl tows were conducted, spaced approximately 12 km apart along transects oriented perpendicular to shore and spaced approximately 25 km apart. The net was towed at a speed of approximately 3 knots for 15 min unless the

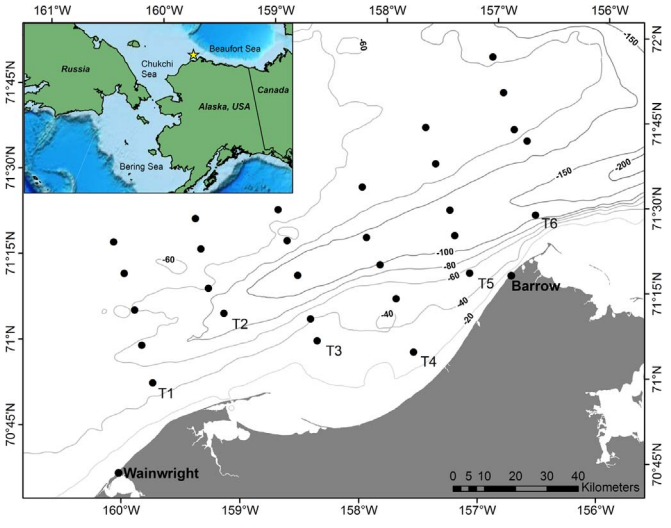

Fig. 2. Study area for 2013 SHELFZ survey of the northeastern Chukchi Sea. 83–112 bottom trawls and CTDs were deployed at the stations shown. Transects 1–6 are indicated by T1, etc. Depth contours in meters.