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Sampling fish with a beach seine at Cooper Island, Alaska, August 2006. Cooper Island is part of the Plover Islands group, a series of barrier islands that separates the western Beaufort Sea from Elson Lagoon, and is located about 30 km east of Point Barrow.

ABSTRACT

Information on fishes in coastal waters of the Alaskan Arctic is outdated or nonexistent, especially in areas targeted for oil exploration and increased transportation activities. To address this information gap, we sampled fish in nearshore waters of Cooper Island, a barrier island in the western Beaufort Sea, in August 2004, 2005, 2006, 2007, and 2009, and in September 2009. Fish were captured with a beach seine and bottom trawl (5 and 8 m depths) on the Beaufort Sea side of the island and with a beach seine on the Elson Lagoon side of the island to identify fish distribution, species composition, and habitat use. A total of 2,807 fish representing 16 species were captured in all sampling periods and with both gear types: 1,567 fish representing 14 species were captured in 24 seine hauls, and 1,240 fish representing 9 species were captured in 16 trawl tows. Of the total fish captured by seine from 2004 to 2006, 95% were from the Beaufort Sea (n = 9 hauls) and 4% were from Elson Lagoon (n = 9 hauls). The most abundant fish captured by seine were capelin (*Mallotus villosus*), Arctic cod (*Boreogadus saida*), juvenile prickleback (Stichaeidae), and juvenile sculpin (Cottidae) in the Beaufort Sea, and least cisco (*Coregonus sardinella*) and juvenile sculpin in Elson Lagoon. Trawl catch was similar by depth; the most abundant species were Arctic cod and slender eelblenny (*Lumpenus fabricii*). Of the total fish captured by trawl, 87% were caught in September 2009. Most fish captured were juveniles based on estimated size at first maturity and length frequency distributions. Total catch in the Beaufort Sea was lowest in August 2006; water temperatures were 4-8º C colder in 2006 than in any other year of the study. Species occupying coastal waters of the Beaufort Sea have remained relatively unchanged during the last 25 years; Arctic cod remain a dominant species, whereas capelin appear to be more widespread and abundant. Continued warming conditions in the Arctic Ocean will likely result in a reorganization of nearshore community structure–new fish

species are expected to migrate to the Arctic with unknown consequences to existing stocks and food webs.

CONTENTS

INTRODUCTION

The Arctic is one of the most rapidly changing ecosystems in the world, yet a large void exists in information on essential fish habitats and what species and life stages use these habitats. Rapid change in polar ecosystems is well documented: the Arctic Ocean Basin has experienced significant warming in recent decades with pronounced decreases in the extent and seasonal duration of sea ice (Moline et al. 2008). The minimum extent of Arctic sea ice in 2009 was the third lowest since the start of satellite measurements in 1979 (National Snow and Ice Data Center 2009). Loss of sea ice from global warming threatens marine life and habitat (e.g., increased coastal erosion) and has the potential to open up formerly inaccessible areas to oil and gas exploration, vessel traffic, mining, and commercial fishing. Increased human activity translates into increased risk to fish and habitat from development and oil spills. Given the new and increased risk to the Arctic, some researchers believe the United States is not prepared to prevent and recover from oil spills in this ecologically fragile area (Torrice 2009). Prior to major development or transportation activities in the Arctic, information is needed on fish distribution, species composition, habitat use, life history characteristics, food webs, and species at risk to make informed management decisions regarding potential effects from human disturbance.

Information on nearshore (shoreline to 8 m depth) fishes in Arctic waters of Alaska is outdated or nonexistent. Information that is available is mostly from studies in the 1970s and 1980s in the eastern Beaufort Sea, prompted by the discovery of oil and gas in Prudhoe Bay in 1968-69 (Craig and Haldorson 1981, Craig et al. 1982, Haldorson and Craig 1984, Craig et al. 1985, Moulton and Tarbox 1987, Cannon et al. 1991). In the western Beaufort Sea near Barrow, Alaska, published information on nearshore fish fauna, distribution, and habitat use is scarce, especially for barrier islands with lagoons and adjacent coastal waters. Nearshore waters, particularly lagoons, are important feeding areas for anadromous and marine fishes during the short Arctic summers (Craig 1984). A species list of known fishes occupying brackish nearshore and marine offshore coastal waters of the Beaufort Sea is provided in Craig (1984).

The importance of nearshore habitats to fishes is well known in most of Alaska (Johnson et al. 2005, Thedinga et al. 2008); exceptions are in the western Beaufort Sea and Chukchi Sea. Many Arctic fish species use nearshore habitats at some time in their life (Craig 1984), but estimates of their abundance and habitat use are poorly documented. In addition, many Arctic nearshore species such as capelin (*Mallotus villosus*) and rainbow smelt (*Osmerus mordax*) are important in the diet of higher-level predators and in Inupiat subsistence fisheries (George et al. 2009). Presently, commercial fishing in the Arctic is prohibited until sufficient information is available to support sustainable fisheries (North Pacific Fishery Management Council 2009). Warming conditions in the Arctic will likely result in a reorganization of community structure; new fish species are expected to migrate to the Arctic with unknown consequences to existing stocks and food webs (Gradinger 1995, Moline et al. 2008).

To gather distribution, species composition, and habitat use information necessary to identify important habitats, we sampled fish in nearshore waters of Cooper Island in the western Beaufort Sea from 2004 to 2009. Cooper Island is one of several barrier islands that separate the Beaufort Sea from Elson Lagoon. Cooper Island was identified as a possible source of gravel to replenish the rapidly eroding beach near Barrow; this led to the selection of Cooper Island as a study site from 2004 to 2006. We continued studies at Cooper Island opportunistically from 2007 to 2009 as part of a larger study in the western Beaufort and Chukchi seas. Our objective was to inventory and compare the nearshore fish fauna on the Beaufort Sea side and Elson Lagoon side of Cooper Island. Because nearshore habitats in the Arctic are changing from coastal erosion (Lynch and

Brunner 2007), and development activities are likely in the future, information is needed to identify and conserve habitats important to forage and subsistence species.

STUDY AREA

Cooper Island is part of the Plover Islands group, a series of barrier islands that separates the western Beaufort Sea from Elson Lagoon (Fig. 1). Cooper Island is located about 30 km east of Point Barrow and is approximately 10 km long and 0.7 km wide at its widest point. We sampled fish with a beach seine at three sites about 2 km apart on the Beaufort Sea side and Elson Lagoon side of Cooper Island for a total of six seine sites (Fig. 1); all seine sites were low gradient beaches of sand and gravel. Offshore of the three Beaufort Sea seine sites, we also sampled fish with a bottom (otter) trawl at depths of 5 and 8 m for a total of six tows (Fig. 1); all tows were over mostly mud substrate. The Beaufort Sea seine sites were sampled in mid-August 2004, 2005, 2006, and 2007, and in mid-September 2009. The Elson Lagoon seine sites were sampled in mid-August 2004, 2005, and 2006. The Beaufort Sea trawl sites were sampled in mid-August 2007, and in mid-August and September 2009. Each seine and trawl site was sampled once per site visit; not all trawl sites could be sampled in August 2009 because of inclement weather. Inclement weather also prevented sampling any sites in 2008. All sampling was during daylight and without regard to tide; tidal range in the Arctic is generally < 0.5 m.

In the Beaufort Sea, the presence of floating ice, water temperature, and salinity can fluctuate widely in summer depending on prevailing winds, ocean currents, and freshwater runoff. A characteristic of the Beaufort Sea in summer is the presence of a warm, brackish water band (5-10º C, 10-25 practical salinity scale (PSS)) that extends the length of the shoreline and can be drastically different from adjacent offshore marine waters (−1º to 3º C, 27-32 PSS) (Craig 1984). A good description of the summer oceanographic characteristics of an Arctic lagoon is provided in Craig et al. (1985).

Sea ice was abundant near Cooper Island in August 2006; ice was stranded ashore, and numerous bergs were visible floating offshore. The presence of sea ice in 2006 did not interfere with beach seining. In all other sampling periods, sea ice was absent or restricted to an occasional berg floating offshore.

MATERIALS AND METHODS

Fish Capture

At beach seine sites (< 5 m deep, < 20 m from shore), fish were captured with a 37-m long variable mesh beach seine that tapers from 5 m deep at the center to 1 m deep at the ends. Outer panels are each 10 m of 32-mm stretch mesh, intermediate panels are each 4 m of 6-mm square mesh, and the bunt is 9 m of 3.2-mm square mesh. We set the seine as a "round haul" by holding one end on the beach, backing around in a skiff with the other end to the beach about 18 m from the start, and pulling the seine onto shore. The seine has a leadline and a floatline so that the bottom contacts the substrate and the top floats on the surface. Net characteristics and methods of setting the seine are the same that we have used throughout Alaska since 1998 (NMFS 2010).

Offshore of each Beaufort Sea seine site, fish were captured with a bottom trawl at two depths: 5 m (about 1.0 km offshore) and 8 m (about 2.5 km offshore). The mouth of the trawl is 2.6 m wide and 1.2 m deep and is attached to a 6.3 m long bridle of 1.3 cm braided line. The trawl has two weighted doors (33 cm by 61 cm) and is 5.2 m in total length; inside the outer skirt of 29-mm stretch mesh is a 1.7 m long codend of 3.2-mm stretch mesh. The trawl was towed from a skiff at about 2.5 knots. Scope of the tow line (1.6 cm polyproprolyene) was 15 and 24 m for the 5 and 8 m tows, respectively. Tows were parallel to shore in opposite direction at each offshore station (Fig. 1); duration of each tow was 5 minutes. We did not sample Elson Lagoon with a trawl because of very shallow water (< 4 m deep) throughout much of the lagoon.

After retrieval of either net, the entire catch was sorted, identified to species, counted, and a subsample (up to 50 fish) of most taxons was measured either to the nearest millimeter fork length (FL) or, in species without a distinct fork in caudal fin, to total length (TL). Fish were anesthetized in a mixture of 1 part carbonated water to 2 parts seawater for identification and measurement. Smaller individuals (< 40 mm length) that could not be identified to species in the field were identified to family (e.g., Cottidae). Length frequency distributions and age-length data from other Arctic studies were used to estimate ages of Arctic cod (*Boreogadus saida*) and capelin; Arctic cod less than 60 mm FL and capelin less than 82 mm FL were assumed to be young-of-the-year (YOY) (Welch et al. 1993, Jarvela and Thorsteinson 1999).

Temperature and Salinity

Surface water temperature and salinity (PSS) were measured at all seine and trawl sites each site visit. Temperature and salinity were measured at about 20-cm depth with a thermometer and hand-held refractometer, respectively.

Data Analysis

Catch data is expressed in absolute numbers (total catch) and as catch-per-unit-effort (CPUE): number of fish per seine haul or trawl tow. Percent frequency of occurrence (FO) was also determined for some of the most abundant species; FO represents the number of seine hauls in which a species was captured divided by the total number of seine hauls multiplied by 100.

Species richness refers to the total number of fish species captured. Individuals identified only to family (e.g., juvenile Cottidae) were counted in the total catch, but they were only considered as a separate species for species richness calculations if no other species from the same family were captured.

We used a one-way ANOVA to examine for differences in seine catch (CPUE, all species) and species richness among years in the Beaufort Sea and Elson Lagoon; we limited our analysis to the same years (2004-2006) that both areas were sampled. If a significant difference was found in CPUE or species richness among years, Holm-Sidak pairwise multiple comparisons were used to isolate groups that differed from each other (SigmaStat 1997). To examine for differences in seine catch and species richness between the Beaufort Sea and Elson Lagoon, we used t-tests; data were pooled (2004-2006) within a location if ANOVA results were not significant. We used the Mann-Whitney Rank Sum test (SigmaStat 1997) to examine for differences in trawl catch (CPUE, all species) by depth (all sampling periods combined), and length of some of the most abundant species by gear type (all sampling periods combined). Seine catch data was transformed to logarithms (ln (X + 1)) prior to analysis. Significance for all tests was set at $P \leq 0.05$.

RESULTS

The fish fauna of Cooper Island is characterized by a diverse assemblage of marine, anadromous, and forage fish species. A total of 2,807 fish representing 16 species were captured in all sampling periods and with both gear types: 1,567 fish representing 14 species were captured in 24 seine hauls (Table 1), and 1,240 fish representing 9 species were captured in 16 trawl tows (Table 2). Capelin accounted for 60% of the of total seine catch, whereas Arctic cod accounted for 89% of the total trawl catch. Median CPUE (all species) was 12 fish (n = 24) for seine catches (Table 1) and 28 fish (n = 16) for trawl catches (Table 2).

The most abundant species captured by seine were capelin (936 fish, FO = 53%) and Arctic cod (356 fish, FO = 27%) in the Beaufort Sea, and least cisco (*Coregonus sardinella*) (38 fish, FO = 78%) in Elson Lagoon (Table 1). Seine catch (CPUE, all species) differed significantly (P = 0.003) among years (2004-2006) in the Beaufort Sea but not in Elson Lagoon; in the Beaufort Sea, all pairwise comparisons among years differed significantly (P < 0.05) with the greatest CPUE in 2004 and the least in 2006. Between locations (Beaufort Sea and Elson Lagoon), seine catch (CPUE) was significantly (P < 0.001) greater in the Beaufort Sea in 2004, similar in 2005, and significantly (P = 0.032) greater in Elson Lagoon in 2006. Seine catch was highly variable, especially in the Beaufort Sea (Fig. 2); median CPUE ranged from 1 fish (2006) to 173 fish (2004) in the Beaufort Sea, and from 2 fish (2005) to 7 fish (2004) in Elson Lagoon (Table 1). Of the total fish captured by seine from 2004 to 2006, 95% were from the Beaufort Sea (n = 9 hauls) and 4% were from Elson Lagoon (n = 9 hauls).

Species richness (seine catch) did not differ significantly among years (2004-2006) in the Beaufort Sea and Elson Lagoon, or between these two locations. Number of species captured per seine haul ranged from 0 to 6 in the Beaufort Sea (0 fish were captured in 1 seine haul) and from 1 to 4 in Elson Lagoon. Among all sampling periods, total species richness in seine hauls ranged from 1 (2006) to 7 (2004) in the Beaufort Sea and from 3 (2006) to 6 (2004) in Elson Lagoon (Table 1).

Overall, the most abundant species captured by trawl were Arctic cod (1,104 fish, FO = 94%) and slender eelblenny (*Lumpenus fabricii*) (69 fish, FO = 56%) (Table 2). Arctic cod accounted for 45% to 93% of the total catch by individual sampling period and depth strata

(Table 2). Trawl catch (all species) did not differ significantly by depth (Fig. 3); among all sampling periods, median CPUE ranged from 2 to 181 fish (Table 2). Of the total fish captured by trawl (1,240 fish), 87% were caught in September 2009. Among all sampling periods and depths, species richness in trawl tows ranged from 1 (August 2007) to 8 (September 2009) (Table 2).

Species composition varied by sampling site, gear type, and time of sampling. Species captured only in the Beaufort Sea included Arctic cod, capelin, Pacific sand lance (*Ammodytes hexapterus*), slender eelblenny, saffron cod (*Eleginus gracilis*), and rainbow smelt (Tables 1 and 2); Coregonids (e.g., least cisco) were captured only in Elson Lagoon. On the Beaufort Sea side of Cooper Island, capelin catches were extremely variable and largely restricted to the shallow nearshore (Fig. 4); only one capelin was captured offshore by trawl. Arctic cod were captured by seine and trawl (Fig. 4). Regardless of gear type, saffron cod and rainbow smelt were captured in low numbers and only in September 2009 (Tables 1 and 2).

Of the most abundant species captured, most were juveniles based on estimated size at first maturity (Table 3). Exceptions were least cisco and rainbow smelt; all least cisco and 13% of rainbow smelt were adults. Length distributions ranged from 25 to 147 mm FL for Arctic cod and from 38 to 138 mm FL for capelin (Fig. 5). Arctic cod were significantly ($P < 0.001$) larger in trawl catches (mean FL = 79 mm) than in seine catches (mean FL = 34 mm). Most (97%) Arctic cod captured by seine and measured were YOY (< 60 mm FL), whereas only 25% of Arctic cod captured by trawl were YOY (Fig. 5). Almost all (99%) capelin captured by beach seine and measured were YOY (< 82 mm FL) (Fig. 5). Saffron cod and slender eelblenny were also significantly ($P < 0.001$) larger in trawl catches than in seine catches. Mean length of some of the other species captured ranged from 56 mm FL for Pacific sand lance to 176 mm FL for rainbow smelt (Table 3).

No clear pattern existed between fish catch and surface water temperature and salinity. In the Beaufort Sea, mean water temperature (from seine and trawl sites) ranged from 8.5º C in August 2004 to 0.5 º C in August 2006 (Fig. 6). Total seine catch (all species) was highest in August 2004 (warmest year) and lowest in August 2006 (coldest year); water temperature was also warm (mean = 8.0º C), however, in August 2005, and few fish were captured by seine (Fig. 6). Total trawl catch (all species) in the Beaufort Sea was over 10 times greater in September 2009 than in August 2007 (same sampling effort) (Fig. 6); mean water temperature and salinity were similar (about 5.0º C and 31 PSS) in both sampling periods. Surface salinities in the Beaufort Sea were relatively stable and ranged from 29 to about 35 PSS in all sampling periods. Water temperature was higher, and salinity was usually lower in Elson Lagoon than in the Beaufort Sea; mean water temperature and salinity in Elson Lagoon was 9.0º C and 24 PSS in August 2004, 9.2º C and 35 PSS in August 2005, and 5.2º C and 10 PSS in August 2006. Ranges in water temperature and salinity where some of the most abundant species were captured are listed in Table 4.

DISCUSSION

The similarity in fish fauna of Cooper Island to other nearshore areas of the Beaufort Sea studied over 20 years ago (Craig and McCart 1976, Haldorson and Craig 1984, Craig et al. 1985, Jarvela and Thorsteinson 1999) indicates that species use of coastal waters has remained relatively unchanged. The dominant species in our catches were Arctic cod, capelin, juvenile prickleback, juvenile sculpin, least cisco, and slender eelblenny–all of these species have been reported as present or abundant in brackish-nearshore or marine-offshore waters of the Beaufort

Sea (Craig and McCart 1976, Craig 1984). Craig (1984) lists capelin and slender eelblenny as present but not abundant and widespread in the nearshore Beaufort Sea; from our catch and FO data, however, we consider these two species to be abundant in the western Beaufort Sea. At lagoon-barrier island environments in the eastern Beaufort Sea, Arctic cod, capelin, fourhorn sculpin (*Myoxocephalus quadricornis*), Arctic cisco (*Coregonus autumnalis*), least cisco, and Arctic char (*Salvelinus alpinus*) were the dominant species in summer (Griffiths et al. 1976, Craig et al. 1985, Jarvela and Thorsteinson 1999). The gear types that we used may not have been efficient in capturing some species. For example, in Simpson Lagoon and adjacent coastal waters of the eastern Beaufort Sea, gillnets and fyke nets were much more efficient than beach seines in capturing Arctic cisco and fourhorn sculpin (Craig et al. 1985). A few species that we captured (longhead dab *Limanda proboscidea* and veteran poacher *Podothecus veternus*), albeit in low numbers, were not reported as part of the fish fauna of the Beaufort Sea by Craig (1984).

The summer spatial distribution and species composition of fish at Cooper Island differed from a lagoon-barrier island environment in the eastern Beaufort Sea. For example, total catch (all species) was usually greater on the Beaufort Sea side of Cooper Island than on the Elson Lagoon side (except in 2006), whereas in the eastern Beaufort Sea near Prudhoe Bay, catch was greater on lagoon-side beaches of a barrier island than on the Beaufort Sea side (Craig et al. 1985). Common species captured on the lagoon-side of barrier island beaches near Prudhoe Bay were Arctic char and Arctic cisco (Craig et al. 1985). The proximity of Prudhoe Bay to the Mackenzie River in Canada, a major spawning drainage and source of Arctic cisco in Alaska (Schmidt et al. 1991, Bond and Erickson 1997, George et al. 2009), likely accounts for the high abundance of this species near Prudhoe Bay. Similarly, the proximity of Cooper Island to major spawning drainages of least cisco (Colville River and drainages to the west towards Barrow, Craig and Haldorson 1981), likely accounts for the high abundance of this species in Elson Lagoon. In addition, we captured no juvenile Arctic cod in Elson Lagoon, whereas Arctic cod was one of the most abundant species captured in Simpson Lagoon near Prudhoe Bay in mid-August 1978 (Craig et al. 1985). Our limited sampling in Elson Lagoon (i.e., beach seine only) may partially explain the absence of Arctic cod in our catches. In addition, fish numbers and relative abundance in lagoon-barrier island ecosystems can fluctuate dramatically from year to year and can affect catch and species composition (Craig et al. 1985).

Our catch of Arctic cod was restricted to the Beaufort Sea side of Cooper Island and may have a seasonal component; trawl catch was much greater in September 2009 (1,003 fish) than in August 2007 (45 fish) and 2009 (56 fish). The migration of Arctic cod from offshore waters to coastal areas in late summer and early fall has been reported in other Arctic regions (Craig and Haldorson 1981, Craig et al. 1982). Moulton and Tarbox (1987), however, reported a net offshore movement of Arctic cod to deeper waters between July (mean depth of capture = 2.7 m) and August (5.8 m) in a 1979 Beaufort Sea study. Although our sample size was limited in September 2009, more Arctic cod were captured at 8 m depth (592 fish) than at 5 m depth (411), supporting the observed preference of Arctic cod for deeper waters in late summer and early fall. Rainbow smelt and saffron cod showed a seasonal presence and were captured only in September. Rainbow smelt are not abundant in Arctic nearshore waters in summer but do migrate to nearshore areas in the fall and winter and become one of the dominant species (Haldorson and Craig 1984, George et al. 2009).

The size distribution of Arctic cod near Cooper Island is similar to other areas in the Beaufort Sea. Arctic cod that we captured ranged from 25 to 147 mm FL compared to 12 to

172 mm FL and 20 to 193 mm TL in the eastern Beaufort Sea (Bendock 1979, Jarvela and Thorsteinson 1999). Seine catch of YOY Arctic cod at Cooper Island was mostly restricted to August 2004; warm water temperatures in 2004 (highest of the study) may have favored survival and recruitment to the nearshore. The relatively large size (mean FL = 32 mm) of YOY Arctic cod at Cooper Island in mid-August 2004 may be indicative of favorable ocean conditions. In an earlier Beaufort Sea study, Bendock (1979) reported a mean size of 24 mm TL for YOY Arctic cod in August. Jarvela and Thorsteinson (1999) captured YOY Arctic cod larger than 30 mm FL in early August 1990 in the eastern Beaufort Sea; the authors described this as exceptional growth, possibly the result of an early hatch and abundant food resources. Arctic cod that we captured by trawl included fish as old as age-3 based on age-length relationships reported in other Beaufort Sea studies (Craig et al. 1982, Lowry and Frost 1981).

The consistent capture of YOY capelin by beach seine identifies the shallow nearshore as important summer habitat. Their use of the nearshore can last for several weeks; we captured YOY capelin in August and September. Adult capelin likely use the nearshore only during short periods while spawning. Based on mean size at age (about 65 mm at 90 days; Leggett and Frank 1990), our catches of capelin were probably from a late May or early June spawning. Multiple spawning events likely occur in summer; mass spawning was observed on beaches near Barrow in July 1993 and 2003 (George et al. 2009). Jarvela and Thorsteinson (1999) are one of the few other studies that describe capelin as abundant in coastal areas of the Beaufort Sea; they captured mostly YOY capelin in the eastern Beaufort Sea by purse seine and surface tows from 1988 to 1991. In several other studies in the Beaufort Sea, only minor catches of capelin were reported (Craig and Haldorson 1981, Craig et al. 1985, Moulton and Tarbox 1987). Use of the shallow nearshore by capelin for spawning and rearing highlights the importance of protecting this habitat from disturbance (e.g., oil spill). In addition, capelin are an important prey species for other fishes, marine mammals, and seabirds (Watts and Draper 1986, Bogstad and Gjǿsǽter 2001, Cherel et al. 2001).

Extreme environmental conditions can influence fish distribution and abundance. For example, we captured very few fish and no Arctic cod or capelin in August 2006; water temperatures were about 4º C to 8º C colder in 2006 (mean = 0.5º C) than in any other sampling period. Cannon et al. (1991) reported peak frequencies of occurrence of juvenile Arctic cod near Prudhoe Bay at water temperature between 4º C and 10º C. Similarly, Jarvela and Thorsteinson (1999) reported juvenile Arctic cod as more abundant and larger in 1990 when sea ice was absent and water temperatures were warmer (mean = 3.5º C) than in 1988 or 1991 when heavy pack ice was present and water temperatures were cooler (mean = 3.2º C and 2.5º C). Young-of-the-year capelin also show a preference for water temperatures greater than 1º C to 3º C (Jarvela and Thorsteinson 1999).

Nearshore studies are a necessary component to any work in the Arctic Ocean. Different species and life stages of fish can use the nearshore at different times of the short Arctic summer. For example, marine species tend to increase in nearshore waters as the open-water season progresses and salinities increase (Craig 1984). In addition, species composition can differ greatly between shallow, nearshore waters (< 10 m deep) and deeper, offshore waters. Some of the species that we captured in nearshore waters (e.g., capelin, least cisco, rainbow smelt, saffron cod) were absent or captured in very low numbers in bottom trawl surveys in deeper waters (> 30 m) in the vicinity of Cooper Island (NMFS 2008).

Our study provides only a snapshot of the nearshore icthyofauna present around one barrier island in the western Beaufort Sea. Studies should be expanded to other areas in the western

Beaufort and Chukchi seas, and include not only barrier island beaches but mainland beaches and the center of lagoons. The spatially explicit data from this study (only beach seine data to date) have been added to an online database for reference by resource managers and the public (NMFS 2010). The database is dynamic, includes other areas in Alaska, and will be updated regularly as new information becomes available. Resource managers can now access the database to identify species and habitats that may be affected by shoreline disturbance. With increased oil and gas exploration, vessel traffic, and other commercial ventures likely in the future, research in the Arctic Ocean should be accelerated to understand and protect this fragile ecosystem.

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Table 1.--Catch of fish by year at Cooper Island in the western Beaufort Sea, Alaska, 2004-2007 and 2009. Fish were captured with a beach seine on the Beaufort Sea side (three sites) and Elson Lagoon side (three sites) of Cooper Island (see Fig. 1). Fish were captured in mid-August of all years except 2009 (mid-September). CPUE = catch per seine haul.

		Total	Beaufort Sea					Elson Lagoon		
Common name	Scientific name	catch	2004	2005	2006	2007	2009	2004	2005	2006
Capelin	*Mallotus villosus*	936	797	2	0	33	104	0	0	0
Arctic cod	*Boreogadus saida*	356	354	2	0	0	0	0	0	0
Juvenile prickleback	Stichaeidae	48	0	0	0	0	48	0	0	0
Juvenile sculpin	Cottidae	42	5	23	0	0	4	10	0	0
Least cisco	*Coregonus sardinella*	38	0	0	0	0	0	14	14	10
Unidentified larvae	Division Teleostei	34	7	0	2	20	0	5	0	0
Pacific sand lance	*Ammodytes hexapterus*	29	9	16	1	1	2	0	0	0
Slender eelblenny	*Lumpenus fabricii*	26	0	0	0	0	26	0	0	0
Saffron cod	*Eleginus gracilis*	24	0	0	0	0	24	0	0	0
Juvenile cod	Gadidae	7	0	5	0	0	0	0	0	2
Unidentified cisco*	*Coregonus* species	5	0	0	0	0	0	1	2	2
Juvenile poacher	Agonidae	4	3	0	0	0	0	1	0	0
Ninespine stickleback	*Pungitius pungitius*	4	0	0	0	0	2	1	1	0
Arctic sculpin	*Myoxocephalus scorpioides*	3	0	1	0	0	0	1	1	0
Fourhorn sculpin	*Myoxocephalus quadricornis*	3	0	2	0	1	0	0	0	0
Longhead dab	*Limanda proboscidea*	3	0	3	0	0	0	0	0	0
Veteran poacher	*Podothecus veternus*	2	2	0	0	0	0	0	0	0
Juvenile snailfish	Liparidae	1	1	0	0	0	0	0	0	0
Kelp snailfish	*Liparis tunicatus*	1	1	0	0	0	0	0	0	0
Yellowfin sole	*Limanda aspera*	1	1	0	0	0	0	0	0	0
Total catch		1,567	1,180	54	3	55	210	33	18	14
Number of species		14	7	6	1	3	6	6	4	3
Number of seine hauls		24	3	3	3	3	3	3	3	3
Median CPUE		12	173	23	1	20	68	7	2	4

* Most likely Bering cisco (*C. laurettae*); George et al. 2009

Table 2.--Catch of fish by year and depth (5 and 8 m) at Cooper Island in the western Beaufort Sea, Alaska, 2007 and 2009.

Fish were captured with a bottom trawl at three sites on the Beaufort Sea side of Cooper Island (see Fig. 1).

Sampling was in mid-August and mid-September. CPUE = catch per 5 minute tow.

		Total	Aug. (2007)		Aug. (2009)		Sept. (2009)	
Common name	Scientific name	catch	5 m	8 m	5 m	8 m	5 m	8 m
Arctic cod	*Boreogadus saida*	1,104	31	14	39	17	411	592
Slender eelblenny	*Lumpenus fabricii*	69	0	0	11	18	5	35
Unidentified fish larvae	Division Teleostei	25	25	0	0	0	0	0
Saffron cod	*Eleginus gracilis*	11	0	0	0	0	8	3
Rainbow smelt	*Osmerus mordax*	8	0	0	0	0	6	2
Juvenile sculpin	Cottidae	6	0	0	0	0	4	2
Juvenile prickleback	Stichaeidae	5	0	5	0	0	0	0
Fourhorn sculpin	*Myoxocephalus quadricornis*	4	0	0	0	1	1	2
Longhead dab	*Limanda proboscidea*	4	0	0	0	0	4	0
Juvenile snailfish	Liparidae	2	0	0	0	1	1	0
Arctic staghorn sculpin	*Gymnocanthus tricuspis*	1	0	0	0	1	0	0
Capelin	*Mallotus villosus*	1	0	0	0	0	1	0
Total catch		1,240	56	19	50	38	441	636
Number of species		9	1	2	2	5	8	5
Number of tows		16	3	3	2	2	3	3
Median CPUE		28	2	6	25	19	143	181

Table 3.--Total catch, number measured (n), mean length (fork length or total length (mm) depending on species) and range, and proportion of each species estimated to be mature. Only the more abundant species captured with a beach seine and bottom trawl near Cooper Island, Alaska, from 2004 to 2007, and 2009 are listed. Least cisco was captured only in Elson Lagoon; see Figure 1 for sample locations.

	Total	Length			Percent
Beach seine	catch	n	Mean	Range	mature[a]
Capelin	936	143	58.6	38-138	0
Arctic cod	356	68	33.7	25-83	0
Least cisco	38	38	288.3	229-341	100
Pacific sand lance	29	27	55.9	39-74	0
Slender eelblenny	26	24	43.2	35-56	0
Saffron cod	24	23	30.3	22-42	0
Bottom trawl					
Arctic cod	1,104	463	78.8	29-147	0
Slender eelblenny	69	66	75.2	44-104	0
Saffron cod	11	11	47.7	34-78	0
Rainbow smelt	8	8	176.4	110-280	13

[a]Based on estimated size at first maturity from FishBase (www.fishbase.org/).

Table 4.--Range in surface water temperature and salinity (practical salinity scale, PSS) where select nearshore fishes were captured with a beach seine or bottom trawl in nearshore waters of Cooper Island in the western Beaufort Sea, Alaska, 2004-2007 and 2009.

Taxon	Temperature (º C)	Salinity (PSS)
Arctic cod	4.0-8.5	29-35
Capelin	4.0-8.5	29-35
Juvenile prickleback	4.0-5.0	30
Juvenile sculpin	4.0-9.0	24-35
Least cisco	5.0-9.0	10-35
Pacific sand lance	0.5-8.5	29-35
Rainbow smelt	4.0-5.0	30
Saffron cod	4.0-5.0	30
Slender eelblenny	4.0-5.0	30-32

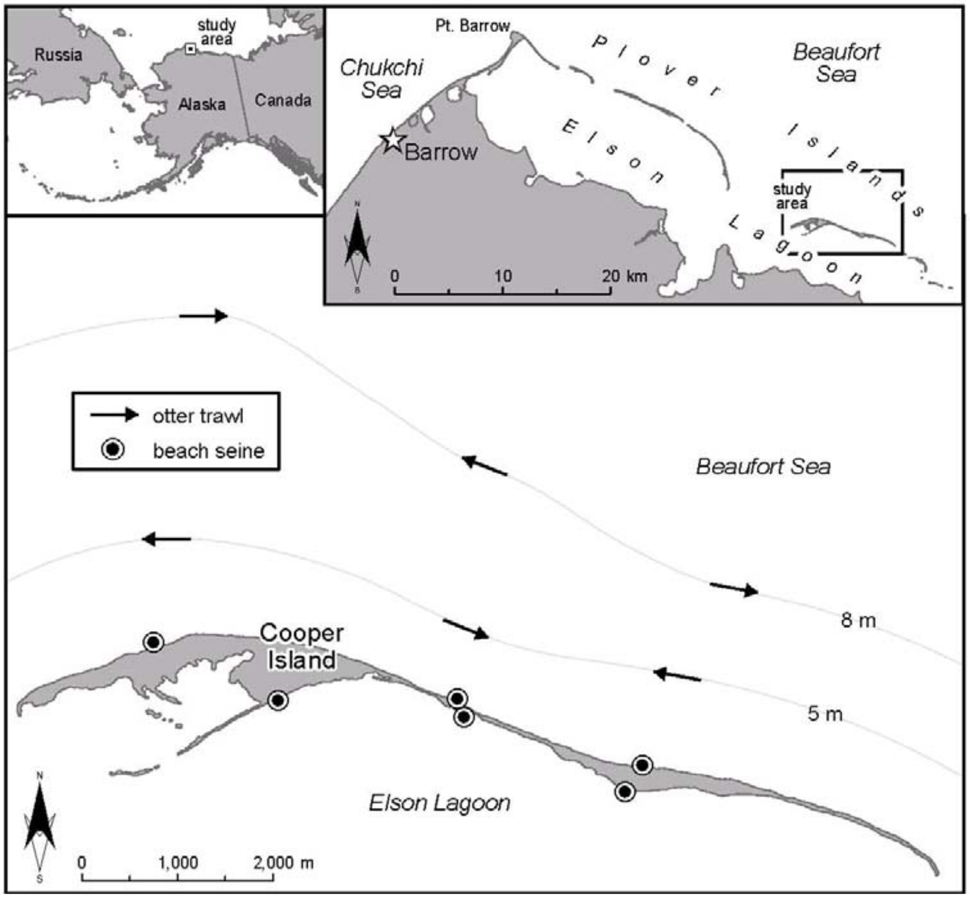

Figure 1.-- Nearshore fish sampling sites at Cooper Island, a barrier island in the western Beaufort Sea, Alaska. Fish were sampled with a beach seine (< 5 m deep) and bottom (otter) trawl at two depths (5 and 8 m) in mid-August 2004, 2005, 2006, 2007, 2009, and in mid-September 2009. Trawl tows were parallel to shore in opposite directions on the Beaufort Sea side of Cooper Island.

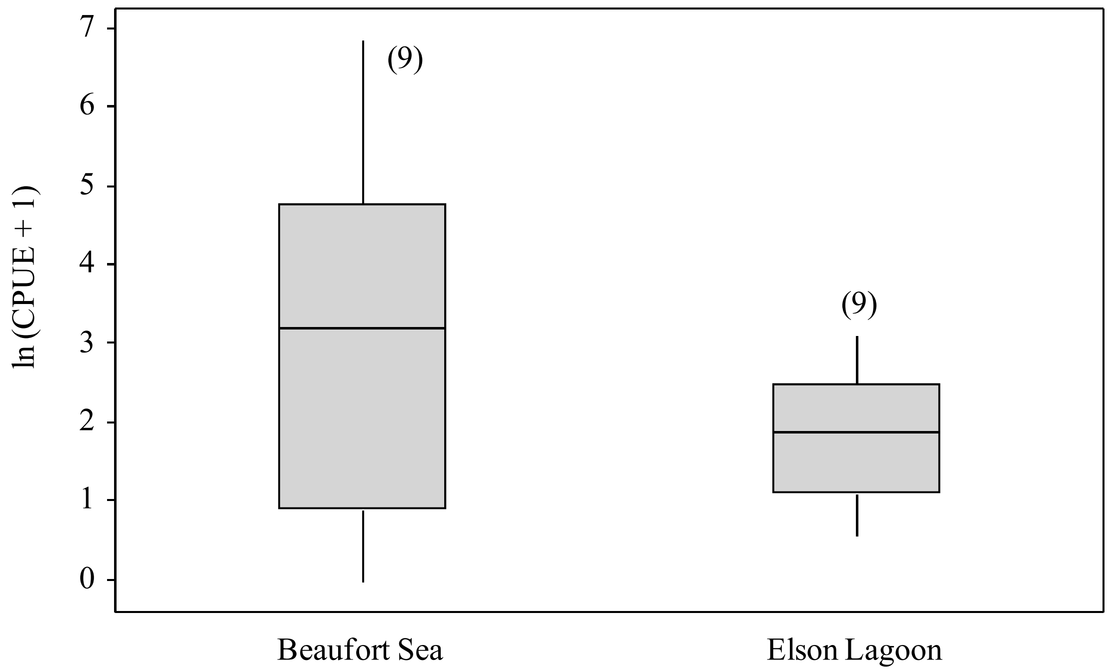

Figure 2.--Box-and-whisker plots of the log*e* transformed catch of fish (all species) per beach seine haul (CPUE) on the Beaufort Sea side and Elson Lagoon side of Cooper Island in the western Beaufort Sea, Alaska, 2004-2006. Bottoms of boxes are the first quartile, and tops of boxes are the third quartile value. Whiskers are the first quartile minus 1.5 times the interquartile range and the third quartile plus 1.5 times the interquartile range. Horizontal line within boxes is the median, and sample size is in parentheses.

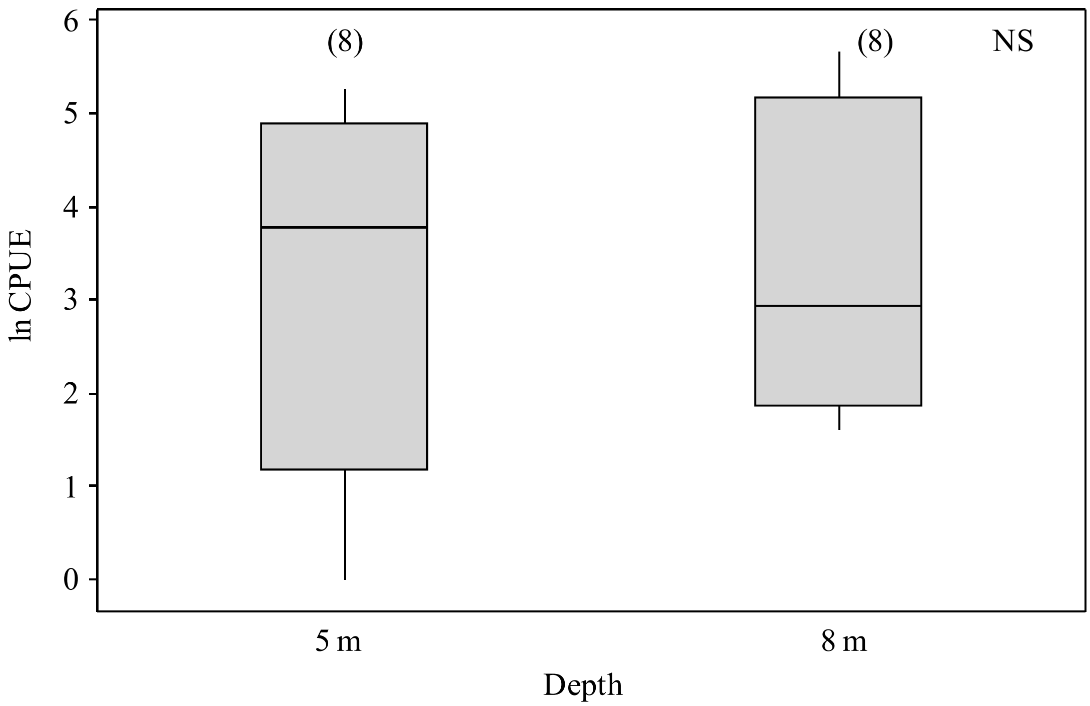

Figure 3.--Box-and-whisker plots of the log*e* transformed catch of fish (all species) per bottom trawl tow (CPUE) by depth on the Beaufort Sea side of Cooper Island in the western Beaufort Sea, Alaska, August 2007, and August and September 2009. Bottoms of boxes are the first quartile, and tops of boxes are the third quartile value. Whiskers are the first quartile minus 1.5 times the interquartile range and the third quartile plus 1.5 times the interquartile range. Horizontal line within boxes is the median, and sample size is in parentheses. NS = not significant.

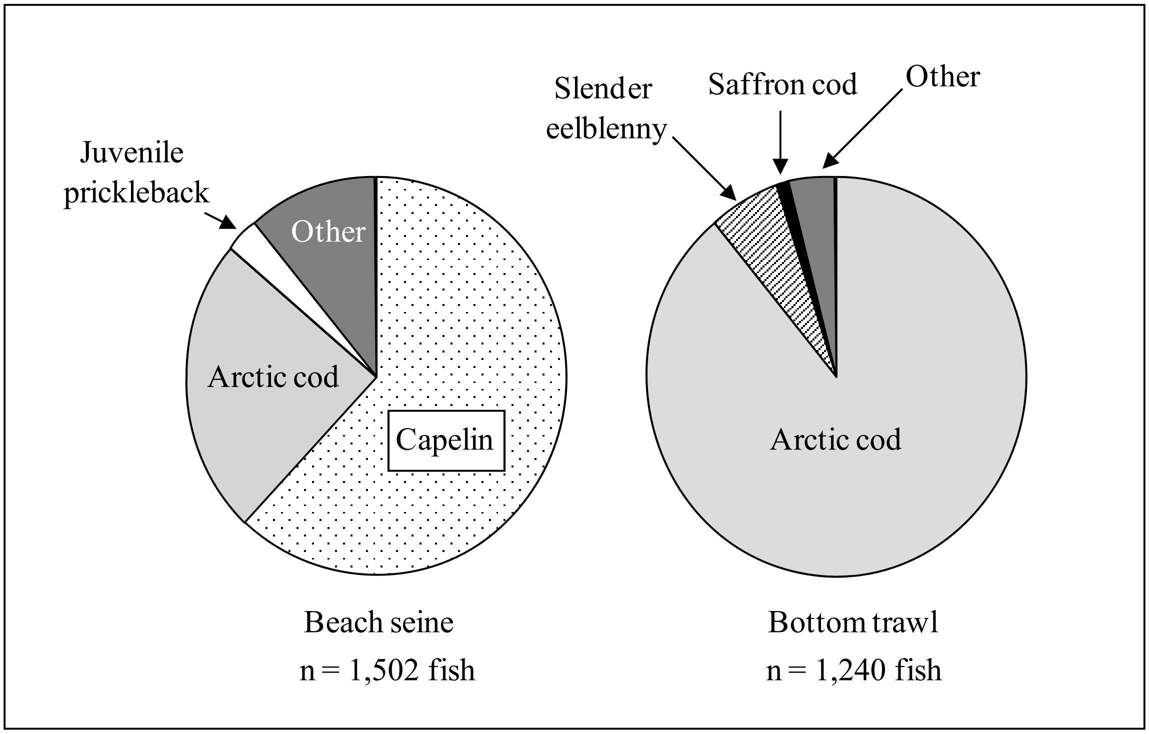

Figure 4.--Fish captured with a beach seine and bottom trawl on the Beaufort Sea side of Cooper Island in the western Beaufort Sea, Alaska. Fish were captured with a seine in mid-August 2004, 2005, 2006, and 2007, and in mid-September 2009, and with a trawl in mid-August 2007 and 2009, and in mid-September 2009. Seines were in shallow water (< 5 m deep), whereas trawls were at 5 and 8 m depths (1.0 to 2.5 km offshore).

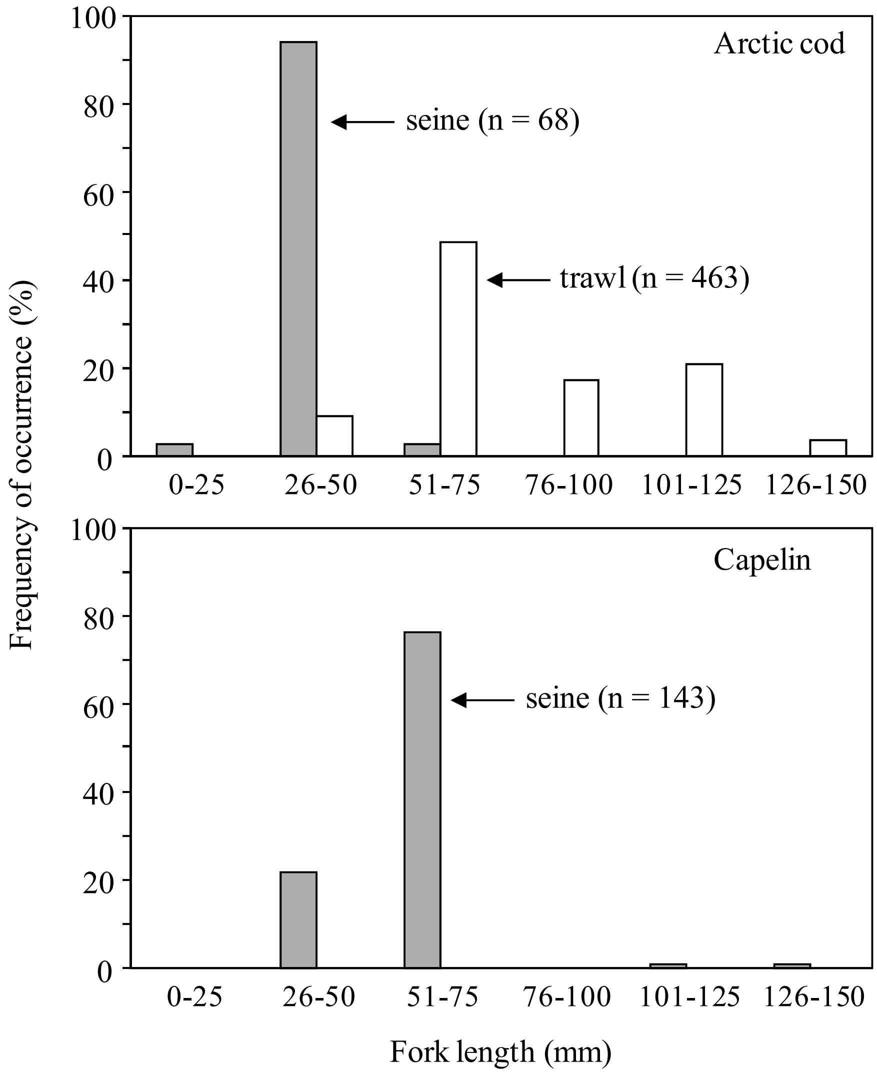

Figure 5.--Length frequency distribution of Arctic cod captured with a beach seine and bottom trawl, and capelin with a beach seine on the Beaufort Sea side of Cooper Island, Alaska, 2004-2007 and 2009. Fish were captured in mid-August of all years except 2009 (mid-September). Seines were in shallow water (< 5 m deep), whereas trawls were at 5 and 8 m depths (1.0 to 2.5 km offshore). Sample size in parentheses.

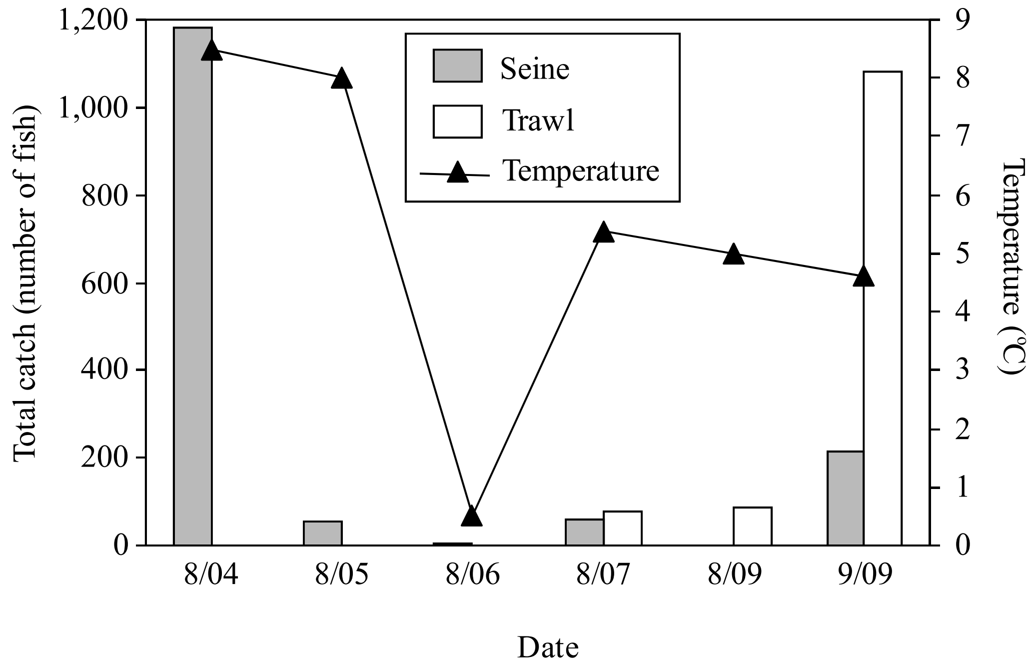

Figure 6.--Total fish catch (all species) and surface water temperature by sampling period on the Beaufort Sea side of Cooper Island, Alaska. Fish were captured with a beach seine in mid-August 2004, 2005, 2006, 2007, and in mid-September 2009, and with a bottom trawl in mid-August 2007 and 2009, and in mid-September 2009. Sampling effort with the seine was the same (n = 3 hauls) in all sampling periods; effort with the trawl was six tows in August 2007 and September 2009, and four tows in August 2009.

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