Fish Community Observations for Three Locations in the Northeastern Chukchi Sea, 2010

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Fish Community Observations for Three Locations in the Northeastern Chukchi Sea, 2010

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EXECUTIVE SUMMARY

Benthic and pelagic trawling for fish occurred aboard the R/V *Westward Wind* in three offshore study areas ("Klondike", "Burger", and "Statoil") in the northeastern Chukchi Sea in September 2010. Fish sampling was coordinated as a part of a multidisciplinary study examining baseline biological and oceanographic conditions. Concurrently collected environmental data were used to evaluate fish catches in relation to measured variables. Sampling was located at 43 predetermined stations using up to four different benthic trawls and two pelagic trawls. These data were collected in order to create a baseline dataset in anticipation of future oil and gas development in the region.

Across all gear types, 2,851 fish were caught, representing at least 25 species and eight families. The majority of fish caught were from benthic trawls (97%). Arctic cod (*Boreogadus saida*) was the most common fish species caught (*n*=1,193), followed by stout eelblenny (*Anisarchus medius*; *n*=250) and hamecon (*Artediellus scaber*; *n*=247). Fish catches and assemblages varied by study area; the Klondike study area had the highest number of fish as well as the highest number of species. Benthic catches of sculpins (Cottidae) in the Klondike study area were significantly higher compared to all other study areas, though proportions of other fish families were similar across study areas. Total catches and relative abundances were similar between the Burger and Statoil study areas. Benthic trawl nets showed similar species composition among gear types. Species' presence at study stations was sporadic for common species. Only two species were present at more than 30 stations, and 12 species were present at fewer than 10 stations. Catches in all nets were dominated by small fish: mean length for demersally-caught Arctic cod was 63 mm. Modeling catches as functions of environmental variables showed that species richness was inversely correlated to the percent of the substrate composed of sand. Ordination analyses showed that the measured environmental variables explained little of the variation in species assemblage structure, though it was more than was expected from chance alone. The most important variables were water temperature, latitude and whether the sample was collected during day or night. Moderate separation by prospect occurred, as well as modest groupings of species.

Temporal and spatial variability of water mass distributions greatly affect the nutrient flux into the Chukchi Sea; low pelagic catches in 2010 were likely a result of this shift. Preliminary oceanographic results indicate that 2010 was a cooler year than 2009. No major differences in the demersal fish community occurred from 2009 to 2010, i.e., the most common species in 2010 were also the most common species in 2009. No species were caught in 2010 that were not present in the 2009 collections. Importantly, current fish sampling yields results which are similar to historical offshore sampling in the region 20 years prior.

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INTRODUCTION

In February 2008, the United States Minerals Management Service (MMS) authorized the second offshore oil and gas lease sale in the northeastern Chukchi Sea (Lease Sale 193). The Chukchi Sea is located south of the Arctic Ocean and north of the Bering Sea, between northwestern Alaska and northeastern Siberia. Lease Sale 193 highlighted the necessity for gathering additional biological data in the lease areas; historical fisheries studies in this region were relatively limited in number and scope. As a result of Lease Sale 193, ConocoPhillips Alaska, Inc. and Shell Exploration and Production Company began a multidisciplinary baseline investigation in 2008. In 2010, investigations were expanded with the addition of another sponsor, Statoil. This report describes the fish studies conducted in 2010 by LGL Alaska Research Associates, Inc. (LGL) as part of the overall research program.

Background

Below, is a brief background on the northeastern Chukchi Sea in terms of its currents and water masses, and the previous fish investigations which have been conducted in this area. This information provides a context for our 2010 fish survey observations.

Currents and Water Masses

In the Chukchi Sea, the primary direction of water flow is northward, originating in the Bering Sea and passing through the Bering Strait. This flow is gradient-driven as the Arctic Ocean is situated 0.5 m lower than the Bering Sea (Overland and Roach 1987; Stigebrandt 1984). South winds, however, can slow the flow of water into the Chukchi Sea and, at times, cause a reversal in flow direction (Coachman and Shigaev 1992). The flux of water into the Chukchi Sea is the lowest in the winter and highest in the summer when north winds accelerate the currents into the Chukchi Sea (Barber et al. 1994).

The flow of water into the Arctic Ocean from the Chukchi Sea occurs mainly through the Herald Sea Valley, east of Wrangel Island, and through Barrow Canyon near Barrow, Alaska (Coachman et al. 1975). With the exception of Herald Shoal (southeast of Herald Sea Valley) and Hanna Shoal (northwest of Barrow Canyon), the sea floor topography between these two drainage points is relatively flat with depths ranging from 30–55 m. The three study areas for this project are located on this flat expanse (Figure 1).

Within the northeastern Chukchi Sea, three main water masses have been identified: Alaska Coastal Water (ACW), Bering Shelf Water (BSW), and Resident Chukchi Water (RCW; Coachman et al. 1975). Each water mass has unique properties that influence the biotic communities (Feder 1994; Wyllie-Echeverria et al. 1994). The boundaries of the water masses vary over time, depending on an array of environmental factors including freshwater input and the direction and force of the prevailing winds. ACW is located along the eastern edge of the Chukchi Sea, and has the lowest salinity levels of any of the Chukchi water masses. The low salinity of this water mass is due in large part to the runoff of freshwater rivers (mainly the Yukon River) along western Alaska. Due to the freshwater influx, this water mass is also the warmest of the three but it is very low in nutrients (Weingartner 1997).

BSW flows north from the Bering Sea into the Chukchi Sea. This cooler, high-salinity water mass is located to the west of the ACW and typically covers a much larger area than the ACW. BSW is high in nutrients and makes a large contribution to nutrient levels in the Chukchi Sea (Walsh et al. 1989).

RCW, found north of BSW, is water that has remained in the Chukchi Sea from the previous winter, or water that has been flushed into the Chukchi from the upper levels of the Arctic Ocean. Due to a long residence time in the Arctic, RCW is the coldest of the three water masses. Ice formed in the winter is comprised mainly of freshwater which leaves the remaining RCW with high salinity (Weingartner 1997).

Density differences among the water masses often lead to horizontal stratification of the water column (e.g., low salinity ACW can be found on top of high salinity BSW). A distinct and persistent thermocline was observed during the 2009 and 2010 field seasons. This boundary layer was located about 20 m off bottom. Interannual and seasonal variations in weather patterns cause the water mass boundaries to have significant variation in all dimensions (Weingartner 1997; Pickart et al. 2010).

The Influence of Ice

Ice cover and relatively cold water dominate the oceanographic habitat in the Chukchi Sea. During the winter, the sea ice forms ridges with deep keels that may reach the bottom. Once grounded, ice keels produce steep sided trenches in the substrate ("ice gouges") as deep as 5 m, tens of meters wide and sometimes kilometers in length (Toimil 1978). Most ice gouges occur in the stamukhi (shear or flaw) zone, an ice zone that lies seaward of the land fast ice. This is a dynamic zone where the moving pack ice meets the more stable land fast ice resulting in the formation of pressure ridges. In the Chukchi Sea, most pressure ridges are formed over water depths of 15 to 40 m. According to Weingartner (1997), regional barometric conditions (wind patterns) play a part in determining circulation within the Chukchi Sea, in turn influencing spring ice melt timing and the extent of ice cover during the spring and summer.

Ecosystem of the northeastern Chukchi Sea

The Chukchi Sea has a benthic-based ecosystem with the majority of the biomass situated on the sea floor (Grebmeier et al. 2006b). Other than Arctic cod, (*Boreogadus saidia*) almost all fish species present are associated with the sea floor and feed on benthic invertebrates (Barber et al. 1994; Coad and Reist 2004; Norcross et al. 2011). Even though most of the ecosystem biomass is benthic, a large portion of the biomass is in species that are of minimal use as forage for fish (e.g., *Ophiura sarsi*, brittle star) (Barber et al. 1994; Norcross et al. 2011). In fact, competition with some benthic invertebrates may limit the demersal fish richness and abundance as areas in the Chukchi Sea holding high benthic invertebrate biomass in 2009 were observed to have low demersal fish catches in 2010 (Blanchard 2010; this report). This possibility merits further investigation.

Overall, the Chukchi Sea fish community structure is dominated by Arctic cod and demersal fishes. Few fish in the northeastern Chukchi Sea are piscivorous. In the Arctic marine environment, the primary predators of fish, especially Arctic cod, are marine mammals and seabirds rather than other fish (Piatt et al. 1990; Welch et al. 1993). The majority of the fish eat a variety of benthic invertebrates (Barber et al. 1994; Norcross et al. 2011).

Semi-demersal Arctic cod are a generalist species widely considered a cornerstone of the Arctic marine ecosystem providing forage for a number of marine mammals and birds (Frost and Lowry 1983; Welch et al. 1993; Hop et al. 1997; Piatt et al. 1990). Arctic cod feed on a wide variety of benthic and pelagic forage (Hop et al. 1997; Barber et al. 1994) and are physiologically adapted to the environment (Chen et al. 1997). This presents a distinct advantage over competing species that are more limited in diet and habitat.

Previous Fish Studies and Key Findings

Fish studies conducted in the Chukchi Sea in the latter half of the 20th century include Alverson and Wilimovsky (1966), Frost and Lowry (1983), Fechhelm et al. (1985) and Barber et al. (1994). More recent studies include Crawford (2010) in 2002, the Russian-American Long-term Census of the Arctic (RUSALCA) in 2004 and 2009, and Chukchi Offshore Monitoring In a Drill Area (COMIDA) in 2009 and 2010. Though recent studies have added much needed knowledge, current fish datasets in the region remain very limited both temporally and spatially. The North Pacific Fishery Management Council (NPFMC) does not allow commercial fishing in the Chukchi or Beaufort seas, in part because there is a lack of information on the present status of resident fish populations (NPFMC 2009).

Fish communities in the Alaskan Arctic are dominated, in terms of numbers and biomass, by cod (Gadidae) (Craig et al. 1982). Arctic cod are the most prevalent species in the Chukchi Sea, and have comprised 34–76% of the total catch in past studies (e.g., Norcross et al. 2011;

Barber et al. 1997). The majority of fish species found in Arctic waters are demersal fishes such as sculpins (Cottidae), eelpouts (Zoarcidae), pricklebacks (Stichaeidae) and flatfishes (Plueronectidae). Barber et al. (1994) captured 66 fish species, while more recent studies such as RUSALCA 2004 (Mecklenberg et al. 2007) and Norcross et al. (2011) captured 33 and 30 fish species, respectively. FishBase (Froese and Pauly 2011) currently lists 82 species as inhabiting the Chukchi Sea, though many of these species are anadromous, nearshore, or expected to only inhabit the southern Chukchi Sea. Barber et al. (1994) observed a general decrease in species diversity and abundance from south to north and from inshore to offshore.

According to Crawford (2010), Arctic cod are distributed throughout the water column with smaller fish near the surface and larger fish deeper, occasionally forming large, dense schools. Logerwell et al. (2010) observed Arctic cod schools near the shelf break by Point Barrow that extended from near bottom to the surface. Hydroacoustic surveys in the southeastern Chukchi Sea showed that Arctic cod distribution throughout the water column was different for ACW and BSW (Piatt et al. 1990).

Trawl surveys in both the eastern Chukchi Sea and western Beaufort Sea have indicated little potential for fisheries (Barber et al. 1994; Logerwell et al. 2010) with few, generally small species (<15 cm) dominating the offshore demersal fish community. All prior studies have noted that benthic invertebrates dominate most trawl catches.

Scope

Complimentary Studies

The goal of the baseline studies program is to provide an understanding of the oceanographic and ecosystem dynamics of the northeastern Chukchi Sea. To achieve this goal, several disciplines conducted sampling concurrent with the fish investigations of 2009 and 2010. These included studies of benthic invertebrates, zooplankton, seabirds and marine mammals. Acoustic buoys were also set to passively detect the movement of whales and walrus through the northeastern Chukchi Sea over the course of a year. Physical oceanographic studies were conducted to provide information on large scale water flow and water mass properties that were possibly influencing the biological observations. As all of the biological and physical processes are interrelated, this work represents a major step towards an ecosystem-scale understanding of the Chukchi Sea.

Current Fish Sampling

Fish sampling for the baseline studies program first occurred during the summer, open-water season of 2009 (Norcross et al. 2011). Two cruises were conducted in 2009, one in August and the other in September/October. Sampling was conducted at two study areas (Klondike and Burger) on each cruise (Figure 1). Each study area roughly corresponded to a prospective area of development (prospect) leased by a corporation. The 2009 fish field studies and laboratory analyses were conducted by University of Alaska Fairbanks (UAF) researchers. In 2010, a third sponsor (Statoil) and a third study area of the same name (Statoil) was added to the study (Figure 1). Fish sampling occurred on only one cruise in 2010. The fish sampling in 2010 was conducted by LGL Alaska Research Associates, Inc (LGL) with the assistance of UAF personnel. Laboratory analyses (diet analysis, otolith aging, and individual weights) of the 2010 samples are being conducted by UAF. All fish caught by LGL were provided to UAF researchers for further analysis.

Objectives

The specific objectives of the 2010 LGL fish study were to:

1) Conduct demersal and pelagic fish sampling at 47 stations in three study areas or prospects (Klondike, Burger, and Statoil) sampled (in part) in 2009.

2) Determine fish community structure, diversity, and the density and relative abundance of dominant and selected species.

3) Determine size composition within species.

4) Relate the observed patterns of diversity and species densities to environmental and ecosystem attributes.

Study Area and Methods

The three study areas (Klondike, Burger, and Statoil) were located approximately 75–150 km northwest of Wainwright, Alaska (Figure 1), in the broad flat region of the northeastern

Chukchi Sea between Barrow Canyon and the Herald Sea Valley. The Klondike and Burger study areas were identical in shape and size at 55.6 x 55.6 km^2 (30 x 30 NM^2; Figures 2 and 3). These two study areas were non-adjacent and centered about 70 km apart; the northeast corner of Klondike was about 19 km from the southwest corner of Burger. The Statoil study area was not square-shaped and was adjoined to the northwestern edge of Burger (Figures 1 and 4). Limited sampling also occurred in the corridor between the Klondike and Burger/Statoil study areas (Transition stations; Figure 5). The number of stations in each study area varied; there were 13 stations in Klondike and Burger, 11 stations in Statoil, and six Transition stations. All of the study areas have relatively uniform shallow depths, a characteristic common to much of the Chukchi Sea.

Environmental Sampling

At each station, water depth (m) was measured using the vessel's sounder. Water temperature and salinity measurements were collected from the surface to several meters off the bottom using a Seasave™ CTD manufactured by Sea-Bird Electronics, Inc. Substrate samples were collected using a 0.1 m^2 Van Veen grab and analyzed by Dr. Arny Blanchard at UAF.

Fish Sampling Gear and Protocols

Fish sampling was conducted aboard the 57.7-m long R/V *Westward Wind*, a converted king crab fishing and processing vessel. The *Westward Wind* is a well deck vessel with the house aft and the working deck forward between the house and forecastle. All sampling gear was deployed from the starboard side, aft of the forecastle using a ship-mounted deck crane. Sampling nets were towed from a davit mounted to the forecastle bulkhead using Rochester .323 standard Hydro wire.

Six types of sampling gear were used to capture pelagic and demersal fishes. These included: a 1.5-m Isaacs-Kidd midwater trawl (IKMT); a 10-m Meyer-Aluette Pelagic Trawl (MAP); a 3-m Plumb Staff Beam Trawl (PSBT); a modified 3-m Plumb Staff trawl (MPSBT); a 3-m model 38 Skate Beam Trawl (3mBT); and a 5-m model 38 Skate Beam Trawl (5mBT). Except for the IKMT, all trawl nets were fitted with a 12-mm codend liner.

Initially, the authors had planned to use only a PSBT (supplied by UAF), a 5mBT, and a 10 x 10 m midwater trawl to sample pelagic fish. However, several complicating factors necessitated the use of four beam trawl configurations and two midwater trawls. The PSBT was used to collect epibenthic invertebrate and fish samples in 2009 and, for consistency, it was employed again in 2010.

The 3mBT was designed to capture small fish (<300 mm) and has been successfully employed by other investigators in similar conditions (Faulkner, Innovative Net Systems, personal communication). Beam trawls have a fixed horizontal opening, important in determining the area swept by the trawl (Gunderson and Ellis 1986). When outfitted with a light beam and wide shoes (to skim lightly over the bottom) beam trawls cause minimal damage to benthic communities. In addition, beam trawls were selected for use in this study because the *Westward Wind* is a well deck vessel with a single trawl winch and could not accommodate a standard otter trawl. The primary disadvantage of a small beam trawl as compared to an otter trawl is that it is selective towards smaller fishes. However, trawl surveys using otter trawls in the northeastern Chukchi Sea did not result in the capture of large, commercial sized fish (>300 mm; Barber et al. 1994).

Midwater Trawls

Midwater trawls are designed to sample the water column for pelagic fishes and invertebrates. These nets were employed to sample for fish that may be present at the thermocline during the ice-free season in the eastern Chukchi Sea to determine if this interface might be an active feeding area for pelagic fish, specifically Arctic cod. However, dense schools of fish were not observed on the vessel's acoustic sounders and trawl catches were small. The IKMT was designed to collect small fish (ichthyoplankton; fish <100 mm), while the much larger MAP trawl was designed to capture larger pelagic fishes, up to 450 mm in length. Sampling with the IKMT and MAP trawls was performed using a double oblique tow protocol, sampling on the way down and back up. The vessel's towing speed was held constant at 1.5 to 2.0 kts during the double oblique tow.

IKMT

The IKMT had a mouth opening of 2.7 m^2 held open with a 1.8-m spreader bar and depressor with 1.5-m long side ropes (Photo 1). The net was constructed from 5-mm mesh netting and fitted with a cod end "cup". The cup was at the terminal end of the net and was constructed of a PVC tube with holes covered by 1-mm mesh.

To deploy the IKMT, trawl operators lowered the net quickly (~15 m/min) until it was clear of the ship's hull. Once past the ship's hull, the IKMT was paid out at a rate of about 12 m/min until 60 m of wire were paid out. Immediately upon reaching 60 m of wire out, net retrieval began (also at 12 m/min) for a total sampling time of about 10 min. At this pay out rate and vessel speed, the tow wire angle was 60° allowing the net to reach a maximum depth of 35 m. When water depth was greater than 35 m, 66 m of wire were paid out to allow for a deeper maximum sample depth. The large ocean swells encountered during most of the cruise prevented deeper sampling.

MAP Trawl

The MAP trawl (Photo 2) had 9-m long head, foot and side ropes, for a maximum mouth opening of 9 x 9 m. The mouth of the MAP trawl was held open horizontally by a pair of trawl doors (roughly analogous to otter boards) and held open vertically by floats on the head rope and 13.6 m of 10-mm galvanized chain on the foot rope. The net was constructed using Sapphire 42-mm mesh netting of number 12 and 15 thread. The net was approximately 25-m long and was fitted with a 12-mm mesh codend liner. The net was fitted with two sets of bridles, the first bridle (25 m in length) extended from the swivel at the end of the tow wire to the trawl doors, and the second set of bridles (10 m in length) extended from the doors to the net. The bridles were constructed from 12-mm Dyneema line. The trawl doors were Polar Hydrodynamic-Wing Pelagic trawl doors designed to maintain the net at depth and maximize the spread on the net mouth. The MAP trawl netting and trawl doors were custom designed and fabricated by Innovative Net Designs.

The MAP trawl tow cable was paid out at a rate of 4 m/min until 60 m of wire were paid out. When the tow angle exceeded 60° an additional 20 m of cable were paid out, resulting in a increased deployment and retrieval speed. Total tow time for the MAP trawl was approximately 30 minutes. When the sea state exceeded ~2 m, the motion of the vessel caused the MAP net to rise and sink. Therefore, during some tows the net likely sampled from near the surface to near bottom several times during each tow. An underwater video camera was attached to the MAP to ensure it was fishing correctly (Photo 3).

Bottom Trawls

The PSBT, MPSBT, 3mBT and 5mBT were all beam trawls designed to sample epibenthic invertebrates and demersal fishes living in, on or near the bottom. Initially, it was planned to use only the 5mBT and the PSBT. Concerns that the 5mBT was too heavy to be safely deployed and recovered from the *Westward Wind* necessitated the modification of the 5mBT into the smaller and lighter 3mBT. A spare PSBT was used as a base model for the MPSBT.

PSBT

The PSBT used aboard the *Westward Wind* was modified slightly from the original design described by Gunderson and Ellis (1986). Modifications included shortening the beam from 3.66 to 3.05 m, attaching a lead-filled line (leadline) to the foot rope and 15-cm lengths of chain at 15-cm intervals along the foot rope and lengthening the codend from 1 to 4 m. The trawl was constructed using 7-mm woven nylon netting and outfitted with a 4-mm mesh codend liner. The effective mouth opening of the net was 2.26 x 1.20 m (Photo 4).

The net was rigged with a double tickler chain that consisted of a "long chain" that was 0.5-m shorter than the foot rope, and a "short chain" that was 0.9 m shorter than the foot rope. The long chain was attached to the thimbles at each end of the net foot rope, and the short chain was attached to the long chain 0.3-m from each end. In an attempt to reduce the amount of mud entering the net, five 10.2-cm trawl floats were attached to the codend to help it float off the bottom.

The PSBT was towed on the bottom for 2 to 3 minutes. This gear was highly effective at sampling benthic invertebrates, which greatly restricted the length of tows. The length of wire deployed was usually twice the water depth (scope = 2.0). In heavy seas a scope of 2.3 was used to ensure bottom contact.

Abookire and Rose (2005) reported difficulty keeping a PSBT in contact with the bottom when using a scope ratio of 4:1. To ensure that the trawls were on the bottom, we painted the bottom of the wingtip weights of the PSBT and MPSBT and the shoe bottoms of the 3mBT and 5mBT between tows. The weights and shoes were inspected after each tow for wear (proof of bottom contact). In our configuration, the forward quarter of the wingtip weights showed little wear but the aft three quarters the paint was worn off with no signs of paint or rust. With the other beam trawls, the paint was worn off the full length of the shoes.

MPSBT

An extra PSBT was modified by removing the tickler and drop chains, adding two additional 10.2-cm floats to the head rope, removing 0.5 m of leadline from the foot rope, and adding a 22.9-cm trawl float to each end of the beam. These changes were made in an attempt to float the footrope off the bottom and reduce the amount of invertebrates captured during each tow and are similar to those described by Abookire and Rose (2005).

The protocol for towing the MPSBT, and 3mBT and 5mBT was the same. These beam trawls were towed on the bottom at 1.5–2 kts for 30 minutes. Occasionally, a 30-minute tow resulted in over sampling of epibenthic invertebrates; when PSBT catches indicated high epibenthic density, the tow time was reduced to 15 minutes. The length of cable deployed was usually twice the water depth (scope = 2.0). In heavy seas, additional cable was paid out (scope = 2.3) to ensure that the net remained in contact with the bottom for the duration of the tow.

The amount of cable paid out was estimated by the winch operator who counted the number of revolutions of the winch drum during pay out. Each revolution of the winch drum paid out approximately 2 m of tow wire. Tow time for the beam trawls was determined to start when the predetermined amount of tow wire had been paid out and ended at a predetermined time when haul back commenced. Trawl time is considered conservative because the nets reached the bottom and started fishing before all of the cable was paid out and continued fishing after retrieval commenced.

3mBT and 5mBT

These trawls consisted of a 5-m model 38 Skate Trawl fitted to a 3- or a 5-m long tubular steel beam. The model 38 Skate Trawl had a 5-m head rope and a 6-m foot rope and 9 m of 1.9-mm galvanized drop chain was attached to the foot rope. The net was constructed using 38-mm Sapphire netting using 9 thread twine on top and 15 thread twine on the bottom and codend. The net was outfitted with a 12- mm mesh codend liner. To help keep the foot rope from digging into the bottom, the foot rope was equipped with 10-cm "mud raisins" (foam rollers). Further, the bridle consisted of 13 m of 20-mm Dyneema line. The vertical opening of the net was 1.0 to 1.5 m. When fitted to the 3-m beam, the net's wing ends were attached directly to the beam. When the 5-m beam was used, the wings were set back one meter from the beam. The arrangement of 3mBT beam, shoes, drop chains and mud raisins are shown in Photo 5. The effective mouth opening of the net was approximately 2.9 by 1.5 m.

The beam of the 3mBT was constructed using 5.1-cm diameter, schedule 80 (wall thickness of 5.54 mm) steel pipe with 1-m skids (shoes) bolted onto each end. The nets were attached directly to the skids. The top of the wing was attached near the top of the skid and the bottom of the wing was attached 15 cm above the bottom of the skid to allow the net to glide over the bottom. The tow bridle was attached to the middle of the leading edge of each skid.

The 5mBT netting, beam, and skids were custom designed and fabricated by Greg Faulkner of Innovative Net Designs, Milton, Louisiana. The modification of this net into the 3mBT was performed shipboard incorporating the advice of Innovative Net Designs.

Fish Processing

Once the nets were landed, the entire catch was photographed. After separating the fish from the rest of the epibenthic catch, all fish were taken to the vessel's wet lab for processing. Fish species were identified, in-field, to the lowest taxonomic class possible using Mecklenburg et al. (2002). Common names within this report are those referenced by Mecklenburg et al. (2002). Individual fish were measured (total length) into 10-mm size classes (50–59 mm, 60–69 mm, etc.). In some cases fish were damaged, either by rocks caught in the net or by predation by crabs and the total length could not be measured. These fish were included in the total catch as "Unmeasureable." When a fish was damaged into multiple pieces, only the head was counted to avoid duplicate counts. Photographs were taken of each fish species to aid in future identification.

Fish species were weighed (aggregate weight of all individuals of that species) and retained (frozen or stored in formalin) for further processing and analysis by researchers at the University of Alaska Fairbanks. Because sample processing was done aboard the ship, conditions were not optimal for weighing samples. Weights were not taken on fish samples that

weighed less than one gram (fluctuations of 1 g or more were common due to the vessel's pitching).

When possible, all fish from the catch were sampled. On one occasion (Station BF-013), the PSBT catch was too large to safely bring aboard. The decision was made to dump half of the haul overboard. Effort for this station was halved.

Data Analysis

Interpolation and Mapping of Environmental Data

Gradient maps for salinity, temperature, species richness, percent sand, and percent gravel were derived using ArcMap© 10 software and the spatial analyst extension (ESRI, Inc). Values for all independent variables were linked to the table of the fixed station points at Klondike, Burger and Statoil study areas. The points were then interpolated using either kriging or Inverse Distance Weighted (IDW) methods.

Kriging assumes the spatial variation in the phenomenon represented is statistically homogenous throughout the surface, and therefore works best with datasets that have little variation between points. Since the salinity and temperature datasets had values with small variations, kriging was used to interpolate each of these surfaces.

IDW operates upon the assumption that phenomena that are close to each other are more alike than those that are farther apart. This assumption means that each point has an influence on all the other points, but the power of the influence decreases as distance increases. The species richness, sand and gravel datasets all had large differences in values, making IDW a better method for interpolation for these variables.

Calculation of Tow Area

Sampling from the starboard side of the vessel did not allow the nets to be towed in a straight line. To keep the net and tow cable from tangling with the vessel's props, the vessel maintained a heading slightly starboard, resulting in a curved tow line. Because the tows were not straight, using beginning and ending GPS locations would not be accurate for measuring the distance towed. To measure distance towed, the start and stop times were recorded for all tows. Start and stop times for midwater trawls began when the nets entered the water and when the net exited the water, respectively. For benthic trawls the start time was taken when the appropriate amount of deployed tow cable was reached. The stop time was taken when retrieval of the net began. The time towed was then multiplied by the vessel's target speed that the captain maintained for the duration of the tow (1.5 kts for midwater trawls and 2.0 kts for benthic trawls)

to get a distance towed. The distance towed was then multiplied by the width of the benthic net mouths or the opening of the midwater nets to get area fished at each station. For the benthic nets, this gave a conservative estimate of the area sampled as the nets likely contacted the bottom before the entirety of the tow cable was paid out.

Fish Lengths

The lengths of fish processed on board the vessel were recorded in 10 mm length class "bins". All fish in a bin were assigned a length at the midpoint of the bin. For example, all fish in the 50-59 mm bin were assigned a length of 55 mm. Average lengths for each species were then calculated using the bin midpoint lengths.

Data Entry

All data were recorded onto field datasheets and reviewed by at least one person in addition to the recorder. Reviewed data were then entered into the TigerNav database and later downloaded into a Microsoft Access™ relational database. All entered data were checked against the reviewed datasheet to ensure consistency before they were used for analysis purposes.

Species Apportioning

Many fish, especially juvenile sculpins, were unidentifiable due to their extremely small size. When possible, unidentified fish were assigned either to a genus or a family. For many analyses, excluding a large proportion of fish because of their size was imprudent. For those analyses, the unidentified fish were added to the catch totals for similar species caught in that gear at that site. For example, if 10 unidentified sculpin (*Cottidae* spp.), 20 hamecon (*Artediellus scaber*) and 20 Arctic staghorn sculpin (*Gymnocanthus tricuspis*) were the only sculpin caught in the 3mBt the apportioned totals would be 25 hamecon, 25 Arctic staghorn sculpin and 0 unidentified sculpin. If no species of the same family were caught in that gear type, catches from similar gear types at that site were used for apportioning. If no similar species were caught in other gear types at that site the proportion of similar species by study area was used. Presented results are for unapportioned catches unless otherwise stated. All statistical analyses used apportioned data.

Statistical Methods

Determining What to Quantify

The overarching purpose of this study was to better identify and quantify the extant populations and communities in the study areas, as well as to determine how they changed as a function of the various measured physicochemical variables. To that end, we had to first determine what population and community metrics to quantify.

The population densities of species were certainly of interest. Observed frequencies for all species collected were reported, but statistical models (see descriptions below) were used to more accurately reflect trends in the four numerically dominant species. Length frequency distributions were described for species where catches were sufficient for this purpose. However, size distributions were not modeled or correlated with any of the explanatory variables.

Community attributes are more difficult to quantify than are most population metrics. This is particularly true for species diversity. Most descriptive reports use metrics such as the Shannon-Wiener index and Simpson's Index to quantify community diversity. These descriptors attempt to reduce diversity into a single, interpretable number. However, species diversity can be separated into two components—richness (the number of species) and evenness (how evenly distributed individuals are across species; Pielou 1977). Most, if not all, diversity indices combine these components in various ways which confounds interpretation of the results (Washington 1984). It is not possible to tell from these diversity indices whether one site yields a higher diversity index relative to another because its individuals are more evenly distributed across species, or because it possesses more species. Healthy communities often have a few dominant species and many rare species leading to high species richness, coupled with low evenness. Disturbed systems typically have fewer species (low richness), but sometimes the species that are present are about equally represented leading to high evenness. Kimbro and Grosholz (2006) reported that evenness increased with increasing disturbance, while Mackey and Currie (2001) found evenness to be unrelated to disturbance in about half the studies they surveyed. Therefore, we chose not to analyze evenness and focused on species richness.

Richness is the number of species standardized to an area or some level of effort as an index of diversity. The usual practice is to standardize samples to the same number of individuals before making comparisons using a technique known as rarefaction analysis (Sanders 1968). This approach allows comparison of samples that have different levels of effort, but does not allow the inclusion of covariates or categorical variables (e.g., temperature, salinity, etc.). In our analysis, species richness was modeled on a per effort basis using generalized linear models (GLMs; see further explanation below) instead of on a per individual basis using rarefaction analysis. This allowed us to control for various covariates and to make comparisons taking

several categorical variables into account. Modeling species richness in this way is becoming increasingly more prevalent in the literature (e.g., Lobo and Martin-Piera 2002; O'hara 2005).

Another important community level feature is the proportionate mix of species, which can be used to define distinct communities. The degree or magnitude of change in this mix across environmental gradients defines the level of beta diversity for an area. This mix is termed the assemblage structure (sometimes called community structure). For a given sample with a positive catch, there will be a certain number of species collected (species richness) and each will have a relative abundance that marks its comparative contribution to the assemblage. A species' relative abundance equals the abundance of that species in the sample divided by the total abundance of all species in the sample.

We report the observed relative abundance of all species collected across all samples. For reasons described below, we modeled six response variables with generalized linear models (GLMs; see *Justification and Parameterization of Generalized Linear Models* below). These responses included: densities of the four dominant species, species richness, and assemblage structure. Independent variables included the three categorical variables gear, day versus night sampling, and wave height measured in feet. There were eight continuous variables: latitude, longitude, water temperature, salinity, depth, percent gravel in the substrate, percent sand in the substrate, and total organic carbon in the substrate. We also measured the percent mud in the substrate, but as the three substrate types summed to 100%, only two were needed, and because sand and mud were the most correlated (inversely; Figure 6) we dropped percent mud instead of percent gravel to reduce multicolinearity (note: we could have just as well dropped percent sand instead of mud and accomplished the same thing). Study area (prospect) was not included the GLMs because it was not biologically relevant; however, observed catches and relative abundances were summarized by study area.

Justification and Parameterization of Generalized Linear Models

The data of interest are catch (count of fish) and the effort required to obtain catch. The simplest approach for analyzing such data is to divide each sample's catch by the corresponding effort to obtain CPUE and report the averages for each observed combination of categorical variables. Comparing levels of categorical variables in this way can be very misleading if sample sizes were uneven across cells and/or the study design is not a complete factorial; i.e., every combination of cells was not observed. Furthermore, ignoring the influence of continuous variables decreases understanding of the habitat, and, at worst, can cause comparisons across levels of categorical variables to be deceptive. By modeling the data to obtain predicted CPUEs, missing cells can be filled, uneven sampling standardized, and covariates can be added to control for confounding effects.

The historical approach for modeling such data has been to divide catch by effort to obtain CPUE, assume a lognormal distribution and apply ANOVA or linear regression analysis, or to combine the two as in analysis of covariance (ANCOVA). Typically, however, CPUE does not have a lognormal distribution and/or contains numerous zeroes, which cannot be log-transformed without adding a constant (such as one). Different conclusions can be reached depending on the choice of the constant. Further, dividing by effort weights each tow equally (tows can vary considerably in the amount of water or bottom surface area they sample). False conclusions can be reached when CPUE does not exhibit a lognormal distribution and samples are incorrectly weighted.

To address these issues, we used Generalized Linear Models (GLMs) with discrete probability distributions to compute the likelihood of observing the counts that were collected. These types of GLMs constitute a relatively new approach for analyzing CPUE data (Stefansson 1996; Power and Moser 1999; Terceiro 2003; Minami et al. 2006; Arab et al. 2008; Shono 2008; Dunn 2009). This approach involved three steps:

1) constructing a model with variables of interest to predict the catch rate (CPUE) for all the observations;
2) multiplying the predicted CPUE from step (1) by the observed effort (called an offset), to obtain the predicted (expected) catch comparable to the observed catch;
3) computing the likelihood of the observed catch given the expected catch assuming some discrete distribution.

These alternate distributions correctly model data that are generated from the *Poisson* process of counting individuals. These discrete models never generate negative values, which are impossible with count data, but may occur if normal distributions are assumed in the modeling approach. Additionally, these models allow for zero counts (something lognormal distributions will not do), and step (2) correctly weights each observation's contribution to the overall likelihood.

The response variables required different GLMs. For species richness and the individual species densities, we considered both *Poisson* and negative binomial regressions. Both utilized a global linear log link function to portray the predicted catch rate:

$$\log_e(\lambda_i) = \mu + x_i\beta \qquad (1)$$

where, λ_i = predicted CPUE for the i^{th} sample tow, μ = overall mean, x_i = the vector of explanatory variables (3 categorical and 8 continuous variables listed above), and β their corresponding vector of coefficients. All independent variables were considered fixed effects and were parameterized with the GLIMMIX Procedure in the SAS Version 9.2 statistical package (SAS Institute, Inc. 2008) by maximizing their respective log likelihoods, which were the sums of the likelihoods for each i^{th} observation:

Poisson

$$l_i = w_i\left(y_i \log_e\{\lambda_i\} - \lambda_i - \log_e\{\Gamma(y_i+1)\}\right) \quad (2)$$

Negative binomial

$$l_i = y_i \log_e\left\{\frac{k\lambda_i}{w_i}\right\} - \left(\frac{y_i + w_i}{k}\right)\log_e\left\{1+\frac{k\lambda_i}{w_i}\right\} + \log_e\left\{\frac{\Gamma(y_i + w_i/k)}{\Gamma(w_i/k)\Gamma(y_i+1)}\right\} \quad (3)$$

where, the predicted catch rate (λ_i) comes from Equation (1), the area sampled (m^2) defines the element size (also called weight or offset), y_i=the observed catch for the i^{th} sample tow, and k=the negative binomial dispersal coefficient (an additional parameter that allows for inflated variance and requires estimation). Akaike's Information Criterion (AICc; Burnham and Anderson 2002) was used to determine which of the two distribution types was most appropriate for the data being considered.

Assemblage structure was modeled as a nominal multinomial distribution, which utilized the generalized logit link function:

$$\log_e\left[\frac{\Pr(y=j|x_i)}{\Pr(y=k|x_i)}\right] = \mu_{jk} + x_i\beta_{jk} \quad (4)$$

where, all j^{th} nominal categories were referenced to a particular category k (in our study we used the most numerically dominant species for k), x_i = the vector of explanatory variables, and μ_{jk} and β_{jk} were parameters specific to the j^{th} category and referenced to k. Hence, we modeled the log odds of being in the j^{th} category as compared to being in the reference category, k, and this relationship was allowed to change with the explanatory variables. The likelihood for each i^{th} observation was given as:

$$l_i = \sum_{j=1}^{J} y_{ij} \log_e\{\mu_{ij}\} \quad (5)$$

where, J=total number of species in the analysis, y_{ij}=the number of individuals in the j^{th} species and i^{th} sample, and μ_{ij}=the predicted number of individuals in the j^{th} species and i^{th} sample.

Information-Theoretic Approach and Model Averaging

In addition to the global model, all nested combinations of independent variables were compared using the Information-Theoretic Approach as recommended by Burnham and Anderson (2002). Typically, the number of models (including the null model) given the number of predictor variables (k) is 2^k. The 11 terms in this study provided 2^{11} = 2,048 possible models. Weights were assigned to each model based upon their (AIC) values. AIC values were modified to AICc values to account for small sample size. When the negative binomial model was used, AICc values were further adjusted to QAICc by dividing the log-likelihood for each model by

the variance inflation factor from the global model as recommended by Burnham and Anderson (2002) as a means to account for over dispersion. Of the suite of models investigated, Akaike weights sum to one and indicate how probable one model is compared to all others considered. The percent chance that an independent variable affected the response was given by summing the weights of all models that contained the variable in question and expressed as a percentage (100 minus this value represents the weight of evidence against that variable affecting the response).

The Information-Theoretic Approach is more straightforward with respect to interpretation of results than classic hypothesis testing. The p-values rendered by the latter represent the percentage of times the data would be randomly selected given that the null hypothesis is true (i.e., no difference among treatments). If this probability is larger than the *a priori* level of α (typically set to 0.05), then differences among treatments are deemed statistically insignificant. Further power analyses are required to move the interpretation beyond "failure to reject the null hypothesis" to the probability that the null would have been rejected had there been real differences of arbitrary levels. This approach is theoretically flawed and many statisticians and quantitative biologists strongly oppose the use of *post hoc* power analyses (Goodman and Berlin 1994; Gerard et al. 1998; Hoenig and Heisey 2001; Anderson et al. 2001; Burnham and Anderson 2002). The Information-Theoretic Approach directly estimates the probability of each hypothesis being true given the observed data and the suite of hypotheses being tested. Thus, the Information-Theoretic Approach is more in keeping with the idea of multiple working hypotheses (Chamberlin 1965; Anderson et al. 2001).

Quantifying Effect Size

Effect size across levels of the categorical variables was determined for species richness and species densities by comparing marginal means; e.g., means that arise when giving equal weight to all levels of all other categorical variables and holding continuous variables constant at their observed averages across all samples. Continuous effect sizes were reported as the change multiplier that must be applied to the response in linear space given a one unit increase in the continuous variable.

The effect size from the multinomial model (assemblage structure response) is difficult, if not impossible, to reduce to a single value. However, ordination techniques are commonly used to reduce species × site matrices to a few dimensions. A common procedure that allows the simultaneous inclusion of environmental variables is canonical correspondence analysis (CCA), a form of direct gradient analysis (ter Braak and Prentice 1988). This procedure helps to visualize results in a biplot that allows simultaneous illustration of (1) how sampling sites compared with respect to assemblage structure (2) how species compared to their distributions across sampling sites, and (3) how both were correlated with environmental variables.

The ordination of samples and species are constrained by their relationship to the environmental variables (gradients) included (McCune and Mefford 2006). Monte Carlo permutations were used to test if the ordination was successful in explaining variance in assemblage structure. If the observed eigenvalues for axes were greater than 95% of eigenvalues from 1,000 randomized matrices (rows in the habitat matrix were randomly reassigned, thus destroying the relationship between the species and habitat matrices) the ordination was deemed successful, and habitat variables were important in explaining variance in assemblage structure across stations. The percent of variance in assemblage structure explained by the ordination was determined by how well distances in the ordination space match the relative Euclidean distances in the main matrix (Økland 1999; McCune and Mefford 2006).

The number of independent variables included in the final CCA was reduced based on the results of the multinomial GLM (only variables receiving a 75% chance or more of being important were included). Continuous variables were converted to z-scores and the percent sand and percent gravel variables were arcsine square root transformed. Furthermore, numerous zeroes will bias CCA (McCune and Mefford 2006); therefore, we dropped species from the analysis that did not occur in at least 25% of the samples.

RESULTS

Detailed results of individual catch by species, station and gear type are listed in Appendices A2–A13. Haul results (successful or unsuccessful) are listed in Appendix A1. Detailed physical parameter results can be found in Appendix A14.

Sampling Effort

A total of 43 stations were sampled from 1–19 September 2010 (Appendix A1). Study areas were sampled sequentially, i.e., all of Klondike's stations were sampled before sampling began in Burger. Klondike was the first study area to be sampled, followed by Burger, then Statoil. Transition stations were sampled opportunistically; sampling occurred en-route from Klondike to Burger and after completion of the Statoil prospect. Trawling occurred at 13 stations in Klondike, 13 stations in Burger, 11 stations in Statoil and at six Transition stations. The PSBT was used at 39 stations, the 3mBT at 36 stations, the 5mBT at five stations and the MPSBT at 15 stations. Pelagic fish sampling was done with IKMT at 41 stations and with the MAP at 20 stations (Table 1).

Environmental Data

Depth

Depths were relatively uniform across all stations, ranging from 36 m (both in Statoil and Klondike) to 47 m in Burger. The average depth at both the Transition stations and in the Burger study area was 42.2 m. Average depths were slightly shallower at the other two study areas, with a mean of 40.5 m for the Klondike study area and a mean of 38.1 m for the Statoil study area.

Temperature

The mean bottom temperature fluctuated greatly between stations, from a low of -1.5 C to a high of 5.1 C. Klondike had the warmest mean temperature (3.41 C) followed by the Transition stations (0.97 C). The mean temperatures at the other two study areas were much cooler: -0.43 C at Statoil and -0.56 C at Burger (Figure 7).

Salinity

Salinity varied little across the study areas, ranging from 31.9 to 32.9 psu (practical salinity units). Burger had the highest mean salinity (32.55 psu) followed by Statoil (32.43 psu), Transition (32.27 psu), and Klondike (32.15 psu; Figure 8).

Substrate

Substrate sampling occurred at all stations in the Klondike, Burger, and Statoil study areas in August 2010. The Transition stations were not sampled for substrate characteristics. The substrate in Klondike had more gravel and sand than either of the other two study areas. Several stations in Klondike had a high composition of gravel: station KF-019 (60.6% gravel), KF-001 (33.9% gravel), and KF-007 (33.0% gravel). Sand composition was highest at KF-015 (86.9%), BF-005 (77.0%) and KF-003 (67.2%). Mud values were the highest at BF-007 and BF019, with 92.5% and 91.5%, respectively (Figures 9 and 10).

Fish Data

A total of 2,851 fish (all gear types combined) were caught from 1–19 September 2010 (Table 2). This catch was distributed among a minimum of 25 species with Arctic cod (42%) being most common (Table 2). Other common species were stout eelblenny (*Anisarchus medius*;

9%), hamecon (9%), Arctic staghorn sculpin (6%), Arctic alligatorfish (*Ulcina olrikii*; 5%) and polar eelpout (*Lycodes polaris*; 5%). In addition, six groups of fish could only be identified to family and one group was only identified to genus. Of these, the *Myoxocephalus* spp. group represented 5% of the total catch (Table 2).

Species that were placed in unidentified categories were later apportioned to known species based upon ratios of identified species. Apportioning unknown species did not significantly change the ratios of species, with the exception of the *Myoxocephalus* spp. group. The only identified member of the *Myoxocephalus* genus was shorthorn sculpin (*Myoxocephalus scorpius)*. As such, all "*Myoxocephalus* spp." were called shorthorn sculpin. This drastically changes the total catch of shorthorn sculpin, moving them from the ninth most common fish (Table 3) to the fourth most common fish (Table 4). Excluding sculpins, all other unidentified fish represented a small portion (<1%) of the total catch.

Catch by Gear

IKMT

The IKMT was used to sample 41 stations; 11 in the Klondike study area and all of the Burger, Statoil and Transition stations. The IKMT contributed 3% of the total 2010 catch (*n*=81 of 2,851). The most productive study area was Klondike with 38 fish followed by Statoil (*n*=19), Burger (*n*=13) and the Transition stations (*n*=11). Station SF-022 had the maximum catch of any station with nine fish caught, while no fish were captured at a number of stations. Overall, a minimum of 15 species of fish were represented in the 17 'taxa' captured in the IKMT. The Klondike study area had the most species collected using this gear (*n*=12), followed by the Transition stations (*n*=11), Burger (*n*=6) and Statoil (*n*=5). Stations KF-011, TF-001 and TF-002 had the most species (*n*=4).

Arctic cod were the most common fish species caught (20% of the total IKMT catch). Arctic alligatorfish (12%), Pacific sandlance (*Ammodytes hexapterus*; 11%) and longhead dab (*Limanda proboscidea*; 5%) each accounted for ≥5% of the IKMT catch (Table 2).

MAP Trawl

The MAP trawl was used to sample 20 stations; 10 stations each in Burger and Statoil study areas. The MAP trawl contributed <1% of the total catch (*n*=6). Two fish were caught at BF-025 and SF-016, and one fish was caught at both SF-005 and SF-022. Fish captured included Pacific sandlance (*n*=3), Arctic cod (*n*=2) and gelatinous seasnail (*Liparis fabricii*, *n*=1; see Table 2).

PSBT

The PSBT was used to sample all 37 of the study area stations and two of the Transition stations. The plumb staff contributed 30% of the total catch (*n*=852; Table 2). Klondike was the most productive study area with 587 fish caught, followed by Burger (*n*=129), Statoil (*n*=98) and the Transition stations (*n*=43). Station KF-001 had the highest catch with 120 fish while BF-001 and SF-020 were the least productive with only two fish at each location. Overall, a minimum of 22 species of fish were captured in the PSBT. Klondike had the most species (*n*=15) followed by Burger (*n*=14), Statoil (*n*=12) and the Transition stations (*n*=8). Stations KF-005 and KF-013 had the most species (10 each).

Arctic cod made up the largest portion of the catch with 48%, followed by stout eelblenny (7%), polar eelpout (6%), Arctic staghorn sculpin (6%), hamecon (5%) and slender eelblenny (*Lumpenus fabricii*, 5%; see Table 2).

3mBT

The 3mBT was used to sample 36 stations; six in the Klondike study area and all of the Burger, Statoil and Transition stations. The 3mBT contributed 43% of the total catch (*n*=1,223; see Table 2). The highest catches were in the Klondike study area (*n*=529), followed by Statoil (*n*=249), Burger (*n*=243) and the Transition stations (*n*=202). Station KF-009 was the most productive site with 193 fish while BF-023 was the least productive with only two fish captured. The 3mBT caught a minimum of 21 species of fish, of which Klondike had the most species (*n*=19) followed by Burger (*n*=16), the Transition stations (*n*=14) and Statoil (*n*=12). Station KF-015 had the most species with 15 while BF-013, BF-017 and SF-005 had only Arctic cod present.

Arctic cod were the most common fish caught with 38% of the 3mBT catch. Hamecon (12%), stout eelblenny (10%), Arctic staghorn sculpin (7%), Arctic alligatorfish (7%) and polar eelpout (5%) each accounted for ≥5% of the 3mBT catch (see Table 2).

MPSBT

The MPSBT was used to sample 15 stations; 11 in Klondike, three in Burger and one Transition station. The MPSBT catch (*n*=573) contributed 20% of the total catch (*n*=2,851). Station KF-001 was the most productive with 116 fish while KF-017 was the least productive with only two fish captured. Overall, a minimum of 19 species of fish were captured in the modified plumb staff bottom trawl. Station KF-005 had the most species with 11, while KF-025 and KF-017 each had a single species, half barred pout and Bering flounder, respectively.

Arctic cod were the most common fish caught with the MPSBT (39%). Stout eelblenny (10%), hamecon (9%) and Arctic alligatorfish (5%) each accounted for ≥5% of the catch (Table 2).

5mBT

The 5mBT was used to sample five stations, all in the Klondike study area and contributed 4% of the total catch (*n*=109). KF-017 was the most productive station with 53 fish while KF-001 was the least productive (*n*=7). Eight fish species were caught with the 5mBT with a high of six fish species at KF-011 and a low of two at KF-001.

Arctic cod comprised 71% of the catch followed by Bering flounder (*Hippoglossoides robustus*), polar eelpout and stout eelblenny each with 6% (see Table 2).

Catch by Family

In total, representatives of eight families of fish were caught in this study and proportions of species families varied by study area (Figures 11 and 12). Eelpouts, sculpins and pricklebacks were all common in the Burger study area. Within these families, stout eelblenny, polar eelpout and shorthorn sculpin were the most abundant species. Prickleback and sculpin abundance was primarily concentrated in one or two species, while eelpout catches were distributed among several species.

Demersal fish abundance in the Klondike study area was much higher than in the other study areas. Arctic cod, while still the most common species in Klondike, were less dominant. Much of this difference was due to much higher catches of sculpins (Cottidae, Table 5) comprised of hamecon, Arctic staghorn sculpin and *Myoxocephalus* spp. Pricklebacks were not as common in Klondike compared to the other study areas.

The Statoil study area had low fish density with a much higher proportion of Arctic cod than did the other study areas. Eelpout, specifically polar eelpout, were the only demersal family present in significant numbers relative to Arctic cod. While the total number of species present was comparable to other study areas, most species had very low abundances.

The species composition of the Transition stations was spread relatively evenly between Arctic cod, eelblenny and poachers. Sculpin were a small portion of the fish catch, especially compared to the other study areas. The Transition stations had extremely high catches of Arctic alligatorfish and stout eelblenny.

Catch by Gear Type

For the 3mBT, cods (Gadidae) were the most common family represented in the collections from Burger, Statoil, and the Transition stations. In Klondike however, sculpins (Cottidae) were most common and cods were the second most common (Figure 11).

Catches in the PSBT showed that cods were the most common family represented in Klondike, Burger and Statoil collections. In the Transition stations, pricklebacks (Stichaeidae) were the most common family, followed by cod (Figure 12).

Catches in the IKMT were too low to examine by prospect. Instead, all locations were combined. Flatfishes (Pleuronectidae) were the most common family, followed closely by cods and pricklebacks (Figure 13).

Species Presence and Richness

Across all stations and all gear types, a minimum of 25 fish species were captured (Table 3). Klondike was the richest prospect with 22 species, while Statoil and Burger each had 18 species and the Transition stations had 15 species (Table 3). Station KF-015 had the highest species richness with 18 species (all gear types combined). Stations TF-003 and BF-023 had the lowest number of species observed (n=3; Figure 14).

Three fish species were found only in the Klondike study area: Arctic shanny (*Stichaeus punctatus*), hairhead sculpin (*Trichocottus brashnikoviki*), and fourhorn poacher (*Hypsagonus quadricornis*). Several more fish species were found predominately in Klondike: fourline snakeblenny (*Eumesogrammus praecisus*), eyeshade sculpin (*Nautichthys pribilovius*), ribbed sculpin (*Triglops pingelii*), Arctic staghorn sculpin and Bering flounder. No species common in another prospect was absent from Klondike.

Catches in the Burger study area were characterized by two fish species not found at any other prospect: gelatinous seasnail and spatulate sculpin (*Icelus spatula*). The fish doctor (*Gymnelus viridis*) was more common in Burger than in any of the other prospects. No unique species were recorded in either Statoil or the Transition stations. Arctic staghorn sculpin were not caught in the Statoil study area, but were present at all of the other study areas.

Lengths

Lengths of fish varied greatly depending upon where in the water column they were caught. The mean length of all fish caught in the IKMT was 36.2 mm. The mean length of all fish caught in the PSBT was 63.3 mm; in the 3mBT the mean length was 65.3 mm. The longest fish caught was a 238 mm polar eelpout caught by the PSBT at station KF-009.

The mean size of Arctic cod was 62.5 mm with a minimum size class of 30–39 mm and a maximum size class of 160–169 mm (Table 6; Figure 15). Arctic cod in Burger and the Transition stations appeared to be larger than those caught in the other study areas. Arctic cod were slightly larger in the 3mBT than the PSBT (Table 7). Both nets had large catches in the 50–59 mm size class, accounting for approximately 50% of the catch from each net. Fish larger

than 60 mm constituted 47% of the 3mBT catch but only 26% of the PSBT catch (Figure 16). Arctic cod caught in the IKMT (*n*=16) were smaller than fish caught in both the 3mBT and PSBT.

A total of 194 stout eelblenny were measured from benthic trawls with a mean size of 107.5 mm (Table 6). Stout eelblenny ranged from the 60–69 mm size class to the 140–149 mm size class. The mean size was relatively constant between all study areas. Fish caught in the 3mBT were larger than fish caught in the PSBT (Table 7; Figure 15). Both nets had peak catches in the 100–109 mm size class which accounted for 40% (3mBT) and 35% (PSBT) of the catch. Only 13% of the 3mBT catch was less than 100 mm while 26% of the PSBT catch was that size (Figure 17).

Hamecon (*n*=246) measured from benthic catches ranged from the 20–29 mm size class to the 80–89 mm size class with an overall mean size of 46.7 mm (Table 6). Only the Klondike study area had a mean fish size smaller than the overall mean. Hamecon caught in the 3mBT were smaller than fish caught in the PSBT (Table 6; Figure 15). The 3mBT had its highest catch in the 30–39 mm size class, which accounted for 61% of the catch. The size class distribution caught with the PSBT was relatively stable with each size class contributing between 14% and 27% (Figure 18).

Arctic staghorn sculpin (*n*=162) ranged from the 30–39 mm size class to the 110–119 mm size class (Table 6) and were primarily sampled in Klondike (*n*=153; 94%). The average size of Arctic staghorn sculpin caught in the 3mBT and PSBT was very similar (Figure 15). Over half of the catch from both nets was in the 30–39 mm size class. Fish larger than 70 mm made up less than 5% of each net's total catch (Figure 19).

A total of 144 polar eelpout were measured from benthic catches. Size classes ranged from a minimum of 30–39 mm to a maximum of 230–239 mm, with an average of 85.1 mm (Table 6). Klondike, Burger and the Transition stations all had average lengths larger than the overall average length while polar eelpout in the Statoil collections had a much lower average size. Fish from both nets had similar mean lengths (Figure 15). Both nets had peaks in abundance in the 40–49 mm size class (3mBT=24%; PSBT=46%) and 70–79 mm size class (3mBT=24%; PSBT=11%; Figure 20).

A total of 92 Arctic alligatorfish were measured from benthic trawls with an average size of 49.8 mm (Table 6). The minimum size class was 30–39 mm and the maximum size class was 70–79 mm. Burger and Statoil both had smaller than average fish (Table 6). The 3mBT (*n*=79) and PSBT (*n*=32) had similar mean lengths at 47.0 mm and 48.1 mm, respectively (Figures 15 and 21).

Biomass

Four of the five species with the highest biomass were also among the five most commonly caught species. Arctic cod had the highest biomass and accounted for 33% of the total fish biomass (Table 8). Polar eelpout made up 11% of the biomass while accounting for only 5.3% of the total catch (Table 2). Similarly, marbled eelpout (*Lycodes raridens*) were only 2% of the total catch but made up 5% of the measured biomass. One station (KF-015) produced 34% of the shorthorn sculpin biomass, but only 5% of the total shorthorn sculpin caught. A Bering flounder weighing 58 g, caught at TF-003, was the heaviest fish captured.

Statistical Analyses

Population Densities

Arctic cod, stout eelblenny, polar eelpout, and hamecon exhibited the greatest overall relative abundances (i.e., were numerically dominant), and their densities were estimated using negative binomial regression models. For these species, the negative binomial models fit the data better than *Poisson* models based upon QAICc values. There was a considerable amount of uncertainty regarding the best model(s) for each of the four species. The best models received only 1–3% of the overall weight (Table 9). In other words, there was only a 1–3% chance that the top model was better than all of the other models (combinations of variables) considered. Results were also equivocal for most of the explanatory variables (Table 10). Most exhibited weights between 70% and 30%, which means there was not much evidence for or against them being useful to account for the observed densities of these species. One exception was "gear type" for Arctic cod which had almost 100% chance of being important. "Gear type" was moderately important for polar eelpout (79%) along with percent gravel in the substrate (80%).

Of particular note was that the PSBT consistently exhibited higher catch rates than the 3mBT; for both Arctic cod and polar eelpout this ratio was about 5:1, but only around 1.5:1 for stout eelblenny and hamecon (Table 11). Species varied in their responses to the continuous explanatory variables, none of which received a convincing amount of evidence (Table 12).

Community Metrics

Model uncertainty was high for species richness (top model received only 4% of the weight), but less for assemblage structure (top model received 39% of the weight and the second best 11%; see Table 9). There was considerable evidence that gear type and percent sand in the substrate affected observed species richness (Table 10). Richness was inversely related to percent sand (Table 12), and about nine times more species per unit effort were caught in the

PSBT than in the 3mBT (per 1000 m^2; Table 11). Curiously, gear type had less influence in affecting assemblage structure (only 18% weight). Important influences on assemblage structure were latitude, longitude, salinity, depth, percent sand in the substrate, and whether tows were made during the day or night.

Canonical correspondence analysis explained 70% of the variation in assemblage structure, and the explanatory variables (those that were important in the GLM output) were significantly related to changes in this structure (p-value <0.001; Figure 22). Beta diversity was high across all stations with the most disparate stations along Axis 1 of the CCA biplot having no species in common (i.e., their assemblage structures were completely different); likewise for Axis 2. Though study area was not included in either the GLM or the CCA analysis (due to it having no biological relevance) it is interesting to note that assemblage structure appeared to be similar between Burger and Statoil, and both differed from Klondike. The CCA showed a strong response by some species to a number of the explanatory variables. Shorthorn sculpin, hamecon and slender eelblenny all comprised a larger portion of the catch in study locations that were 1) located more westward and 2) had a higher percentage of sand in the substrate. Arctic cod made up a larger portion of the catch during daytime as opposed to nighttime sampling.

DISCUSSION

Fish Catches

Arctic cod dominated catches in 2010 in proportions similar to previous offshore fish studies in the region (Logerwell et al. 2010; Norcross et al. 2011; Fechhelm et al. 1985). While Arctic cod are semi-demersal, all other major fish families caught were exclusively demersal (sculpins, eelpouts, and pricklebacks). In total, 25 different species of fish were caught, distributed among eight families. All fish caught were very small; total length never exceeded 250 mm.

Species Diversity

Arctic diversity of fishes, expressed as the number of species, is low as compared to temperate waters (Stevens 1996). Arctic fishes are relatively evolutionarily young and have not yet expanded into all niches (Eastman 1997). Species adapted to survive in other areas have trouble adapting to the extreme environment (cold temperatures, ice cover, and seasonal food supply) of the Arctic. The relatively uniform topography of the northeastern Chukchi Sea provides few differing macro-habitats that are necessary to support diverse biological

assemblages. Low fish density limits the ability of the ecosystem to support piscivorous species. These factors all play a role in limiting Arctic fish diversity.

In the GLM results, species richness was expressed as the number of species sampled for each net per standardized area (1000 m^2). The PSBT exhibited a greater number of species per sampling effort as compared to the 3mBT. This finding could have been because the PSBT disturbed the substrate more causing the catchability of demersal species to increase. While this hypothesis may be valid, we suspect the degree of difference between the two gears (PSBT:3mBT ≈ 9:1) was at least partially inflated due to the sampling protocol. The PSBT was only fished for about 3 minutes versus the 3mBT, which was fished for about 30 minutes. The shorter tow times for the PSBT was necessary because the number of invertebrates and quantity of sediment increased due to greater scouring of the substrate; sampling any longer was not logistically feasible. For the most part, the 3mBT did not contact substrate during sampling, which drastically reduced invertebrates and sediment, and in turn afforded a much longer tow time. As mentioned above, there are a limited number of species. If at least one individual from all species at a station was collected quickly (say, in the first 3 minutes of the tow), then the difference between the two gears with respect to species density (richness on a per area basis) may have only been a function of the longer sampling time for the 3mBT. In other words, both gears were sampling what was present in the first few minutes, but there were only so many species that could be caught, and the longer sampling time for the 3mBT caused the denominator (effort) to increase, while the numerator (richness) had reached an asymptote within the first few minutes.

That gear type was not important in describing assemblage structure supports this latter hypothesis. Why would gear type so drastically affect the number of species caught, but not have an effect on assemblage structure? These results make sense when one considers that assemblage structure was not measured on a per effort basis; catches were converted to relative abundances and it was each species' catch proportionate to the others that was being measured for assemblage structure. Thus, if catchability between gear types was more or less equal across species, then we would not expect a gear affect for assemblage structure. Standardizing richness to a per individual basis (as with rarefaction analysis) by using the total catch as an offset instead of area may help to delineate the underlying mechanism that generated these results and will be the focus of future analyses. Preliminary results from using this approach suggest that gear was still important, but the ratio of PSBT to 3mBT was reduced from 9:1 to 1.6:1.

Comparison to Prior Fish Sampling

Similar to past studies we found the fish community of the northeastern Chukchi Sea to be dominated by Arctic cod along with a number of benthic species. There have been some noticeable differences with recent work to historical catches. For instance, saffron cod (*Eleginus gracilis*) were the second most common species found by Barber (1997), yet no saffron cod were

caught in 2010 and only two were caught in 2009 (Norcross et al. 2011). Bering flounder were the fifth most common species for Barber while we observed them only occasionally and never in large numbers. Conversely, Barber (1997) caught only one stout eelblenny during two years of sampling whereas stout eelblenny were the second most common fish in 2010 and made up almost 10% of the total catch. While absences in our study may be the result of our relatively small study area, it is surprising that fish common in our study were essentially not found by Barber. These differences could potentially be explained by changes in the fish community over time or by differences in the catchability between gear types.

Our finding of 25 species is lower than observed by Norcross et al. (2011) and much lower than the 66 found by Barber (1994) or the 82 species FishBase (Froese and Pauly 2011) lists as present in the Chukchi Sea. Much of this discrepancy is likely due to different sampling methods and locations. Norcross et al. (2011) sampled the same area in 2009 but had two sample events separated over the summer. In 2009, large seasonal abundance shifts were observed for pricklebacks and cod in the Burger study area and sculpins in the Klondike study area. Fish that migrate seasonally may have been present at different times in the study area and would not have been available for capture with only one sampling event. Barber (1994) sampled a much larger geographic area and more habitat types. Likewise, the total species count from FishBase includes fish from a large geographic area, many of which are most likely not available for capture in the northeast Chukchi Sea. For example, saffron cod have been found in coastal fish assemblages lacking Arctic cod (Norcross et al. 2010); thus is it not surprising that saffron cod were not encountered during our offshore sampling.

With the exception of Norcross et al. (2011), pelagic catches have not been substantial in the Chukchi Sea. We observed similar results this year with the two midwater trawls catching only a small fraction of what the benthic trawls caught. Past studies have noted large fluctuations in the age structure of fish in the Chukchi Sea from year to year. It is speculated that due to the harsh environment of the Chukchi Sea, juvenile fish recruitment may only occur sporadically (Barber et al. 1994). Thus, 2010 may have been a year of poor recruitment whereas the abundance of juvenile fish observed in 2009 was potentially caused by more favorable environmental conditions.

Data from several disciplines associated with this project indicate that 2009 may have been an anomalous year. Seabird observations for 2009 were a level of magnitude higher than those seen in either 2008 or 2010; copepod-feeding alcids were seen in record numbers (A. Gall, ABR Inc., unpublished data). The low concentration of seabirds within the study area in 2010 suggests that there were few small pelagic fish in the study area, similar to the observations of Piatt (1990). This observation is supported by the low numbers of Arctic cod caught in the midwater trawls during the 2010 field season. Zooplankton levels were likewise at very high levels in 2009 compared to 2008 and initial results from 2010 (J. Questel, unpublished data). This indicates that oceanic conditions in 2010 were likely not favorable for juvenile fish recruitment. Water masses greatly influence the fish composition in the Chukchi Sea (Wyllie-

Echeverria et al. 1997); our 2010 catch results are therefore a consequence of which water masses were present within the study areas. As the water mass boundaries fluctuate interannually, so will the relative proportions and density of fishes.

Bering flounder, Arctic cod and Arctic staghorn sculpin all had smaller total lengths in 2010 compared to the 1990–1991 Barber et al. study (1994). This is perhaps attributable to Barber sampling at inshore stations (different habitat) or because the 83/112 otter trawl was designed to target larger fish (size selectivity of gear). Fishes displayed similar sizes in the 2009 study as they did in 2010 (Norcross et al. 2011).

Size of Arctic Fishes

Arctic marine fish tend to be very small (Mecklenburg et al. 2007; Barber et al. 1997; Frost and Lowry 1983). Larger fish are found primarily in nearshore waters while dense schools of fish occur only in localized areas and are uncommon (Crawford 2010; Crawford and Jorgenson 1996). Most marine fishes are demersal and may compete with benthic invertebrates for space and forage. Benthic invertebrates are much more common than benthic fishes, both in terms of biomass and species diversity (Logerwell et al. 2010); size restriction may be a function of limited resources. Low fish densities and fluctuating environmental conditions may preclude the opportunity for a niche for large, predatory fish in the marine Arctic. While large demersal fish may exist in the northeastern Chukchi Sea—potentially as a result of advection from the Bering Sea—our 2010 results agree with prior research showing that Arctic fishes are generally small.

Arctic Cod Catchability

It is likely that both of the demersal trawls used were not effectively sampling for Arctic cod. While the catches per 1000 m^2 for the nets were vastly different in regards to Arctic cod, the total catch per tow are similar. We interpret these observations to suggest that the nets captured cod as they were being deployed and recovered, and not while the nets were on the bottom. The occasional cod foraging along the bottom would be captured by the nets and would explain why the 3mBT with its longer tow time had a higher total catch of cod. If cod were holding a few meters off of the bottom, the 83-112 eastern otter trawl or a beam trawl with a higher mouth opening would sample them more effectively during the tow than would the PSBT and 3mBT. The latter would be the preferred gear type due to benthic invertebrates bycatch problems associated with the 83-112 otter trawl.

Karp and Walters (1994) discussed the difficulty involved in assessing a semi-pelagic cod population, and acknowledged that bottom trawling is insufficient on its own to describe such a population. Hydroacoustic surveys in the southeastern Chukchi Sea showed that Arctic cod

distribution throughout the water column was different for ACW and BSW (Piatt et al. 1990). In 2010, we were not able to effectively fish our midwater trawl near the sea floor. It is possible that a large portion of the cod were located between the two portions of the water column we were sampling. Crawford (2010) hypothesized that commercial fishing for Arctic cod in the Chukchi Sea would require high-rise bottom trawls to catch the suspended fish effectively. The CCA showed that Arctic cod were a larger part of catch during daytime sampling. Due to their semi-pelagic nature they may be dispersing into the water column during the night. We were not able to fish the MAP during the night so we could not confirm this directly.

Arctic cod are often observed in large, dense schools (Quast 1974; Piatt et al. 1990; Crawford 2010; Logerwell et al. 2010). Logerwell et al. (2010) conducted an acoustic survey paired with directed midwater trawling on Arctic cod schools near Point Barrow, Alaska, observing schools of Arctic cod extending from near bottom to the surface. Importantly, Logerwell et al. (2010) noted that over the shelf break, young-of-the-year Arctic cod were in surface waters (<75 m) while older fish were deeper. Most of the Chukchi Sea (and all of the study areas) is less than 50 m.

Sampling Considerations

Challenges when conducting offshore operations in the Arctic are often logistical. Ice is common even during the open-water season, there are no deep-water ports in the area and no harbors are available for refuge in the event of a storm. Vessels capable of operating in the Arctic may include "Well Deck Vessels" as well as conventional oceanographic vessels with an open working deck aft. Therefore, in consideration of standardizing future research in the Arctic, equipment selected to sample fish should be capable of being deployed from multiple vessel types.

Sea floor conditions in the Alaskan Arctic are generally hard but with a veneer of soft mud having embedded cobbles and boulders and relict ice scours, a meter or more in depth (Toimil 1978). In addition, the area supports large populations of epibenthic invertebrates including tanner crab, brittle stars, etc. We and others (Barber et al. 1994; Logerwell et al. 2010) conducting trawl surveys in this region have experienced problems with trawls filling with large amounts of epibenthic invertebrates, cobbles and mud resulting in catches that required subsampling and in the worst case, resulted in the loss of nets and samples.

Beam trawls were selected to collect demersal fish because they can be effectively deployed over the side of a well deck vessel or over the stern from a conventional oceanographic vessel. Beam trawls have a fixed horizontal width (making it easier to determine area swept by the trawl) and can be towed with a single cable. When configured with lightweight beams and shoes (skids) they cause minimal damage to the seabed.

Both the PSBT and 3mBT proved useful for sampling demersal fish. The PSBT was designed to dig into the soft mud on the bottom and proved effective in capturing small fish. However, the PSBT could be towed for only a short time because it quickly filled with invertebrates and mud. This oversampling of invertebrates significantly increased the time required to handle and sort the catches. The 3mBT has a lower CPUE but can be fished longer, sampling a larger area and possibly more microhabitats. The 3mBT was designed to skim over the bottom to minimize the catch of epibenthic invertebrates and mud, resulting in a cleaner haul and much less bycatch.

Bottom trawls employed during the course of this study suffered from a common problem: oversampling of epibenthic invertebrates. In some cases, the large catches of mud and invertebrates led to the loss of the nets and samples. Our experience was not unique as other authors such as Barber et al. (1997) and Logerwell et al. (2010) reported losing nets to large catches of invertebrates, mud and boulders.

In our discussions with net designers it was pointed out that mud usually enters a net through bottom meshes when the codend becomes weighed down, either from fish, invertebrates, rocks or mud balls (G. Faulkner, personal communication). This has a positive feedback effect: the heavy codend is then highly susceptible to have even more mud enter the net through the meshes. In the Arctic, mud also can enter the codend when the net impacts the sidewall of an ice gouge. Rock chutes sewn into the bottom of the net would permit cobbles and larger mud balls to exit the net without weighing down the codend and reducing fish catch rates. Fitting mud raisins to the foot rope appears to reduce the invertebrate bycatch. In areas with high invertebrate populations, shortening the tow from 30 minutes down to 10–15 minutes was determined to be a practical method to deal with invertebrate oversampling and mud problems.

Suggested modifications to the sampling gear and protocols to more effectively sample fishes in the study area are presented in Appendix C.

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Table 1. Summary of gear types used for fisheries aboard the R/V *Westward Wind*, cruise WW1003, September 2010. All sampling locations in the northeastern Chukchi Sea are combined.

Gear	Code	Dates of use	Attempted Tows	Successful Tows	Stations Sampled
Bottom Trawls					
3-meter Beam Trawl	3mBT	9/3 – 9/19	41	38	36
Plumb Staff Beam Trawl	PSBT	9/1 – 9/18	47	40	39
Modified Plumb Staff Beam Trawl	MPSBT	9/1 – 9/7, 9/11	20	15	15
5-meter Beam Trawl	5mBT	9/2 – 9/3	5	5	5
Midwater Trawls					
Isaac-Kidd Midwater Trawl	IKMT	9/2 – 9/19	42	41	41
9-meter Midwater Trawl	MAP	9/10 – 9/18	22	20	20

Table 2. Total catch of fish species by gear type from the northeastern Chukchi Sea. a) Benthic gear types.

	3mBT		5mBT		MPSBT		PSBT		Benthic Total	
Species	n	%	n	%	n	%	n	%	n	%
Alligatorfish							2	0.2%	2	0.1%
Arctic alligatorfish	79	6.5%	2	1.8%	29	5.1%	32	3.7%	142	5.1%
Arctic cod	466	38.1%	77	70.6%	224	39.1%	408	47.5%	1,175	42.5%
Arctic shanny	6	0.5%					1	0.1%	7	0.3%
Arctic staghorn sculpin	85	7.0%	3	2.8%	22	3.8%	52	6.1%	162	5.9%
Bering flounder	7	0.6%	7	6.4%	17	3.0%	10	1.2%	41	1.5%
Eelblennies - unidentified										
Eelpouts - unidentified							1	0.1%	1	0.0%
Eyeshade sculpin	38	3.1%			7	1.2%	1	0.1%	46	1.7%
Fish doctor	7	0.6%					4	0.5%	11	0.4%
Flatfishes - unidentified										
Fourhorn poacher	2	0.2%					1	0.1%	3	0.1%
Fourline snakeblenny	11	0.9%			4	0.7%			15	0.5%
Gelatinous seasnail										
Hairhead sculpin	1	0.1%							1	0.0%
Halfbarred pout	10	0.8%			15	2.6%	21	2.4%	46	1.7%
Hamecon (sculpin)	152	12.4%			51	8.9%	44	5.1%	247	8.9%
Kelp snailfish	20	1.6%			7	1.2%	14	1.6%	41	1.5%
Longhead dab										
Marbled eelpout	18	1.5%	2	1.8%	16	2.8%	18	2.1%	54	2.0%
Myoxocephalus spp.	52	4.3%			51	8.9%	59	6.9%	162	5.9%
Pacific sandlance					1	0.2%	1	0.1%	2	0.1%
Polar eelpout	66	5.4%	7	6.4%	24	4.2%	54	6.3%	151	5.5%
Pricklebacks - unidentified							1	0.1%	1	0.0%
Ribbed sculpin	12	1.0%			2	0.3%	1	0.1%	15	0.5%
Sculpins - unidentified	17	1.4%			10	1.7%	11	1.3%	38	1.4%
Shorthorn sculpin	28	2.3%	4	3.7%	24	4.2%	14	1.6%	70	2.5%
Slender eelblenny	20	1.6%			12	2.1%	42	4.9%	74	2.7%
Snailfishes - unidentified										
Spatulate sculpin	3	0.2%					4	0.5%	7	0.3%
Stout eelblenny	122	10.0%	7	6.4%	56	9.8%	62	7.2%	247	8.9%
Variegated snailfish	1	0.1%			1	0.2%	1	0.1%	3	0.1%
Total	1,223		109		573		859		2,764	

….continued

Table 2 continued. Total catch of fish species by gear type from the northeastern Chukchi Sea. b) Pelagic gear types and the total for all gear types.

	IKMT		MWT		Midwater Total		All Gear Types	
	n	%	n	%	n	%	n	%
Alligatorfish	3	3.7%			3	3.4%	5	0.2%
Arctic alligatorfish	10	12.3%			10	11.5%	152	5.3%
Arctic cod	16	19.8%	2	33.3%	18	20.7%	1,193	41.8%
Arctic shanny							7	0.2%
Arctic staghorn sculpin	2	2.5%			2	2.3%	164	5.8%
Bering flounder	1	1.2%			1	1.1%	42	1.5%
Eelblennies - unidentified	3	3.7%			3	3.4%	3	0.1%
Eelpouts - unidentified							1	0.0%
Eyeshade sculpin							46	1.6%
Fish doctor							11	0.4%
Flatfishes - unidentified	13	16.0%			13	14.9%	13	0.5%
Fourhorn poacher							3	0.1%
Fourline snakeblenny							15	0.5%
Gelatinous sea snail	1	1.2%	1	16.7%	2	2.3%	2	0.1%
Hairhead sculpin							1	0.0%
Halfbarred pout							46	1.6%
Hamecon (sculpin)							247	8.7%
Kelp snailfish	2	2.5%			2	2.3%	43	1.5%
Longhead dab	4	4.9%			4	4.6%	4	0.1%
Marbled eelpout							54	1.9%
Myoxocephalus spp.	1	1.2%			1	1.1%	163	5.7%
Pacific sandlance	9	11.1%	3	50.0%	12	13.8%	14	0.5%
Polar eelpout							151	5.3%
Pricklebacks - unidentified	8	9.9%			8	9.2%	9	0.3%
Ribbed sculpin							15	0.5%
Sculpins - unidentified							38	1.3%
Shorthorn sculpin	3	3.7%			3	3.4%	73	2.6%
Slender eelblenny	1	1.2%			1	1.1%	75	2.6%
Snailfishes - unidentified	1	1.2%			1	1.1%	1	0.0%
Spatulate sculpin							7	0.2%
Stout eelblenny	3	3.7%			3	3.4%	250	8.8%
Variegated snailfish							3	0.1%
Total	81		6		87		2,851	100%

Table 3. Total catches of fish species by study area in the Chukchi Sea, 2010. All gear types are combined. The amount of effort among study areas was not equal and represents differing numbers of stations (13 stations in Burger, 13 stations in Klondike, 11 stations in Statoil, and six Transition stations).

Common name	Scientific name	Burger	Klondike	Statoil	Transition	Total
Alligatorfish	*Aspidophoroides monopterygius*		4	1		5
Arctic alligatorfish	*Ulcina olrikii*	14	63	11	64	152
Arctic cod	*Boreogadus saida*	203	684	224	82	1,193
Arctic shanny	*Stichaeus punctatus*		7			7
Arctic staghorn sculpin	*Gymnocanthus tricuspis*	5	155		4	164
Bering flounder	*Hippoglossoides robustus*	1	36	4	1	42
Eelblennies - unidentified	*Anisarchus* sp. or *Lumpenus* sp.		3			3
Eelpouts - unidentified	*Zoarcidae* spp.		1			1
Eyeshade sculpin	*Nautichthys pribilovius*		45	1		46
Fish doctor	*Gymnelus viridis*	8	2	1		11
Flatfish - unidentified	*Pleuronectidae* spp.		2	11		13
Fourhorn poacher	*Hypsagonus quadricornis*		3			3
Fourline snakeblenny	*Eumesogrammus praecisus*	1	14			15
Gelatinous seasnail	*Liparis fabricii*	2				2
Hairhead sculpin	*Trichocottus brashnikovi*		1			1
Halfbarred pout	*Gymnelus hemifasciatus*	21	12	7	6	46
Hamecon	*Artediellus scaber*	22	206	7	12	247
Kelp snailfish	*Liparis tunicatus*	7	27	3	6	43
Longhead dab	*Limanda proboscidea*			3	1	4
Marbled eelpout	*Lycodes raridens*	15	16	12	11	54
Myoxocephalus - unidentified	*Myoxocephalus* spp.		162		1	163
Pacific sandlance	*Ammodytes hexapterus*	2	6	4	2	14
Polar eelpout	*Lycodes polaris*	37	59	37	18	151
Pricklebacks - unidentified	*Stichaeidae* spp.	3	3	2	1	9
Ribbed sculpin	*Triglops pingelii*	1	12	1	1	15
Sculpin - unidentified	*Cottidae* spp.	2	33	3		38
Shorthorn sculpin	*Myoxocephalus scorpius*	29	37	6	1	73
Slender eelblenny	*Lumpenus fabricii*	6	62	4	3	75
Snailfishs - unidentified	*Liparidae* spp.				1	1
Spatulate sculpin	*Icelus spatula*	7				7
Stout eelblenny	*Anisarchus medius*	40	106	27	77	250
Variegated snailfish	*Liparis gibbus*		2	1		3
Total species		18	22	18	15	25
Total fish		426	1,763	370	292	2,851

Table 4. The most common benthic fish species caught in the northeastern Chukchi Sea with apportioning of unknown species. All sampling locations are combined. The sorting was by total catch of all benthic gear types combined. All unknown species were apportioned to known species based upon catches at the capture location.

Species	Total	3mBT	5mBT	MPSBT	PSBT
Arctic cod	1,175	466	77	224	408
Hamecon	263	160		55	48
Stout eelblenny	248	122	7	56	63
Shorthorn sculpin	240	82	4	78	76
Arctic staghorn sculpin	175	91	3	25	56
Polar eelpout	152	66	7	24	55
Arctic alligatorfish	142	79	2	29	32
Slender eelblenny	74	20		12	42
Marbled eelpout	54	18	2	16	18
Eyeshade sculpin	46	38		7	1
Halfbarred pout	46	10		15	21
Bering flounder	41	7	7	17	10
Kelp snailfish	41	20		7	14
Ribbed sculpin	16	13		2	1
Fourline snakeblenny	15	11		4	
Fish doctor	11	7			4
Arctic shanny	7	6			1
Spatulate sculpin	7	3			4
Fourhorn poacher	3	2			1
Variegated snailfish	3	1		1	1
Alligatorfish	2				2
Pacific sandlance	2			1	1
Hairhead sculpin	1	1			
Total	2,764	1,223	109	573	859

Table 5. Catch by family and prospect for all benthic gear types. Totals are displayed in the top row for each family.

Family	Species	Burger	Klondike	Statoil	Transition	Total
Cods (Gadidae)		**203**	**684**	**224**	**82**	**1,193**
	Arctic cod	203	684	224	82	1,193
Sculpins (Cottidae)		**66**	**606**	**17**	**19**	**708**
	Arctic staghorn sculpin	5	155		4	164
	Hairhead sculpin		1			1
	Hamecon	22	206	7	12	247
	Myoxocephalus spp.		162		1	163
	Ribbed sculpin	1	12	1	1	15
	Shorthorn sculpin	29	37	6	1	73
	Spatulate sculpin	7				7
	Sculpin - unidentified	2	33	3		38
Eyeshade sculpins (Hemitripteridae)			**45**	**1**		**46**
	Eyeshade sculpin		45	1		46
Poachers (Agonidae)		**14**	**70**	**12**	**64**	**160**
	Alligatorfish		4	1		5
	Arctic alligatorfish	14	63	11	64	152
	Fourhorn poacher		3			3
Flatfishes (Pleuronectidae)		**1**	**38**	**18**	**2**	**59**
	Bering flounder	1	36	4	1	42
	Longhead dab			3	1	4
	Flatfish - unidentified		2	11		13
Pricklebacks (Stichaeidae)		**50**	**188**	**33**	**81**	**352**
	Fourline snakeblenny	1	14			15
	Slender eelblenny	6	62	4	3	75
	Stout eelblenny	40	106	27	77	250
	Prickleback - unidentified	3	3	2	1	9
	Eelblenny - unidentified		3			3
Eelpouts (Zoarcidae)		**81**	**97**	**57**	**35**	**270**
	Arctic shanny		7			7
	Fish doctor	8	2	1		11
	Halfbarred pout	21	12	7	6	46
	Marbled eelpout	15	16	12	11	54
	Polar eelpout	37	59	37	18	151
	Eelpouts - unidentified		1			1
Snailfishes (Liparidae)		**9**	**29**	**4**	**7**	**49**
	Gelatinous seasnail	2				2
	Kelp snailfish	7	27	3	6	43
	Variegated snailfish		2	1		3
	Snailfish - unidentified				1	1
Sandlances (Ammodytidae)		**2**	**6**	**4**	**2**	**14**
	Pacific sandlance	2	6	4	2	14
All Families		426	1,763	370	292	2,851

Table 6. Length data for the most common species in benthic catches from the northeastern Chukchi Sea. Data are presented for each study area as well as for the entire study area.

Study Area		Arctic cod	Stout eelblenny	Hamecon	Polar eelpout	Arctic staghorn sculpin	Arctic alligatorfish
Klondike	Number	654	105	206	59	153	56
	Average	60.7	107.4	44.4	97.7	41.8	51.4
	St Dev	16.1	18.5	14.0	55.6		10.0
	Max	125	145	135	235	115	75
	Min	35	65	85	35	35	35
Burger	Number	195	39	22	37	5	14
	Average	67.4	107.3	60.0	90.4	53.0	45.7
	St Dev	18.8	15.3	14.4	36.9	14.8	2.7
	Max	165	135	75	185	75	55
	Min	35	65	35	35	35	45
Statoil	Number	214	27	7	37		9
	Average	61.6	107.2	53.6	53.4		42.8
	St Dev	12.1	13.1	14.6	15.7		4.4
	Max	125	125	75	105		45
	Min	45	65	35	45		35
Transition	Number	33	23	11	11	4	13
	Average	75.0	108.9	59.5	105.9	45.0	51.9
	St Dev	21.7	18.5	16.3	30.5	11.5	9.5
	Max	125	145	75	145	55	65
	Min	35	75	25	65	35	45
Overall	Number	1096	194	246	144	162	92
	Average	62.5	107.5	46.7	85.1	42.2	49.8
	St Dev	16.4	17.1	15.1	45.7	12.5	9.2
	Max	165	145	135	235	115	75
	Min	35	65	25	35	35	35

Table 7. Mean lengths of fish species for the three representative gear types used in the northeastern Chukchi Sea, 2010. All lengths are in mm.

	3mBT			PSBT			IKMT		
Species	*n*	mean	σ	*n*	mean	σ	*n*	mean	σ
Alligatorfish				2	70.0	7.1	3	38.3	5.8
Arctic alligatorfish	79	47.0	6.1	32	48.1	9.0	10	35.0	0.0
Arctic cod	458	65.1	15.9	394	60.7	16.5	16	39.4	8.9
Arctic shanny	6	110.0	5.5	1	115.0	0.0			
Arctic staghorn sculpin	85	42.6	11.9	52	41.2	14.7	2	35.0	0.0
Bering flounder	7	76.4	54.3	10	58.0	22.6	1	15.0	0.0
Eelblenny - unidentified							3	35.0	0.0
Eelpouts - unidentified				1	45.0	0.0			
Eyeshade sculpin	38	46.6	16.9	1	25.0	0.0			
Fish doctor	7	120.7	31.0	4	105.0	11.5			
Flatfish - unidentified							13	24.2	4.9
Fourhorn poacher	2	75.0	14.1	1	35.0	0.0			
Fourline snakeblenny	11	117.7	20.0						
Gelatinous seasnail							1	35.0	0.0
Hairhead sculpin	1	45.0	0.0						
Halfbarred pout	10	79.0	20.7	21	66.0	21.7			
Hamecon	152	45.1	14.8	44	55.0	15.7			
Kelp snailfish	20	50.0	28.6	14	41.4	19.1	2	30.0	7.1
Longhead dab							4	22.5	9.6
Marbled eelpout	18	77.2	41.4	18	66.1	39.4			
Myoxocephalus sp.	52	45.2	2.4	59	44.3	5.5	1	35.0	0.0
Pacific sandlance				1	55.0	0.0	9	46.1	18.3
Polar eelpout	66	85.3	39.1	54	81.9	51.9			
Prickleback - unidentified				1	75.0	0.0	8	40.0	5.3
Ribbed sculpin	12	61.7	15.0	1	75.0	0.0			
Sculpin - unidentified	17	28.5	11.1	11	31.4	14.3			
Shorthorn sculpin	27	69.4	36.5	13	60.4	20.7	3	45.0	0.0
Slender eelblenny	20	90.0	19.1	42	90.2	20.9	1	55.0	0.0
Snailfish - unidentified							1	25.0	0.0
Spatulate sculpin	3	78.3	20.8	4	80.0	12.9			
Stout eelblenny	122	110.3	14.0	62	102.7	19.0	3	55.0	0.0
Variegated snailfish	1	155.0	0.0	1	25.0	0.0			
Total	1,214	65.1	28.4	844	63.3	26.9	81	36.2	11.6

Table 8. Total biomass (g) of the apportioned catches from all study areas in the northeast Chukchi Sea, 2010. All unknown species were apportioned to known species based upon catches at the capture location. Weights were measured in aggregate of all the species captured in a haul. Weights were not taken on catches less than 1 g (due to inaccuracies caused by the vessel's motion).

Species	Burger	Klondike	Statoil	Transition	Total Weight
Alligatorfish		1			1
Arctic alligatorfish	8	46	2	40	96
Arctic cod	469	1,079	354	184	2,086
Arctic shanny		50			50
Arctic staghorn sculpin	11	138		2	151
Bering flounder	5	93	2	58	158
Eyeshade sculpin		83			83
Fish doctor	34	26	3		63
Fourhorn poacher		12			12
Fourline snakeblenny	4	183			187
Halfbarred pout	31	30	9	8	78
Hamecon	84	373	19	47	523
Kelp snailfish	41	79	27		147
Marbled eelpout	93	162		59	314
Polar eelpout	177	414	26	80	697
Ribbed sculpin	3	60			63
Shorthorn sculpin	100	428	12	4	544
Slender eelblenny	24	106	2	3	135
Spatulate sculpin	45				45
Stout eelblenny	141	312	85	269	807
Variegated snailfish			42		42
Total Weight	1,270	3,675	582	754	6,281

Table 9. Top ten models for each of the six response variables. An "X" indicates that the term was present in the model; the weight of evidence (expressed as a percent chance that this model was the most appropriate versus all other considered) is reported for each model.

Categorical variables			Continuous Variables								Evidence for model
Gear	Nightday	Wave height	Salinity	Depth	Gravel	Sand	Total organic carbon	Water temperature	Latitude	Longitude	(% chance)
Assemblage structure											
	X		X	X		X			X	X	39.0%
X	X		X	X		X			X	X	11.4%
X	X	X	X	X		X			X	X	7.1%
	X	X	X	X	X				X	X	0.2%
	X		X	X	X	X			X	X	0.1%
	X		X	X	X				X	X	0.0%
	X	X	X	X		X		X	X		0.0%
X	X		X	X	X				X	X	0.0%
X	X	X	X	X	X				X	X	0.0%
	X		X	X	X			X	X	X	0.0%
Species richness											
X			X			X		X		X	4.3%
X						X		X		X	3.3%
X	X		X		X	X					3.3%
X	X		X			X		X		X	3.1%
X	X		X			X					3.0%
X	X		X		X	X			X		2.6%
X	X		X			X			X		2.5%
X	X					X		X		X	1.8%
X	X		X			X		X			1.8%
X			X		X	X		X		X	1.7%
Arctic cod											
X						X		X			1.9%
X				X		X		X			1.3%
X					X	X		X			1.1%
X						X				X	1.0%
X	X		X					X			0.9%
X				X		X			X		0.9%
X	X					X		X			0.8%
X		X				X		X			0.8%
X				X	X	X		X			0.8%
X							X	X			0.8%
Stout eelblenny											
					X			X			1.0%
	X				X						1.0%
	X				X			X			1.0%
X	X				X						0.9%
	X				X					X	0.8%
	X		X		X						0.8%
	X	X			X						0.7%
X	X										0.7%
X					X			X			0.7%
	X										0.6%
Polar eelpout											
X	X				X						2.9%
X	X				X				X		1.7%
X	X				X			X	X		1.2%
X					X			X		X	1.1%
X	X			X	X						1.0%
X	X				X		X				1.0%
X	X		X		X						1.0%
X	X				X			X			0.9%
X	X								X		0.9%
X					X						0.9%
Hamecon											
									X		1.8%
X									X		1.1%
		X							X		1.0%
								X			0.9%
		X	X								0.9%

Table 10. The percent chance that each independent variable affected the response variables (100 minus the reported value would indicate the evidence against the variable in question). Assemblage structure refers to the proportionate mix of species and is unitless; species richness and the three species densities were compared as per 1000 m^2. All possible models were used and averaged as per Burnham and Anderson (2002) to derive the percentages.

		Response variable					
Type of data	Independent variable	Assemblage structure	Species richness	Arctic cod	Stout eelblenny	Polar eelpout	Hamecon
Categorical	Gear	18%	100%	100%	44%	79%	35%
	Day versus night sampling	100%	69%	32%	57%	62%	24%
	Wave height	49%	6%	37%	30%	22%	42%
Continuous	Latitude	100%	38%	31%	28%	42%	54%
	Longitude	100%	57%	34%	29%	30%	26%
	Water temperature	0%	63%	56%	43%	45%	30%
	Salinity	100%	69%	30%	31%	27%	36%
	Depth	100%	28%	37%	28%	26%	30%
	% gravel in substrate	0%	38%	29%	59%	80%	28%
	% sand in substrate	100%	97%	58%	26%	32%	28%
	Total organic carbon	0%	25%	38%	25%	27%	25%

Table 11. Mean responses for all levels of categorical variables to gauge effect size. Predicted marginal mean values (i.e., the means that are estimated while holding all other variables constant) from the generalized linear models are reported as the count of each response variable per 1000 m^2. All possible models were used and averaged as per Burnham and Anderson (2002) to derive the percentages.

Categorical variable	Evidence for	Level	Predicted marginal mean
		Richness	
Gear	100%	PSBT	15.6
		3MBT	1.8
Day versus night	69%	Night	9.9
		Day	7.6
Wave height	6%	1	8.9
		2	8.7
		3	8.7
		4	8.7
		5	8.5
		Arctic cod	
Gear	100%	PSBT	23.7
		3MBT	4.1
Day versus night	32%	Night	12.8
		Day	14.9
Wave height	37%	1	16.6
		2	14.9
		3	13.6
		4	12.6
		5	11.8
		Stout eelblenny	
Gear	44%	PSBT	3.0
		3MBT	1.8
Day versus night	57%	Night	3.6
		Day	1.3
Wave height	30%	1	1.9
		2	2.0
		3	2.3
		4	2.7
		5	3.3
		Polar eelpout	
Gear	79%	PSBT	3.7
		3MBT	0.8
Day versus night	62%	Night	3.4
		Day	1.0
Wave height	22%	1	2.2
		2	2.2
		3	2.2
		4	2.2
		5	2.2
		Hamecon	
Gear	35%	PSBT	2.0
		3MBT	1.5
Day versus night	24%	Night	1.8
		Day	1.7
Wave height	42%	1	3.4
		2	1.9
		3	1.3
		4	1.1
		5	1.0

Table 12. Model averaged coefficients for the continuous variables estimated with the generalized linear models. Coefficient values are for the linear predictor, while the 1-unit-change-multiplier indicates how much the predicted response must be scaled given a one unit change in each continuous variable. The range in continuous each variable across the study is given (Highest observed-Lowest observed=Range across study), which was used to render the Across-study multiplier. This metric facilitates comparison of the continuous variables with respect to effect size.

Continuous variable	Evidence for	Coefficient	Lowest observed	Highest observed	Range across study	1 unit change multiplier	Across study multiplier
				Richness			
Total organic carbon	25%	0.001	1.0	9.1	8.1	1.00	1.01
%Gravel	38%	-0.002	0.0	60.6	60.6	1.00	0.88
%Sand	97%	-0.011	7.5	86.9	79.3	0.99	0.41
Latitude	38%	-0.129	70.6	72.0	1.3	0.88	0.84
Longitude	57%	0.116	-166.0	-162.2	3.8	1.12	1.56
Salinity	69%	-0.716	31.9	32.9	1.0	0.49	0.49
Depth	28%	-0.005	36.0	47.0	11.0	1.00	0.95
Water temperature	63%	0.101	-1.5	5.1	6.6	1.11	1.94
				Arctic cod			
Total organic carbon	38%	0.068	1.0	9.1	8.1	1.07	1.73
%Gravel	29%	-0.004	0.0	60.6	60.6	1.00	0.78
%Sand	58%	-0.013	7.5	86.9	79.3	0.99	0.35
Latitude	31%	-0.143	70.6	72.0	1.3	0.87	0.82
Longitude	34%	-0.086	-166.0	-162.2	3.8	0.92	0.72
Salinity	30%	0.296	31.9	32.9	1.0	1.34	1.34
Depth	37%	-0.041	36.0	47.0	11.0	0.96	0.64
Water temperature	56%	0.174	-1.5	5.1	6.6	1.19	3.15
				Stout eelblenny			
Total organic carbon	25%	0.028	1.0	9.1	8.1	1.03	1.25
%Gravel	59%	-0.065	0.0	60.6	60.6	0.94	0.02
%Sand	26%	-0.004	7.5	86.9	79.3	1.00	0.75
Latitude	28%	0.217	70.6	72.0	1.3	1.24	1.34
Longitude	29%	-0.037	-166.0	-162.2	3.8	0.96	0.87
Salinity	31%	-0.507	31.9	32.9	1.0	0.60	0.60
Depth	28%	0.035	36.0	47.0	11.0	1.04	1.47
Water temperature	43%	0.173	-1.5	5.1	6.6	1.19	3.13
				Polar eelpout			
Total organic carbon	27%	-0.052	1.0	9.1	8.1	0.95	0.66
%Gravel	80%	-0.140	0.0	60.6	60.6	0.87	0.00
%Sand	32%	-0.009	7.5	86.9	79.3	0.99	0.49
Latitude	42%	0.770	70.6	72.0	1.3	2.16	2.82
Longitude	30%	0.116	-166.0	-162.2	3.8	1.12	1.56
Salinity	27%	-0.093	31.9	32.9	1.0	0.91	0.91
Depth	26%	-0.005	36.0	47.0	11.0	0.99	0.95
Water temperature	45%	0.210	-1.5	5.1	6.6	1.23	4.00
				Hamecon			
Total organic carbon	25%	0.026	1.0	9.1	8.1	1.03	1.23
%Gravel	28%	0.006	0.0	60.6	60.6	1.01	1.41
%Sand	28%	-0.005	7.5	86.9	79.3	1.00	0.68
Latitude	54%	-1.917	70.6	72.0	1.3	0.15	0.08
Longitude	26%	-0.068	-166.0	-162.2	3.8	0.93	0.77
Salinity	36%	-1.528	31.9	32.9	1.0	0.22	0.22
Depth	30%	-0.048	36.0	47.0	11.0	0.95	0.59
Water temperature	30%	0.073	-1.5	5.1	6.6	1.08	1.62

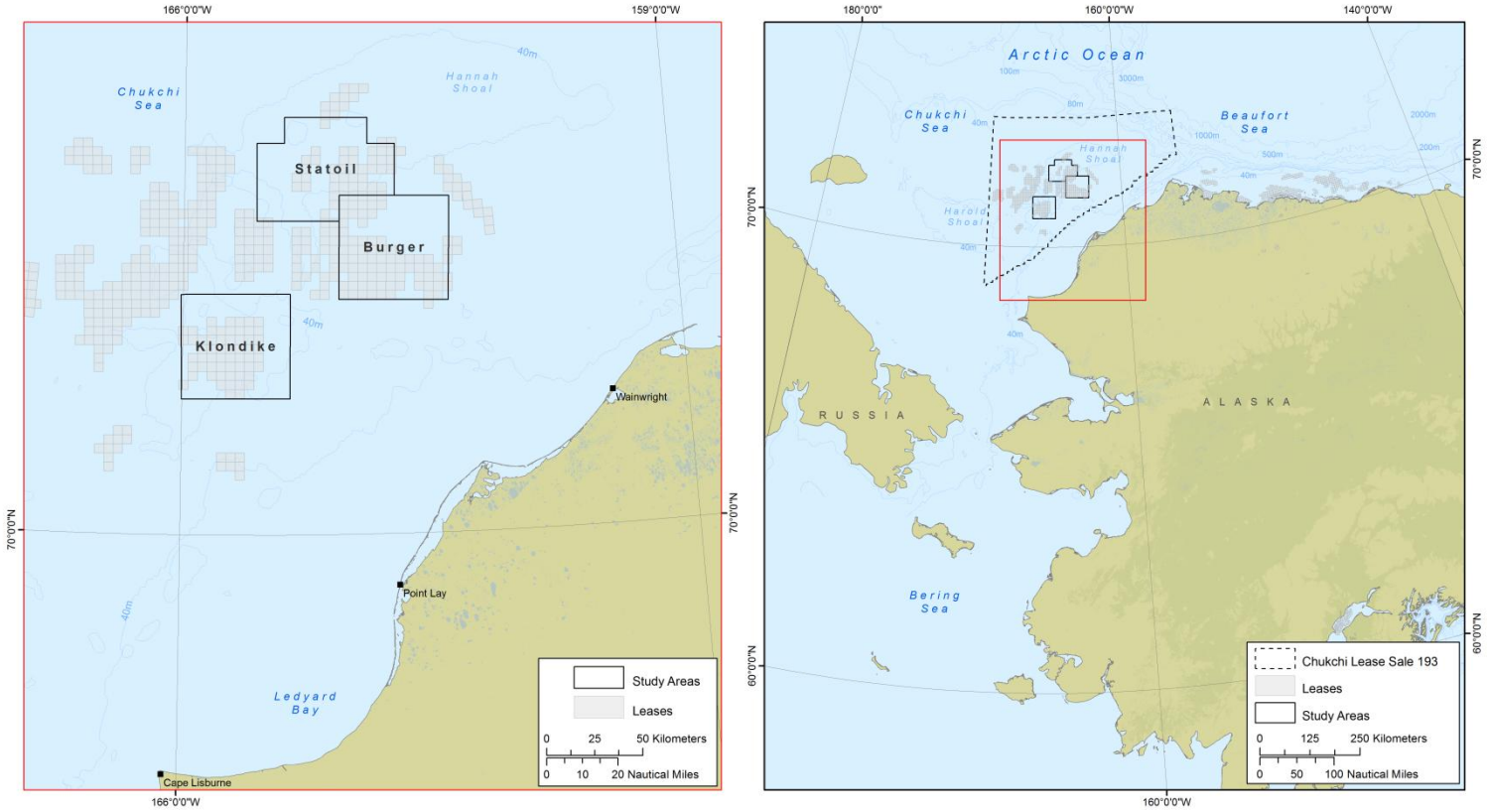

Figure 1. Overview map of the three study areas and the Chukchi Sea.

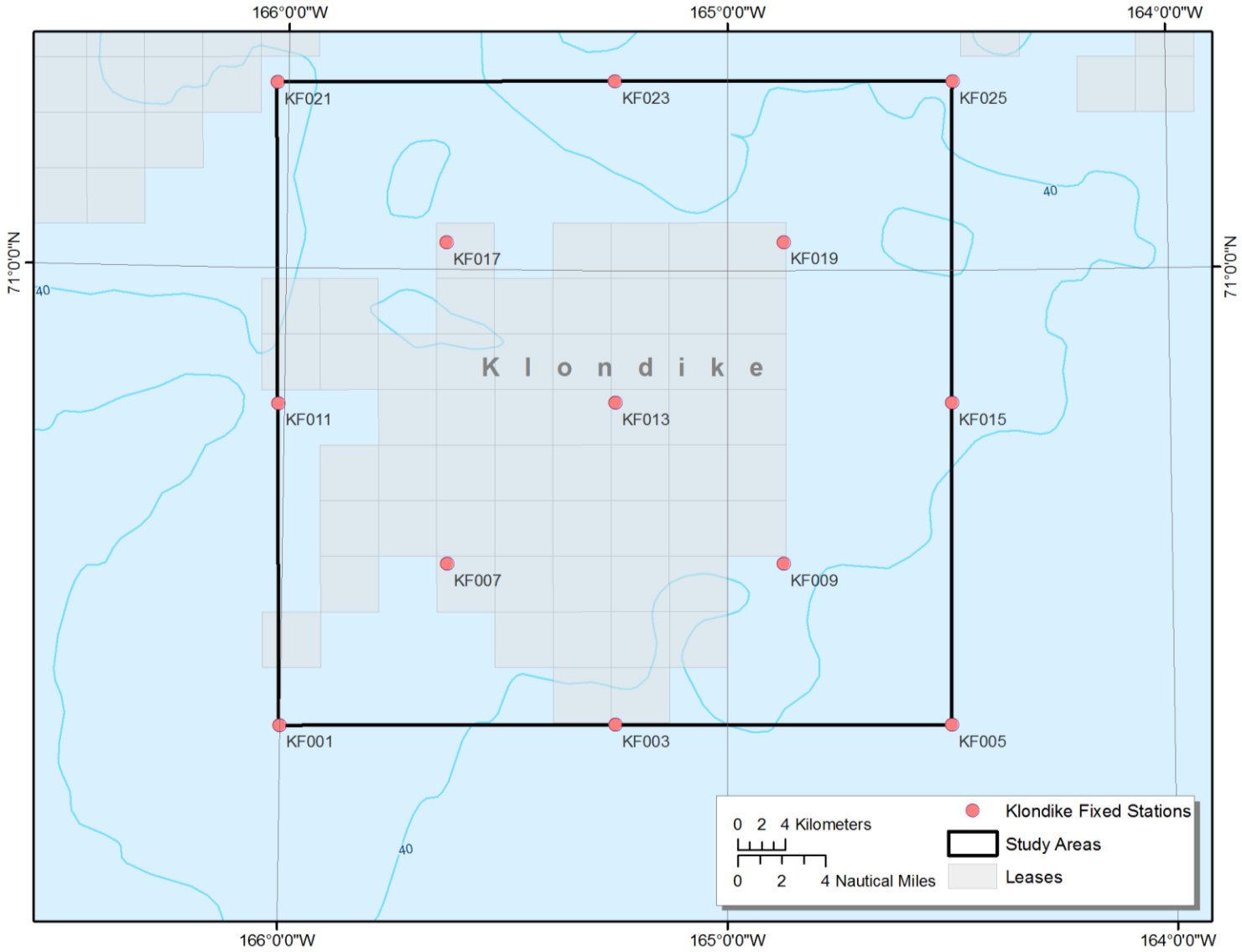

Figure 2. Map of the Klondike study area, northeastern Chukchi Sea showing fixed sampling stations occupied during the study.

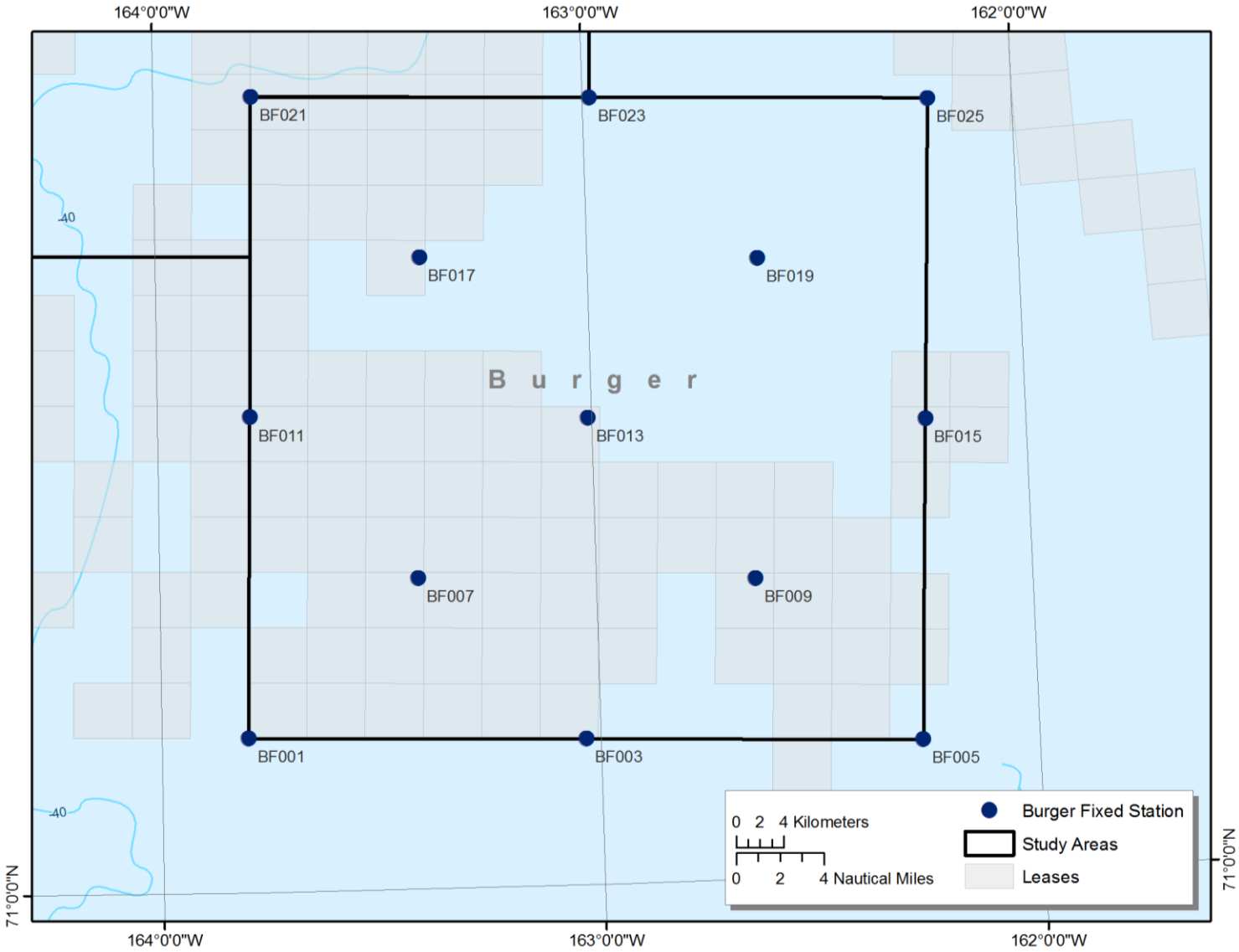

Figure 3. Map of the Burger study area, northeastern Chukchi Sea showing fixed sampling stations occupied during the study.

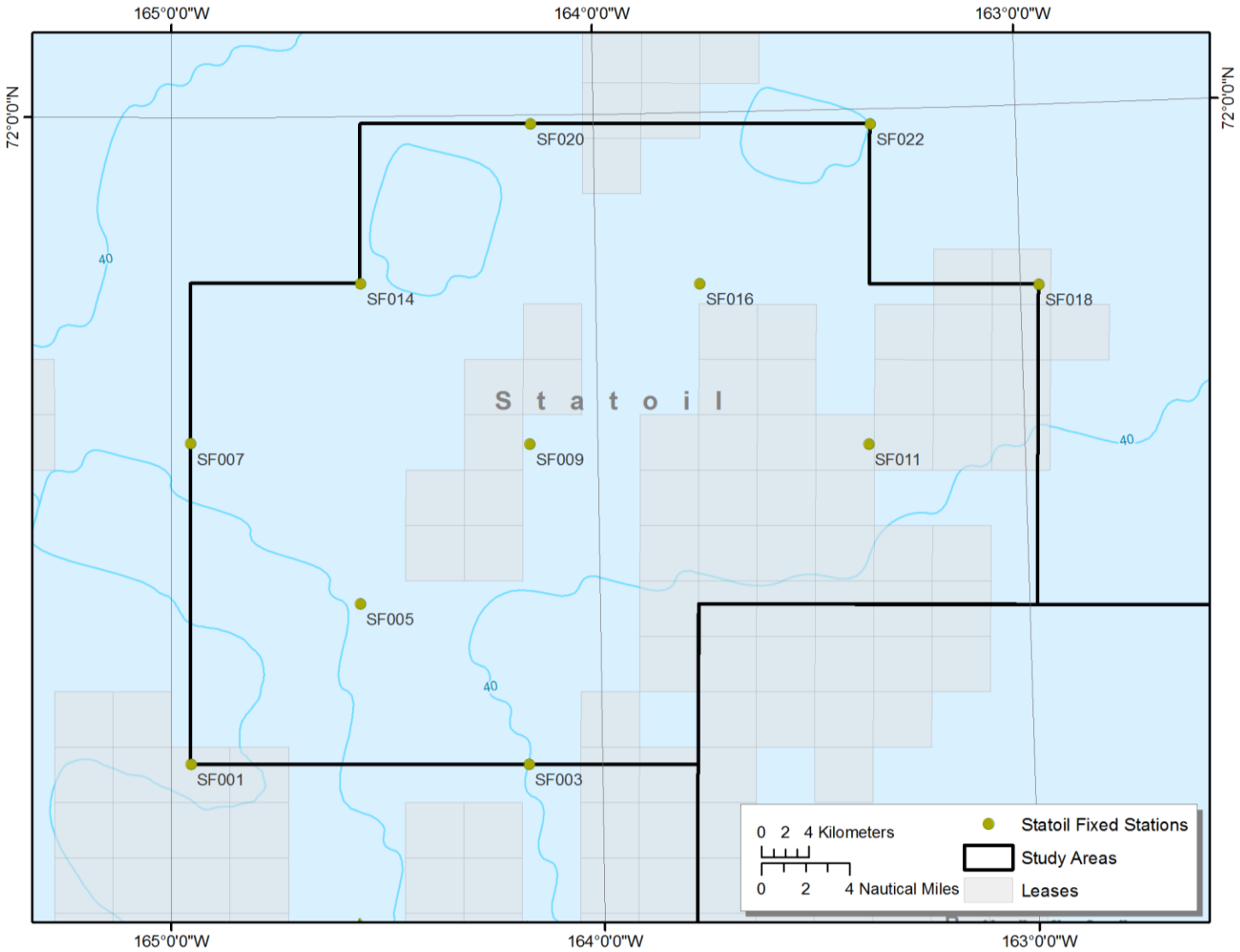

Figure 4. Map of the Statoil study area, northeastern Chukchi Sea showing fixed sampling stations occupied during the study.

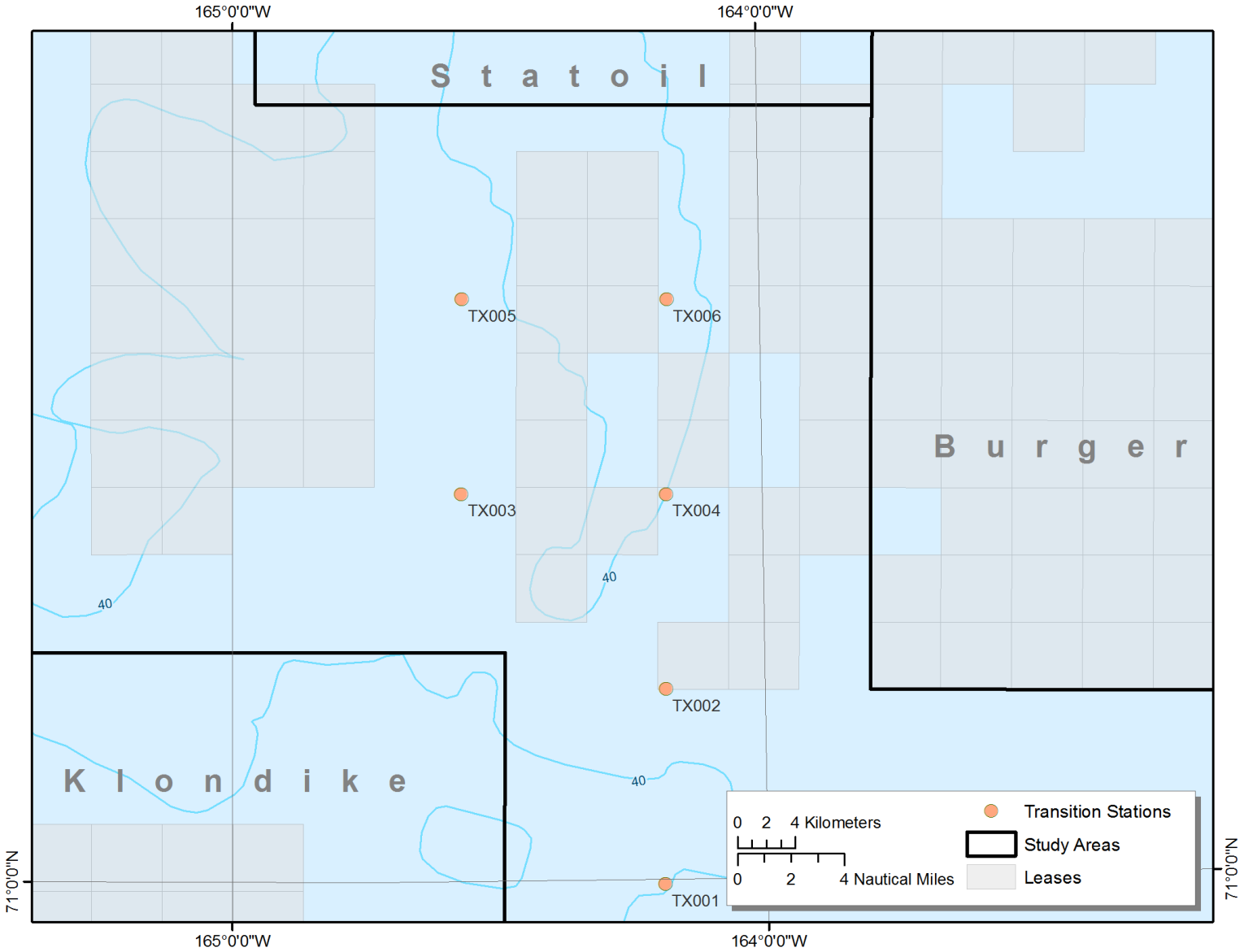

Figure 5. Map showing the location of Transition stations relative to the study areas.

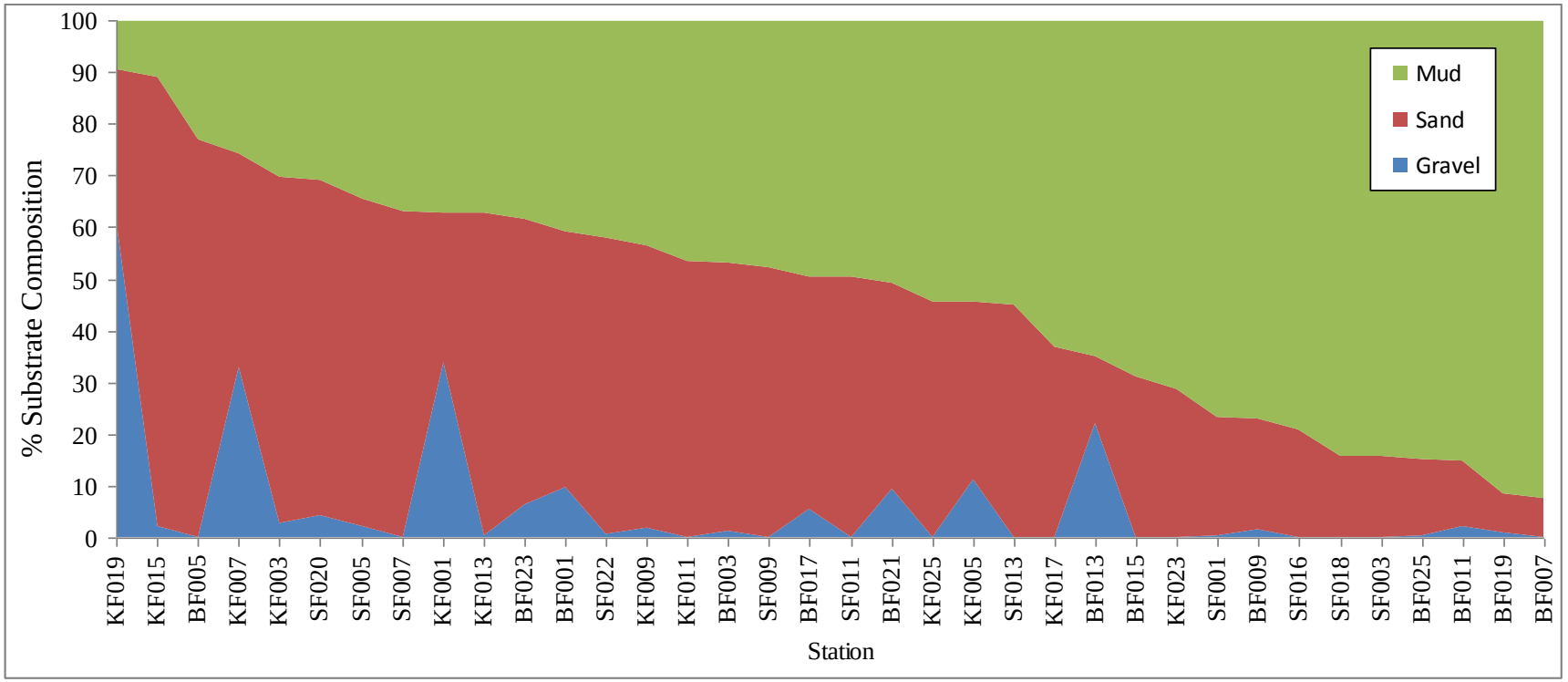

Figure 6. Substrate composition from study locations in the northeastern Chukchi Sea. The stations are organized from lowest to highest percent mud. Data are from Blanchard and Parris (unpublished).

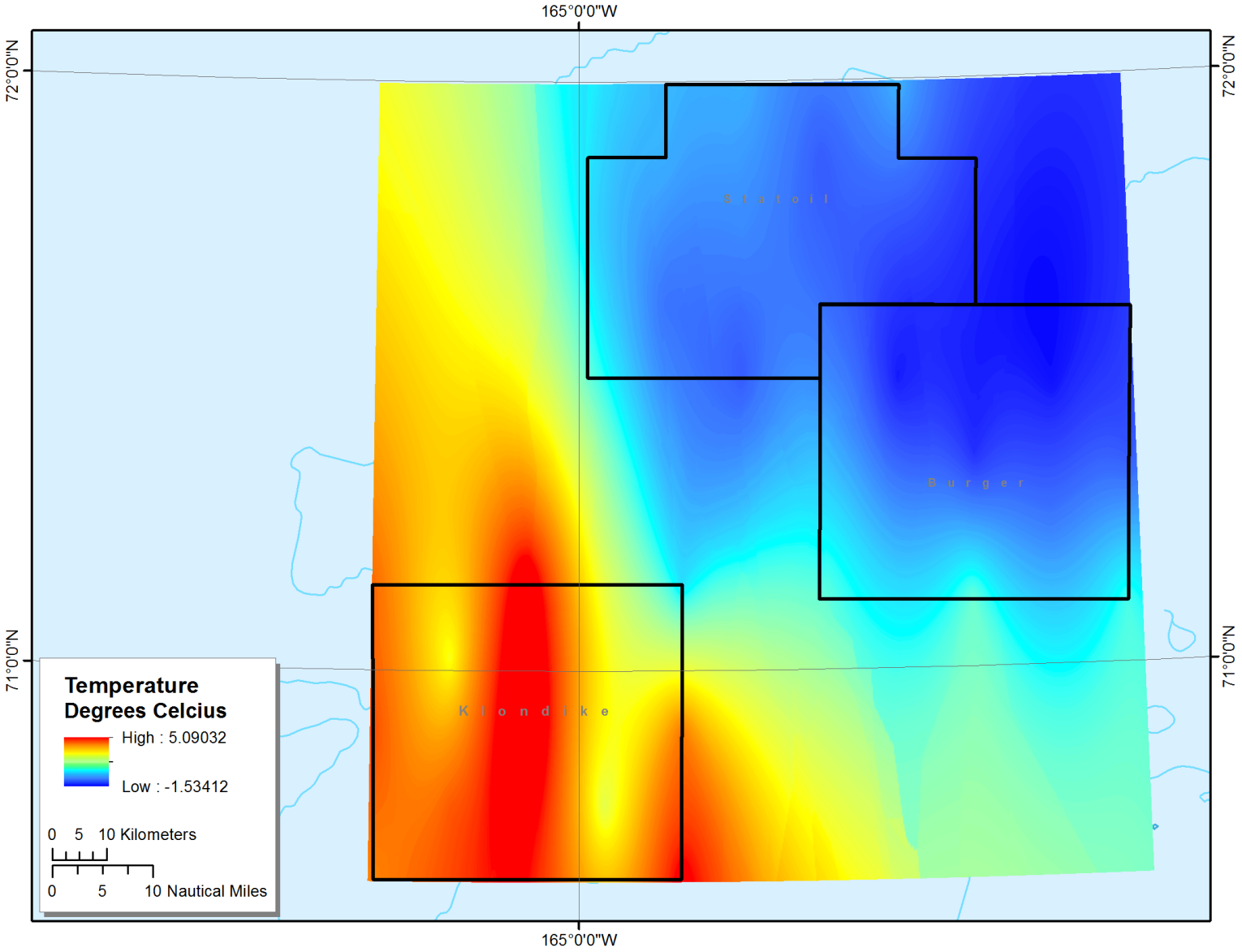

Figure 7. Bottom temperature gradient map of the northeastern Chukchi Sea, 2010. Data are calculated using an inverse-distance weighted (IDW) model.

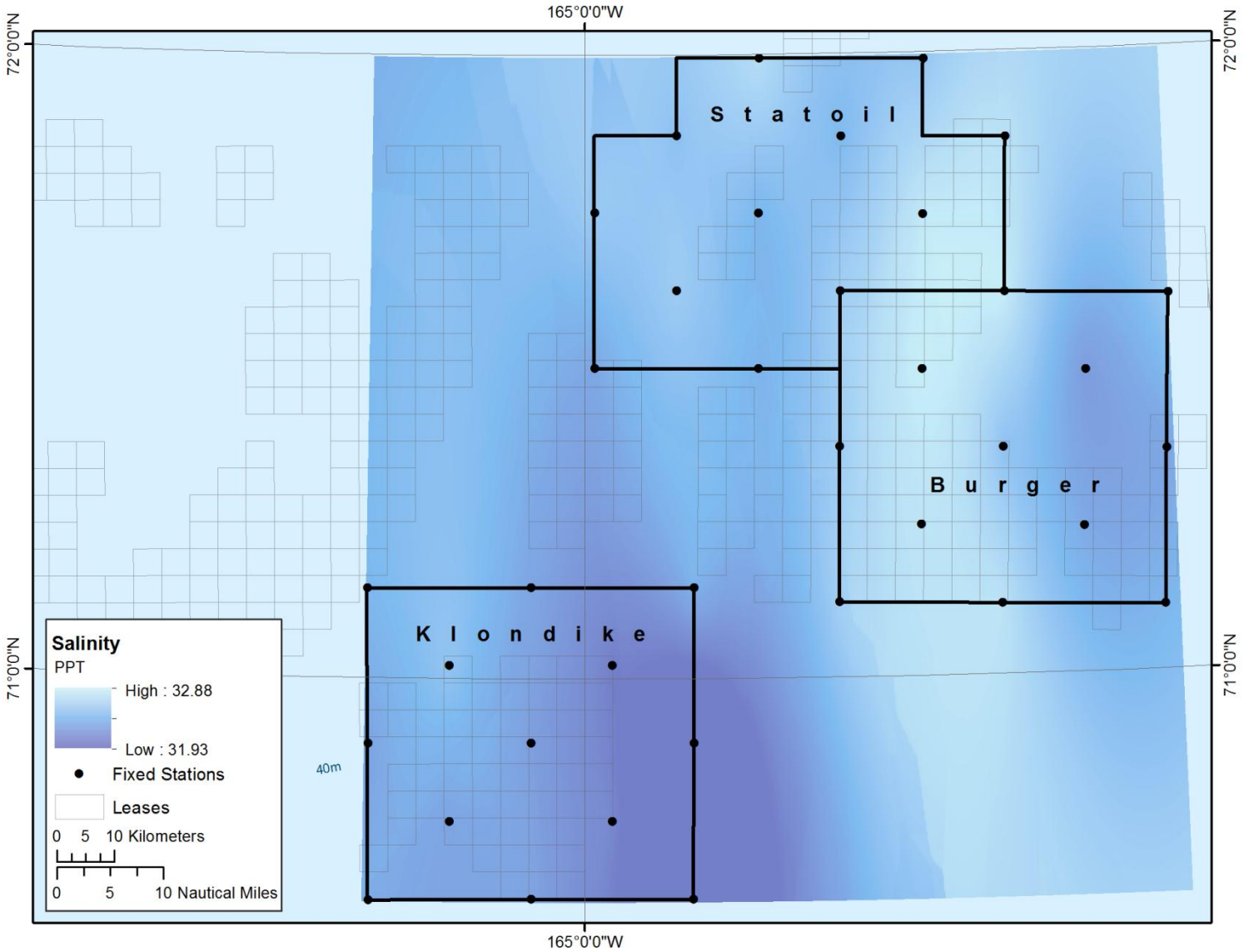

Figure 8. Bottom salinity gradient map of the northeastern Chukchi Sea, 2010. Data are calculated using an inverse-distance weighted (IDW) model.

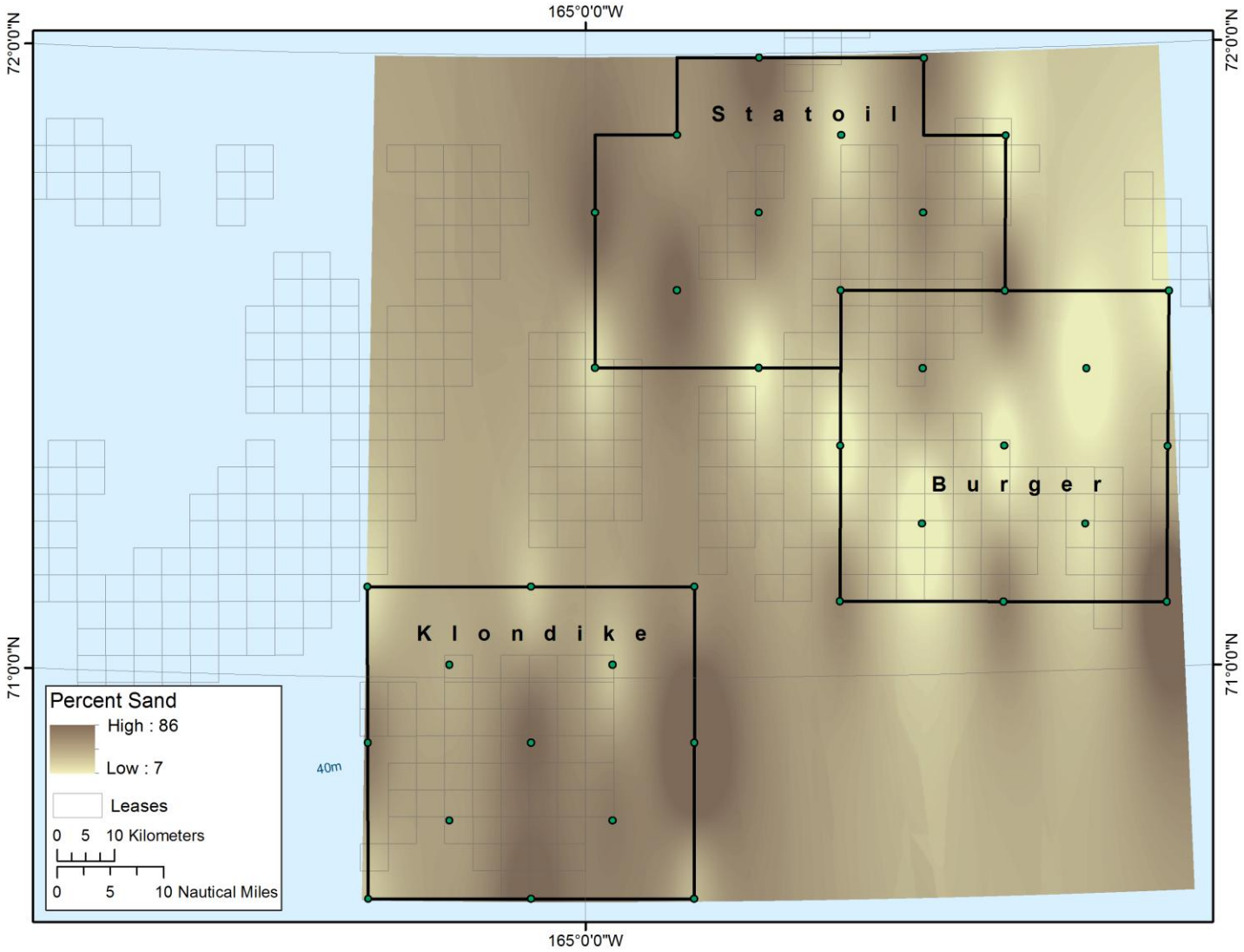

Figure 9. Gradient map of percent substrate comprised of sand, northeastern Chukchi Sea, 2010. Data are calculated using an inverse-distance weighted (IDW) model. Data are from Blanchard and Parris (unpublished).

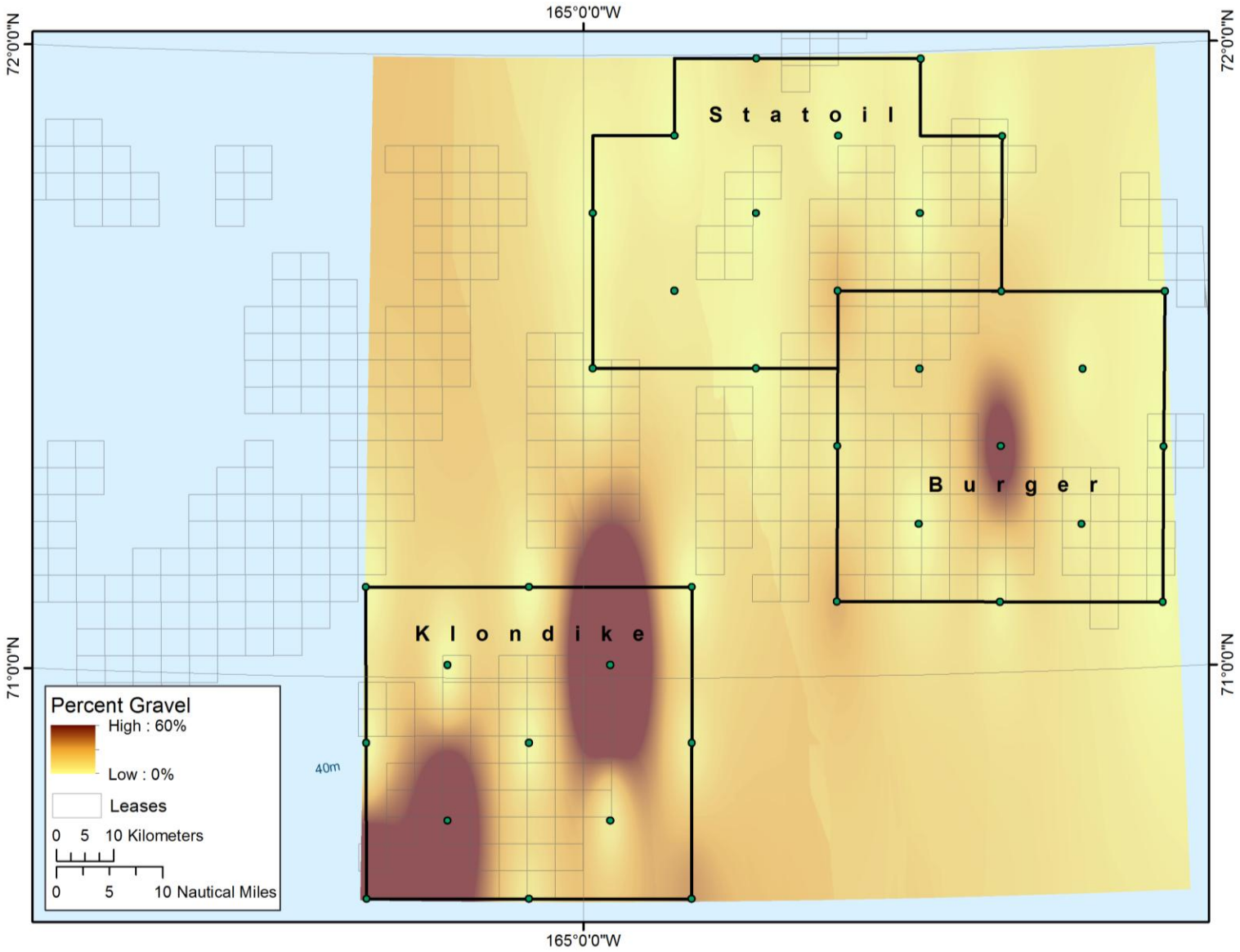

Figure 10. Gradient map of percent substrate comprised of gravel, northeastern Chukchi Sea, 2010. Data are calculated using an inverse-distance weighted (IDW) model. Data are from Blanchard and Parris (unpublished).

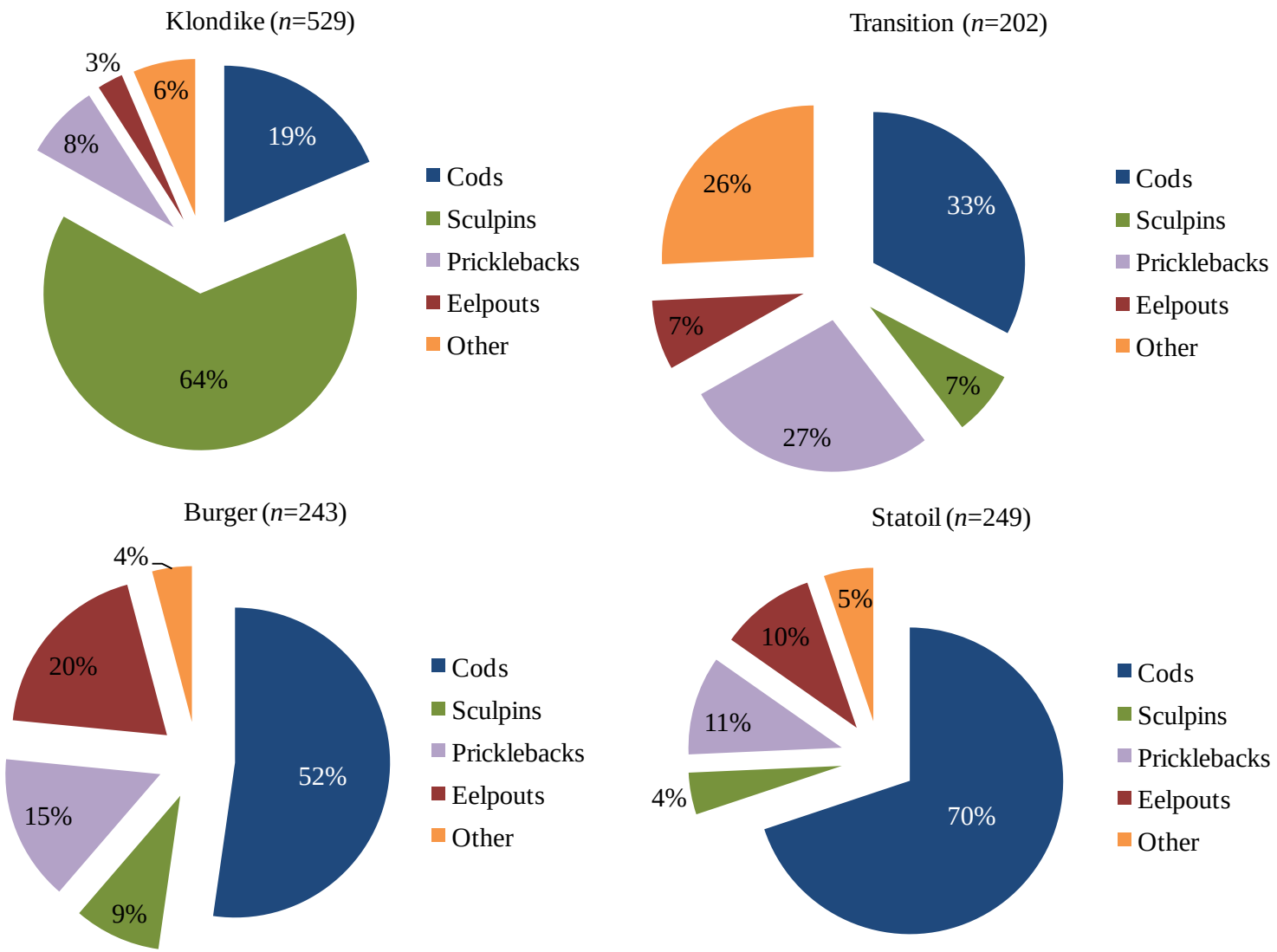

Figure 11. Species composition of the 3mBT catch by family and study area from the northeastern Chukchi Sea, September 2010.

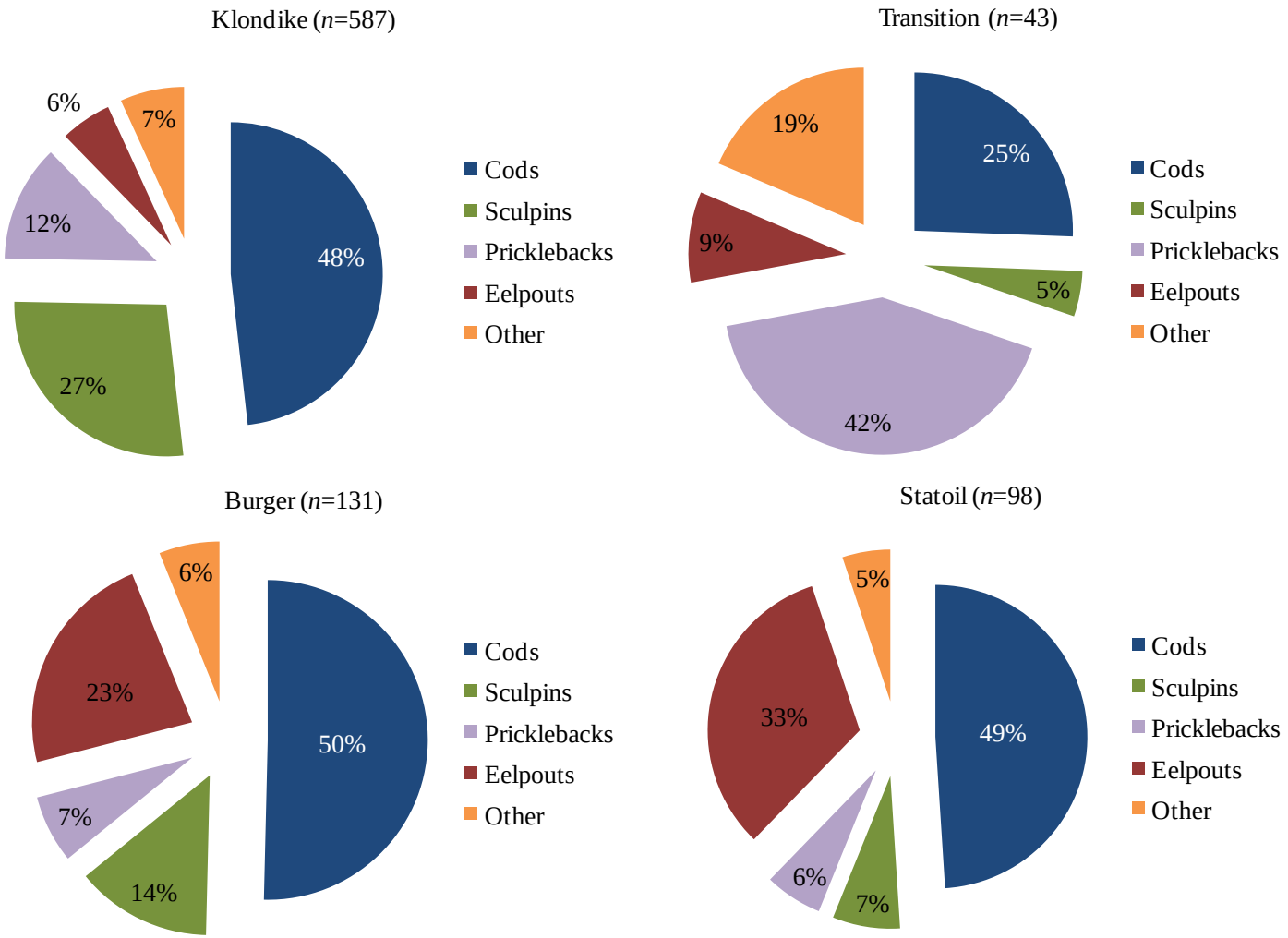

Figure 12. Species composition of the PSBT catch by family and study area from the northeastern Chukchi Sea, September 2010.

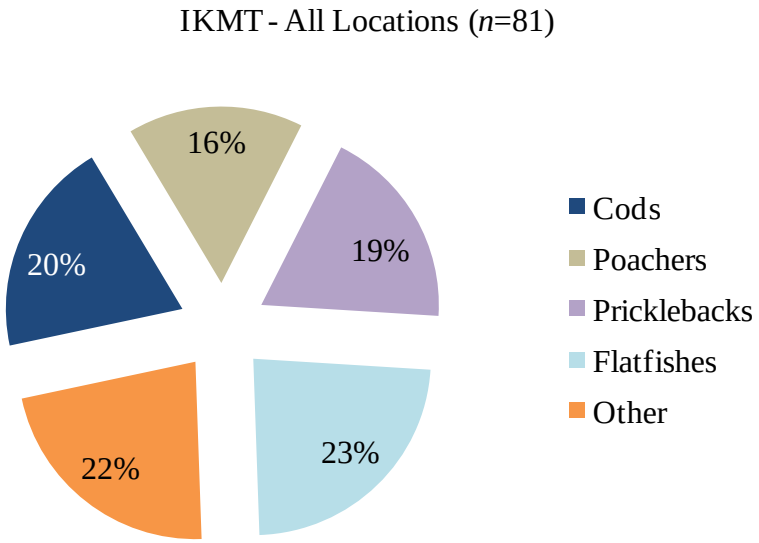

Figure 13. Species composition of the IKMT catch by family. All northeastern Chukchi Sea locations are combined.

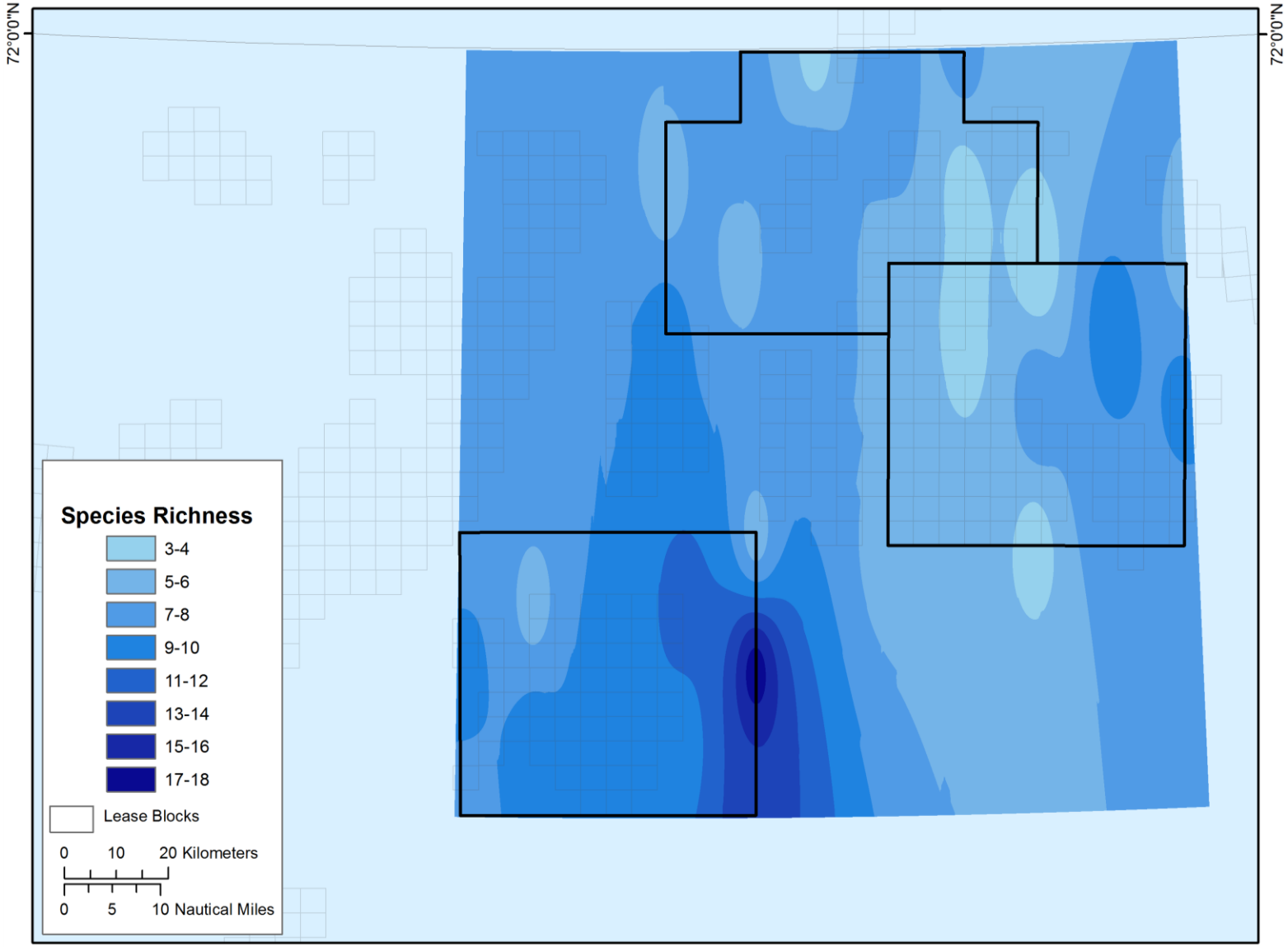

Figure 14. Number of fish species present (species richness) in bottom trawls in the northeastern Chukchi Sea, September 2010.

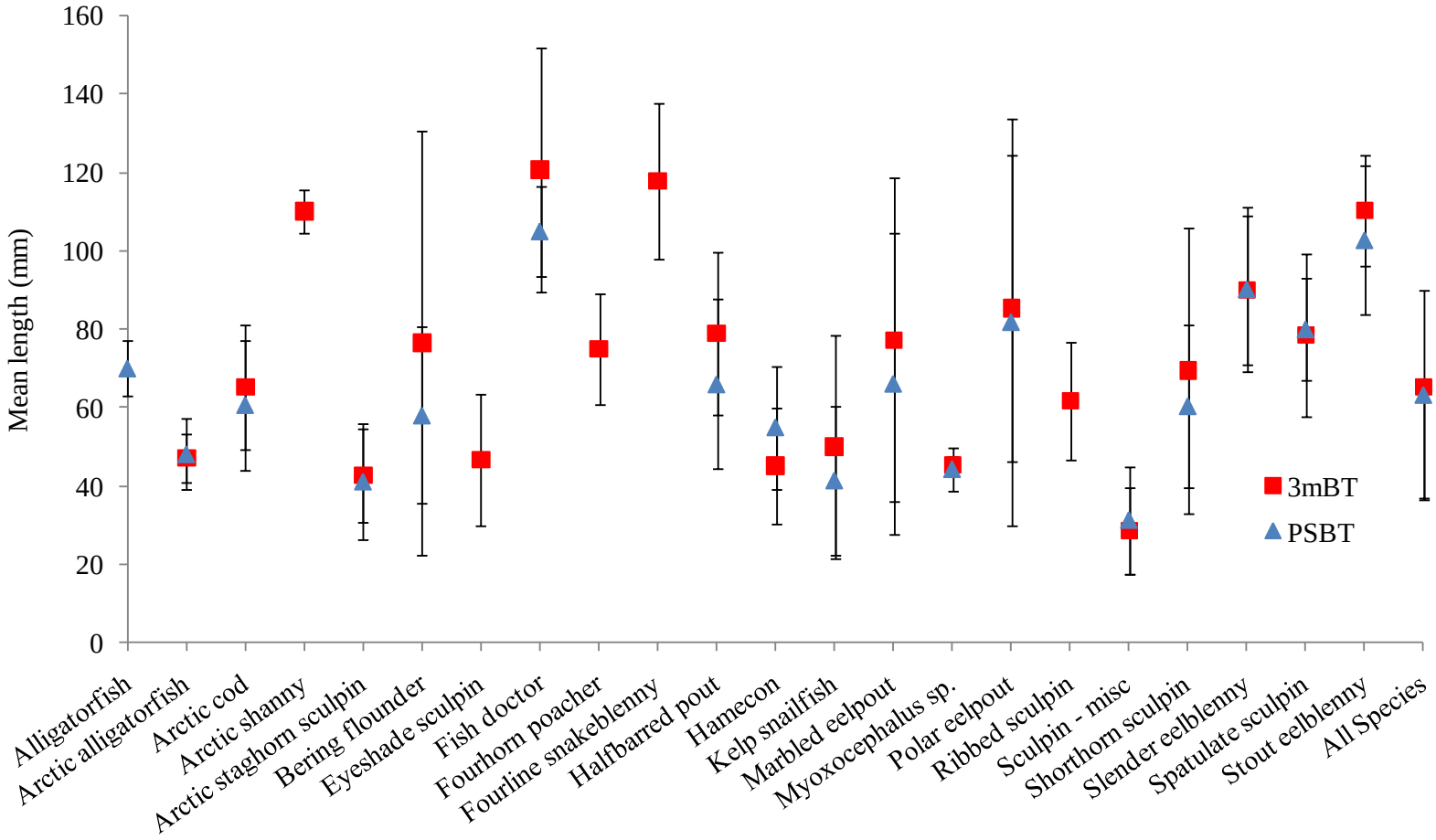

Figure 15. The mean length of all species caught in the 3mBT and PSBT, northeastern Chukchi Sea, 2010. All locations are combined. Error bars represent the Standard Deviation (σ). Data are unapportioned. Species with only one measured fish (*n*=1) were excluded.

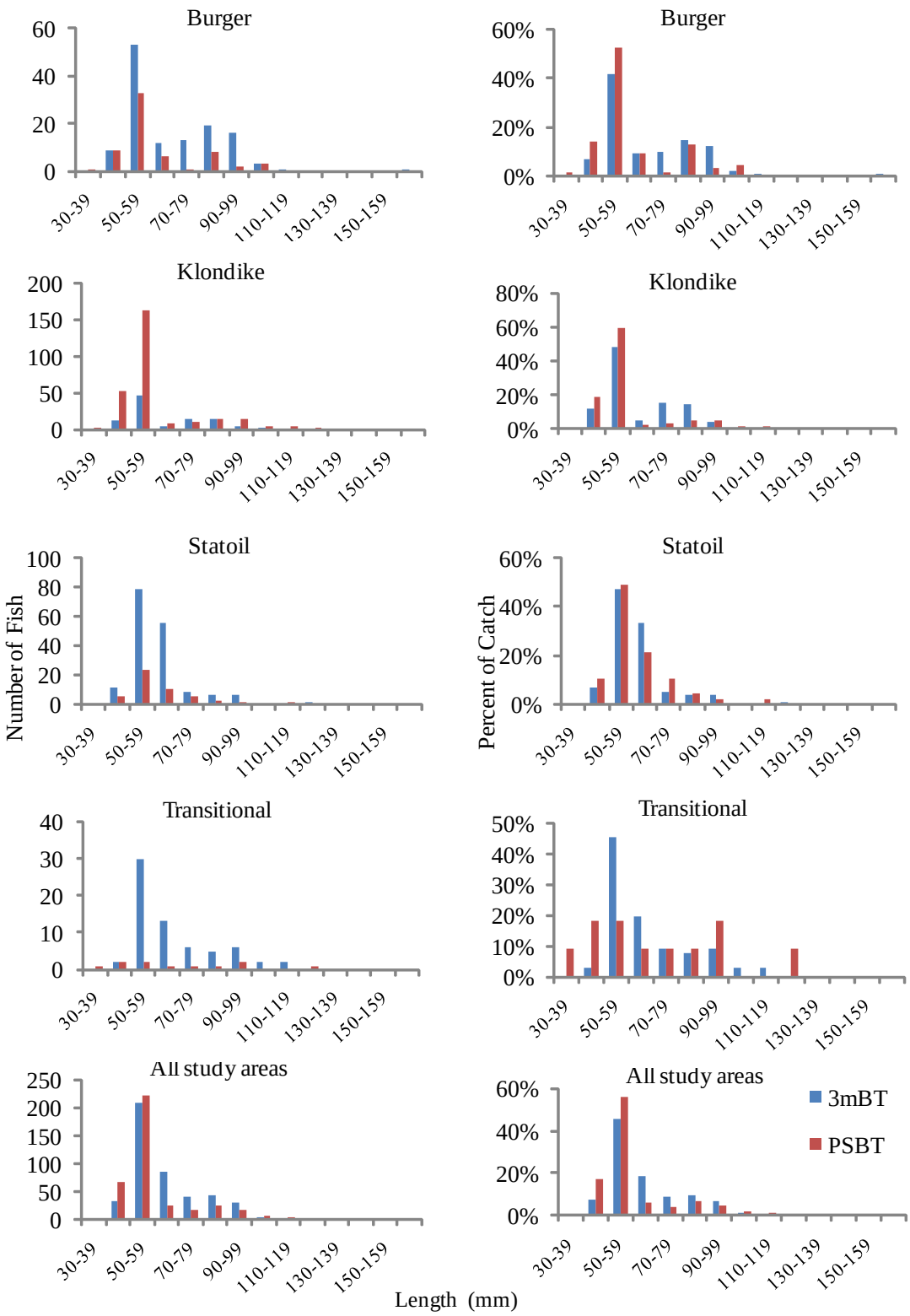

Figure 16. Length frequency of Arctic cod caught by 3mBT and PSBT in the northeastern Chukchi Sea. Results are displayed as total measured per size class and percentage of catch in each size class.

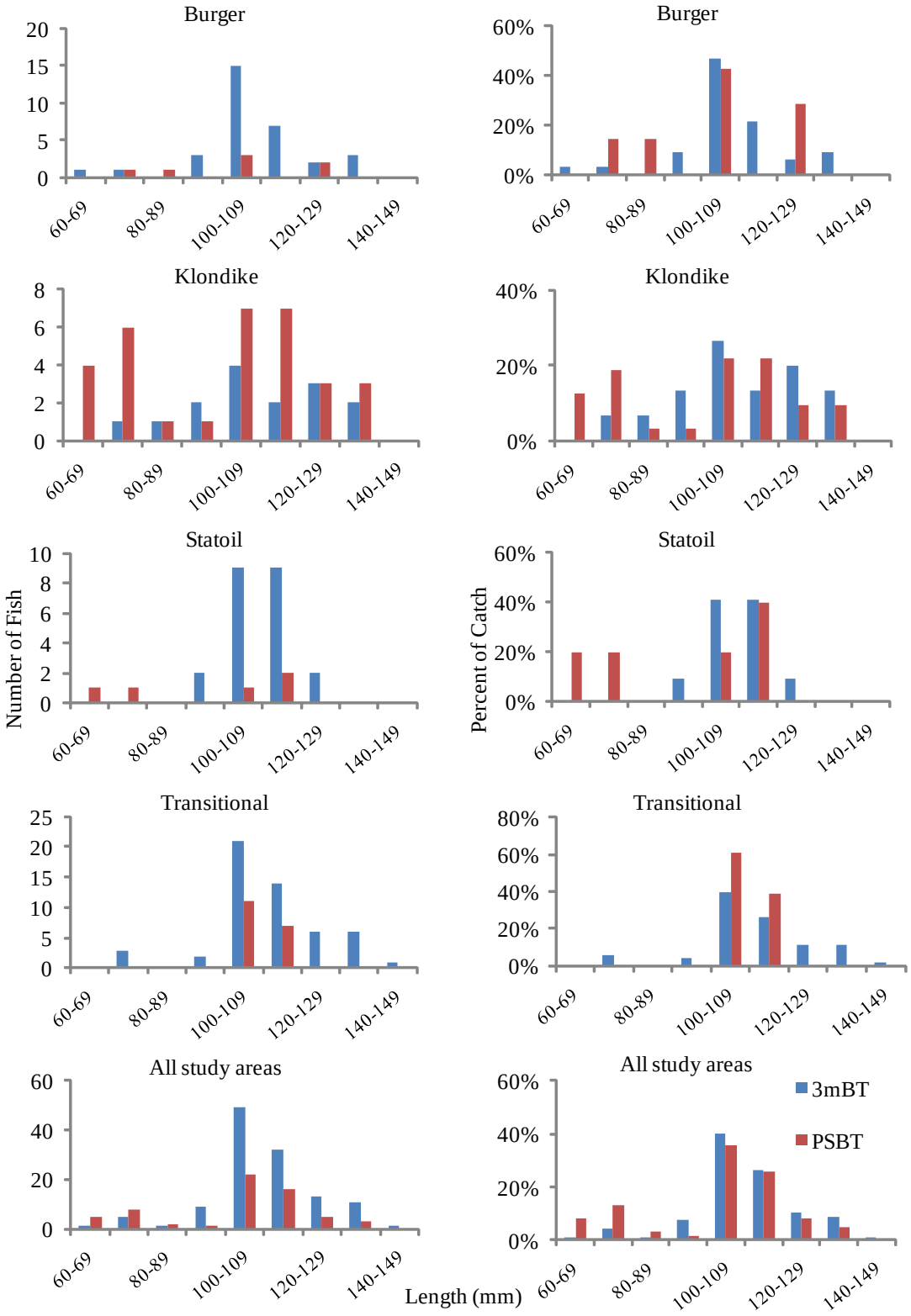

Figure 17. Length frequency of stout eelblenny caught by 3mBT and PSBT. Results are displayed as total measured per size class and percentage of catch in each size class.

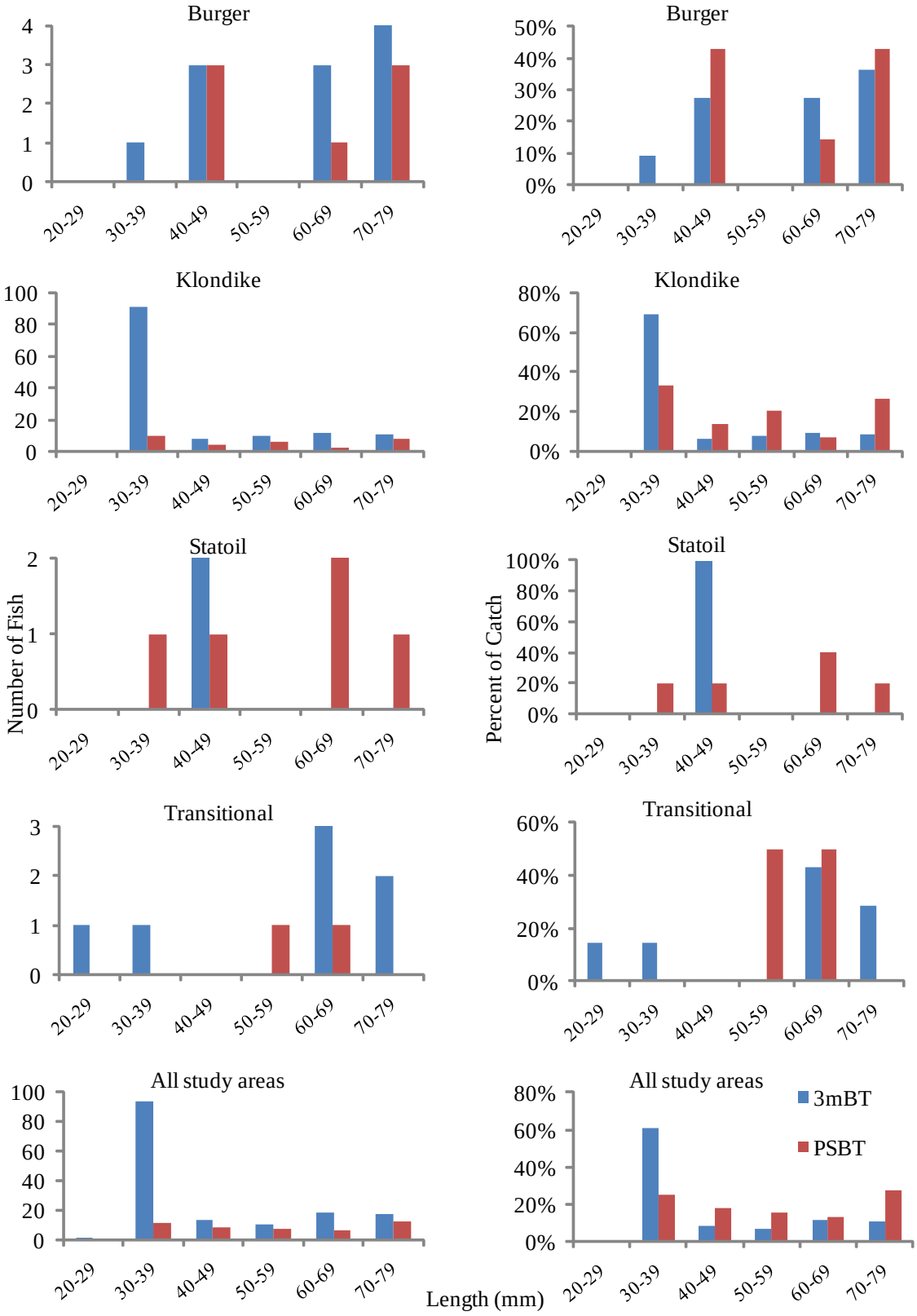

Figure 18. Length frequency of hamecon caught by 3mBT and PSBT. Results are displayed as total measured per size class and percentage of catch in each size class.

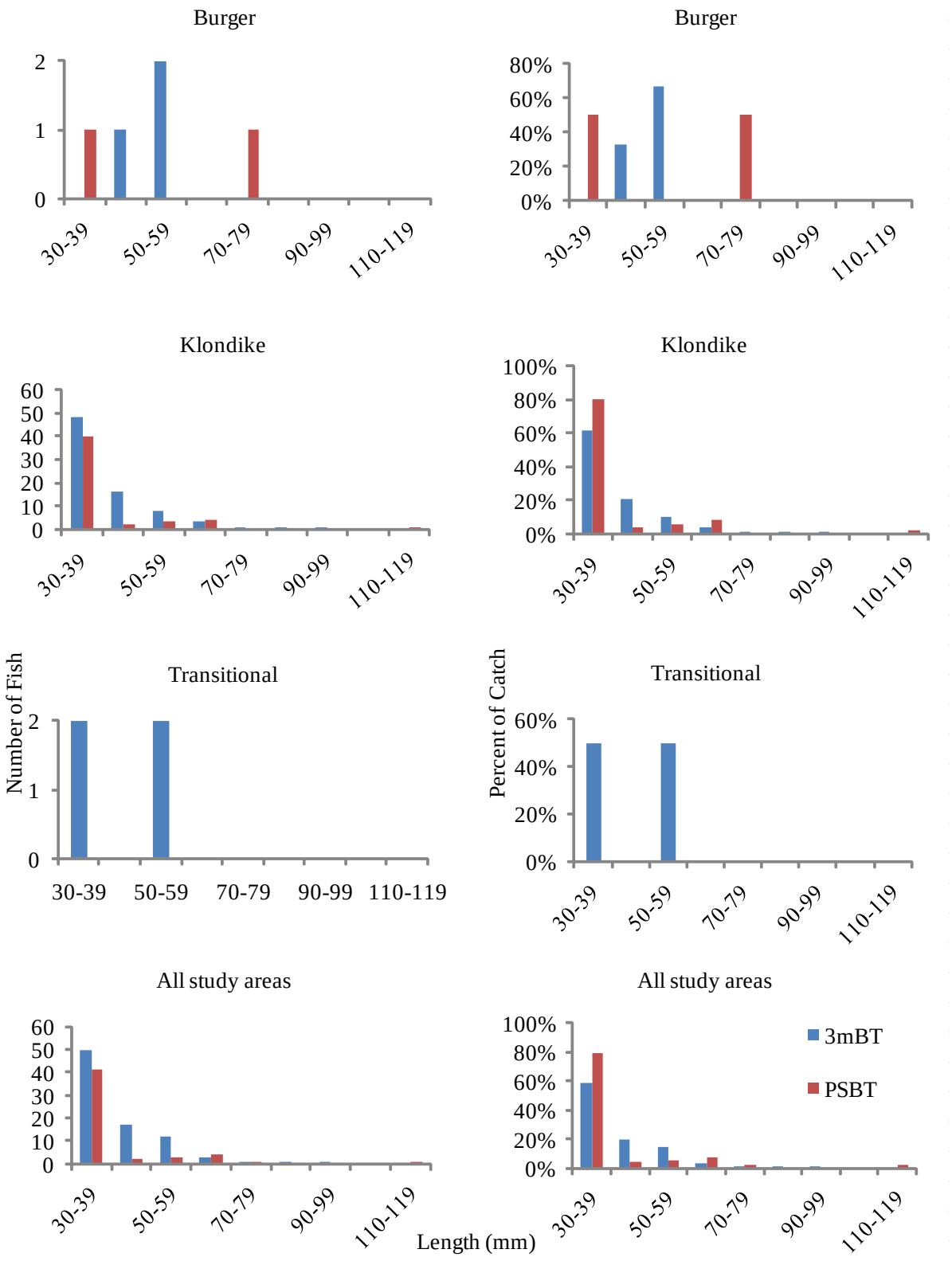

Figure 19. Length frequency of Arctic staghorn sculpin caught by 3mBT and PSBT. Results are displayed as total measured per size class and percentage of catch in each size class.

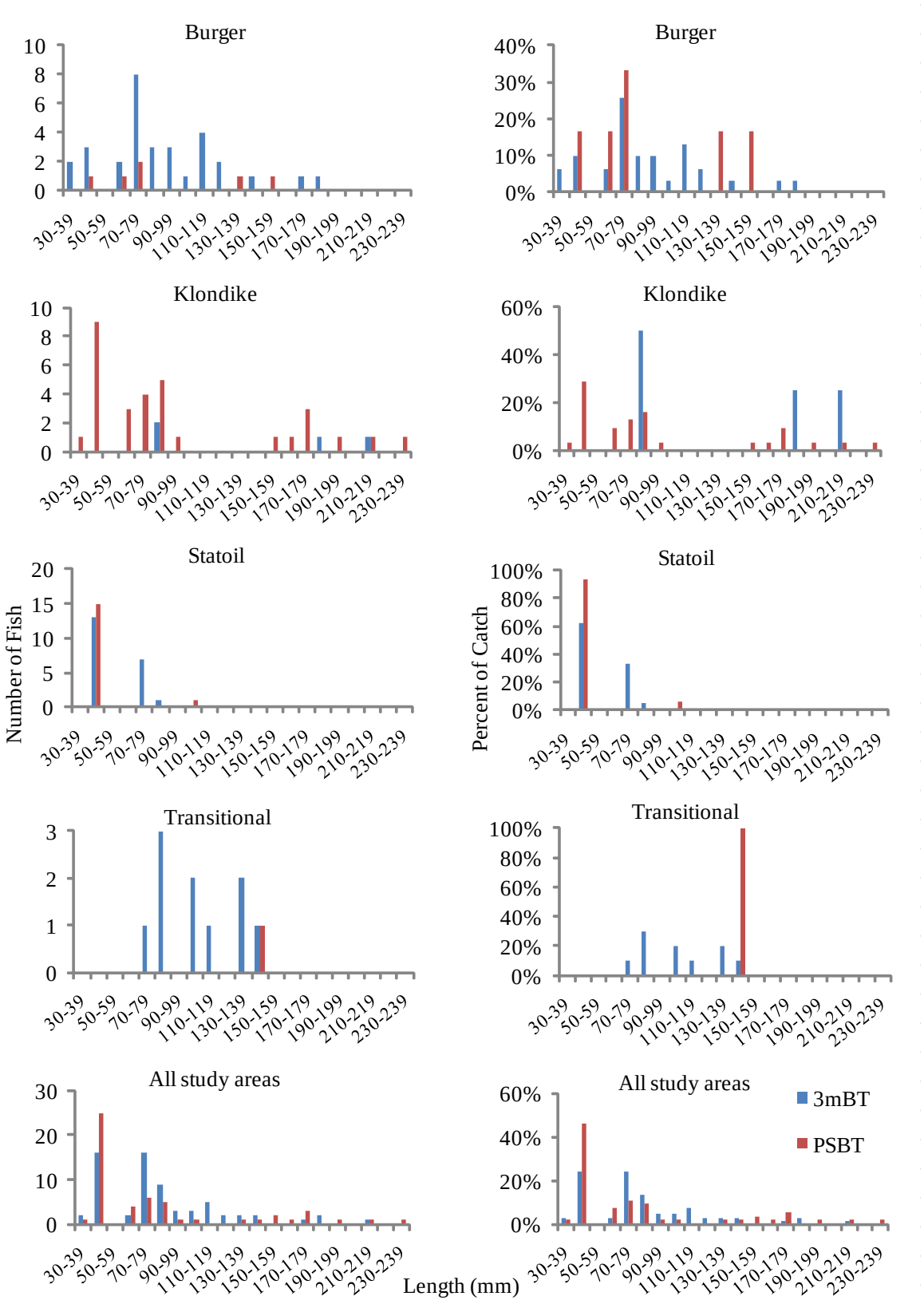

Figure 20. Length frequency of polar eelpout caught by 3mBT and PSBT. Results are displayed as total measured per size class and percentage of catch in each size class.

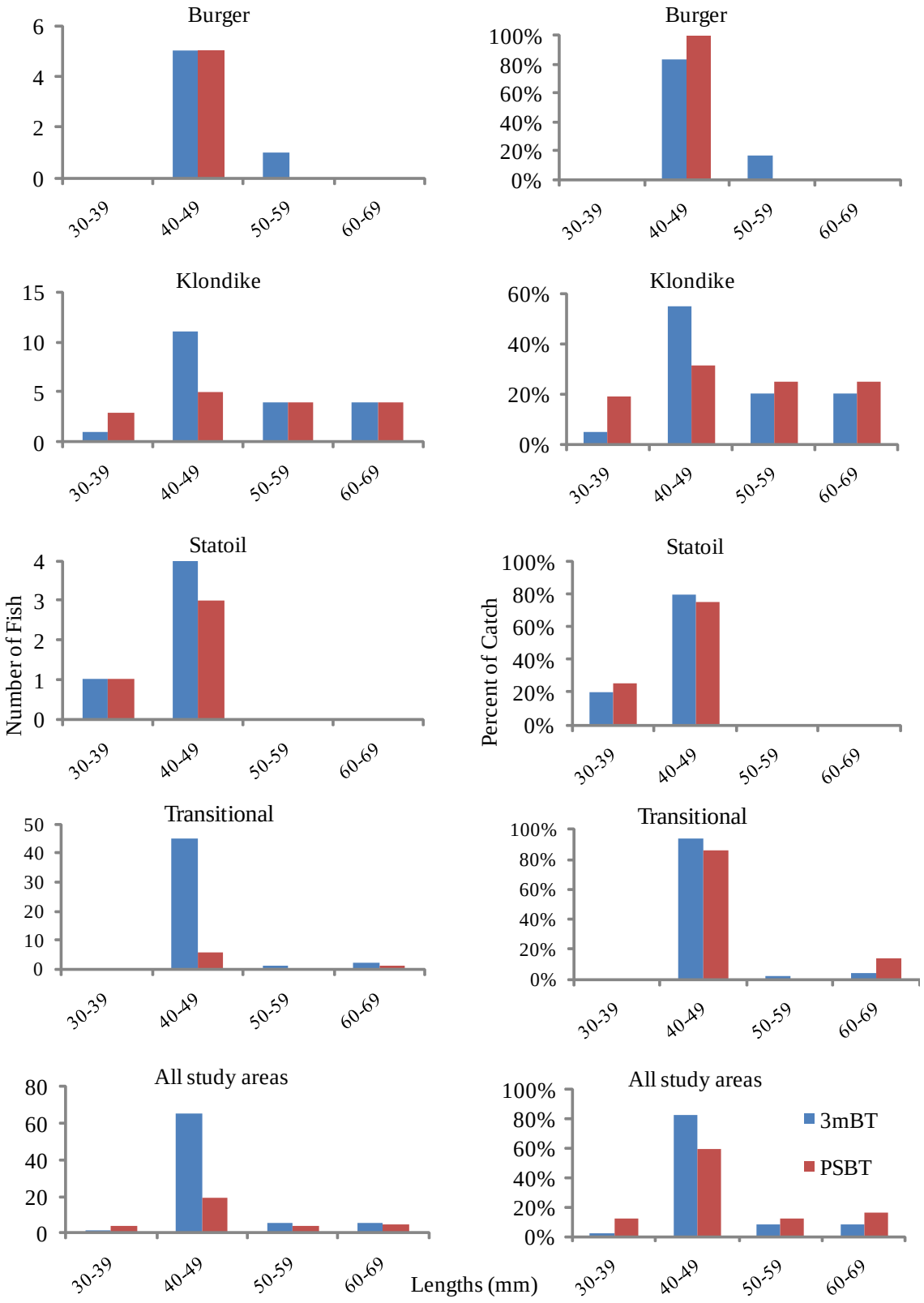

Figure 21. Length frequency of Arctic alligatorfish caught by 3mBT and PSBT. Results are displayed as total measured per size class and percentage of catch in each size class.

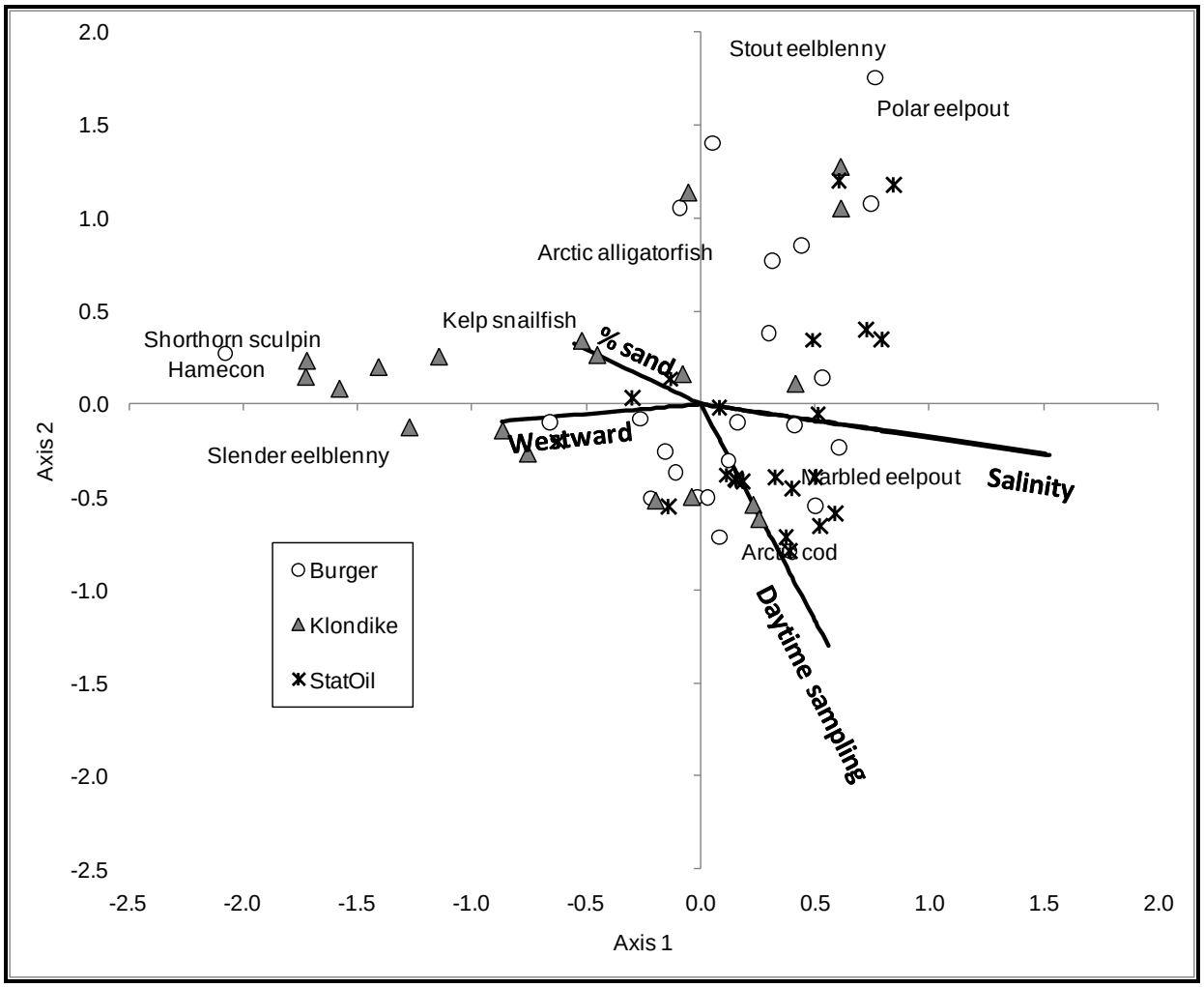

Figure 22. Canonical Correspondence Analysis (CCA) ordination of stations and species relative abundances based on their relative distribution across stations with independent variable correlations with axes overlaid. The 3mBT and PSBT samples were included separately with gear type entered as an independent dummy variable.

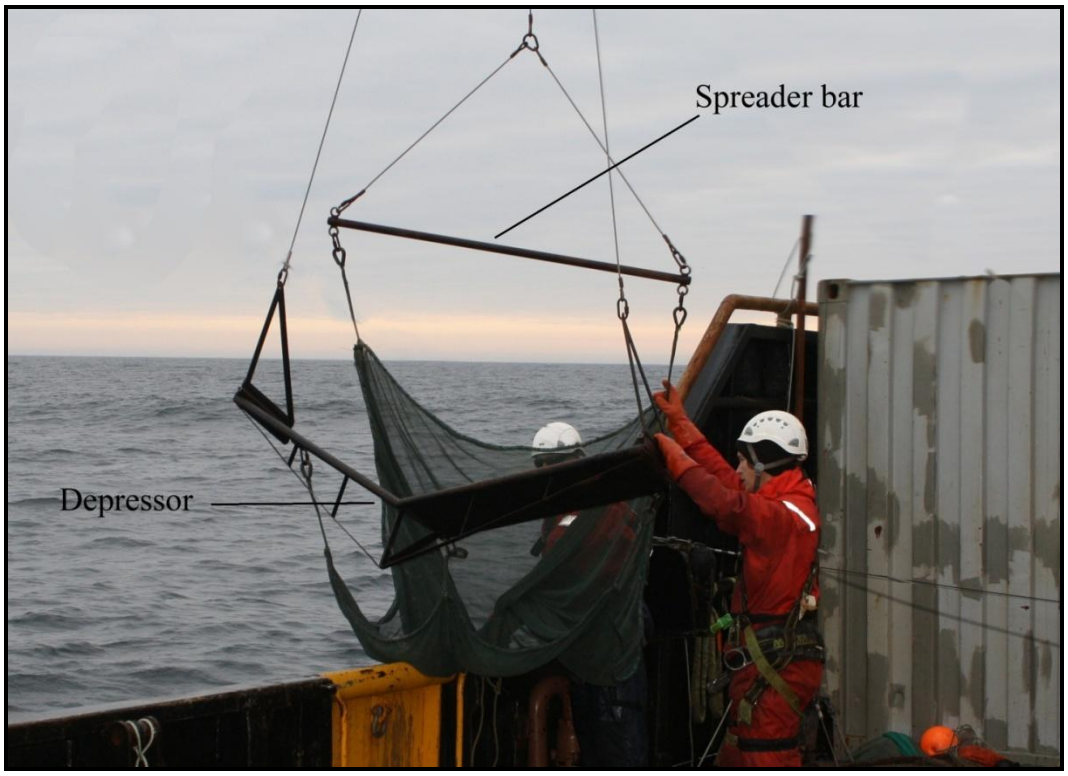

Photo 1. Deploying the IKMT into the Chukchi Sea, September 2010. The codend is hanging overboard. The spreader bar and depressor keep the net mouth open.

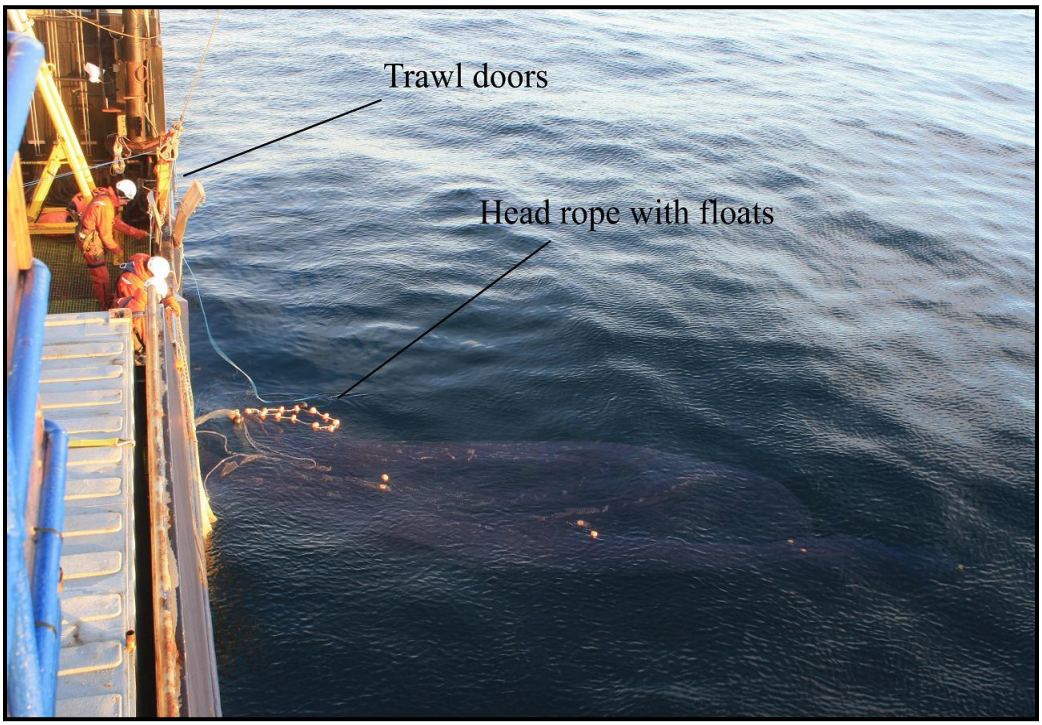

Photo 2. Deploying the MAP trawl over the starboard side of the R/V *Westward Wind*, Chukchi Sea, summer 2010.

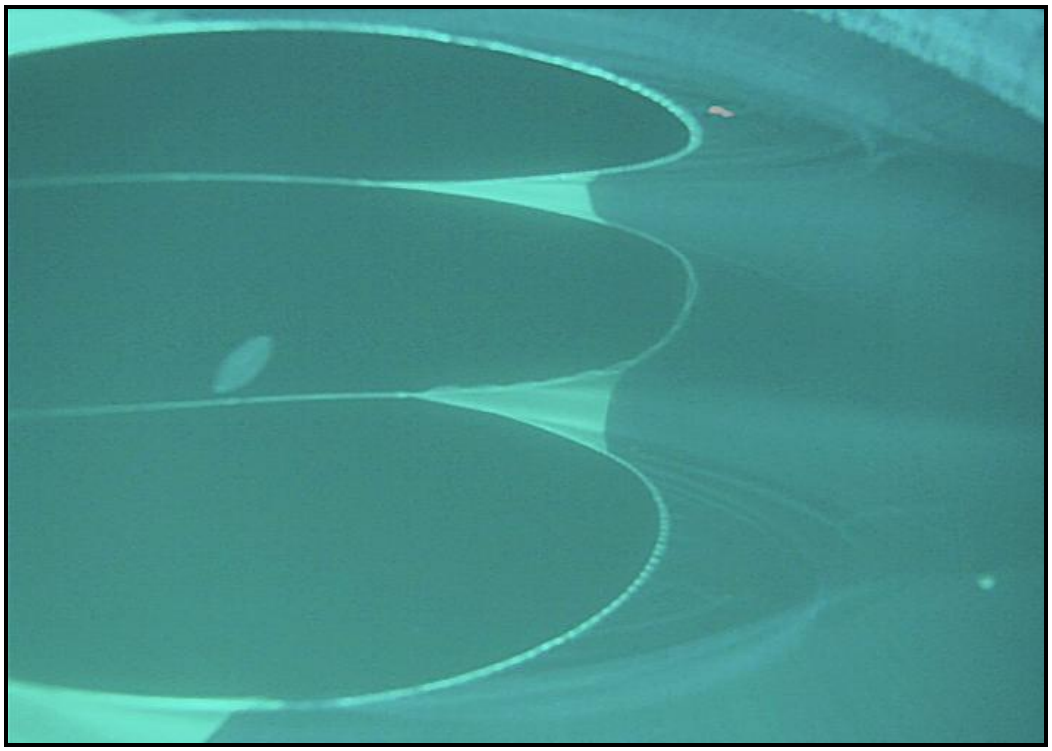

Photo 3. Underwater view of the MAP trawl fishing in the Chukchi Sea, September 2010. The light colored oval is a jellyfish entering the net.

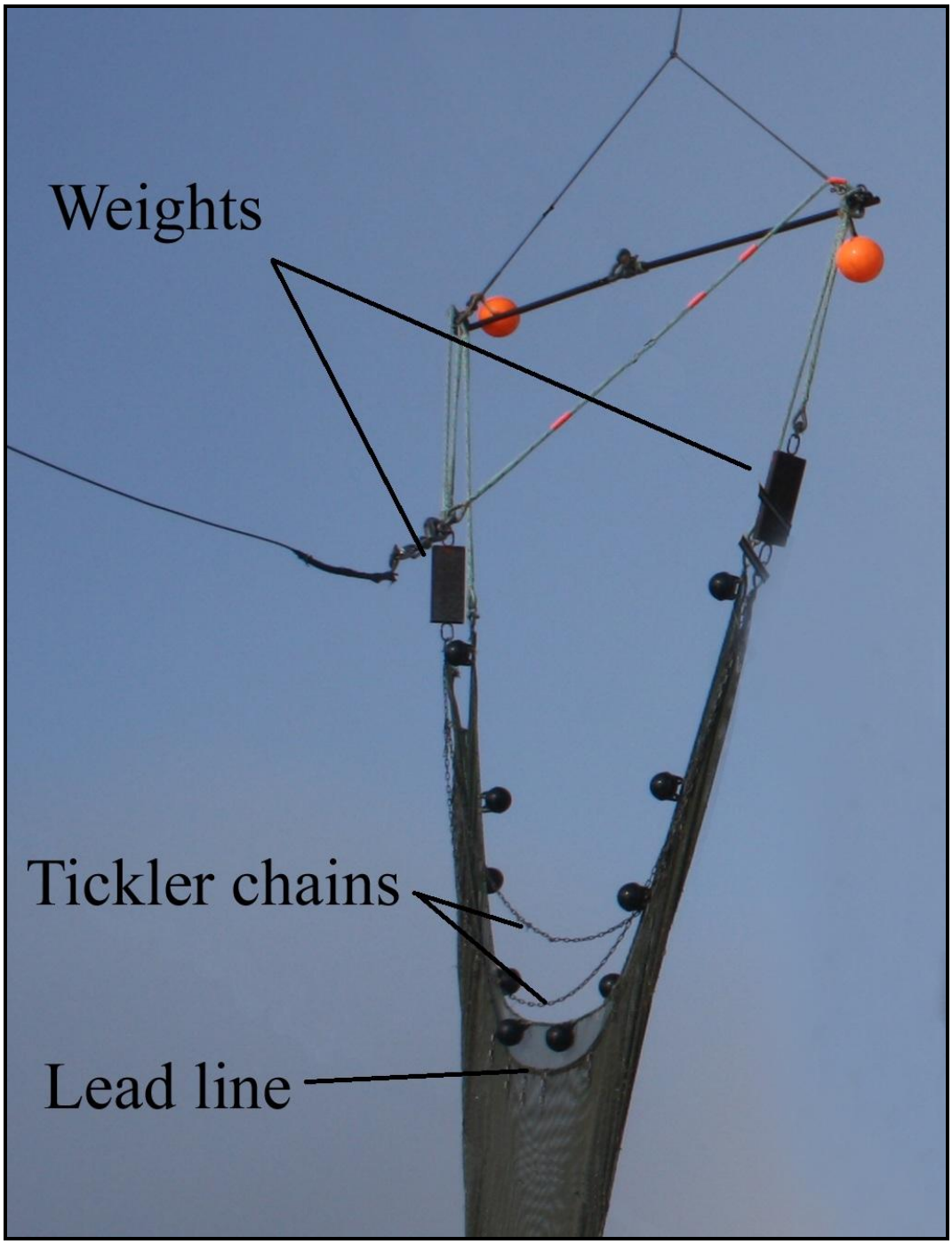

Photo 4. PSBT being brought on board after a sample, Chukchi Sea, September 2010. Note that the PSBT does not have "shoes".

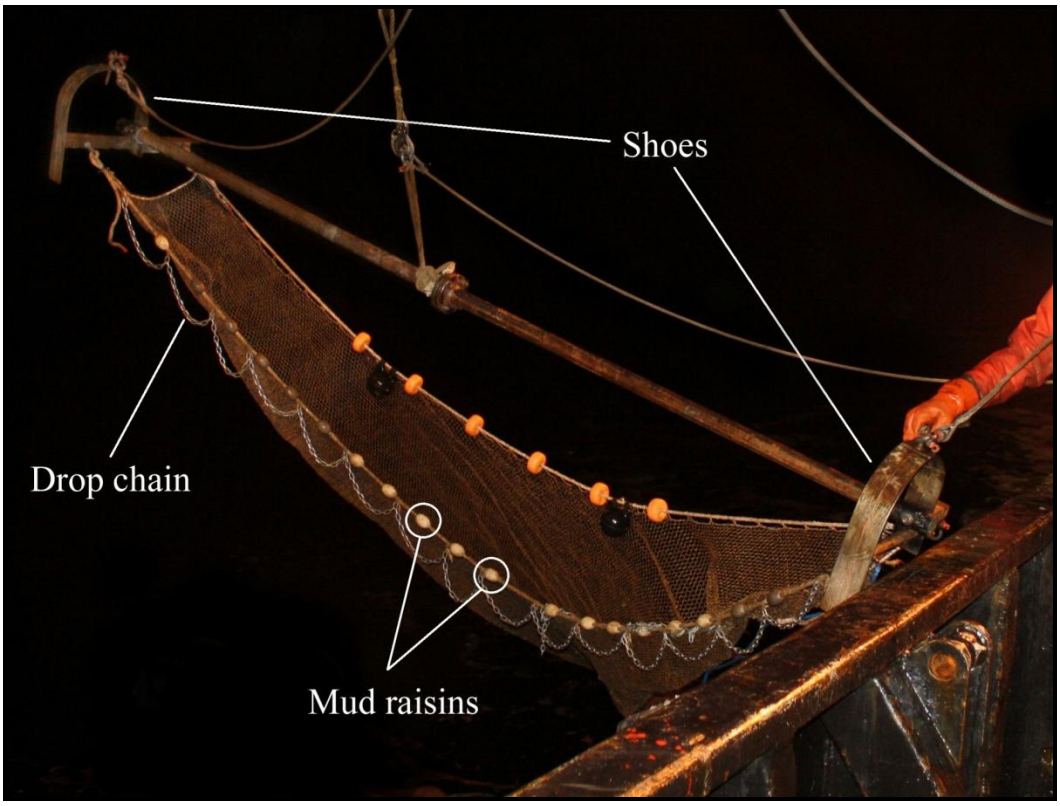

Photo 5. The mouth of the 5mBT as it is being deployed. The main body of the net is hanging out of view.

APPENDIX A – TABLES

Appendix A1. Summary of the dates, stations occupied, and gear types deployed in the northeastern Chukchi Sea, 1–19 September 2010 aboard the R/V *Westward Wind*. Station prefixes correspond to the following prospects: KF = Klondike Fixed station, TF = Transition Fixed station, BF = Burger Fixed station, SF = Statoil Fixed station. Numbers indicate the haul number. Crossed out numbers indicate hauls that were unusable for quanitative analysis.

		Haul Number					
Date	Station	PSBT	MPSBT	5mBT	3mBT	IKMT	MWT
1-Sep	KF-013	1, 2	–	–	–	–	–
1-Sep	KF-009	3	–	–	–	–	–
1-Sep	KF-003	4	1, ~~2~~	–	–	–	–
2-Sep	KF-023	5	3	1	–	1	–
2-Sep	KF-017	6	~~4~~	2	–	2	–
2-Sep	KF-021	7	5	3	–	3	–
3-Sep	KF-011	8	6	4	–	4	–
3-Sep	KF-001	9	7	5	–	5	–
3-Sep	KF-007	~~10~~, 11	8	–	1, 2	6	–
4-Sep	KF-005	12	9	–	3	7	–
4-Sep	KF-025	~~13~~, 14	10	–	4	8	–
5-Sep	KF-019	15	11	–	5	9	–
5-Sep	KF-015	16	12	–	6	10	–
5-Sep	KF-009	–	13	–	~~7~~, 8	~~11~~,12	–
6-Sep	TF-001	17	14	–	9	13	–
6-Sep	TF-002	18	~~15~~	–	10	14	–
6-Sep	BF-001	19	~~16~~, ~~17~~, 18	–	11	15	–
7-Sep	BF-005	~~20~~, 21	19	–	12	16	–
8-Sep	BF-009	22	–	–	13	17	–
8-Sep	BF-025	23	–	–	14	18	–
9-Sep	BF-015	24	–	–	15	19	–
10-Sep	BF-019	25	–	–	16	20	4
10-Sep	BF-005	–	–	–	–	–	1
10-Sep	BF-015	–	–	–	–	–	2
10-Sep	BF-025	–	–	–	–	–	3
10-Sep	BF-009	–	–	–	–	–	5
11-Sep	BF-003	26	20	–	17	21	6
11-Sep	BF-013	27	–	–	18, 19	22	7
11-Sep	BF-023	28	–	–	20	23	8
12-Sep	BF-017	29	–	–	21	24	–
12-Sep	BF-007	30	–	–	22	25	–

Appendix A1 continued. Summary of the dates, stations occupied, and gear types deployed in the northeastern Chukchi Sea, 1–19 September 2010 aboard the R/V *Westward Wind*.

		Haul Number					
Date	Station	PSBT	MPSBT	5mBT	3mBT	IKMT	MWT
13-Sep	BF-001	–	–	–	–	–	9
13-Sep	BF-011	31	–	–	23	26	~~10~~
13-Sep	BF-021	32	–	–	24	27	11
14-Sep	SF-001	33	–	–	25	28	12
14-Sep	SF-007	~~34~~, ~~35~~, 36	–	–	26	29	13
15-Sep	SF-005	37	–	–	27	30	14
15-Sep	SF-014	~~38~~, 39	–	–	28	31	15
16-Sep	SF-020	40	–	–	29	32	16
16-Sep	SF-009	41	–	–	30	33	17
16-Sep	SF-003	42	–	–	31	34	18
17-Sep	SF-016	43	–	–	32	35	19
18-Sep	SF-011	44	–	–	~~33~~, 34	36	20
18-Sep	SF-018	45	–	–	35	37	~~21~~
18-Sep	SF-022	~~46~~, 47	–	–	~~36~~, 37	38	22
19-Sep	TF-006	–	–	–	38	39	–
19-Sep	TF-004	–	–	–	39	40	–
19-Sep	TF-003	–	–	–	40	41	–
19-Sep	TF-005	–	–	–	41	42	–

Appendix A2. Counts of fish captured with a 3-meter beam trawl in the Burger study area, northeastern Chukchi Sea, summer 2010.

Species	BF-001	BF-003	BF-005	BF-007	BF-009	BF-011	BF-013	BF-015	BF-017	BF-019	BF-021	BF-023	BF-025	Total
Alligatorfish *Aspidophoroides monopterygius*	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Arctic alligatorfish *Ulcina olrikii*	3	-	1	-	-	1	-	-	-	1	-	-	-	6
Arctic cod *Boreogadus saida*	1	3	3	7	2	34	3	8	3	26	12	-	25	127
Arctic shanny *Stichaeus punctatus*	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Arctic staghorn sculpin *Gymnocanthus tricuspis*	-	-	1	-	-	2	-	-	-	-	-	-	-	3
Bering flounder *Hippoglossoides robustus*	-	-	-	-	-	-	-	-	-	-	1	-	-	1
Eelblenny - unidentified	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Eelpouts - unidentified	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Eyeshade sculpin *Nautichthys pribilovius*	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Fish doctor *Gymnelis viridis*	-	-	-	4	-	-	-	1	-	-	-	-	-	5
Flatfish - unidentified	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Fourhorn poacher *Hypsagonus quadricornis*	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Fourline snake blenny *Eumesogrammus praecisus*	-	-	-	-	-	-	-	-	-	1	-	-	-	1
Gelatinous sea snail *Liparis fabricii*	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Hairhead sculpin *Trichocottus brashnikovi*	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Halfbarred pout *Gymnelus hemifasciatus*	-	-	3	-	1	-	-	1	-	-	-	-	-	5
Hamecon (sculpin) *Artediellus scaber*	-	-	-	-	-	3	-	1	-	4	2	-	1	11
Kelp snailfish *Liparis tunicatus*	-	-	-	-	1	-	-	1	-	1	-	-	-	3
Longhead dab *Limanda proboscidea*	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Marbled eelpout *Lycodes raridens*	-	-	-	-	2	-	-	1	-	-	-	-	3	6
Myoxocephalus spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Pacific sandlance *Ammodytes hexapterus*	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Polar eelpout *Lycodes turneri*	-	-	-	-	8	-	-	10	-	-	1	1	11	31
Prickleback - unidentified	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Ribbed sculpin *Triglops pingelii*	-	-	-	-	-	-	-	-	-	1	-	-	-	1
Sculpin - unidentified	1	-	-	-	-	-	-	-	-	-	-	-	-	1
Shorthorn sculpin *Myoxocephalus scorpius*	-	1	-	-	-	1	-	1	-	-	-	-	-	3
Slender eelblenny *Lumpenus fabricii*	-	-	-	-	3	1	-	-	-	-	-	-	-	4
Snailfish - unidentified	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Spatulate sculpin *Icelus spatula*	-	-	-	1	-	-	-	-	-	2	-	-	-	3
Stout eelblenny *Anisarchus medius*	4	-	2	-	2	6	-	8	-	1	3	1	5	32
Variegated snailfish *Liparis gibbus*	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Total	9	4	10	12	19	48	3	32	3	37	19	2	45	243

Appendix A3. Counts of fish captured with a 3-meter beam trawl in the Klondike study area. "X" denotes species that were present when the site was sampled with a 5-meter beam trawl. Sites KF-003 and KF-013 were not sampled with either beam trawl.

Species	KF-001	KF-003	KF-005	KF-007	KF-009	KF-011	KF-013	KF-015	KF-017	KF-019	KF-021	KF-023	KF-025	Total
Alligatorfish *Aspidophoroides monopterygius*	-	N/A	-	-	-	-	N/A	-	-	-	-	-	-	0
Arctic alligatorfish *Ulcina olrikii*	-	N/A	2	1	9	-	N/A	1	-	7	X	X	-	20
Arctic cod *Boreogadus saida*	X	N/A	12	16	57	X	N/A	6	X	6	X	X	2	99
Arctic shanny *Stichaeus punctatus*	-	N/A	-	-	-	-	N/A	5	-	1	-	-	-	6
Arctic staghorn sculpin *Gymnocanthus tricuspis*	-	N/A	1	1	48	X	N/A	28	-	-	X	-	-	78
Bering flounder *Hippoglossoides robustus*	-	N/A	-	-	1	X	N/A	-	X	-	X	X	-	1
Eelblenny - unidentified	-	N/A	-	-	-	-	N/A	-	-	-	-	-	-	0
Eelpouts - unidentified	-	N/A	-	-	-	-	N/A	-	-	-	-	-	-	0
Eyeshade sculpin *Nautichthys pribilovius*	-	N/A	-	1	-	-	N/A	34	-	3	-	-	-	38
Fish doctor *Gymnelis viridis*	-	N/A	-	-	-	-	N/A	2	-	-	-	-	-	2
Flatfish - unidentified	-	N/A	-	-	-	-	N/A	-	-	-	-	-	-	0
Fourhorn poacher *Hypsagonus quadricornis*	-	N/A	-	-	-	-	N/A	2	-	-	-	-	-	2
Fourline snake blenny *Eumesogrammus praecisus*	-	N/A	-	-	-	-	N/A	10	-	-	-	-	-	10
Gelatinous sea snail *Liparis fabricii*	-	N/A	-	-	-	-	N/A	-	-	-	-	-	-	0
Hairhead sculpin *Trichocottus brashnikovi*	-	N/A	-	-	-	-	N/A	1	-	-	-	-	-	1
Halfbarred pout *Gymnelus hemifasciatus*	-	N/A	-	-	-	-	N/A	2	-	-	-	-	-	2
Hamecon (sculpin) *Artediellus scaber*	-	N/A	4	3	46	-	N/A	23	-	53	-	-	3	132
Kelp snailfish *Liparis tunicatus*	-	N/A	2	-	3	-	N/A	-	-	6	-	-	-	11
Longhead dab *Limanda proboscidea*	-	N/A	-	-	-	-	N/A	-	-	-	-	-	-	0
Marbled eelpout *Lycodes raridens*	-	N/A	3	-	-	X	N/A	1	-	2	-	-	-	6
Myoxocephalus spp.	-	N/A	1	-	8	-	N/A	13	-	29	-	-	-	51
Pacific sandlance *Ammodytes hexapterus*	-	N/A	-	-	-	-	N/A	-	-	-	-	-	-	0
Polar eelpout *Lycodes turneri*	-	N/A	3	-	-	X	N/A	-	-	-	-	X	1	4
Prickleback - unidentified	-	N/A	-	-	-	-	N/A	-	-	-	-	-	-	0
Ribbed sculpin *Triglops pingelii*	-	N/A	-	-	-	-	N/A	3	-	6	-	-	-	9
Sculpin - unidentified	-	N/A	-	1	10	-	N/A	1	-	1	-	-	-	13
Shorthorn sculpin *Myoxocephalus scorpius*	X	N/A	-	-	1	-	N/A	11	-	7	-	-	-	19
Slender eelblenny *Lumpenus fabricii*	-	N/A	1	1	7	-	N/A	1	-	-	-	-	-	10
Snailfish - unidentified	-	N/A	-	-	-	-	N/A	-	-	-	-	-	-	0
Spatulate sculpin *Icelus spatula*	-	N/A	-	-	-	-	N/A	-	-	-	-	-	-	0
Stout eelblenny *Anisarchus medius*	-	N/A	4	-	3	X	N/A	-	X	-	-	X	8	15
Variegated snailfish *Liparis gibbus*	-	N/A	-	-	-	-	N/A	-	-	-	-	-	-	0
Total	X	N/A	33	24	193	X	N/A	144	X	121	X	X	14	529

Appendix A4. Counts of fish captured with a 3-meter beam trawl in the Statoil study area.

Species	SF-001	SF-003	SF-005	SF-007	SF-009	SF-011	SF-014	SF-016	SF-018	SF-020	SF-022	Total
Alligatorfish *Aspidophoroides monopterygius*	-	-	-	-	-	-	-	-	-	-	-	0
Arctic alligatorfish *Ulcina olrikii*	1	3	-	1	-	-	-	-	-	-	-	5
Arctic cod *Boreogadus saida*	5	31	7	4	5	7	3	17	83	5	7	174
Arctic shanny *Stichaeus punctatus*	-	-	-	-	-	-	-	-	-	-	-	0
Arctic staghorn sculpin *Gymnocanthus tricuspis*	-	-	-	-	-	-	-	-	-	-	-	0
Bering flounder *Hippoglossoides robustus*	1	-	-	-	2	-	-	-	-	1	-	4
Eelblenny - unidentified	-	-	-	-	-	-	-	-	-	-	-	0
Eelpouts - unidentified	-	-	-	-	-	-	-	-	-	-	-	0
Eyeshade sculpin *Nautichthys pribilovius*	-	-	-	-	-	-	-	-	-	-	-	0
Fish doctor *Gymnelis viridis*	-	-	-	-	-	-	-	-	-	-	-	0
Flatfish - unidentified	-	-	-	-	-	-	-	-	-	-	-	0
Fourhorn poacher *Hypsagonus quadricornis*	-	-	-	-	-	-	-	-	-	-	-	0
Fourline snake blenny *Eumesogrammus praecisus*	-	-	-	-	-	-	-	-	-	-	-	0
Gelatinous sea snail *Liparis fabricii*	-	-	-	-	-	-	-	-	-	-	-	0
Hairhead sculpin *Trichocottus brashnikovi*	-	-	-	-	-	-	-	-	-	-	-	0
Halfbarred pout *Gymnelus hemifasciatus*	-	-	-	-	-	-	-	-	-	-	-	0
Hamecon (sculpin) *Artediellus scaber*	-	2	-	-	-	-	-	-	-	-	-	2
Kelp snailfish *Liparis tunicatus*	1	-	-	-	-	-	1	-	-	-	1	3
Longhead dab *Limanda proboscidea*	-	-	-	-	-	-	-	-	-	-	-	0
Marbled eelpout *Lycodes raridens*	-	1	-	-	1	-	-	-	1	-	1	4
Myoxocephalus spp.	-	-	-	-	-	-	-	-	-	-	-	0
Pacific sandlance *Ammodytes hexapterus*	-	-	-	-	-	-	-	-	-	-	-	0
Polar eelpout *Lycodes turneri*	-	2	-	-	-	-	-	1	1	1	16	21
Prickleback - unidentified	-	-	-	-	-	-	-	-	-	-	-	0
Ribbed sculpin *Triglops pingelii*	-	-	-	-	-	-	-	-	-	-	1	1
Sculpin - unidentified	-	1	-	-	1	-	-	-	-	-	1	3
Shorthorn sculpin *Myoxocephalus scorpius*	-	-	-	2	-	-	2	-	1	-	-	5
Slender eelblenny *Lumpenus fabricii*	-	1	-	-	1	-	-	1	-	-	1	4
Snailfish - unidentified	-	-	-	-	-	-	-	-	-	-	-	0
Spatulate sculpin *Icelus spatula*	-	-	-	-	-	-	-	-	-	-	-	0
Stout eelblenny *Anisarchus medius*	-	1	-	1	-	1	-	2	1	-	16	22
Variegated snailfish *Liparis gibbus*	1	-	-	-	-	-	-	-	-	-	-	1
Total	9	42	7	8	10	8	6	21	87	7	44	249

Appendix A5. Counts of fish captured with a 3-meter beam trawl in the Transition study locations.

Species	TF-001	TF-002	TF-003	TF-004	TF-005	TF-006	Total
Alligatorfish *Aspidophoroides monopterygius*	-	-	-	-	-	-	0
Arctic alligatorfish *Ulcina olrikii*	13	2	28	2	2	1	48
Arctic cod *Boreogadus saida*	12	4	3	9	17	21	66
Arctic shanny *Stichaeus punctatus*	-	-	-	-	-	-	0
Arctic staghorn sculpin *Gymnocanthus tricuspis*	1	2	-	-	1	-	4
Bering flounder *Hippoglossoides robustus*	-	-	1	-	-	-	1
Eelblenny - unidentified	-	-	-	-	-	-	0
Eelpouts - unidentified	-	-	-	-	-	-	0
Eyeshade sculpin *Nautichthys pribilovius*	-	-	-	-	-	-	0
Fish doctor *Gymnelis viridis*	-	-	-	-	-	-	0
Flatfish - unidentified	-	-	-	-	-	-	0
Fourhorn poacher *Hypsagonus quadricornis*	-	-	-	-	-	-	0
Fourline snake blenny *Eumesogrammus praecisus*	-	-	-	-	-	-	0
Gelatinous sea snail *Liparis fabricii*	-	-	-	-	-	-	0
Hairhead sculpin *Trichocottus brashnikovi*	-	-	-	-	-	-	0
Halfbarred pout *Gymnelus hemifasciatus*	2	1	-	-	-	-	3
Hamecon (sculpin) *Artediellus scaber*	2	-	2	-	-	3	7
Kelp snailfish *Liparis tunicatus*	-	1	1	-	1	-	3
Longhead dab *Limanda proboscidea*	-	-	-	-	-	-	0
Marbled eelpout *Lycodes raridens*	2	-	-	-	-	-	2
Myoxocephalus spp.	1	-	-	-	-	-	1
Pacific sandlance *Ammodytes hexapterus*	-	-	-	-	-	-	0
Polar eelpout *Lycodes turneri*	9	1	-	-	-	-	10
Prickleback - unidentified	-	-	-	-	-	-	0
Ribbed sculpin *Triglops pingelii*	-	-	1	-	-	-	1
Sculpin - unidentified	-	-	-	-	-	-	0
Shorthorn sculpin *Myoxocephalus scorpius*	-	-	-	-	-	1	1
Slender eelblenny *Lumpenus fabricii*	-	1	1	-	-	-	2
Snailfish - unidentified	-	-	-	-	-	-	0
Spatulate sculpin *Icelus spatula*	-	-	-	-	-	-	0
Stout eelblenny *Anisarchus medius*	34	12	5	-	1	1	53
Variegated snailfish *Liparis gibbus*	-	-	-	-	-	-	0
Total	76	24	42	11	22	27	202

Appendix A6. Counts of fish captured with a 3-meter plumb staff beam trawl in the Burger study area. "X" denotes fish observed in a non-quantitative sample. NOTE: BF-013 catch totals are from only half of the total catch. Due to the amount of material in the net it was subsampled.

Species	BF-001	BF-003	BF-005	BF-007	BF-009	BF-011	BF-013	BF-015	BF-017	BF-019	BF-021	BF-023	BF-025	Total
Alligatorfish *Aspidophoroides monopterygius*	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Arctic alligatorfish *Ulcina olrikii*	-	-	-	-	1	3	1	-	-	-	-	-	-	5
Arctic cod *Boreogadus saida*	-	-	X	3	-	8	13	1	10	11	6	6	6	64
Arctic shanny *Stichaeus punctatus*	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Arctic staghorn sculpin *Gymnocanthus tricuspis*	-	-	-	1	-	-	-	1	-	-	-	-	-	2
Bering flounder *Hippoglossoides robustus*	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Eelblenny - unidentified	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Eelpouts - unidentified	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Eyeshade sculpin *Nautichthys pribilovius*	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Fish doctor *Gymnelis viridis*	-	1	-	1	-	-	1	-	-	-	-	-	-	3
Flatfish - unidentified	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Fourhorn poacher *Hypsagonus quadricornis*	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Fourline snake blenny *Eumesogrammus praecisus*	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Gelatinous sea snail *Liparis fabricii*	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Hairhead sculpin *Trichocottus brashnikovi*	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Halfbarred pout *Gymnelus hemifasciatus*	-	-	2	2	-	-	6	-	2	1	-	-	-	13
Hamecon (sculpin) *Artediellus scaber*	1	-	2	-	-	1	1	-	-	2	-	-	-	7
Kelp snailfish *Liparis tunicatus*	-	-	-	-	1	-	1	-	-	1	-	-	-	3
Longhead dab *Limanda proboscidea*	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Marbled eelpout *Lycodes raridens*	-	1	3	-	-	-	-	-	2	-	-	-	2	8
Myoxocephalus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Pacific sandlance *Ammodytes hexapterus*	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Polar eelpout *Lycodes turneri*	-	-	-	-	-	-	-	2	1	1	-	-	2	6
Prickleback - unidentified	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Ribbed sculpin *Triglops pingelii*	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Sculpin - unidentified	-	1	-	-	-	-	-	-	-	-	-	-	-	1
Shorthorn sculpin *Myoxocephalus scorpius*	1	-	-	-	-	1	1	-	-	1	-	-	-	4
Slender eelblenny *Lumpenus fabricii*	-	-	X	-	-	-	-	-	-	-	1	-	-	1
Snailfish - unidentified	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Spatulate sculpin *Icelus spatula*	-	-	-	1	-	-	3	-	-	-	-	-	-	4
Stout eelblenny *Anisarchus medius*	-	-	1	-	3	-	-	1	-	-	-	2	-	7
Variegated snailfish *Liparis gibbus*	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Total	2	3	11	8	5	13	27	5	15	17	7	8	10	124

Appendix A7. Catches of fish captured with a 3-meter plumb staff beam trawl in the Klondike study area.

Species	KF-001	KF-003	KF-005	KF-007	KF-009	KF-011	KF-013	KF-015	KF-017	KF-019	KF-021	KF-023	KF-025	Total
Alligatorfish *Aspidophoroides monopterygius*	-	-	-	-	-	-	-	-	-	-	-	1	1	2
Arctic alligatorfish *Ulcina olrikii*	1	4	1	1	2	-	6	-	-	-	-	1	-	16
Arctic cod *Boreogadus saida*	59	68	10	1	1	2	11	1	24	4	94	6	2	283
Arctic shanny *Stichaeus punctatus*	-	-	-	-	-	-	-	1	-	-	-	-	-	1
Arctic staghorn sculpin *Gymnocanthus tricuspis*	7	11	3	1	21	-	4	2	-	1	-	-	-	50
Bering flounder *Hippoglossoides robustus*	-	-	1	-	-	-	2	-	-	-	2	5	-	10
Eelblenny - unidentified	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Eelpouts - unidentified	-	-	-	-	-	-	1	-	-	-	-	-	-	1
Eyeshade sculpin *Nautichthys pribilovius*	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Fish doctor *Gymnelis viridis*	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Flatfish - unidentified	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Fourhorn poacher *Hypsagonus quadricornis*	-	-	-	-	-	-	-	-	-	1	-	-	-	1
Fourline snake blenny *Eumesogrammus praecisus*	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Gelatinous sea snail *Liparis fabricii*	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Hairhead sculpin *Trichocottus brashnikovi*	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Halfbarred pout *Gymnelus hemifasciatus*	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Hamecon (sculpin) *Artediellus scaber*	5	2	-	4	2	-	7	3	-	7	-	-	-	30
Kelp snailfish *Liparis tunicatus*	-	2	2	1	2	-	2	1	-	-	-	-	-	10
Longhead dab *Limanda proboscidea*	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Marbled eelpout *Lycodes raridens*	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Myoxocephalus spp.	40	6	5	-	-	-	1	2	1	-	4	-	-	59
Pacific sandlance *Ammodytes hexapterus*	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Polar eelpout *Lycodes turneri*	-	2	1	-	3	2	10	-	-	-	3	10	-	31
Prickleback - unidentified	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Ribbed sculpin *Triglops pingelii*	-	-	-	-	-	-	-	-	-	1	-	-	-	1
Sculpin - unidentified	1	4	1	-	-	-	4	-	-	-	-	-	-	10
Shorthorn sculpin *Myoxocephalus scorpius*	4	-	-	1	3	-	-	-	-	1	-	-	-	9
Slender eelblenny *Lumpenus fabricii*	3	6	4	-	12	-	10	1	1	-	3	-	-	40
Snailfish - unidentified	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Spatulate sculpin *Icelus spatula*	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Stout eelblenny *Anisarchus medius*	-	-	6	-	1	3	2	-	2	-	2	15	1	32
Variegated snailfish *Liparis gibbus*	-	-	1	-	-	-	-	-	-	-	-	-	-	1
Total	120	105	35	9	47	7	60	11	28	15	108	38	4	587

Appendix A8. Catches of fish captured with a 3-meter plumb staff beam trawl in the Statoil study area. "X" denotes fish observed in a non-quantitative sample.

Species	SF-001	SF-003	SF-005	SF-007	SF-009	SF-011	SF-014	SF-016	SF-018	SF-020	SF-022	Total
Alligatorfish *Aspidophoroides monopterygius*	-	-	-	-	-	-	-	-	-	-	-	0
Arctic alligatorfish *Ulcina olrikii*	1	1	1	-	-	-	-	-	-	-	1	4
Arctic cod *Boreogadus saida*	3	6	3	7	1	2	-	2	8	1	15	48
Arctic shanny *Stichaeus punctatus*	-	-	-	-	-	-	-	-	-	-	-	0
Arctic staghorn sculpin *Gymnocanthus tricuspis*	-	-	-	-	-	-	-	-	-	-	-	0
Bering flounder *Hippoglossoides robustus*	-	-	-	-	-	-	-	-	-	-	-	0
Eelblenny - unidentified	-	-	-	-	-	-	-	-	-	-	-	0
Eelpouts - unidentified	-	-	-	-	-	-	-	-	-	-	-	0
Eyeshade sculpin *Nautichthys pribilovius*	1	-	-	-	-	-	-	-	-	-	-	1
Fish doctor *Gymnelis viridis*	-	1	-	-	-	-	-	-	-	-	-	1
Flatfish - unidentified	-	-	-	-	-	-	-	-	-	-	-	0
Fourhorn poacher *Hypsagonus quadricornis*	-	-	-	-	-	-	-	-	-	-	-	0
Fourline snake blenny *Eumesogrammus praecisus*	-	-	-	-	-	-	-	-	-	-	-	0
Gelatinous sea snail *Liparis fabricii*	-	-	-	-	-	-	-	-	-	-	-	0
Hairhead sculpin *Trichocottus brashnikovi*	-	-	-	-	-	-	-	-	-	-	-	0
Halfbarred pout *Gymnelus hemifasciatus*	2	2	-	-	1	-	1	1	-	-	-	7
Hamecon (sculpin) *Artediellus scaber*	1	3	-	1	-	-	-	-	-	-	-	5
Kelp snailfish *Liparis tunicatus*	-	-	-	-	-	-	-	-	-	-	-	0
Longhead dab *Limanda proboscidea*	-	-	-	-	-	-	-	-	-	-	-	0
Marbled eelpout *Lycodes raridens*	1	-	2	-	1	1	X	2	-	-	-	7
Myoxocephalus spp.	-	-	-	-	-	-	-	-	-	-	-	0
Pacific sandlance *Ammodytes hexapterus*	-	-	1	-	-	-	-	-	-	-	-	1
Polar eelpout *Lycodes turneri*	1	2	1	1	-	-	2	3	-	1	5	16
Prickleback - unidentified	-	1	-	-	-	-	-	-	-	-	-	1
Ribbed sculpin *Triglops pingelii*	-	-	-	-	-	-	-	-	-	-	-	0
Sculpin - unidentified	-	-	-	-	-	-	-	-	-	-	-	0
Shorthorn sculpin *Myoxocephalus scorpius*	-	-	-	-	-	-	-	-	1	-	-	1
Slender eelblenny *Lumpenus fabricii*	-	-	-	-	-	-	-	-	-	-	-	0
Snailfish - unidentified	-	-	-	-	-	-	-	-	-	-	-	0
Spatulate sculpin *Icelus spatula*	-	-	-	-	-	-	-	-	-	-	-	0
Stout eelblenny *Anisarchus medius*	-	-	2	-	-	-	X	-	1	-	1	4
Variegated snailfish *Liparis gibbus*	-	-	-	-	-	-	-	-	-	-	-	0
Total	10	16	10	9	3	3	5	8	10	2	22	98

Appendix A9. Catches of fish captured with a 3-meter plumb staff beam trawl in the Transition study locations.

Species	TF-001	TF-002	Total
Alligatorfish	-	-	0
Aspidophoroides monopterygius			
Arctic alligatorfish	4	3	7
Ulcina olrikii			
Arctic cod	2	9	11
Boreogadus saida			
Arctic shanny	-	-	0
Stichaeus punctatus			
Arctic staghorn sculpin	-	-	0
Gymnocanthus tricuspis			
Bering flounder	-	-	0
Hippoglossoides robustus			
Eelblenny - unidentified	-	-	0
Eelpouts - unidentified	-	-	0
Eyeshade sculpin	-	-	0
Nautichthys pribilovius			
Fish doctor	-	-	0
Gymnelis viridis			
Flatfish - unidentified	-	-	0
Fourhorn poacher	-	-	0
Hypsagonus quadricornis			
Fourline snake blenny	-	-	0
Eumesogrammus praecisus			
Gelatinous sea snail	-	-	0
Liparis fabricii			
Hairhead sculpin	-	-	0
Trichocottus brashnikovi			
Halfbarred pout	1	-	1
Gymnelus hemifasciatus			
Hamecon (sculpin)	1	1	2
Artediellus scaber			
Kelp snailfish	1	-	1
Liparis tunicatus			
Longhead dab	-	-	0
Limanda proboscidea			
Marbled eelpout	2	-	2
Lycodes raridens			
Myoxocephalus spp.	-	-	0
Pacific sandlance	-	-	0
Ammodytes hexapterus			
Polar eelpout	1	-	1
Lycodes turneri			
Prickleback - unidentified	-	-	0
Ribbed sculpin	-	-	0
Triglops pingelii			
Sculpin - unidentified	-	-	0
Shorthorn sculpin	-	-	0
Myoxocephalus scorpius			
Slender eelblenny	-	-	0
Lumpenus fabricii			
Snailfish - unidentified	-	-	0
Spatulate sculpin	-	-	0
Icelus spatula			
Stout eelblenny	1	17	18
Anisarchus medius			
Variegated snailfish	-	-	0
Liparis gibbus			
Total	13	30	43

Appendix A10. Catches of fish captured with an Isaacs-Kidd midwater trawl in the Burger study area.

Species	BF-001	BF-003	BF-005	BF-007	BF-009	BF-011	BF-013	BF-015	BF-017	BF-019	BF-021	BF-023	BF-025	Total
Alligatorfish *Aspidophoroides monopterygius*	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Arctic Alligatorfish *Ulcina olrikii*	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Arctic cod *Boreogadus saida*	-	-	-	-	2	-	-	2	-	-	-	-	-	4
Arctic staghorn sculpin *Gymnocanthus tricuspis*	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Bering flounder *Hippoglossoides robustus*	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Eelblenny - misc	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Flatfish - misc	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Gelatinous sea snail *Liparis fabricii*	-	-	-	-	-	-	1	-	-	-	-	-	-	1
Kelp Snailfish *Liparis tunicatus*	-	-	-	-	-	-	-	1	-	-	-	-	-	1
Longhead dab *Limanda proboscidea*	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Myoxocephalus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Pacific sandlance *Ammodytes hexapterus*	-	-	-	-	2	-	-	-	-	-	-	-	-	2
Prickleback -misc	-	-	-	-	1	-	-	-	-	-	-	-	2	3
Shorthorn sculpin *Myoxocephalus scorpius*	1	-	-	-	-	-	-	-	-	-	-	-	-	1
Slender eel blenny *Lumpenus fabricii*	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Snailfish - misc	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Stout eel blenny *Anisarchus medius*	-	-	-	-	-	-	-	1	-	-	-	-	-	1
Total	1	0	0	0	5	0	1	4	0	0	0	0	2	13

Appendix A11. Catch of fish captured with an Isaacs-Kidd midwater trawl in the Klondike study area.

Species	KF-001	KF-003	KF-005	KF-007	KF-009	KF-011	KF-013	KF-015	KF-017	KF-019	KF-021	KF-023	KF-025	Total
Alligatorfish *Aspidophoroides monopterygius*	-	N/A	-	-	-	-	N/A	-	-	-	-	2	-	2
Arctic Alligatorfish *Ulcina olrikii*	1	N/A	1	-	-	-	N/A	2	1	2	-	-	-	7
Arctic cod *Boreogadus saida*	-	N/A	3	-	-	5	N/A	-	-	-	-	1	-	9
Arctic staghorn sculpin *Gymnocanthus tricuspis*	-	N/A	-	-	-	1	N/A	-	-	1	-	-	-	2
Bering flounder *Hippoglossoides robustus*	1	N/A	-	-	-	-	N/A	-	-	-	-	-	-	1
Eelblenny - misc	-	N/A	-	-	-	-	N/A	-	1	-	-	2	-	3
Flatfish - misc	-	N/A	-	-	2	-	N/A	-	-	-	-	-	-	2
Gelatinous sea snail *Liparis fabricii*	-	N/A	-	-	-	-	N/A	-	-	-	-	-	-	0
Kelp Snailfish *Liparis tunicatus*	-	N/A	-	-	-	-	N/A	-	-	-	-	-	-	0
Longhead dab *Limanda proboscidea*	-	N/A	-	-	-	-	N/A	-	-	-	-	-	-	0
Myoxocephalus sp.	1	N/A	-	-	-	-	N/A	-	-	-	-	-	-	1
Pacific sandlance *Ammodytes hexapterus*	-	N/A	-	1	-	1	N/A	1	-	2	-	-	-	5
Prickleback -misc	-	N/A	-	-	-	1	N/A	-	-	-	-	-	2	3
Shorthorn sculpin *Myoxocephalus scorpius*	-	N/A	-	-	-	-	N/A	-	-	-	2	-	-	2
Slender eel blenny *Lumpenus fabricii*	-	N/A	-	-	-	-	N/A	-	-	-	-	-	-	0
Snailfish - misc	-	N/A	-	-	-	-	N/A	-	-	-	-	-	-	0
Stout eel blenny *Anisarchus medius*	-	N/A	-	-	-	-	N/A	1	-	-	-	-	-	1
Total	3	N/A	4	1	2	8	N/A	4	2	5	2	5	2	38

Appendix A12. Catches of fish captured with an Isaacs-Kidd midwater trawl in the Statoil study area.

Species	SF-001	SF-003	SF-005	SF-007	SF-009	SF-011	SF-014	SF-016	SF-018	SF-020	SF-022	Total
Alligatorfish *Aspidophoroides monopterygius*	-	-	-	-	1	-	-	-	-	-	-	1
Arctic Alligatorfish *Ulcina olrikii*	-	-	-	-	-	1	-	1	-	-	-	2
Arctic cod *Boreogadus saida*	-	-	-	-	-	-	-	-	1	-	-	1
Arctic staghorn sculpin *Gymnocanthus tricuspis*	-	-	-	-	-	-	-	-	-	-	-	0
Bering flounder *Hippoglossoides robustus*	-	-	-	-	-	-	-	-	-	-	-	0
Eelblenny - misc	-	-	-	-	-	-	-	-	-	-	-	0
Flatfish - misc	-	-	-	-	1	-	-	1	-	-	9	11
Gelatinous sea snail *Liparis fabricii*	-	-	-	-	-	-	-	-	-	-	-	0
Kelp Snailfish *Liparis tunicatus*	-	-	-	-	-	-	-	-	-	-	-	0
Longhead dab *Limanda proboscidea*	-	-	-	-	1	-	1	-	-	1	-	3
Myoxocephalus sp.	-	-	-	-	-	-	-	-	-	-	-	0
Pacific sandlance *Ammodytes hexapterus*	-	-	-	-	-	-	-	-	-	-	-	0
Prickleback -misc	-	-	-	-	-	-	-	-	1	-	-	1
Shorthorn sculpin *Myoxocephalus scorpius*	-	-	-	-	-	-	-	-	-	-	-	0
Slender eel blenny *Lumpenus fabricii*	-	-	-	-	-	-	-	-	-	-	-	0
Snailfish - misc	-	-	-	-	-	-	-	-	-	-	-	0
Stout eel blenny *Anisarchus medius*	-	-	-	-	-	-	-	-	-	-	-	0
Total	0	0	0	0	3	1	1	2	2	1	9	19

Appendix A13. Catches of fish captured with an Isaacs-Kidd midwater trawl in the Transition study locations.

Species	TF-001	TF-002	TF-003	TF-004	TF-005	TF-006	Total
Alligatorfish *Aspidophoroides monopterygius*	-	-	-	-	-	-	0
Arctic Alligatorfish *Ulcina olrikii*	-	1	-	-	-	-	1
Arctic cod *Boreogadus saida*	1	1	-	-	-	-	2
Arctic staghorn sculpin *Gymnocanthus tricuspis*	-	-	-	-	-	-	0
Bering flounder *Hippoglossoides robustus*	-	-	-	-	-	-	0
Eelblenny - misc	-	-	-	-	-	-	0
Flatfish - misc	-	-	-	-	-	-	0
Gelatinous sea snail *Liparis fabricii*	-	-	-	-	-	-	0
Kelp Snailfish *Liparis tunicatus*	1	-	-	-	-	-	1
Longhead dab *Limanda proboscidea*	-	-	-	1	-	-	1
Myoxocephalus sp.	-	-	-	-	-	-	0
Pacific sandlance *Ammodytes hexapterus*	1	1	-	-	-	-	2
Prickleback -misc	-	1	-	-	-	-	1
Shorthorn sculpin *Myoxocephalus scorpius*	-	-	-	-	-	-	0
Slender eel blenny *Lumpenus fabricii*	1	-	-	-	-	-	1
Snailfish - misc	1	-	-	-	-	-	1
Stout eel blenny *Anisarchus medius*	-	-	-	-	-	1	1
Total	5	4	0	1	0	1	11

Appendix A14. Environmental data associated with fish sampling sites. CTD data were collected by vertical cast of a SeaBird CTD at the site. Substrate analysis is from Blanchard (2010) and Blanchard and Parris (unpublished data). All data are from 2010 except for station KF-021; this location was not substrate sampled in 2010 so 2009 data is substituted.

				H_2O	Total Organic	Substrate		
Site	Depth (m)	Temperature (°C)	Salinity (psu)	Content (%)	Carbon (%)	% Gravel	% Sand	% Mud
BF001	42	0.80	32.20	14.43	2.99	9.8	49.5	40.7
BF003	43	0.80	32.40	13.24	3.94	1.3	51.9	46.8
BF005	47	0.60	32.20	10.49	3.92	0.0	77.0	23.0
BF007	42	-0.30	32.40	20.99	5.68	0.0	7.5	92.5
BF009	43	-0.60	32.60	23.03	5.56	1.6	21.4	77.0
BF011	41	-0.09	32.50	24.11	9.09	2.2	12.5	85.3
BF013	44	-1.30	32.60	19.46	7.53	22.0	12.9	65.1
BF015	44	-0.95	32.60	16.92	2.44	0.0	31.1	68.9
BF017	39	-1.43	32.70	27.86	4.84	5.4	44.9	49.7
BF019	42	-1.50	32.70	24.95	7.82	0.9	7.6	91.5
BF021	39	-0.70	32.50	16.67	4.19	9.3	40.1	50.7
BF023	41	-1.40	32.80	14.56	5.41	6.2	55.5	38.3
BF025	41	-1.20	32.90	14.63	7.28	0.3	14.8	84.9
KF001	42	3.50	32.20	11.06	2.92	33.9	29.0	37.1
KF003	41	4.35	32.20	15.34	1.97	2.7	67.2	30.1
KF005	45	4.49	32.20	16.09	4.37	11.2	34.4	54.5
KF007	41	3.87	32.10	8.96	2.38	33.0	41.2	25.7
KF009	39	2.00	32.15	15.98	3.72	1.9	54.5	43.6
KF011	42	3.95	32.20	13.10	3.46	0.1	53.5	46.4
KF013	39	5.10	32.25	11.49	2.43	0.4	62.3	37.3
KF015	36	3.60	31.90	10.33	2.16	2.2	86.9	11.0
KF017	41	2.30	32.10	15.97	4.39	0.1	36.9	63.0
KF019	36	2.40	32.10	6.93	1.24	60.6	30.0	9.5
KF021	41	3.75	32.20	22.26	3.84	0.3	22.5	77.2
KF023	42	4.80	32.10	15.69	4.70	0.0	28.7	71.3
KF025	42	0.20	32.30	14.69	5.56	0.0	45.7	54.3
SF001	42	0.80	32.40	18.64	5.03	0.4	22.8	76.8
SF003	41	-0.90	32.40	20.27	4.42	0.0	15.6	84.4
SF005	37	-0.70	32.50	12.46	1.86	2.2	63.5	34.3
SF007	37	0.20	32.20	10.49	2.29	0.0	63.1	36.9
SF009	36	-0.50	32.50	12.90	0.98	0.0	52.2	47.8
SF011	38	-1.00	32.50	15.05	3.67	0.0	50.3	49.7
SF014	37	-0.20	32.50	14.53	2.25	0.0	45.1	54.9
SF016	41	-0.90	32.50	19.68	4.84	0.0	20.9	79.1
SF018	36	-1.20	32.60	14.49	5.60	0.0	15.7	84.3
SF020	37	-0.19	32.40	14.84	1.08	4.2	65.0	30.8
SF022	37	-0.19	32.20	13.01	2.30	0.7	57.3	42.1
TF001	42	1.80	32.10					
TF002	43	1.30	32.19					
TF003	43	2.40	32.30					
TF004	41	0.30	32.30					
TF005	41	0.90	32.20					
TF006	43	-0.90	32.50					

APPENDIX B – PHOTOS

Appendix B1. Various species of sculpins found within the study areas.

Appendix B2. A very diverse haul from Klondike shows many different species of benthic invertebrates.

Appendix B3. A typical haul from Burger shows the high amount of benthic invertebrates, especially brittle stars and basket stars.

Appendix B4. The catch results of an IKMT haul were often jellyfish (seen in the bucket) and small ichthyoplankton (seen in the sieve). This haul is from Klondike.

Appendix B5. An Arctic cod caught in Burger.

Appendix B6. A very large shorthorn sculpin caught in Klondike.

APPENDIX C

Recommended Modifications to Sampling Equipment and Protocols

Recommendation 1:

Based on the authors experience and that of other authors, sampling for pelagic fish should be accompanied with an acoustic survey to find concentrations of fish so that sampling efforts are directed toward specific targets.

Recommendation 2:

Results of this study have demonstrated the efficacy of Model 38 Skate beam trawls as tools for sampling the small sized fish found in Arctic waters. However, even with mud raisins fitted to the foot rope permitting the net to glide over the bottom there were times when the net mudded up due to high invertebrate catches or cobble sized rocks or mud balls or all three. Discussions with the net designer indicated that the net could be fitted with rock chutes that will allow cobbles and mud balls to pass out of the net before reaching the cod end and thereby reducing the amount of mud entering the net. Installation of a rock chute does not affect the net's ability to capture and retain fish.

Recommendation 3:

To further reduce catches of invertebrates, we recommend shortening tow time for the 3mBT from 30 to 15 minutes.

Recommendation 4:

Review of the catch data indicate that the beam trawls used during this study may have under sampled Arctic cod. Discussions with the net designer indicate that the existing beam trawl nets can be modified into high-rise nets to better sample Arctic cod without reducing the nets ability to capture small demersal fishes. These nets can be modified to have a vertical (2-3m) opening similar to the standard NMFS 83/112 eastern otter trawl.

Recommendation 5:

All nets should be equipped with a temperature-depth-tilt recorder to ensure that the duration of each tow can be determined accurately. During this study, the duration of each tow was considered conservative because the net likely reached the bottom before all of the tow cable had been paid out and remained on the bottom after haul back commenced.