University of Alaska

Coastal Marine Institute

Recent and Historical Distribution and Ecology of Demersal Fishes in the Chukchi Sea Planning Area

Principal Investigator
Brenda L. Norcross
School of Fisheries and Ocean Sciences
University of Alaska Fairbanks

Collaborators
Brenda A. Holladay
Catherine W. Mecklenburg

Final Report

March 2013
OCS Study BOEM 2012-073

Bureau of Ocean Energy Management

University of Alaska Fairbanks

Contact Information:
email: cmi@alaska.edu
phone: 907.474.6782
fax: 907.474.7204

Coastal Marine Institute
School of Fisheries and Ocean Sciences
University of Alaska Fairbanks
P. O. Box 757220
Fairbanks, AK 99775-7220

This study was funded in part by the U.S. Department of the Interior, Bureau of Ocean Energy Management (BOEM) through Cooperative Agreement M07AC12462 (previously as M07AC13416) between BOEM, Alaska Outer Continental Shelf Region, and the University of Alaska Fairbanks. This report, OCS Study BOEM 2012-073, is available through the Coastal Marine Institute, select federal depository libraries, and electronically at: *http://www.boem.gov/Environmental-Stewardship/Environmental-Studies/Alaska-Region/Index.aspx.*

Contents

List of Figures

Chapter I

Chapter II

List of Tables

Chapter I

Chapter II

Executive Summary

Assessment of fish resources in the eastern Chukchi Sea is particularly important not only because of the lack of current knowledge but also because of the potential for changes to the ecosystem concurrent with changing climate and anthropogenic use of the region, e.g., oil and gas exploration, fisheries, and vessel use of the area. In the northeastern Chukchi Sea, U.S. Lease Sale 193 is now being explored for oil and gas reserves.

Prior to this study, fish survey information in the Chukchi Sea was limited to a few historical surveys conducted from 1959 through 1992 and in 2004, and collection data from most of these surveys were not readily accessible in electronic format. The objectives of this report were to make historical haul-catch databases available in georeferenced electronic format and to conduct scientific cruises in 2007 and 2008 to collect new fish data to provide a current ecological perspective that could be compared with historical records and could serve as a baseline for future comparisons. Because fish distributions are affected by the Alaska Coastal Water, Bering Sea Water and Winter Water, the study area of this CMI research project was expanded beyond Lease Sale 193 to include as much of the eastern Chukchi Sea as we were able to sample.

The eastern Chukchi Sea, including parts of Lease Sale 193 that are being considered for oil and gas development, was sampled for abundance of fishes historically (1990 and 1991) and recently (2004, 2007 and 2008). Catch-per-unit-effort was lower in the historical catches than in the recent ones. Based on previous collections (Alverson and Wilimovsky, 1966; Frost and Lowry, 1983; Barber et al., 1997), we had expected Arctic cod (*Boreogadus saida*) to play a more dominant role in recent collections, but that was not the case. The larger nets used in collections prior to 2004 have higher mouth openings thus enabling capture of *B. saida* not directly on the bottom, which likely contributes to the apparent decline in *B. saida* over 15 years. Although gear affects the number of fishes captured, the dominant fishes caught were the same in the recent and historical collections: Arctic cod (*B. saida*), Arctic staghorn sculpin (*Gymnocanthus tricuspis*), shorthorn sculpin (*Myoxocephalus scorpius*), eelpouts (*Lycodes* spp.), Bering flounder (*Hippoglossoides robustus*) and saffron cod (*Eleginus gracilis*). There are differences in composition of the demersal fish assemblages in the eastern Chukchi Sea in 2004–2008 (Table I-8) and in 1990–1991 (Table I-10). Examination of voucher specimens from the historical cruises (Mecklenburg et al. 2006, 2007; Mecklenburg and Mecklenburg 2009; this study) revealed misidentifications that, when corrected, reduced the at least 60 species (and six taxa reported as genus) originally reported (Barber et al., 1997) to three pelagic species, at least 45 demersal species and nine taxa we report at genus or family level from 15 presently recognized families; we recently captured two pelagic species, at least 46 demersal species, and five taxa we report at genus or family, from 13 families (Table I-2). Catchability affects abundance, which in turn affects assemblage composition, thus the differences in assemblages are confounded by the use of different trawls in the two decadal assemblages. In both time frames fish assemblages are closely associated with cruise, i.e., year and season of collections, than with physical parameters. Furthermore, the physical parameters that correlate with fish abundance differ interannually and no single factor has a consistent effect on abundance. These results indicate that timing, exact locations, and gear selection are important determinants of fish abundance and assemblage compositions and should be considered when designing studies to test effects of physical factors on fish populations.

Fishes were collected in the Chukchi Sea in 13 years over the 50-year period from 1959 through 2008. Over the 15 cruises for which we had sufficient data to analyze, there were 501 unique bottom hauls, at 406 stations. Cruises were in the ice-free months June–September, though most cruises were in August and September. Approximately 169,000 fishes were collected, representing at least 59 species from 17 families. Eight different configurations of trawl gears were used; therefore we based all analyses, except calculations of species richness and diversity, on presence/absence instead of abundance. Richness and diversity indices were high, indicating stable community structures, at and straight north of Bering Strait, including the southwest part of Lease Sale 193. In contrast, richness and diversity were low, indicating low stability, in the northern parts of Lease Sale 193. All diversity measures are higher in 2004–2008 than in the preceding decades. Richness and diversity patterns of fish communities are known to be affected by the physical environment which changes over time and space. Although these analyses were based on presence, not abundance, use of various trawl nets over the 50-year time frame confounds the interpretation of the results. Despite that, low diversity in the northern part of Lease Sale 193 is indicated by every analytical tool that we used in this study. Therefore, direct comparisons of gear, especially between the 83-112 eastern otter trawl used in 1990–1991 with equipment that measured horizontal opening and the plumb staff beam trawl used in 2004–2008 as reported here, and in 2009–2012, are needed to verify these findings.

This report consists of an Executive Summary, two chapters detailing and analyzing fish data in the eastern Chukchi Sea, acknowledgements, study products and literature cited. Appendices include a list of acronyms (Appendix A), database design and structure (Appendix B), cruise reports for 2007–2008 collections (Appendix C), details of the process of incorporating data from 1959–2004 collections (Appendix D), and some analyses of historical fish (1959–1992) and water mass (1983–2008) distributions (Appendix E). The two sections address the objectives for Coastal Marine Institute M07AC13416. The overall project objective is to document the abundance and distribution of fishes in the Chukchi Sea. Chapter I reports on recent (2004–2008) scientific demersal fish collections in the eastern Chukchi Sea and compares recent and historical fish communities. Chapter II corrects identification of historical archived fishes from collections in the eastern Chukchi Sea, and describes the design of the database of recent and historical fish data resulting from this Coastal Marine Institute project. Both chapters provide a baseline for future research and monitoring of the fish resource in relation to oil and gas exploration.

One objective of this study was to develop a database of demersal fish catches and associated habitat parameters from research collections within Lease Sale 193. The design of the Chukchi Demersal Fish (CDF) Database is presented in Appendix B. This database is more comprehensive than just Lease Sale 193. It includes all hauls in the Chukchi Sea from each cruise that entered the Lease Sale area, i.e., collections south, west and east. Two major historical collections were included although all hauls were south of the lease area. Data were retrieved from a variety of sources including published journal articles, contract reports, and electronic databases. A brief description of each historical cruise and catch method is found in Appendix D, along with details of the sources of data, and steps taken during the present research to standardize and correct those data. Fish specimens preserved from past cruises were examined by C.W. Mecklenburg during a series of visits to museums, and the identifications on record were either confirmed or revised (Mecklenburg et al. 2006, 2007; Mecklenburg and Mecklenburg 2009; this study). A summary of the discrepancies encountered in museum collections and earlier reported identification versus Mecklenburg's review and our recommendation for taxonomic level of analysis for past collections are presented in Appendix D.

Objectives

Comparisons of recent (2004–2008) and historical (1990–1991) collections of demersal fishes in the eastern Chukchi Sea (Chapter I)

1. Collect and retain demersal fishes in the eastern Chukchi Sea in 2007 and 2008.
2. Combine Chukchi demersal fish data from all available fish collections that used identical fishing gear during 2004–2008 to document recent species abundance, distribution, geographic range, species assemblages, and habitat parameters in the offshore eastern Chukchi Sea.
3. Determine and compare physical characteristics of the habitats that define demersal fish communities.
4. Compare 2004–2008 and 1990–1991 demersal fish communities in and near the Chukchi Sea Lease Sale 193.

Historical collections of demersal fishes in the eastern Chukchi Sea over 50 years, 1959–2008 (Chapter II, Appendices)

5. Contribute to the effort (Mecklenburg et al., 2006, 2007; Mecklenburg and Mecklenburg, 2009) to review and correct the identification of fish specimens from historical 1959–1992 collections in the northeastern Chukchi Sea, that presently are archived in museums in the United States, Canada, Japan, and Russia, to allow for accurate comparison with recent collections.
6. Incorporate recent and historical scientific fish collection data from the eastern Chukchi Sea into an electronic database (Chukchi Demersal Fish Database provided to BOEM).
7. Analyze historical distribution patterns of demersal fish communities in the eastern Chukchi Sea.

Major Project Conclusions

1. This examination indicates that no single physical variable always influences the composition of demersal fish assemblages in the eastern Chukchi Sea. Bottom temperature most often has an effect, though depth, salinity or water mass may at times affect composition of demersal fish assemblages.
2. This recent research on 2004–2008 collections analyzed abundance instead of presence, had a greater number of samples, and had a narrower geographic focus in only the eastern Chukchi than the Norcross et al. (2010) research that examined the entire Chukchi Sea. In contrast to the whole Chukchi Sea, in the eastern Chukchi Sea, water mass does not appear consistently to contribute significantly to the composition of fish assemblages.
3. Although gear affects the number of fishes captured, the dominant species are the same in recent and historical collections: Arctic cod (*Boreogadus saida*), shorthorn sculpin (*Myoxocephalus scorpius*), Arctic staghorn sculpin (*Gymnocanthus tricuspis*), eelpouts (*Lycodes* spp.), Bering flounder (*Hippoglossoides robustus*) and saffron cod (*Eleginus gracilis*).
4. Arctic cod appears not to be as abundant in recent years as in the Barber et al. (1997) historical cruises. This may be a true change over time, or it quite likely may be, in part, an artifact of gear.

5. Interannual and seasonal timing and physical parameters at location of collections are important determinants of fish abundance and assemblage compositions and should be considered when designing studies to test effects of physical factors on fish populations.
6. Using smaller mesh nets to collect fish in the eastern Chukchi Sea produces greater richness and diversity indices, i.e., more fish taxa are collected because small-sized species are retained.
7. There appears to have been an increase in fish diversity in recent years. Although 2004–2008 collections were all from small-mesh nets, the diversity was greater compared to collections from similar nets in 1973–1983.
8. Low indices of richness and evenness, which typify low stability communities, have been observed in the northern region of Lease Sale 193. These low indices may, in part, be due to the few samples collected here.
9. Fish diversity is highest at and straight north of Bering Strait, including the southwest portion of Lease Sale 193. High indices of richness and evenness in this area are indicative of high community stability.
10. Variability in year, month and location of collections over 50 years confound interpretation of effects on fish in this study of physical environment factors, i.e., temperature, salinity, depth and water mass.
11. Fish collections during 1959–2008 are not directly comparable because various trawl net configurations were used to collect fish, and therefore the conclusions of this report should be considered with caution.
12. Direct comparisons of gear, especially the 83-112 eastern otter trawl and the 3 m plumb staff beam trawl (Table II-1), are needed to verify these findings.
13. Caution should be exercised when interpreting all results because of small and large scale spatial and temporal variability in historical fish collections.
14. Based on this study, we recommend that consistent monitoring of fish and associated oceanographic variables in Lease Sale 193 be conducted with the same trawl gear, in late August every 3–5 years.

Chapter I. Comparisons of recent (2004–2008) and historical (1990–1991) collections of demersal fishes in the eastern Chukchi Sea Authors: Brenda Norcross, Brenda Holladay

I.1 Introduction

Simultaneous climate change and development activities, e.g., potential exploration for oil and gas, are under way in the eastern Chukchi Sea (Figure I-1), but until recently knowledge of the fish in this area was limited to a few historical surveys conducted from 1959 through 1992 (see Chapter II). Interest in oil and gas exploration prompted fish surveys in 1990 and 1991 (Barber et al., 1997) as well as more recently. The paucity of fish and ecosystem data can be attributed to several reasons. Logistics and sampling in this remote Arctic region are particularly expensive, and traditional fish surveys can only be accomplished during the ice-free summer season. The Chukchi Sea is outside the range of the National Oceanic and Atmospheric Administration's Alaska Fishery Science Center regular fish trawl surveys, there has been no notable effort for commercial fishing in the eastern Chukchi Sea, and subsistence fishing is limited to large fishes for human consumption that are taken closer to shore than the Chukchi Sea Lease Sale 193. In 2009, the North Pacific Fisheries Management Council adopted, and the Secretary of Commerce approved, an Arctic Fishery Management Plan (FMP) that prohibits new commercial fishing in U.S. Chukchi Sea waters. The FMP closes the Arctic Management Area to commercial fishing so that unregulated fishing does not occur until information is sufficient that fishing can be conducted sustainably and with due concern for other ecosystem components (*www.fakr.noaa.gov/npfmc/current_issues/Arctic/arctic.htm*; NPFMC, 2009). Knowledge of the current status of fish populations in the eastern Chukchi Sea is necessary to identify vulnerable fish species, their life stages, and essential habitats.

The Chukchi Sea is a shallow, approximately 50 m deep, marginal sea of the Arctic Ocean. It is bordered on the west by the Russian coast and the East Siberian Sea, on the north by the deep waters of the Arctic Ocean basins, on the east by the Beaufort Sea and Alaskan coast, and on the south by Bering Strait. Waters flow northward into the Chukchi Sea from the Pacific Ocean through Bering Strait. The area of primary interest to the Bureau of Ocean Energy Management (BOEM) is the Chukchi Sea Lease Sale 193 area in the northeastern Chukchi Sea that is being considered for oil and gas exploration (Figure I-1). Understanding fish distribution in the Lease Sale 193 area requires knowledge of circulation of water into, around and through that area, and therefore the study area of this CMI research project includes the entire eastern Chukchi Sea. Bering Sea Water (BSW) flows into the Chukchi Sea as a combination of cooler Anadyr Water from the west and the relatively warm and salty Bering Shelf Water from the east. BSW flows northward, westward (Weingartner et al., 2008) and through Lease Sale 193. Warm, dilute Alaskan Coastal Water (ACW) flows northward through Bering Strait and generally flows alongshore and through the eastern part of Lease Sale 193. Warm and salty Atlantic Water upwells into Barrow Canyon, along the northeastern edge of Lease Sale 193. Winter Water (WW) is a very cold and salty subsurface mass on the west side of BSW that is transported eastward across the Chukchi Sea (Pickart et al., 2010). This area is affected by reduced or absent sea ice cover (ACIA, 2004; Polyak et al., 2010), which impacts circulation (Perovich, 2011). Hydrographic features, which may be permanent or transient, are expected to have significant biological implications (Weingartner et al., 1999).

Surveys of bottom fishes provide information about fish assemblages over broad areas and environmental associations (Ellis et al., 2000). Assemblages are groups of species that respond similarly to environment cues (Tyler et al., 1982; Overholtz and Tyler, 1985) and consist of mainly the same group of species over time, although their geographical distribution might change (Fossheim et al., 2006). Therefore, the objective of Chapter I is to use our four recent demersal fish surveys, i.e., 2004–2008 (Figure I-2a), to compare to historical quantitative fish collections in the eastern Chukchi Sea. Short-term interannual comparisons could be made within and between our recent collections and the set of historical cruises that used the same gear in the northeastern Chukchi Sea in two consecutive years (Barber et al., 1997; i.e., 1990–1991 (Figure I-2b).

I.2 Methods

I.2.1 Recent field collections (2004–2008)

We collected demersal fishes with a small bottom trawl during four multidisciplinary oceanographic research cruises in 2004, 2007 and 2008 (Table I-1). All four cruises sampled in the eastern Chukchi Sea and Bering Strait. The 2004 cruise sampled south of Chukchi Sea Lease Sale 193 area, and two cruises in 2007 and 1 in 2008 sampled within and south of the lease area (Figure I-2a). The Russian-American Long-term Census of the Arctic (RUSALCA) program aboard the R/V *Professor Khromov* sampled fishing sites over a wide area of the Chukchi Sea during 1–22 August 2004 (cruise RUSALCA-2004, cruise 2004-Norcross in this report). Fish presence from the entire collection area was reported previously (Mecklenburg et al., 2007; Norcross et al., 2010). Abundance of fish from the four easternmost stations in the 2004-Norcross collections from the eastern Chukchi Sea and Bering Strait were reinterpreted for the more limited geographic extent of the present report. This Coastal Marine Institute (CMI) project provided support for field sampling from the T/S *Oshoro-Maru* during 5–15 August 2007 (cruise OS180, cruise 2007a-Norcross in this report) and 6–17 July 2008 (cruise OS190, cruise 2008-Norcross in this report). The Bering–Aleutian Salmon International Survey (BASIS cruise OD0710, cruise 2007b-Norcross in this report) sampled from the R/V *Oscar Dyson* during 29 August – 17 September 2007. Holladay participated in each of the four cruises; Mecklenburg participated aboard 2004-Norcross and 2007b-Norcross. While the CMI did not financially support Holladay and Mecklenburg's participation during the 2004-Norcross and 2007b-Norcross cruises, the data are relevant to this CMI project and this is the first comprehensive report of fish abundance from those cruises; Mecklenburg et al. (2007) had previously reported the number caught per haul of some species during 2004-Norcross. Our research aboard each of these cruises was to assess the distribution and abundance of small (mostly <150 mm) demersal fishes in the Lease Sale 193 and adjoining areas.

The overall sampling area of each cruise was selected by our hosts, i.e., RUSALCA, Hokkaido University Faculty of Fish (*Oshoro-Maru*), and BASIS research programs and the chief scientists aboard each cruise. A generous amount of time for bottom trawling was provided on each cruise to conduct our project. Fishing sites in 2004 were selected to provide geographic coverage of the entire Chukchi Sea and included multiple sites within each water mass. Fishing sites in 2007 and 2008 were selected to provide as comprehensive a geographic coverage as possible near and inside Chukchi Sea Lease Sale 193, to sample as far north as the ice-cover, and to sample multiple sites as opposed to replicate sampling of a small number of sites. Collections in the eastern Chukchi Sea during 2004-Norcross and 2007b-Norcross were well south of the ice edge, while 2007a-Norcross and 2008-Norcross sampled close to and south of the retreating ice edge north to 71º N. The western limit of each 2007–2008 cruise was near the 169º W border between Russian and US waters; therefore for this CMI research we selected a study area consisting of Bering Strait and the Chukchi Sea east of 169º W and north of 65.5º N. From this study area, we collected fish at six sites during 2004-Norcross, 16 sites during each of 2007a-Norcross and 2008-Norcross, and 23 sites during 2007b-Norcross (Table I-1, Figure I-2a).

The same fishing techniques were used during each of the four cruises (Table I-1). The 2004-Norcross, 2007a-Norcross and 2008-Norcross collections took place day and night, while the 2007b-Norcross collections were made only at night. We deployed a small bottom trawl, i.e., a 3.05 m plumb staff beam trawl (PSBT) with 7 mm mesh in the body and 4 mm mesh in the codend, modified with a lead-filled footrope and six inch sections of chain seized to the footrope every six inches (after Gunderson and Ellis, 1986). While fishing, the vertical opening of the net was approximately 1.2 m. The effective horizontal swath was 2.26 m, i.e. 74% of the beam length. The net was fished with scope of wire 3–4:1 and vessel speed of approximately 1–1.5 kt. Latitude and longitude of the vessel were marked by Global Positioning System (GPS) when all cable was deployed and again when cable retrieval began; distance towed was calculated between these positions. The trawl was fished on the bottom for 1–8 minutes, although most hauls were only 2–5 minutes or less where we anticipated mud, rock, or a large biomass of animals. Tows were considered quantitative for catch-per-unit-effort (CPUE) where the net was not damaged nor filled beyond the codend, and where the tow cable was observed to vibrate in a fairly constant manner during the tow. Catches containing a notable quantity of mud were towed at the surface to reduce mud content before being brought aboard. Substrate observed within the catch contents was recorded. Bottom samples collected with sediment grabs during 2004-Norcross were examined for percent grain size (Grebmeier et al., 2006). As no scientific collections of substrate occurred during the 2007–2008 cruises, substrate observations from net sampling were used with the following caution. The PSBT was effective at collecting shell hash, gravel, cobble, and boulder. Sand from 2007–2008 sites was likely underreported because the small grain size of sand allows it to pass through the mesh without being collected. Mud often clogs the mesh and thus is more accurately reported. From each cruise, other investigators analyzed conductivity, temperature, density (CTD) casts at fishing and additional sites: 2004-Norcross: R. Pickart, Woods Hole Oceanographic Institution; 2007a-Norcross: Hokkaido University (2008); 2007b-Norcross: L Eisner, Alaska Fisheries Science Center/NOAA; 2008-Norcross: Hokkaido University (2009).

Fishes were processed at sea. Fishes were assigned a preliminary identification, to species whenever possible, and measured for total length in millimeters. Published fish identification keys and descriptions of morphological features (e.g., Matarese et al., 1989; Mecklenburg et al., 2002, 2010), as well as largely unpublished morphological and genetic information gained by C. W. Mecklenburg through research on the region's fishes, were used for identification of fishes. Species were reported using nomenclature in the American Fisheries Society's most recent publication of scientific and common names (Nelson et al., 2004). One weight per fish taxon was recorded using hand-held hanging scales (2007a-Norcross and 2008-Norcross) or a Marel motion compensating scale (2007b-Norcross); no weights were recorded during 2004-Norcross.

Post-cruise processing of fishes included verification or determination of identifications in the laboratory, fixation and preservation of voucher specimens, and deposition of specimens and tissues. Whole specimens of all fish species were retained to document the catch and for taxonomic research. Specimens were deposited in the permanent fish collections of the California Academy of Sciences (CAS); the University of Alaska Museum of the North (UAMN); the Russian Academy of Sciences (Zoological Institute, St. Petersburg; ZIN); and the Institute of Marine Science, University of Alaska Fairbanks. For the 2007 and 2008 collections, muscle tissue was excised from selected vouchers for verification of identifications by DNA sequencing ("barcoding"). This was particularly important for small juveniles, which can be quite different in appearance from the adults. Sequences were provided and statistically compared by the Biodiversity Institute of Ontario, University of Guelph, Guelph, Canada, to samples from other Arctic cruises, in the Barcode of Life Database (*www.fishbol.org*), thereby providing confirmation of identification (Mecklenburg et al., 2011). Fish specimens from which tissues were excised for barcoding have been archived at CAS, UAMN, and ZIN, and collection details and barcode sample ID numbers are available from Mecklenburg et al. (2010; Online Resources 3 and 4).

I.2.2 Data analyses – Recent (2004–2008) and historical (1990–1991)

Analyses of abundance were limited to demersal fish taxa. As with all bottom trawl collections, it is possible that some fishes were captured off the sea floor. This is because nets are open during setting and retrieving as well as while on the bottom. Fishes generally considered to be demersal may also be caught in midwater, including larval and early juvenile stages of cods, sculpins, pricklebacks, and flatfishes, and late juvenile and adult cods, all of which can be present in large numbers in the water column during the same time frame as they are caught on the sea floor. Larval and early juvenile stages of snailfishes, poachers, eelpouts, and some other demersal fishes generally do not enter the plankton or midwater, but develop at the same depths the adults inhabit and are more likely to have been caught on the bottom. Regardless, there is no way to assess whether fishes were actually caught in the water column or on the sea floor. For all analyses we included all fish species that are considered to be demersal and excluded those that are considered to be pelagic, i.e., herrings, smelts, sticklebacks.

The four recent cruises all collected fishes using a single gear type, and thus a comparable catch-per-unit-effort (CPUE) could be calculated. CPUE was calculated as the number of fish captured per square kilometer by multiplying the haul distance in meters by the 2.26 m effective swath of the trawl, and proportionally multiplying the count of fish to number per square kilometer. Demersal fishes captured in quantitative hauls at a station were included in analyses; stations with qualitative hauls, i.e., presence only, were not included in analysis. For stations (sample sites) at which replicate hauls were made, CPUE values from all quantitative hauls were averaged.

Two cruises in the early 1990s (1990-Barber and 1991-Barber) used the same type of net and same vessel as part of a Minerals Management Service (now BOEM) study in the northeastern Chukchi Sea (Table I-1). During those two cruises an 83-112 eastern otter trawl was towed for 30 minutes from the F/V *Ocean Hope III* (Barber et al., 1997). Net mensuration gear was attached to the net to measure horizontal and vertical opening during hauls in the 1990 survey. The mean horizontal opening was 15.3±0.9 m and vertical opening was 2.7±0.2 m. The mean width of trawl path during the 1990 survey was applied to catches during the 1991 survey. Bottom depth, temperature and salinity data were taken from Smith et al.

(1994). CPUE was calculated from the area swept for the historical collections as for the recent collections, i.e., length of haul as measured by GPS multiplied by width of trawl path during tow. Although fish assemblages were previously presented (Barber et al., 1997), for the present analysis we applied our methods to original 1990 and 1991 data, as modified by corrected identifications from review and examination of voucher specimens in a series of visits to the University of Alaska Museum of the North by C.W. Mecklenburg in 2000, 2002, 2004 and 2006 (Mecklenburg et al. 2002, 2006, 2007; Mecklenburg and Mecklenburg 2009) (Chapter II and Appendix D). Within the recent and historical collections, CPUE values were compared to each other. However, as trawl nets were not the same in the two collection sets, fish abundance (CPUE) could not be statistically compared between them.

To analyze fish assemblages, we used separate hierarchical cluster analyses (CLUSTER, PRIMER v. 6.1) for CPUE of species at stations using the Bray-Curtis dissimilarity coefficient. CPUE values were 4^{th}-root transformed prior to constructing Bray-Curtis dissimilarity coefficients that were used in cluster and similarity analyses. Cluster analysis was used because it resolves inter-species associations, allowing an examination of community structure (as adapted from Doyle et al., 2002). A hierarchical cluster analysis for 1000 permutations identified fish assemblages that grouped stations according to their species composition. The resulting dendrogram displays groupings of stations into smaller numbers of groups containing more stations. The dendrogram that was produced for each cruise was used to establish station groups for demersal fishes.

When employing cluster analysis, the biological or environmental conditions that are being examined must be considered. Cluster analysis may find groups even if they are not relevant in nature, i.e., it is possible for random data to produce groups. A Similarity Profile test (SIMPROF, PRIMER v.6.1) is a permutation test of the null hypothesis (Clarke and Gorley, 2006), i.e., it tests whether distributions of fishes are equal. SIMPROF was used to test the significance of each grouping of fish presence that resulted from the cluster analysis. When the statistical test of clusters (SIMPROF) is not significant, it is inappropriate to consider further differentiation (Clarke et al., 2008).Alternatively, it may be appropriate to group supersets of statistically different clusters when cluster analysis results in only 1 or two stations, as those might not be valid groups (Clarke et al., 2008). Therefore we interpreted the results of cluster analyses based on our accompanying knowledge of the fishes and the environment in the Chukchi Sea.

Bottom temperature and salinity data from fishing and other stations were examined using both standard potential density plots and cluster analyses to delineate bottom water masses. Water masses were identified using a standard oceanographic technique, i.e., potential density plots derived from temperature and salinity (Ocean Data View v.2.3.3, Schlitzer, 2007) and a technique that is described above and is commonly employed by biologists and ecologists, i.e., dendrograms. One thousand permutations of cluster analysis (CLUSTER, PRIMER v. 6.1) were used to delineate water masses from CTD records of bottom temperature and salinity. Temperature and salinity data were normalized and Euclidean distances were calculated between stations, as is appropriate for physical data (Clarke and Gorley, 2006).

For each cruise, Analysis of Similarity (ANOSIM, PRIMER software v. 6.1) was used to estimate differences in species abundance and composition relative to water mass, bottom temperature, bottom salinity, and depth. ANOSIM is a nonparametric, multivariate permutation test, somewhat analogous to the parametric, univariate ANOVA. ANOSIM treatment groups were defined *apriori*, i.e., the environmental factors examined. Because the habitat parameters were not symmetrical, multiple 1-way ANOSIMs were run; the Bonferroni is not applied to ANOSIM. CPUE values for each taxon at each station were 4th root transformed prior to calculate Bray-Curtis dissimilarity matrices. To provide the best reasonable result, 1000 permutations were run for each ANOSIM. An R statistic, defined as a comparison of the average between-group rank similarity to the average within-group rank similarity, was calculated using the following formula:

$$R = \frac{\left(\bar{r}_B - \bar{r}_W\right)}{n(n-1)}$$

where $\bar{r}_B$ and $\bar{r}_W$ are the average rank similarities for each pair of intervals between and within groups, respectively, and n is the sample size. The R value is between -1 and 1, and the closer R is to 1, the more distinct the groups are.

Species that were good discriminators within cruises and between cruises were identified using Similarity Percentage (SIMPER, PRIMER v. 6.1). SIMPER provides a statistical mechanism to characterize groups and to compare between groups. This test is a breakdown, by species, of Bray-Curtis similarities within groups and dissimilarities between two groups. The objective was to find typicality, i.e., what species typify group A and not group B and vice versa. The result was a list in decreasing order of each species' contribution to the group. Because we performed these analyses on abundance (CPUE), a 4th root transformation was employed prior to the SIMPER analysis.

Habitat characteristics of fishes were examined using bottom temperature (ºC), bottom salinity, bottom depth (m), and sediment type. Substrate observations made from net sampling in 2004 were combined with sediment grab data; only observation data, and no sediment analysis, existed for 2007–2008. Rock, gravel, shell, sand and mud were each categorized as present or absent for inclusion in the analysis based on one or a combination of these methods. The fish CPUE data from each cruise were normalized and all possible combinations of physical variables were examined using Biota and/or Environment + STepwise matching (BEST, PRIMER v. 6.1). This test identifies the 'best' match between the multivariate fish assemblage patterns and the environmental variables associated with those samples (Clarke and Gorley, 2006). Determination of the best subset of correlated variables, i.e., habitat characteristics, was based on the highest overall correlation. However, fewer explanatory parameters are preferable; when little improved correlation was to be gained by including additional parameters.

I.3 Results

I.3.1 Recent collections (2004–2008)

I.3.1.2 Within collections

We collected 14,266 fishes by small bottom trawl at 60 stations in Bering Strait and the eastern Chukchi Sea during four recent cruises: 2004-Norcross, August – 515 fish; 2007a-Norcross, August – 1465 fish; 2007b-Norcross, September – 11,359 fish; 2008-Norcross, July – 2236 fish (Figure I-2a). Catches were predominantly (>80% by number) sculpins, pricklebacks, cods, and flatfishes. Fishes representing at least 45 demersal species in 11 families were captured (Table I-2). The uncertainty of number of taxa is due to some taxa having been identified only to genus or family rather than to species.

Three bottom water masses were distinguished in the recent collections, but all water masses were not found in each year (Table I-3; Appendix E Figures E.3.30–E.3.44). Alaska Coastal Water (ACW) was detected during 2004-Norcross and 2007a-Norcross, Bering Sea Water (BSW) was identified during all cruises, and Winter Water (WW) was found only during 2007b-Norcross. In 2004, BSW extended beyond our eastern Chukchi Sea study area (Norcross et al., 2010.) Water masses and their characteristics varied interannually and seasonally; i.e., the range of temperature and salinity values that determined the water masses were not static (Table I-3).

During cruise 2004-Norcross, four fishing stations within the eastern Chukchi study area had quantitative catches of fishes (Figure I-2a). Cluster analyses of species abundance yielded two assemblages ($P<0.01$) of stations that were 75% dissimilar. Fishing stations were located in two water masses (Table I-3). Assemblage 2004-A was made up of two stations in the ACW (Norcross et al., 2010). Shorthorn sculpin (*Myoxocephalus scorpius*), slender eelblenny (*Lumpenus fabricii*) and saffron cod (*Eleginus gracilis*) made up 43% of the abundance in Assemblage 2004-A. Assemblage 2004-B included 1 station in each of two different water masses, the ACW and the BSW (Norcross et al., 2010). Stout eelblenny (*Anisarchus medius*), Bering flounder (*Hippoglossoides robustus*) and Arctic staghorn sculpin (*Gymnocanthus tricuspis*) composed 80% of the abundance of Assemblage 2004-B. The two fish assemblages from four stations in 2004 were not significantly related to any of the measured physical parameters (Table 1-4), which had a wide range of measurements (Table I-1).

Cruise 2007a-Norcross had nine fishing stations with quantitative catches of fish CPUE (Figure I-2a). Cluster analyses of this cruise yielded two assemblages of fish abundances within a single water mass. The two groups of stations ($P<0.05$) were 72% dissimilar. Station C16, in the southwestern part of the Lease Sale area at ~70^{o} N, grouped by itself as Assemblage 2007a-A. It had fewer species than Assemblage 2007a-B, had no *H. robustus,* and had three species not found in the immediately surrounding stations. The remaining eight stations were grouped as Assemblage 2007a-B, of which 55% was characterized by *H. robustus, G. tricuspis* and *M. scorpius.* All fishing stations from cruise 2007a-Norcross were in the BSW. There were no significant relationships between physical parameters and fish assemblages in cruise 2007a-Norcross (Table I-4). The bottom temperature range of these stations was broad, though the salinity range was not (Table I-1). These values yielded a wide range of densities for BSW (Table I-3).

Fish communities were examined at 20 stations from cruise 2007b-Norcross (Figure I-2a). Cluster analyses of this cruise yielded five assemblages for fish abundances ($P<0.01$), more than from the other cruises, from two water masses. Assemblage 2007b-A was made up of just two stations (1 and 37) near Bering Strait, the southernmost of which was in BSW while the other was in ACW. The composition of 78% of Assemblage 2007b-A was Arctic cod (*Boreogadus saida*), *H. robustus* and *L. fabricii.* Similar to fish grouping in 2007a-Norcross, Assemblage 2007b-B contained only 1 station (2) at the outer edge of the Lease Sale area at ~70^{o} N in BSW; likewise it had fewer fish species than the other assemblages. Another 2-station cluster, Assemblage 2007b-C, included station 38 very near Assemblage 2007b-A in

Bering Strait and a second station (22) due north at 68° N; these stations were in different water masses. Forty-four percent of the fishes in Assemblage 2007b-C were *L. fabricii, M. scorpius* and *H. robustus.* Assemblage 2007b-D was made up of seven stations that could be loosely characterized as the outer edges of the sampling area. The three most abundant species (56%) in Assemblage 2007b-D were *H. robustus, G. tricuspis* and *L. fabricii.* Five of the seven stations were in BSW. Assemblage 2007b-E, the fifth and final assemblage, included stations in southern Kotzebue Sound southeast of Point Hope and in Ledyard Bay off Cape Lisburne and Point Lay. The composition of species (56%) was *L. fabricii, M. scorpius* and *G. tricuspis.* Dissimilarity between pairs of these five assemblages ranged from a high of 74% between Assemblages 2007b-A and 2007b-E to a low of 48% between Assemblages 2007b-D and 2007b-E. Seven of the eight stations closest to the coast were in ACW. Cluster analysis of bottom temperatures and salinities resulted in two significantly (P<0.01) different groups. The ACW had temperatures of 4.6–10.7°C and salinities of 30.9–32.3. The water mass was divided into two coastal components above and below Point Hope. The BSW temperatures were cooler, -0.5 to 4.3°C, with salinities 32.1–33. The BSW was broadly distributed offshore. These values yielded a characteristic range of densities for BSW and a wider range for ACW (Table I-3). Depth, temperature and water mass were significantly related to fish assemblages in cruise 2007b-Norcross (Table I-4).

For cruise 2008-Norcross, fish communities were examined at 15 stations (Figure I-2a). Cluster analysis yielded groups for fish abundances and water masses. There were two assemblages (P<0.05) of station groups of fishes that were 53% dissimilar. Three stations off Cape Lisburne (C12, C15, and C31) composed Assemblage 2008-A; these stations were in BSW. The fish assemblage was composed primarily (86%) of *L. fabricii, H. robustus* and *Anisarchus medius.* Assemblage 2008-B included the remaining 12 stations, and 52% of Assemblage 2008-B was composed of *L. fabricii, G. tricuspis* and *B. saida.* Cluster analysis of bottom temperatures and salinities resulted in three significantly (P<0.01) different groups, though the standard potential density plots only yielded two water masses: BSW and Winter Water (WW). No ACW was identified. The BSW had a narrow range of cool temperatures, 0.7–3.2°C, and a narrow range of salinity, 31.9–32.9. All the southernmost stations were in this water mass. The northernmost stations were in WW, which had cold temperatures, -1.7 to -0.61.7°C, and slightly higher salinities, 32.1–33.4. These values yielded characteristic densities for both BSW and WW (Table I-3). For cruise 2008-Norcross, temperature, but not water mass, was significantly related to fish assemblage (Table I-4).

I.3.1.2 Among collections

The abundance of fish species differed among, as they did within, cruises. Species assemblages during all four cruises had five species in common (Table I-5). Three of the cruises shared six species, including the six species that characterized the 2004-Norcross assemblage. The most abundant species was not the same for any of the four cruises. *Gymnocanthus tricuspis* was the most abundant in 2004-Norcross, and among the top four most abundant species in all cruises. However, similarity of species collected in all four stations during 2004-Norcross was only 42%. *Myoxocephalus scorpius* was #1 in 2007a-Norcross, #2 in Norcross-2007b, but only #6 in the other two years. The 2007a-Norcross and 2008-Norcross cruises included five of the six shared species plus *B. saida* (Table I-5). *Hippoglossoides robustus* was the most abundant species in 2007b-Norcross. This cruise was different from the others in that *A. medius* did not contribute to the top 92% of the fish collected. However, three additional species contributed 11%, for a total of nine species characterizing the fish assemblage of 2007b-Norcross. Fish collections were most likely (57%) to be similar to each other in the 2008-Norcross cruise, where *L. fabricii* was the most abundant species. Species composition and abundance observed during the four cruises differed significantly (Table I-6) among cruises (*P*=0.016), but provided little insight into the interannual variability of fish species assemblages in the Chukchi Sea. Dissimilarity between each pair of the four cruises was slightly less between pairs containing 2008-Norcross (48–50%) though not notably different (52–56%). Fish assemblages were only significantly dissimilar between 2007a-Norcross and 2008-Norcross (Table I-6).

The particular physical parameters that affected fish abundances were not consistent over each cruise (Table I-7). For both the 2007 cruises and the 2008 cruise, sufficient data existed to test the effect of eight physical parameters on structuring fish assemblages: bottom temperature (ºC), bottom salinity, depth (m), and presence of rock, gravel, shell, sand and mud. Fish abundance was measured at only four stations in the eastern Chukchi Sea during 2004-Norcross, which was an insufficient quantity of stations for correlations between fish species abundance and physical parameters. The collections in 2007 and 2008 were sampled during different months. In each instance, the cruise went as far north as allowed by the ice pack. Thus the highest correlation coefficient (0.82) used only 1 parameter, the presence of mud, for the 2007a-Norcross cruise in August. Cruise 2007b-Norcross occurred in September; the best correlation with fish abundance (0.58) required three physical parameters: bottom temperature, bottom salinity and depth. In 2008-Norcross during July, a lower correlation (0.46) was achieved that required four parameters: bottom temperature, depth, presence of rock and presence of sand (Table I-7).

Combining fish abundances from all four cruises yielded five assemblages (Figure I-4a). Assemblage A was only two stations that were very near the coast; both were in ACW. Assemblage B was made up of five stations, three in Bering Strait and two near 169^{o} W but separated longitudinally (Figure I-5a); these stations were in both ACW and BSW. Three stations made up Assemblage C; all were in BSW. The geographic distribution of Assemblage C was somewhat similar to that of Assemblage B, spread longitudinally. Assemblage D was composed of 11 mostly nearshore stations between Kotzebue Sound and Point Lay. Seven of the stations were from cruise 2007b-Norcross and in ACW, whereas the other four stations were from cruises 2007a-, 2007b- and 2008-Norcross in both ACW and BSW. Assemblage E had the largest number of stations (n=27). Assemblage E included all the northernmost stations in WW, but also contained stations spread throughout the eastern Chukchi Sea in ACW and BSW (Figures I-4a and I-5b).

The composition of the five combined-fish assemblages (Figure I-4a) differed in the average within-assemblage similarity of species abundance, number of taxa that contributed to 90% of abundance, and dominant taxa. Three of the assemblages had >59% similarity, whereas two assemblages had only 43–47% similar species composition in all stations (Table I-8). Eight families, comprising 19 taxa, made up the assemblages. The number of taxa within an assemblage ranged from 5 to 11. There was no pattern between similarity and number of taxa within an assemblage, nor between number of stations (Figure I-4a) and number of taxa (Table I-8) within an assemblage. Assemblage C, which only contained five taxa, and Assemblage E, which contained eight taxa, had the same first, second and third-ranking species.

Hippoglossoides robustus, the only species to dominate two assemblages, was also the third or fourth ranked species in Assemblages B and D. The second, *L. fabricii*, and third, *G. tricuspis*, most abundant species were the only ones that contributed to the top 90% of all five assemblages. Assemblages C and E also were similar in that the fourth or fifth-ranked species was *A. medius*. Assemblage A contained nine taxa similarly distributed over two stations. The dominant species was *M. scorpius*, which was among the top four species in Assemblages B, D and E. Assemblage A contained four taxa in the top 90% that were not contained in any other assemblage: great sculpin (*Myoxocephalus polycanthocephalus),* eyeshade sculpin (*Nautichthys pribilovius)*, *Gymnelus* spp., and Arctic shanny (*Stichaeus punctatus)*. Assemblage B had 11 taxa over five relatively dissimilar stations. This was the only assemblage for which *B. saida* was the dominant species; it was ranked sixth or lower in other assemblages. The second-ranked species, saddled eelpout (*Lycodes mucosus)*, was not among the top 90% taxa in any other assemblage, nor were Arctic alligatorfish (*Ulcina olrikii*[1]*),* variegated snailfish *(Liparis gibbus)* or halfbarred pout (*Gymnelus hemifasciatus)*. Assemblage D also had 11 taxa but over 11 fairly similar stations. *Lumpenus fabricii* was the dominant species in this assemblage. Ribbed sculpin (*Triglops pingelii),* veteran poacher *(Podothecus veternus)* and wattled eelpout (*Lycodes palearis)* were unique to the top 90% of this assemblage.

I.3.2 Historical collections (1990–1991)

Three bottom water masses were distinguished in each of the historical collections (Table I-3; Appendix E Figures E.3.14–E.3.17, E.3.21–E.3.23). The ACW, BSW and WW were all found in both 1990 and 1991 (Figure I-3b.)

Although both the 1990-Barber and 1991-Barber cruises collected bottom fishes in the northeastern Chukchi Sea off the Alaska coast, they did not yield similar results. Cruise 1990-Barber sampled a broader area, including nearer to shore, for a longer period of time resulting in 48 stations being occupied. Bad weather limited the sampling area and collection time of 1991-Barber to only 16 stations (Barber et al., 1997.) The average dissimilarity in fish communities between the two collections was 58% (Table I-6). The two collections had three of the top five most abundant fish species in common (Table I-9). The relative contribution of *G. tricuspis* and of *H. robustus* was almost the same in each time period. However, the contribution of *B. saida* in 1991 was 160% of the contribution of that species in 1990. Because such a large component of the collection was *B. saida*, only three species made up 94% of the total catch in 1991. *Boreogadus saida* was a small portion of the total catch in 1990; thus six species were required to compose 91% of the catch. The small number of samples collected over a limited area in 1991 meant that samples from that cruise were more similar to each other (60%) than those collected over a broader area in 1990 (49%) and that the species composition and abundance were significantly different between the collections (R = 0.28, P = <0.01 Table I-6).

In the 1990s, bottom temperature, bottom salinity and depth were measured, but sediment characteristics were not. Therefore three was the maximum number of independent variables that could be correlated with fish abundance. Bottom temperature had a better correlation coefficient for 1990-Barber fish

---

[1] The Arctic alligatorfish *Ulcina olrikii* has more recently been classified as *Aspidophoroides olrikii* (Mecklenburg et al., 2011; Eschmeyer, 2013)

abundance than yielded by including bottom temperature, bottom salinity and depth for 1991-Barber (Table I-7).

Fish communities were examined at 48 stations from cruise 1990-Barber (Figure I-2b). Cluster analyses of this cruise yielded six assemblages for fish abundances ($P<0.05$) from three water masses. Assemblage 1990-a was made up of only two disconnected stations: 1 at Point Hope and 1 at Cape Lisburne. The composition of 55% of Group 1990-a was *Myoxocephalus* spp., yellowfin sole (*Limanda aspera*), walleye pollock (*Theragra chalcogramma*[2]), and Pacific cod (*Gadus macrocephalus*). Assemblage 1990-b comprised 14 stations at the southern extent of sampling. The most abundant taxa (52%) in Assemblage 1990-b were *B. saida*, *Myoxocephalus* spp. and *H. robustus.* Assemblage 1990-c contained five stations in Ledyard Bay. A single station (14) that was closely associated, though statistically different, was included in Assemblage 1990-c. Fifty-five percent of the fishes in Assemblage 1990-c were *B. saida*, saffron cod (*Eleginus gracilis*), *G. tricuspis,* and *Myoxocephalus* spp. The 13 stations of Assemblage 1990-d were north and offshore of Assemblages 1990-a, -b, and -c. The two most abundant taxa (64%) in Assemblage 1990-d were *B. saida* and *Lycodes* spp. Assemblage 1990-e was a unique assemblage of seven north and nearshore stations that was composed (63%) of *B. saida* and *Myoxocephalus* spp. Assemblage 1990-f included the six stations of the northeastern border of the sample area of which 92% was *Boreogadus saida*. Dissimilarity between pairs of these six groups was greatest (84%) between Assemblage 1990-a and 1990-f and least (44%) between Assemblage 1990-b and 1990-c.

Cluster analysis of bottom temperatures and salinities at 41 stations from cruise 1990-Barber resulted in three significantly ($P<0.01$) different groups. Temperature and salinity data were not available from the other seven stations. The ACW had a wide range of temperatures, 5.7–12.7º C, and characteristic low salinity of 29.5–30.4 (Table I-3). The ACW was found at 11 stations nearshore from Point Hope to just north of Point Lay, underlying Assemblages 1990-a and 1990-c. The BSW was classified by combining statistically different groups. That resulting water mass was very wide and distributed offshore of the ACW and encompassed most of the sample area. The BSW temperatures were -0.2 to 7.1º C and salinities were 30.8–32.6. The WW was confined to four northeastern stations and had cold temperatures, -1.2 to -0.6º C, and higher salinities, 32.6–33.3. Temperature and water mass were significantly related to fish assemblage in cruise 1990-Barber ($P<0.01$, Table I-4). No bottom substrate data were recorded during 1990-Barber or 1991-Barber.

For cruise 1991-Barber, cluster analyses of species abundance from 16 stations (Figure I-2b) yielded three assemblages ($P<0.05$). Fishing stations were located in three water masses (Table I-3). Assemblage 1991-a was made up of four nearshore stations from Point Hope to Icy Cape. The southernmost station was in ACW while the others were in WW. Assemblage 1991-b included five stations in the southwestern portion and two stations in the eastern portion of Lease Area 193, all of which were in WW. *Boreogadus saida* was the dominant species in both Assemblage 1991-a (95%) and Assemblage 1991-b (74%). The four stations in Assemblage 1991-c was widely separated: two were north of Cape Lisburne in BSW and

---

[2] The walleye pollock *Theragra chalcogramma* has more recently been classified as *Gadus chalcogrammus* (Mecklenburg et al., 2011; Eschmeyer, 2013)

two were in the northeast portion of Lease Area 193 in WW. *Boreogadus saida*, *G. tricuspis* and *M. scorpius* made up 78% of the abundance in Assemblage 1991-c.

Cluster analysis of bottom temperatures and salinities from 1991-Barber resulted in three significantly (P<0.01) different groups (Table I-3). The ACW was found at only 1 very nearshore station off Point Hope. It had a temperature of 7.1ºC and salinity of 29.5. The BSW was limited to two stations just off Cape Lisburne. The temperature range was 1.5–4.2ºC and salinity was 31.0–31.8. The WW was present at most of the stations sampled. It had characteristically cold temperatures, -01.7 to 0.4ºC, and higher salinities, 32.2–33.5. These characteristics yielded a wide range of densities for WW (Table I-3). There were no significant relationships between fish abundance and physical factors (Table I-4.)

Combining fish abundances from the 1990 and 1991-Barber cruises yielded five assemblages (Figure I-4b). These were not markedly different from 1990-Barber alone, as 75% of the data came from that collection. Assemblages V, W and X contained no 1991-Barber stations; they were the same as 1990-a, 1990-b and 1990-c (Figure I-5b). Assemblage Y had the largest number of stations (n=32) and was composed of all the stations from Assemblages 1990-d and 1990-e, plus station 1990-26 from Assemblage 1990-f. It also contained all the stations from Assemblages 1991-a and 1991-b. Assemblage Z included all the stations from 1990-f and all the stations from 1991-c.

The composition of the five assemblages from the combined historical data (Figure I-4b) differed in the average within-assemblage similarity of species abundance, number of taxa that contributed to 90% of abundance, and dominant taxa. All of the assemblages had >52% similar species composition in all stations (Table I-10). Seven families, comprising 16 taxa, made up the assemblages. The number of taxa within an assemblage ranged from only 1 in Assemblage Z to 11 in Assemblage X. There was no pattern between similarity and number of taxa within an assemblage, nor between pattern of stations (Figure I-5b) and number of taxa (Table I-10) within an assemblage. There was a strong latitudinal pattern of fish assemblages (Figure I-5b). Assemblage W was offshore from Point Hope north to 69.5°N, and was in the southern part of Lease Sale 193. Assemblage V and X were in ACW inshore of Lease Sale 193, Assemblage V was near shore by Point Hope and Cape Lisburne, and Assemblage X extended from Cape Lisburne to Point Lay. Most of the stations examined during 1990–1991 were in Assemblage Y, which was offshore of Assemblages V, W, and X to the south, and extended into the nearshore north of Point Lay. Assemblage Z was found north of 71°N. *Boreogadus saida* was the most abundant species in all assemblages except Assemblage V. Assemblages V and W had the same second-ranked species, *Myoxocephalus* spp.

I.3.3 Taxa in recent (2004–2008) and historical (1990–1991) collections

Species classified as circumpolar (Mecklenburg et al., 2011) were among the most abundant demersal fish taxa collected in this study. Only one species, *Gymnocanthus tricuspis*, was among the most abundant in all of the six collections that we analyzed (Tables I-5 and I-9). It was an important contributor to all five recent and four of five historical combined-fish assemblages. *Lumpenus fabricii* was equally important in the recent collections, but not among the most abundant in historical fish collections. *Myoxocephalus scorpius* is an Arctic–boreal species (reproducing at both subzero and higher temperatures) found on continental shelves (Mecklenburg et al., 2011), where these cruises were conducted which explains its abundance on all four 2004–2008 cruises and in four of the combined-fish assemblages. It is likely that this species dominated the abundant catches of *M. scorpius* in 1990. *Boreogadus saida* is the other circumpolar species that was collected during all cruises; it contributed to just three fish assemblages in 2004–2008, and to all five assemblages historically. *Ulcina olrikii*, though abundant in all recent cruise samples, was not abundant in the historical cruises but was only a minor contributor to three fish assemblages. Although circumpolar, *Anisarchus medius* was not captured on every cruise nor was it important in every assemblage. *Triglops pingelii* composed 90% of the abundance in 1990 (Table I-9), but its contribution was small compared to the abundant species in 2004–2008 (Table I-5).

The remaining species that we observed to contribute notably to the recent (Tables I-8) and historical (Table I-10) fish assemblages are not circumpolarly distributed but have wide distribution in the Pacific-Arctic. *Hippoglossoides robustus* is distributed from the Pacific Ocean to the East Siberian, Chukchi and Beaufort Seas (Mecklenburg et al., 2011) and was the only non-circumpolar species to be collected on all cruises and to contribute significantly to nine of the ten combined-fish assemblages. *Eleginus gracilis* occupies the North Pacific, Chukchi and Beaufort seas (Mecklenburg et al. 2010). It was only collected on 1 recent and 1 historical cruise but contributed to two of each of the combined-fish assemblages.

I.4 Discussion

The eastern Chukchi Sea, including parts of Lease Sale 193 that are being considered for oil and gas exploration, was sampled in 1990, 1991, 2004, 2007 and 2008. Because fish distributions are affected by the Alaska Coastal Water, Bering Sea Water and Winter Water, the study area of this CMI research project was expanded beyond Lease Sale 193 to include as much of the eastern Chukchi Sea as we were able to sample. This study analyzed abundance of fishes as opposed to the previous research that was conducted on presence/absence of species (Norcross et al., 2010). The recent and historical collections examined here were more geographically concentrated and collected fish from larger numbers of stations than the earlier research that extended into the western Chukchi Sea, covered an area approximately twice as large, and sampled fewer stations (n=17); the present study includes four stations sampled in 2004 that also were part of the earlier study (Norcross et al., 2010). Comparing our recent collections from 2004–2008 with Barber et al.'s (1997) historical collections provides a new perspective on fish in the eastern Chukchi Sea over time.

In general, absolute numbers of fish caught are misleading; in this study, CPUE was lower in the historical catches than in the recent ones. More than 25,000 fish were captured at 64 stations in the early 1990s (Barber et al., 1997), whereas 60 stations over four years in the 2000s yielded about 14,000 fish. However, two hauls were made at 59 of the historical stations; i.e., there were 119 total historical hauls compared to 60 recent hauls. Furthermore, the historical catches were made with an 83-112 eastern otter trawl which was almost twice as wide as the plumb staff beam trawl (PSBT) used recently, and tow times were 6–15 times as long. The 83-112 trawl net had a codend liner 10 times as large as that of the PSBT. When catches from all cruises were calculated on the same basis of number per 1 km^2 (Tables I-5 and I-9) it became obvious that recent catches had greater CPUE of fish than did the historical catches. In all recent catches the most abundant species, *L. fabricii*, *M. scorpius*, *H. robustus* and *G. tricuspis*, were equal to or up to four times greater than the most abundant historical species, *B. saida*.

Based on previous collections (Alverson and Wilimovsky, 1966; Frost and Lowry, 1983; Barber et al., 1997), we had expected *B. saida* to play a more dominant role in our collections. *B. saida* catches in 1990 were an order of magnitude larger than catches of other species in the historical catches (Table I-9), and they were also an order of magnitude larger than *B. saida* in 1991 or in our recent catches (Table I-5). The larger net used in the collections prior to 2004 had higher mouth openings, thus enabling capture of *B. saida* not directly on the bottom, which may contribute to the appearance of a decline in *B. saida* over 15 years. Additionally, the only year that had the unusually high abundance of *B. saida* was 1990, when the broader sampling range may have encountered more *B. saida* schools. Thus it is possible that *B. saida* abundance has declined over 15 years, but the marked difference in the catch sizes of this species between 1990 and 1991 make it unlikely.

A recent analysis of biodiversity determined that there are at least 242 species of marine fishes in the Arctic region (Mecklenburg et al., 2011.) That source defined the Arctic region as including the entire Arctic Ocean and its seas and adjacent arctic waters of the North Atlantic and North Pacific. Compared to the circum-Arctic total of 242, it is not surprising that only 52 fish species in total were collected in the eastern Chukchi Sea in 1990–2008 (Table I-2). This total is 61–63% of the total number (83–85) of benthic (or demersal) fish species estimated to inhabit the Chukchi Sea (Mecklenburg et al. 2007). Eleven additional taxonomic levels could only be identified to genus or family, and may actually be represented in the species-level identifications. Our 2004–2008 collections included at least 45 demersal species from 11 families.

Barber et al. (1997) reported capturing 66 taxa (60 species and six higher level taxa) during 1990 and 1991. Although this appears to be more taxa than were captured in recent years, the numbers reported for 1990 and 1991 are incorrect. Examination of voucher specimens from the historical cruises led to corrections of species identifications (Mecklenburg et al., 2002, 2006, 2007, 2010; Mecklenburg and Mecklenburg 2009; Chapter II, Appendix D). For instance, examination of the voucher specimens from the 1990 and 1991 cruises determined that specimens identified as *Myoxocephalus* sp. were *M. scorpius* (Mecklenburg et al. 2007). They were morphologically similar to those identified as *M. verrucosus,* which is an older name for *M. scorpius* (Mecklenburg et al. 2002, 2007, 2010). Consequently, fish identified in the 1990 and 1991 catch records as *Myoxocephalus* sp. and *M. verrucosus* were counted in this study as *M. scorpius*. Recent reclassification of families has increased the number of families captured in these historical cruises by 4, i.e., the addition of families Hemitripteridae (sailfin sculpins) and Psychrolutidae (Fathead sculpins), which have been removed from Cottidae (sculpins), and Liparidae (snailfishes), which has been removed from Cyclopteridae. Revised results show a reduction to at least 45 demersal species from 13 families captured during the two historical cruises.

Using revised identifications, Mecklenburg et al. (2007) compared relative abundance by number of fish caught of some of the most common species in the RUSALCA 2004 beam (2004-Norcross) and otter trawls to abundance reported for the Barber et al. (1997) trawls. Similarly, for historical assemblages (Table I-10) we used the revised identifications. Reanalysis of the 1990 historical fish data using the corrected identifications resulted in slightly different fish assemblages than originally published by Barber et al. (1997). The corrected identifications, as well as recent changes in taxonomy, which affect what the species are named (but not necessarily their numbers), are summarized in Table I-2.

Differences were found in composition of the demersal fish assemblages in the eastern Chukchi Sea in 2004–2008 (Table I-8) and in 1990–1991 (Table I-10). Sixteen taxa contributed to the five fish assemblages in 1990–1991 compared to 19 taxa in the five assemblages in 2004–2008. Seven of the same species were important in at least one of the assemblages in each decade: two cods – *B. saida* and *E. gracilis*; two sculpins – *G. tricuspis* and *T. pingelii*; 1 snailfish – *Liparis gibbus*; 1 prickleback – *Lumpenus fabricii*; and 1 flatfish – *H. robustus*. Three other taxa are assumed to be shared, but because of incomplete or indefinite identifications and lack of voucher specimens they could not be classified to species level for the 1990–1991 assemblage analysis: unidentified Agonidae and *Lycodes* spp. In the historical assemblages gadids and pleuronectids had a stronger role than in recent collections (Table I-10); *B. saida* dominated four of the five assemblages. As catchability affects abundance, which in turn affects assemblage composition, the differences in assemblages are confounded by the use of different trawls in the two decadal assemblages.

In both time frames fish assemblages are closely associated with cruise, i.e., year and season of collections. For example, in the recent cruises Assemblages B and D are primarily from 2007b-Norcross (Figure I-4a.) In the historical cruises there is an even clearer demarcation in clustering of stations between years (Figure I-4b). We were not able to examine season, but in 2007 the collections were in non-overlapping cruises in August and September. The stations within, but not between, those cruises are closely aggregated with each other.

Although gear affected the number of fishes captured, the relative composition of dominant fishes caught was the same in recent and historical collections. Of the ten most abundant species or species groups in recent cruises (Table I-5), six also were among the most abundant historically: *B. saida*, *M. scorpius*, *G. tricuspis*, *Lycodes* spp., *H. robustus* and *E. gracilis* (Table I-9). However, total number and composition of fish taxa were not more similar within a cruise than between cruises, indicating that both spatial and temporal variability have an effect. Unfortunately, the cruises from which these fishes were examined were not designed cohesively to examine confounding effects of spatial variability on temporal variability.

The physical parameters correlated with fish abundance differed interannually (Table I-7), which is understandable for bottom temperature and salinity but not for the more conservative parameters of depth and sediment. Therefore, these results indicate that timing and exact location of collections were important determinants of fish assemblage compositions. Structure of fish assemblages appears to be dependent upon year and within season time of sampling.

Despite the record ice retreat in the latter years, timing of the cruises did not coincide with minimum ice extent (*nsidc.org/arcticseaicenews/index.html*). As with most cruises in the Chukchi Sea, the northward extent of sampling was limited by the southern extent of ice. Time of sampling and of ice retreat could have influenced the abundance and distribution of fishes. That is the case in the eastern Bering Sea, where timing of ice retreat affects the spring bloom and subsequent recruitment of walleye pollock (*Theragra chalcogramma*) (Mueter et al., 2006; Hunt et al., 2011) and the distribution of several boreal species has moved northward (Mueter and Litzow, 2008). However, the effect of ice retreat on distribution of fishes in the Chukchi Sea has not been measured; e.g., if the fish are under the ice they cannot be sampled by bottom trawl.

In this study the physical parameters that correlate with fish abundance differ interannually and no single factor has a consistent effect on abundance of species. That is understandable for bottom temperature and salinity but not for the more conservative parameters of depth and sediment. However, sampling during these cruises differed in the region and extent of the Chukchi Sea, number of stations, position of and space between stations, and interannual variability in fish abundance and physical parameters, all or any of which could affect correlations with fish abundance. Therefore, the results presented here indicate that timing and exact locations of collections are important determinants of fish abundance and assemblage compositions and should be considered when designing studies to test effects of physical factors on fish populations.

Fish assemblages in the Chukchi Sea have been found to separate into nearshore and offshore groupings (Barber et al., 1997) and to exhibit a strong latitudinal pattern (Figure I-5b). Similarly in the southwestern Barents Sea southern, northern and deep species assemblages are found (Fossheim et al., 2006). In the eastern Arctic Ocean assemblages relate to temperature, depth, longitude and latitude (Fossheim et al., 2006) and position of the Polar Front (Byrkjedal and Høines, 2007). As in the Barents Sea, temperature is the strongest correlate of fish abundance in the Chukchi Sea. Because individual species may be components of more than one assemblage, assemblages typify geographic or oceanographic areas better than do individual species (Jaureguizar et al., 2003).

Assemblages should be consistent through time (Fossheim et al., 2006). Nevertheless, we did not find the same patterns of assemblages in recent and historical collections. Persistence of fish assemblages can be attributed to spatial structure in physical environment (Jaureguizar et al., 2003), thus the discrepancy in our results may be attributed to changes in the environment of the Chukchi Sea over time. Although ranges of measured temperature and salinity did not differ greatly between time periods, differences in distribution of water masses were apparent. It is likely that the difference in locations of sample collections affected apparent discontinuity in fish assemblages through time. The use of different types of trawls to collect fish 15 years apart makes it impossible to definitely determine if the assemblages actually changed.

There are obvious differences in observations of fishes collected in the Chukchi Sea in 2004–2008 and in 1990–1991. In recent years Arctic cod (*B. saida*) appeared to be less abundant and other species more abundant than in the historical collections. Although species abundance was not the same across time periods, the same or similar species were the most numerous in both periods, though the fish assemblages were not. These results indicate that abundance does not have to change for assemblages of fish species in the Chukchi Sea to be restructured. Individual species may change their distributions differently from other species; therefore when one or more species changes its distribution, new community combinations will result (Parmesan et al., 2005). If monitoring fish assemblage patterns can give insight into effects of fisheries exploitation (Fossheim et al., 2006), it might also be a valuable tool for evaluating effects of oil and gas exploration, increased vessel traffic, or climate change in Arctic waters. Unfortunately, the difference in gear used to sample the two time periods confounds the conclusions as to changes in fish population structure over time. Fortunately, these confounding results may be resolved by a BOEM-funded comparison study of these two trawls, PSBT and 83-112, in the Chukchi Sea in August 2012.

I.5. Chapter I Conclusions

1. This examination indicates that no single physical variable always influences the composition of demersal fish assemblages in the eastern Chukchi Sea. Bottom temperature most often has an effect, and depth, salinity or water mass may at times affect composition of demersal fish assemblages.

2. This research analyzed abundance instead of presence, had a greater number of samples, and had a narrower geographic focus in only the eastern Chukchi than the Norcross et al. (2010) research that examined the entire Chukchi Sea. In contrast to the whole Chukchi Sea, in the eastern Chukchi Sea, water mass does not appear consistently to contribute significantly to the composition of fish assemblages.

3. Although gear affects the number of fishes captured, the dominant fishes caught were the same in recent and historical collections: Arctic cod (*Boreogadus saida*), shorthorn sculpin (*Myoxocephalus scorpius*), Arctic staghorn sculpin (*Gymnocanthus tricuspis*), eelpouts (*Lycodes* spp.), Bering flounder (*Hippoglossoides robustus*) and saffron cod (*Eleginus gracilis*).

4. Arctic cod appears not to be as abundant in recent years as indicated by Barber et al. (1997) for the 1990 and 1991 catches. This may be a true change over time, or it quite likely may be an artifact of gear.

5. Interannual and seasonal timing and physical parameters at location of collections are important determinants of fish abundance and assemblage compositions and should be considered when designing studies to test effects of physical factors on fish populations.

Table I-1. Summary of stations fished in the eastern Chukchi Sea during recent (2004–2008) and historical (1990–1991) cruises. We assigned CDF (Chukchi Demersal Fish) Cruise as a unique identifier for each cruise and gear. The division between south and north is at Point Hope (68.3°N). The number of stations fished and the number of stations with hauls quantitative for catch-per-unit-effort are indicated. Fishing gear is abbreviated as PSBT for 3 m plumb staff beam trawl and 83-112 for the 83-112 eastern otter trawl.

CDF Cruise	Cruise	Month and Year	Area of Chukchi Sea	Gear	# Fished (and CPUE) Stations	Depth (m)	Bottom Temp. (°C)	Bottom Salinity
2004-Norcross	RUSALCA-2004	Aug 2004	SE	3PSBT	6(4)	38−54	3.7−10.5	30.6−32.3
2007a-Norcross	OS180	Aug 2007	E	3PSBT	16(9)	26−51	0.4−7.5	31.9−32.6
2007b-Norcross	OD0710	Sep 2007	E	3PSBT	23(20)	28−57	-0.5−8.9	31.5−32.9
2008-Norcross	OS190	Jul 2008	E	3PSBT	16(15)	34−51	-1.7−2.9	32.2−33.1
1990-Barber	OH902	Aug-Sep 1990	NE	83-112	48(48)	14−54	-1.2−12.7	29.5−33.3
1991-Barber	OH91	Aug-Sep 1991	NE	83-112	16(16)	27−52	-1.7−0.3	32.2−33.6

Table I-2. Fish species, grouped by family, caught during recent (2004–2008) and historical (1990–1991) cruises.

Scientific name	Common name	2004-Norcross	2007a-Norcross	2007b-Norcross	2008-Norcross	1990-Barber	1991-Barber
Clupeidae	**Herrings**						
Clupea pallasi [1]	Pacific herring					x	x
Osmeridae	**Smelts**						
Osmerus mordax [1]	Rainbow smelt			x		x	x
Mallotus villosus [1]	Capelin					x	x
Gadidae	**Cods**						
Boreogadus saida	Arctic cod	x	x	x	x	x	x
Eleginus gracilis	Saffron cod	x	x	x	x	x	
Gadus macrocephalus	Pacific cod			x		x	
Theragra chalcogramma	Walleye pollock	x		x		x	
Gasterosteidae	**Sticklebacks**						
Gasterosteus aculeatus [1]	Threespine stickleback			x			
Hexagrammidae	**Greenlings**						
Hexagrammos stelleri	Whitespotted greenling	x				x	
Cottidae	**Sculpins**						
Artediellus scaber	Hamecon	x	x	x	x	x	x
Artediellus spp.	*Artediellus* spp.					x	
Gymnocanthus tricuspis	Arctic staghorn sculpin	x	x	x	x	x	x
Enophrys diceraus	Antlered sculpin	x	x	x			x
Enophrys spp.	*Enophrys* spp.					x	
Hemilepidotus papilio	Butterfly sculpin		x	x		x	x
Icelus spatula	Spatulate sculpin	x	x	x	x	x	x
Icelus spp.	*Icelus* spp.					x	
Megalocottus platycephalus	Belligerent sculpin					x	x
Myoxocephalus jaok	Plain sculpin			x			x
M. polyacanthocephalus	Great sculpin	x					
M. scorpius	Shorthorn sculpin	x	x	x	x	x	x
Trichocottus brashnikovi	Hairhead sculpin		x	x		x	x
Triglops pingelii	Ribbed sculpin	x	x	x	x	x	x
Triglops spp.	*Triglops* spp.					x	
Hemitripteridae	**Sailfin sculpins**						
Blepsias bilobus	Crested sculpin					x	
Nautichthys pribilovius	Eyeshade sculpin	x	x	x	x	x	x
Psychrolutidae	**Fathead sculpin**						
Eurymen gyrinus	Smoothcheek sculpin					x	x
Agonidae	**Poachers**						
Agonidae, unid.	Poacher, unid.					x	
Aspidophoroides monopterygius	Alligatorfish		x	x	x	x	
Ulcina olrikii	Arctic alligatorfish	x	x	x	x	x	
Hypsagonus quadricornis	Fourhorn sculpin		x	x			
Pallasina barbata	Tubenose poacher	x		x			x
Podothecus veternus	Veteran poacher	x	x	x	x		x
Cyclopteridae	**Lumpsuckers**						
Eumicrotremus andriashevi	Pimpled lumpsucker					x	x
Eumicrotremus spp.	*Eumicrotremus* spp.					x	

Table I-2. Continued.

Scientific name	Common name	2004-Norcross	2007a-Norcross	2007b-Norcross	2008-Norcross	1990-Barber	1991-Barber
Liparidae	**Snailfishes**						
Liparis fabricii	Gelatinous seasnail	x		x			
L. gibbus	Variegated snailfish	x	x	x	x	x	x
L. tunicatus	Kelp snailfish	x	x	x	x	x	x
Liparis spp.	*Liparis* spp.	x	x	x	x	x	
Zoarcidae	**Eelpouts**						
Gymnelus hemifasciatus	Halfbarred pout	x	x	x	x		x
G. viridis	Fish doctor	x	x	x	x		x
Gymnelus spp.	Gymnelus spp.	x	x	x	x	x	
Lycodes mucosus	Saddled eelpout	x	x	x	x		x
L. palearis	Wattled eelpout	x	x	x	x		x
L. polaris	Canadian eelpout	x	x	x	x		x
L. raridens	Marbled eelpout	x	x	x			x
Lycodes spp.	Lycodes spp.				x	x	x
Zoarcidae, unid.					x		
Stichaeidae	**Pricklebacks**						
Anisarchus medius	Stout eelblenny	x	x	x	x	x	x
Eumesogrammus praecisus	Fourline snakeblenny		x	x	x	x	x
Leptoclinus maculatus	Daubed shanny			x	x		
Lumpenus fabricii	Slender eelblenny	x	x	x	x	x	x
Stichaeus punctatus	Arctic shanny	x	x	x	x	x	x
Stichaeidae, unid.				x			
Pholidae	**Gunnels**						
Pholis fasciata	Banded gunnel	x			x		
Anarhichadidae	**Wolffishes**						
Anarhichas orientalis	Bering wolffish			x		x	
Ammodytidae	**Sand lances**						
Ammodytes hexapterus	Pacific sand lance						x
Pleuronectidae	**Flatfishes**						
Hippoglossoides robustus	Bering flounder	x	x	x	x	x	x
Hippoglossus stenolepis	Pacific halibut			x		x	
Isopsetta isolepis	Butter sole			x			
Lepidopsetta polyxystra	Northern rock sole			x			
Limanda aspera	Yellowfin sole	x	x	x		x	
L. proboscidea	Longhead dab			x		x	
L. sakhalinensis	Sakhalin sole				x	x	
Platichthys stellatus	Starry flounder			x		x	
Pleuronectes quadrituberculatus	Alaska plaice			x		x	
Reinhardtius hippoglossoides	Greenland halibut			x		x	
17 families comprised of at least 56 species							

[1] Although present, this species was not demersal and was therefore excluded from Chapter I analyses.

Table I-3. Potential density ranges for the bottom water masses assigned from the Chukchi Sea during each cruise. # Stations is count over which density is expressed (# stations in the eastern Chukchi Sea where fish abundance is reported).

CDF Cruise	Water mass	# Stations	Potential density	Temperature (°C)	Salinity
2004-Norcross[1]	Alaska Coastal Water	n=2(3[2])	23.5−24.4	8−10.5	30.6−31.3
	Bering Sea Water	n=4(1)	25.2−26	2.8−4.4	31.7−32.6
2007a-Norcross	Bering Sea Water	n=30(9)	24.8−26.2	0.3−7.6	31.8−32.9
2007b-Norcross	Alaska Coastal Water	n=17(11)	23.6−25.5	4.6−10.7	30.9−32.2
	Bering Sea Water	n=21(9)	25.5−26.3	-0.5−5.0	32.2−33.0
2008-Norcross	Bering Sea Water	n=18(8)	25.4−26.4	-0.7−3.2	31.9−32.9
	Winter Water	n=14(8)	26.1−26.8	-1.7 to -0.6	32.5−33.4
1990-Barber	Alaska Coastal Water	n=10(10)	22.3−25.3	5.7−12.7	29.5−30.4
	Bering Sea Water	n=27(27)	25.3−26.0	-0.2−7.1	30.8−32.6
	Winter Water	n=4(4)	26.2−26.8	-1.2 to -0.6	32.6−33.3
1991-Barber	Alaska Coastal Water	n=1(1)	23.1	7.1	29.5
	Bering Sea Water	n=2(2)	24.3-25.6	1.5−4.2	31.0−31.8
	Winter Water	n=14(14)	25.9-27.0	-1.7−0.4	32.2−33.5

[1] Water masses from 2004-Norcross are after Norcross et al. (2010).

[2] One fishing station during 2004-Norcross was assigned as Alaska Coastal Water although no bottom temperature or salinity was recorded.

Table I-4. Similarity (ANOSIM R) and significance between physical parameters and composition and abundance of fish species within each cruise. The presence, rather than the proportion, of substrate was tested. Blanks indicate there were insufficient data with which to run ANOSIM. Asterisks indicate significant differences: * P<0.05, ** P<0.01.

CDF Cruise	Depth	Temperature	Salinity	Water Mass	Rock	Gravel	Shell	Sand	Mud
2004-Norcross	-0.200			0.556		1	-0.11	-0.11	-0.11
2007a-Norcross	-0.238	-0.022	0.045			-0.214	0.000	-0.080	1.000
2007b-Norcross	0.235 *	0.273 *	0.019	0.142 *	0.227	0.125	-0.351	-0.277	0.081
2008-Norcross	0.176	0.327 *	0.078	0.145	0.301	0.056	0.078	0.237	-0.009
1990-Barber	0.103	0.397 **	0.156	0.314 **					
1991-Barber	0.138	-0.078	-0.062	0.555					

Table I-5. Similarity percentage comparisons (SIMPER) for fish collections during four recent cruises in the Chukchi Sea. Average similarity is percentage of fish species' abundance that stations within a cruise share. Catch-per-unit-effort, in number of fish per square kilometer, is averaged over all stations partitioned by cruise. Only those species contributing >90% are listed.

Species	Avg CPUE	Contrib%	Cum.%
2004-Norcross (Average similarity: 42.4%)			
Gymnocanthus tricuspis	19.5×10^3	25.8	25.8
Anisarchus medius	9.4×10^3	17.7	43.5
Hippoglossoides robustus	8.3×10^3	15.4	58.9
Lumpenus fabricii	9.3×10^3	13.7	72.7
Ulcina olrikii	1.9×10^3	11.9	84.6
Myoxocephalus scorpius	9.0×10^3	11.2	95.8
2007a-Norcross (Average similarity: 47.8%)			
Myoxocephalus scorpius	16.6×10^3	19.1	19.1
Gymnocanthus tricuspis	11.9×10^3	18.8	37.9
Hippoglossoides robustus	20.7×10^3	17.6	55.5
Lumpenus fabricii	9.0×10^3	13.3	68.8
Ulcina olrikii	2.3×10^3	9.3	78.2
Anisarchus medius	2.7×10^3	8.1	86.2
Boreogadus saida	1.6×10^3	4.5	90.8
2007b-Norcross (Average similarity: 50.1%)			
Hippoglossoides robustus	26.2×10^3	18.4	18.4
Myoxocephalus scorpius	75.8×10^3	16.8	35.2
Lumpenus fabricii	85.7×10^3	16.6	51.8
Gymnocanthus tricuspis	22.7×10^3	13.7	65.5
Boreogadus saida	5.8×10^3	9.8	75.3
Ulcina olrikii	1.3×10^3	5.9	81.1
Lycodes palearis	1.2×10^3	4.2	85.3
Eleginus gracilis	1.2×10^3	3.7	88.9
Podothecus veternus	0.4×10^3	3.1	92.1
2008-Norcross (Average similarity 56.5%)			
Lumpenus fabricii	72.0×10^3	26.0	26.0
Hippoglossoides robustus	16.9×10^3	17.3	43.3
Gymnocanthus tricuspis	19.0×10^3	16.0	59.3
Anisarchus medius	5.8×10^3	9.8	69.1
Boreogadus saida	7.1×10^3	9.8	78.9
Myoxocephalus scorpius	2.9×10^3	6.7	85.6
Ulcina olrikii	1.4×10^3	5.5	91.1

Table I-6. Analysis of similarity (ANOSIM R), significance and dissimilarity percentage of fish species composition and abundance between pairs of recent (2004–2008) and between historical (1990–1991) cruises. The four recent cruises differed significantly among themselves, global R sample statistic = 0.128, P = 0.016.

CDF Cruises	R	*P*	Average Dissimilarity
2004-Norcross & 2007a-Norcross	-0.045	0.543	51.96%
2004-Norcross & 2007b-Norcross	0.193	0.134	55.60%
2004-Norcross & 2008-Norcross	0.234	0.099	50.05%
2007a-Norcross & 2007b-Norcross	0.076	0.204	52.53%
2007a-Norcross & 2008-Norcross	0.087	0.045	48.64%
2007b-Norcross & 2008-Norcross	0.125	0.060	49.82%
1990-Barber & 1991-Barber	0.283	0.001	58.02%

Table I-7. Correlations of fish species' abundance and physical habitat parameters. Temperature, salinity and depth were measured at collection sites, and sediments were observed as presence/absence. Spearman r is the value when each of the parameters indicated by "x" is included in the relationship. Dashes indicate parameters that did not contribute to the correlation. 2004-Norcross had only four stations, an insufficient number for correlations.

	3 m plumb staff beam trawl			NMFS 83-112 eastern otter trawl	
	2007a-Norcross	2007b-Norcross	2008-Norcross	1990-Barber	1991-Barber
Spearman r	0.818	0.577	0.456	0.447	0.435
Bottom temp (^{o}C)	-	x	x	x	x
Bottom salinity	-	x	-	-	x
Depth (m)	-	x	x	-	x
Rock	-	-	x	-	-
Gravel	-	-	-	-	-
Shell	-	-	-	-	-
Sand	-	-	x	-	-
Mud	x	-	-	-	-

Table I-8. Five fish assemblages as determined by cluster analysis (see Figure I-4a) from four recent (2004–2008) cruises combined. Letters A−E identify assemblages (# stations within assemblage). The numbers listed in the column under letters is the percent contributed by that species to the assemblage; data are presented only for species contributing to >90% composition. Average similarity is percentage species' abundance that stations within each assemblage share.

Family	Taxa	A (2) Average Similarity: 63.1	B (5) Average Similarity: 43.3	C (3) Average Similarity: 47.1	D (11) Average Similarity: 62.4	E (27) Average Similarity: 59.4
Gadidae	*Boreogadus saida*		18.6		5.1	8.6
	Eleginus gracilis	13.0			6.3	
Cottidae	*Gymnocanthus tricuspis*	11.7	4.1	13.9	11.3	17.8
	Myoxocephalus scorpius	16.2	12.5		18.3	10.2
	M. polyacanthocephalus	6.7				
	Triglops pingelii				4.6	
Hemitripteridae	*Nautichthys pribilovius*	11.6				
Agonidae	*Ulcina olrikii*		3.9		4.7	7.5
	Podothecus veternus				6.6	
Liparidae	*Liparis gibbus*		4.1			
Zoarcidae	*Gymnelus* spp.	9.5				
	Gymnelus hemifasciatus		9.7			
	Lycodes mucosus		16.4			
	Lycodes palearis				3.5	
Stichaeidae	*Eumesogrammus praecisus*		4.8			
	Lumpenus fabricii	13.9	5.8	22.2	21.4	18.0
	Anisarchus medius			13.0		9.5
	Stichaeus punctatus	10.6				
Pleuronectidae	*Hippoglossoides robustus*		11.8	41.2	10.9	19.1

Table I-9. Similarity percentage comparisons (SIMPER) for fish collections during two historical cruises in the Chukchi Sea (Barber et al., 1997). Average similarity is percentage of fish species abundance that stations within a cruise share. Catch-per-unit-effort, in number of fish per square kilometer, is averaged over all stations partitioned by cruise. Only those species contributing >90% are listed.

Cruise: 1990-Barber (Average similarity: 49.05%)			
Taxa	Avg CPUE	Contrib%	Cum.%
Boreogadus saida	19.4×10^3	43.81	43.81
Myoxocephalus scorpius	1.8×10^3	14.37	58.18
Gymnocanthus tricuspis	7.8×10^2	11.6	69.78
Lycodes spp.	3.0×10^2	9.29	79.06
Hippoglossoides robustus	4.9×10^2	5.51	84.57
Eleginus gracilis	1.6×10^3	3.64	88.21
Triglops pingelii	1.4×10^2	2.58	90.79

Cruise: 1991-Barber (Average similarity: 59.53%)			
Taxa	Avg CPUE	Contrib%	Cum.%
Boreogadus saida	5.7×10^3	76.58	76.58
Gymnocanthus tricuspis	5.0×10^2	12.61	89.19
Hippoglossoides robustus	2.6×10	4.99	94.18

Table I-10. Five fish assemblages as determined by cluster analysis (see Figure 4b) from two historical cruises (1990–1991) combined. Letters V−Z identify assemblages (# stations within assemblage). The numbers listed in the column under letters is the percent contributed by that species to the assemblage; data are presented only for species contributing to >90% composition of each assemblage. Average similarity is percentage species' abundance that stations within each assemblage share.

Family	Taxa	V (2) Average Similarity: 52.7	W (14) Average Similarity: 74.3	X (6) Average Similarity: 66.3	Y (32) Average Similarity: 55.5	Z (9) Average Similarity: 69.3
Gadidae	*Boreogadus saida*	6.1	27.9	16.2	59.4	95.2
	Eleginus gracilis		5.3	13.2		
	Gadus macrocephalus	12.2		3.6		
	Theragra chalcogramma	13.2		2.3		
Cottidae	*Gymnocanthus tricuspis*	7.5	10.5	13.1	15.9	
	Hemilepidotus papilio		4.8			
	Myoxocephalus scorpius	15.5	12.8	12.4	7.4	
	Triglops pingelii			11.0		
Agonidae	Agonidae	7.9		6.7		
Liparidae	*Liparis gibbus*			3.5		
Zoarcidae	*Lycodes* spp.		10.8	5.1	5.1	
Stichaeidae	*Lumpenus fabricii*		7.4			
Pleuronectidae	*Hippoglossoides robustus*		11.2	3.0	6.5	
	Limanda aspera	13.9				
	Limanda proboscidea	7.4				
	Pleuronectes quadrituberculatus	10.2				

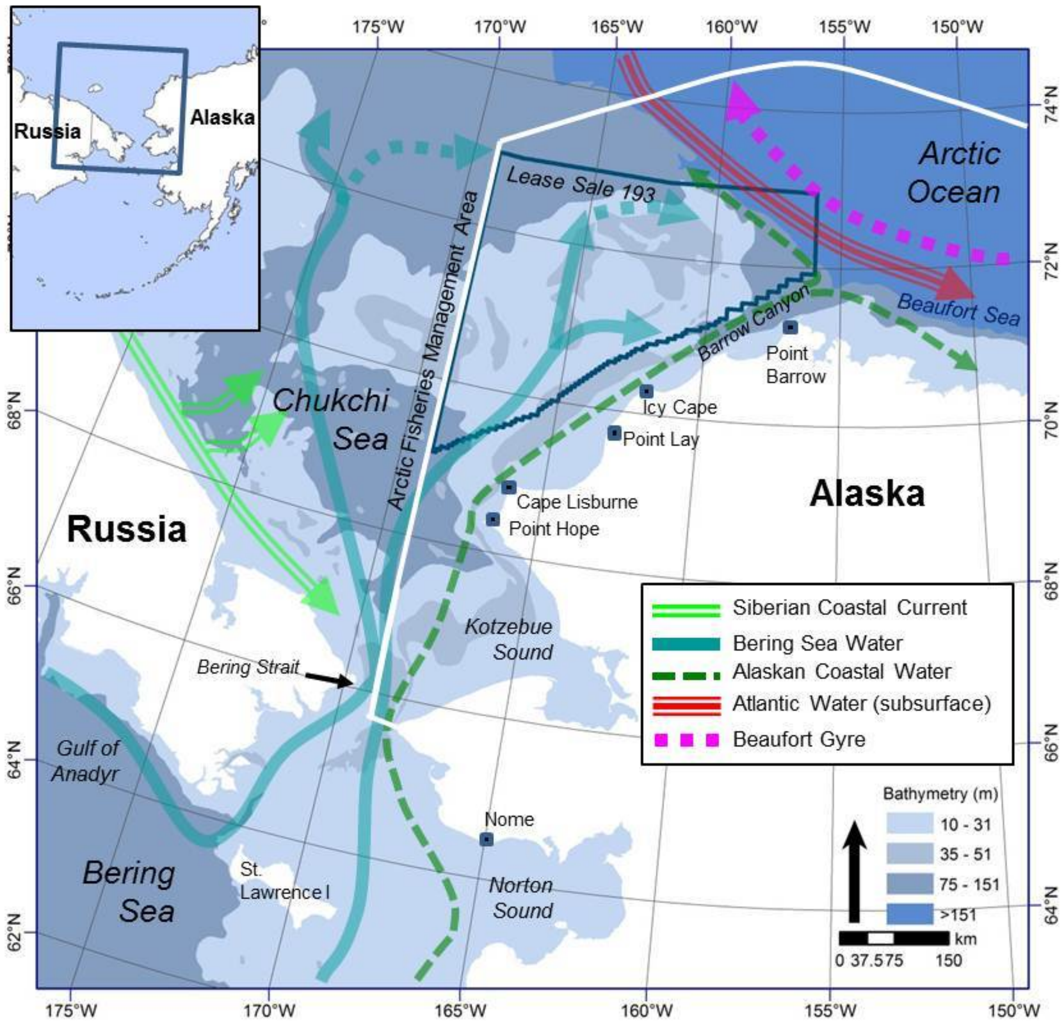


Figure I-1. Generalized positions of circulation and water masses in the Chukchi and adjacent seas (modified from Weingartner et al., 2008 and Day et al., In press).

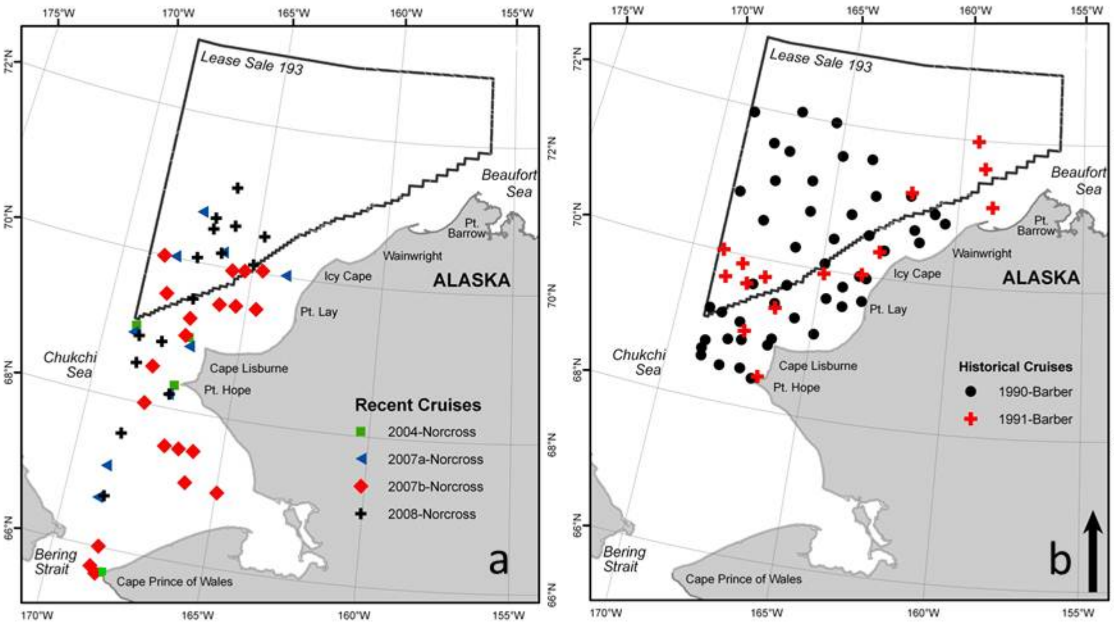


Figure I-2. Maps of fishing stations occupied in the eastern Chukchi Sea during (a) recent (2004–2008) and (b) historical (1990–1991) cruises.

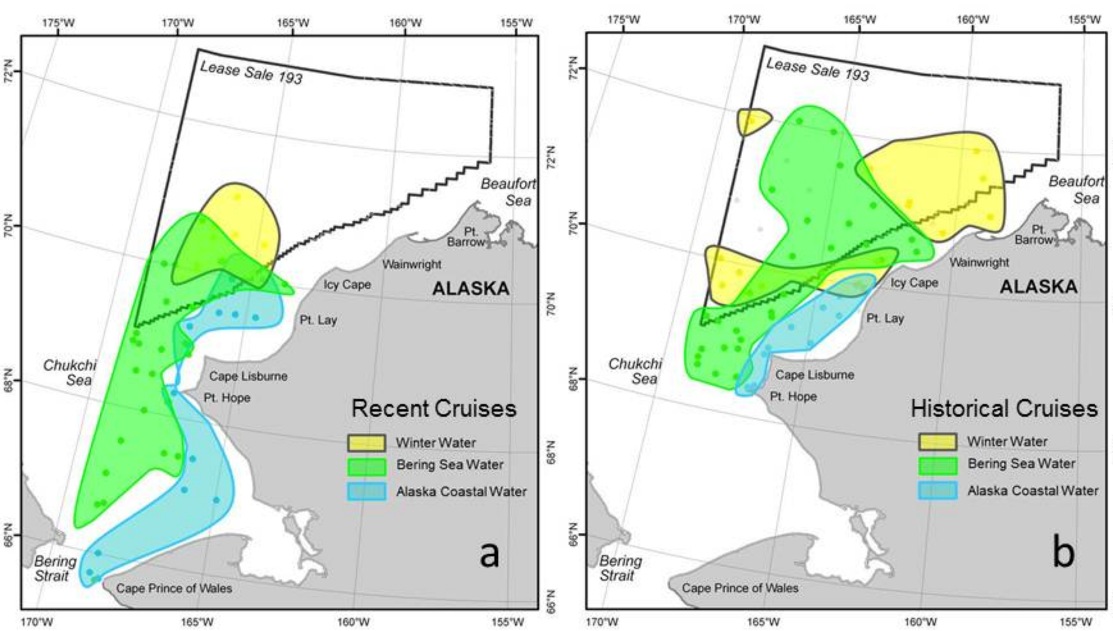


Figure I-3. Maps of bottom water masses sampled in the eastern Chukchi Sea during (a) 2004–2008 and (b) 1990–1991.

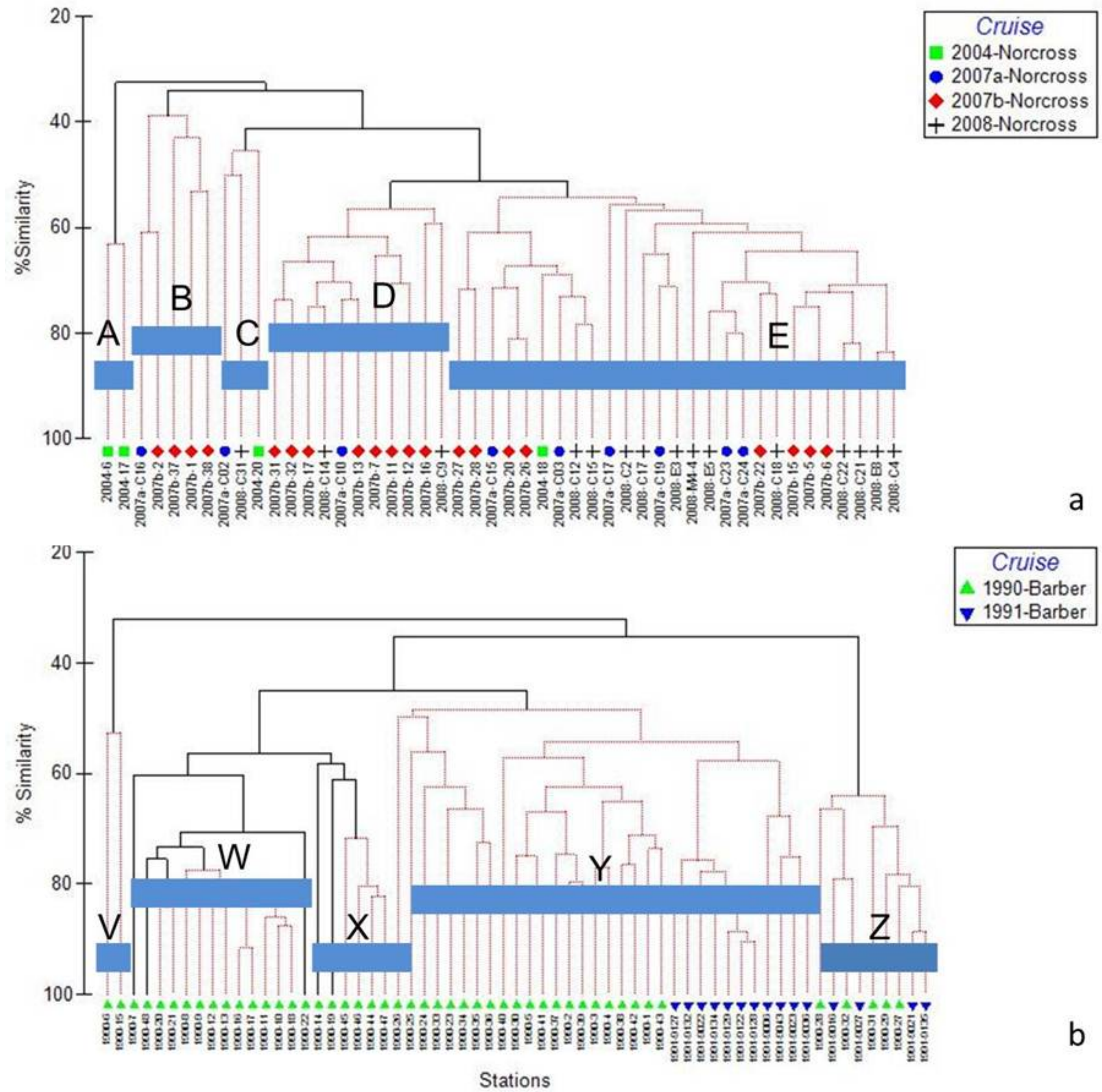


Figure I-4. Dendrogram of community assemblages based on species abundance from (a) recent (2004–2008) and (b) historical (1990–1991) fish collections. Black lines indicate significant differences between assemblages (*P*<0.05).

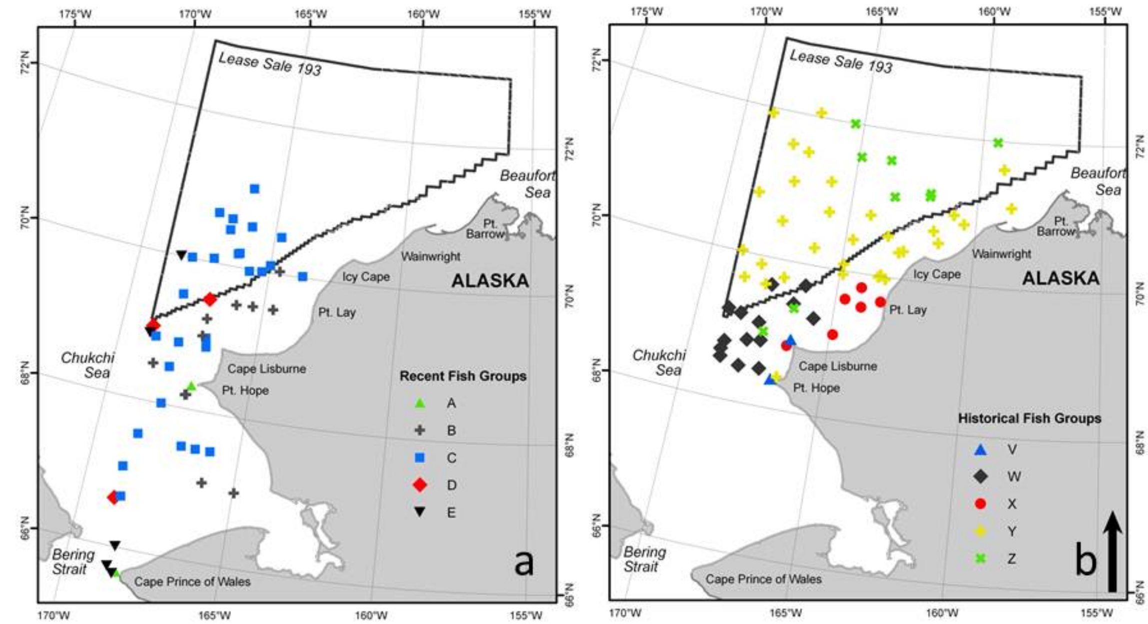


Figure I-5. Fish assemblage maps of (a) recent (2004–2008) and (b) historical (1990–1991) stations as plotted in the dendrogram based on fish abundance in Figure I-4.

Chapter II. Historical collections of demersal fishes in the eastern Chukchi Sea over 50 years, 1959–2008 Authors: Brenda Norcross, Brenda Holladay, Catherine W. Mecklenburg

II.1 Introduction

Prior to this report, catch records of fishes in the Chukchi Sea were mainly from historical surveys conducted from 1959 through 1992 and in 2004, many of which were not readily accessible in electronic format. This report makes historical collections available for comparisons with recent fish research efforts in the Chukchi Sea (Appendices C, D, and E).

The accurate characterization of fish presence and abundance in the eastern Chukchi Sea requires an evaluation of previous collections from the region. Fish are the least well studied component of the Arctic vertebrate fauna (Mecklenburg et al., 2008). Alaskan Arctic fish species identifications are often different from their original designations (e.g., Mecklenburg et al., 2002, 2006, 2007, 2008; Mecklenburg and Mecklenburg 2009). Confusion about identities confounds interpretation of species diversity and distribution.

The ongoing shift in oceanographic conditions that affect the distribution and abundance of fishes makes it important to understand the physical environment that they occupy. Furthermore, water flowing into the Chukchi Sea influences the distribution of fish there. Generalized water masses and currents are recognizable in the Chukchi Sea (Figure II-1). The Alaska Coastal Current (ACC) flows rapidly northward along the east side of the Bering Strait and is recognizable as the warm, dilute Alaska Coastal Water (ACW) along the east side of the Chukchi Sea and into the Arctic Ocean (Weingartner 1997). The ACW can be isolated from the rest of the Chukchi Sea by a well-defined front ~50 km from the Alaskan coast that extends northward from Bering Strait to the Lisburne Peninsula (Weingartner 1997). Bering Sea Water (BSW) is a mixture of waters from the western and eastern Bering Sea that also flow northward through Bering Strait, and is found on the west side of this front. The front, which extends to the bottom, usually appears annually in the northeastern Chukchi Sea. Although the exact position can vary with winds, its mean position is based on bathymetry, i.e., where the bottom depth is equal to the mean depth of the mixed layer. Resident Chukchi Water (RCW) is derived from the upper layers of the Arctic Ocean or from shelf water left from the previous winter (Gillespie et al., 1997; Weingartner 1997). The RCW is found offshore in the northern Chukchi Sea, and is separated from ACW in the northeastern Chukchi Sea by a semi-permanent front that extends to the bottom at ~70–71° N (Weingartner 1997). The Siberian Coastal Current (SCC) flows southeastward from the East Siberian Sea along the eastern coast of Siberia (Weingartner 1997; Weingartner et al., 1999). A broad front separates the cold, dilute SCC from the warmer, saltier BSW. The SCC continues its southward flow and converges with northward flow through the Bering Strait. It is usually deflected on the Chukchi shelf, but occasionally northerly wind events force the SCC to flow south through Bering Strait. Winter Water (WW) is the subsurface very cold and salty water on the west side of BSW that is transported eastward across the Chukchi Sea (Pickart et al., 2010).

The objective of this research was to examine patterns of richness and diversity of fishes collected in research bottom trawls in the eastern Chukchi Sea over 50 years. To accomplish that we acquired the haul-catch records of the individual cruises and revised them by applying the corrected identifications provided by C.W. Mecklenburg from examination of the voucher specimens in museum collections. Cruise vouchers examined included collections from 1959 to 1992 archived in museums in the United States, Canada, Japan, and Russia. Using this corrected data set of taxon presence, we synthesized historical distribution patterns of demersal fish communities in the eastern Chukchi Sea.

II.2. Methods

II.2.1 Historical fish collections

Haul-catch records from research cruises to collect fish in the eastern Chukchi Sea were available for cruises from 1959 to the present (Appendices C, D and E). Analyses in Chapter II utilized the historical collections, from vouchers and records examined by C.W. and T.A. Mecklenburg prior to this study (Mecklenburg et al. 2002, 2006, 2007; Mecklenburg and Mecklenburg 2009), during this study, and additionally from the collections made as part of this project from recent cruises (Chapter I). The data set spans 50 years (1959–2008). In an easy-to-reference format, Table II-1 summarizes historical cruises during which fish were collected, enabling the reader to quickly discern differences and similarities among sampling methods and types of available data. These historical haul-catch data (Table II-1) were incorporated in the Chukchi Demersal Fish (CDF) database. Detailed methods explain the structure of the CDF database (Appendix B) and incorporation of historical data (Appendix D). As in the CDF Database, this analysis (Chapter II) reports species using nomenclature in the American Fisheries Society's most recent publication of scientific and common names (Nelson et al., 2004).

All bottom trawl collections allow the possibility that some fishes reported were captured off the sea floor, as nets are open during setting and retrieval as well as while on the bottom, and because the vertical opening of some bottom trawl nets is several meters. Fishes generally considered to be demersal may also be caught in midwater, including Gadidae (cods), and larval and early juvenile stages of Cottidae (sculpins), Stichaeidae (pricklebacks), and Pleuronectidae (flatfishes), which can be present in large numbers in the water column during the same time frame as they are caught on the sea floor. There is no way to assess whether fishes were actually caught in the water column or on the sea floor, and therefore we included in the present analyses those fish species that are considered to be demersal but excluded those species that are pelagic, i.e. Clupeidae (herrings), Osmeridae (smelts), Salmonidae (salmons), and Gasterosteidae (sticklebacks).

We examined distribution patterns of fish communities from cruises (Appendix D) that we located and were able to incorporate into the CDF Database (Table II-1). Although that database incorporates more data, for the purposes of analyzing the eastern Chukchi Sea (Chapter II), we only included samples from Bering Strait northward, west of Barrow, Alaska, and east of 169^{o} W. This eliminated samples from the northern Bering Sea, the Beaufort Sea, and the western Chukchi Sea.

II.2.2 Statistical and graphical analyses

Fish samples were collected by a variety of bottom trawls (Table II-1). To enable comparison among cruises, all analyses were performed on a binary value of fish presence. Demersal fish taxa were included from both quantitative hauls, from which catches could be assessed per unit time, distance, or area fished, and from qualitative hauls (unsatisfactory net deployments) (Appendix D). Taxa composition in each haul was determined as the presence or absence of each taxon in the entire suite of fish taxa collected across all cruises combined. Numbers of fish captured in an individual haul were only used for comparisons made within that haul.

Biodiversity was examined using a suite of standard indices (DIVERSE, PRIMER v. 6.1). Richness is the total number of fish taxa at each sample site and is dependent upon the sampling effort; i.e., the more time a net is deployed, the more likely a different species will be captured. Diversity indices provide more information than simple richness as they consider the relative abundance of individual species (Clarke and Gorley, 2006). Evenness is equality or equality in numbers of each fish taxa at each sample site. The Shannon diversity index (H', $\log_e$) attempts to balance between richness and evenness and tends to flatten out. The inverse of Simpson's evenness index is the probability that two species drawn from a sample will be the same, i.e., Simpson's diversity index (1-λ'). Diversity and evenness were calculated on numbers of each fish taxon captured within a single haul. These indices were calculated for each individual haul location and kriged using ArcMap v. 10.0 (ESRI, 2010) to show spatial patterns. The kriging method was ordinary and used a semivariogram circular model. For kriging, Jenks optimization method (Jenks, 1967) was used to classify features using natural breaks in values of richness, and Shannon diversity and Simpson's diversity indices. Natural breaks are based on natural groupings inherent in the data that are identified to best group similar values and maximize the differences between groupings. Boundaries are set where there are relatively big differences in the data values (de Smith et al., 2009). The Jenks optimization method is also known as the goodness of variance fit (GVF), and is used to minimize the squared deviations of the class means. Optimization is achieved when the quantity GVF is maximized: (ESRI 2010). Because our objective was to compare richness, Shannon diversity index, and Simpson's diversity index among decades, the natural breaks determined for the complete 1959–2008 data were also used to plot the decadal data,

Taxonomic distinctness (Δ+) is a tool that can be used to examine changes in fish taxa over time when the sampling effort is not equal (Clarke and Warwick, 2001). It calculates the taxonomic distance between all pairs of fishes of different taxa (Somerfield et al., 1997), i.e., the Δ+ value is lower if the taxa are all the same genus and increases as their taxonomic classification becomes farther apart. As taxonomic distinctness is calculated on presence/absence and not abundance, it was used here because station number and distribution, gear type and catch-per-unit-effort were not the same on all cruises and thus they were not comparable among collections. We used equal weighting for each taxonomic level: species, genus, family and order. When plotted against the number of species captured, Δ+ values are dispersed around a theoretical mean. Values falling outside the 95% confidence limits indicate a significant difference from the expected. We used taxonomic distinctness to evaluate changes in presence of fish species over the 1959–2008 time frame of the data. As the objective was to examine changes across years without consideration for month of collection, all data available within a single year for which at least partial presence data were available were pooled, e.g., three cruises in 2007, yielding 13 years.

When data were available, habitat characteristics of fish communities were examined. Habitat data from each of 11 collection periods were assessed, with data from 1983 and 2004 combined over both gear types. The ranges of potential density, temperature and salinity were described for bottom water masses. Analysis of Similarity (ANOSIM, PRIMER software v. 6.1) was used to estimate differences in species composition relative to depth, bottom temperature, bottom salinity, bottom water mass, and sediment type. Depth, temperature and salinity could not be analyzed as continuous variables, therefore those data were binned. ANOSIM bottom depth bins were in 10 m increments with bin label being the lowest number in the bin, e.g., a depth bin of 10 m included all stations between 10 and 19.9 m. Likewise, 1^{o} C bins for bottom temperature and 0.25 unit bins for bottom salinity were labeled with the lowest number of the bin. Actual values were used for graphical analyses. Because substrate collected in the trawl was consistently recorded for 2004–2008 cruises and for occasional 1977-Frost hauls, those in-trawl data were combined with sediment grab data; each of rock, gravel, shell, sand and mud was categorized as present or absent for inclusion in the analysis.

ANOSIM is a nonparametric, multivariate permutation test, somewhat analogous to the parametric, univariate ANOVA. For fish presence, Bray-Curtis similarity matrices coefficients were ranked and reordered to group samples within each physical factor group. Because only presence/absence of fish at each haul was used, no additional transformation was necessary prior to calculating Bray-Curtis similarity matrices. To provide the best reasonable result, one thousand permutations were run for each ANOSIM. An R statistic, defined as a comparison of the average between-group rank similarity to the average within-group rank similarity, was calculated using the following formula:

$$R = \frac{(\bar{r}_B - \bar{r}_W)}{n(n-1)}$$

where $\bar{r}_B$ and $\bar{r}_W$ are the average rank similarities for each pair of intervals between and within groups, respectively, and n is the sample size. The R value is between -1 and 1, and the closer R is to 1, the more distinct the groups are.

II.3. Results

Fishes were collected in the Chukchi Sea in 13 years from 1959 through 2008 (Figure II-2). We identified 23 unique cruise and gear combinations (CDF Cruises) that targeted fishes (Table II-1; Appendices D and E). Catch data from three cruises in 1991 could not be recovered because they were not quantified in the field and specimens were lost in transit (1991a, b, d-Barber; see Appendix D.3.10). We excluded data for two cruises, 2007-Hokkaido and 2008-Hokkaido, because the net was fished mid-water as well as on the sea floor. Of the remaining 18 CDF Cruises, 14 principally examined the northeastern Chukchi, three (1973-Morrow, 2004-Mecklenburg, 2004-Norcross) included the Russian waters of the western Chukchi Sea in addition to the eastern Chukchi Sea, five (1959-Alverson, 1976-Wolotira, 1990-Hokkaido, 2004-Mecklenburg, 2004-Norcross) only sampled the eastern Chukchi Sea south of Lease Sale 193, and 1 (1970-Quast) sampled only 1 station. Only voucher data, i.e., presence of fishes at only some stations, were available for 1973-Morrow at the time of this report; the full catch will be reported in a future publication by Mecklenburg. Over the 15 cruises for which we had sufficient data to analyze, there were 501 unique bottom hauls at 406 stations. Eight different configurations of trawl gears were used with a large range of headropes (2.7–43 m) and mesh sizes (4–90 mm). The most frequently used trawls were: 3 m plumb staff beam trawl (PSBT; after Gunderson and Ellis, 1986: used four times), 25.2 m 83-112 eastern otter trawl (83-112 OT; RACE, 2010: used three times), and 4.9 m otter trawl (data from two cruises) (Table II-1). Cruises were in the ice-free months June–September, though most cruises were in August and September. Approximately 169,000 fishes were collected, with 59 species and 80 taxa, i.e., including species and higher level classification, from 13 families. Total number of taxa captured was dependent upon the sampling effort, i.e., the more times a trawl net was hauled, the more likely additional taxa would be caught. In the eastern Chukchi Sea 60% of taxa could be captured in 84 hauls, whereas the effort to capture 75% of the taxa would have to be increased to 382 hauls (Figure II-3). On average there were 6.6 taxa caught per haul with a range of 0–21.

Richness and diversity indices revealed interesting spatial and temporal patterns. When evaluated for all 1959–2008 fish collections combined, taxon richness was highest in three areas: north of Bering Strait, in Kotzebue Sound, and north of Point Hope and Cape Lisburne (Figure II-4a). The patterns of Shannon (Figure II-4b) and Simpson (Figure II-4c) indices were similar, relatively high diversity north of Bering Strait, inner Kotzebue Sound, and near shore from south of Point Hope to Wainwright. Over decades, overall richness was lowest in 1959 and highest in 2004–2008 (Figure II-5). Richness was consistently high offshore of Point Hope and Cape Lisburne in all years, though lowest in 1959. The overall low Shannon and Simpson diversity indices in the Lease Sale 193 (Figure II-4b, 4c) were attributable to 1989–1992 (Figure II-6c, 7c). Both diversity indices had moderate values in 1973–1983 (Figure II-6b, 7b), when a large portion of the area was sampled, albeit sparsely. Conversely, all three indices (Figure 5d, 6d, 7d) were high in southwest Lease Sale 193 in 2004–2008. Plotting limitations of ArcMap v. 10.0 erroneously made richness and diversity indices appear to be high in Kotzebue Sound in 1973–1983, where no data were available; the inner part of Kotzebue Sound was only sampled in 1976.

Taxa and catches of fishes displayed temporal patterns. Fifteen demersal fish taxa made up 99% of all fishes captured and dominated the eastern Chukchi Sea over 50 years (Figure II-8). Cumulative relative abundance (i.e., using all gear types) of fishes was composed of five families: cods – 69%, sculpins – 20%, pricklebacks – 5%, flatfishes – 4%, and eelpouts – <1%. The expected taxonomic distinctness (Δ^+) of fishes in the Chukchi Sea collected over the 50-year period was mainly within the 95% confidence limits , i.e., there was no taxa were lost or gained 1959–2008 (Figure II-9). With more than ten taxa per haul, taxonomic distinctness indices were tightly clustered around a mean of 70. When fewer taxa were captured in a haul, confidence limits had wider 95% confidence limits. The number of species caught was variable over the shorter time frame of month, with a range of only 0–6 found in July and 1–21 found in September (Figure II-10). Catch of fishes was different among decades (ANOSIM, $R = 0.238$, $P<0.001$), years (ANOSIM, $R = 0.408$, $P<0.001$) and month (ANOSIM, $R = 0.008$, $P<0.001$).

Eleven collection periods from 1983 to 2008 had temperature and salinity data from which bottom water masses could be calculated. Results of analyses of fish data and physical variables from each cruise are summarized in Appendix D. Within those cruises, four bottom water masses were distinguished (Appendix E); all water masses were not found in each year (Table II-2). In six years there were three water masses and in four years there were two waters masses detected. Alaska Coastal Water (ACW) was detected in 9 of 11 collection periods, Bering Sea Water (BSW) during all cruises, Winter Water (WW) in 6 of 11, and Resident Chukchi Water (RCW) was detected only during 1 cruise. Water masses and their characteristics vary interannually and seasonally, i.e., the ranges of temperature and salinity values that determined the water mass potential densities were not static (Table II-2). Composition and presence of fishes were affected by water mass in three of the nine collections for which data were available (Table II-3).

Catches of fishes were significantly affected by the physical environment. Catch size differed with depth of capture (ANOSIM, R = 0.136, $P<0.001$). In five collection periods from 1983 to 1990, composition and presence of fish catches were significantly affected by depth of capture (Table II-3), 1 of those was 1983a&b-Fechhelm, the collection with the lowest mean depth. Although the average depth of capture was <50 m in all but 1 of 15 collections, ranges differed with the cruise in which the samples were collected (Figure II-11). The maximum depths >100 m in two years were due to trawls taken in Barrow Canyon. Bottom temperature affected fish catches (ANOSIM, R = 0.444, $P<0.001$). Demersal fish catches were significantly affected by temperature in four years, each in a different decade (Table II-3). Coldest bottom temperatures of -2ºC were fished in July and September. Ranges of maximum monthly bottom temperature at fishing sites over the ice-free season increased from 4ºC in July to 13ºC in September (Figure II-12). Plots of mean bottom temperature showed interannual and seasonal variability. Salinity affected fish catch (ANOSIM, R = 0.310, $P<0.001$), but only in two years (Table II-3). Minimum salinity was lowest in September, and though lowest means were also in September, not all September means were low (Figure II-13). Although limited data were available to test impact of sediment type on composition of fish catches, presence of rock, gravel, sand and mud each affected at least one collection. Effects of the physical environment on fish catches were compounded by the location of the cruise.

II.4. Discussion

This project is a major advance in knowledge of fishes in the Chukchi Sea. Recent cruises increase the number of collections within specific months and provide information about fishes currently in the Chukchi Sea and about the composition of fish communities. The retrieval of historical data affords a basis against which recent data can be compared. Together they allowed analysis of fishes in the Chukchi Sea over a 50-year time frame.

Ecosystem stability is related to both richness and evenness (Hillebrand et al., 2008). Diversity indices, which combine the components of richness and evenness, are well-defined statistical measures that use absolute frequencies within a single collection (Frosini, 2006). That makes them ideal for comparisons of fishes collected with various trawl gears over a 50-year time span. There are many indices of diversity, all of which have merits and drawbacks, one of which is the goal of creating a univariate index from multivariate data by accounting for richness, which is the number of taxa captured in one trawl haul, and evenness, which is the inverse of dominance. The measures of diversity we use to show patterns in the 50 years of fish collection attempt to quantify richness (number of species) and evenness (Simpson's diversity index) and to balance between richness and evenness (Shannon's diversity index, H', $\log_{e;}$ Clarke and Warwick, 2001). High stability in a community is characterized by high richness and high evenness (Hillebrand, et al., 2008). Over 50 years, as seen in Figure II-4, diversity is highest at and straight north of Bering Strait. Conversely, low richness and low evenness typify communities with low stability such as found over most of Lease Sale 193, except the southwest part. Communities with high species richness are thought to be more resistant and more stable than those with low diversity (Frank et al., 2006), which implies that the fish communities of the more northern parts of Lease Sale 193 are less stable and less resistant to disturbance than the southwest part. However, data from the northern area are very limited and none came from the most recent decade. This emphasizes the need for studies in this area such as were conducted under the Chukchi Sea Environmental Studies Program in 2009–2011 (CSESP; *www.fairweatherscience.com/*), the Arctic Ecosystem Impact Survey in summer 2012 (Arctic Eis; *www.commerce.state.ak.us/dca/planning/cciap/ArcticEcosystemIntegratedSurvey.htm*), and the Alaska Monitoring and Assessment Program in 2010 and 2011 (AKMAP; *http://dec.alaska.gov/water/wqsar/monitoring/AKMAP.htm*).

Changes in diversity may appear over time given a long times series of data such as this 50-year time frame from the Chukchi Sea. A strong annual set of fish collections on the Scotian Shelf over 40 years, 1970–2000, revealed common areas of high diversity and areas of only temporal aggregation (Shackell and Frank, 2003). The examination of changes in diversity indices for the eastern Chukchi Sea over approximately decadal increments (Figures II-5, II-6 and II-7) dissects some patterns from the aggregate presentation, though there are limits because the areas over which samples were collected in each time frame were not consistent. All diversity measures are higher in 2004–2008 than in the preceding decades. The high diversity, as evidenced by the integrative index of Shannon diversity, in the area north of Bering Strait is consistent over all time frames. The low diversity area is heavily influenced by collections in 1989–1992, which indicate that the entire Lease Sale 193 has very low diversity. The northeast portion of the Lease Sale 193 was also sampled in 1973–1983, when, while not high, diversity indices were higher than in 1989–1992. There is a strong increase in diversity measures in southwest portion due to collections 2004–2008 (Figures II-5d, II-6d, II-7d). On the Scotian Shelf species richness was seen to increase in the second half of the 1970–2000 time series, i.e., new species were discovered in the area, indicating possible immigration (Shackell and Frank, 2003). The superficial increase in number of species that gave the appearance of biodiversity increasing over time on the Scotian Shelf was actually a function of sampling effort (Shackell and Frank, 2003).

Anthropogenic changes in an ecosystem might be seen in evenness indices, which often respond more rapidly than richness (Hillebrand et al., 2008). Because dominance and evenness are inverse indices of the same measure, an increase in evenness means a loss of dominance by one or more taxa, which is not necessarily good. Change in dominance structure will precede change in composition, which may cause changes in ecosystem function (Shackell and Frank, 2003). For example, as a result of overfishing, Atlantic cod (*Gadus morhua*) abundance and area occupied decreased on the Scotian Shelf (Zwanenburg, 2000). Food for cod increased; species that previously competed with cod increased and filled the niche of cod. Thus, changes in evenness reveal changes in distribution, with consequences for species interactions, e.g., in 1990-Barber *B. saida* was the single dominant species, while in 2004–2008, species dominance was shared by sculpins, pricklebacks, cods, and flatfishes (Chapter I).

Richness and evenness are coarse descriptors of communities whereas taxonomic distinctness attempts to measure traits of dominant species compared to the community (Hillebrand et al., 2008). Evenness indices alone do not suggest how traits of dominant species differ from those of rare species (Hillebrand et al., 2008). Quantifying how closely related taxonomically the taxa are in each haul, or taxonomic distinctness, is a measure of diversity within each haul that allows comparisons among all 501 hauls that we analyzed. A low number for a haul means that all fish are the same species or genus. Therefore if a haul was almost entirely 1 species, e.g., *Boreogadus saida*, in 1990, the distinctness is outside the 95% confidence limit (Figure II-9). These are the same hauls that contribute to the low stability structure of the northeast Chukchi Sea in Lease Sale 193. In the northeast Atlantic values of average taxonomic distinctness outside the lower 95% confidence limit, similarly, were from stations with the smallest numbers of taxa present (Rogers et al., 1999). The total number of taxa collected in the eastern Chukchi Sea over 50 years is low and the highest number captured in a single haul was 21. Despite this, it is clear that there are some hauls, mostly 1989–1992 when few taxa were captured. It could be that the methods of collecting or identifying fish were not refined enough to capture the true richness and diversity. Thus the low values for the average taxonomic distinctness could be because of taxonomic reclassification, i.e., taxa were combined at the family or genus level, thus making it appear that there were fewer taxa than actually caught.

Richness patterns of fish communities are known to be affected by abiotic factors (Therriault and Kolasa, 1999), which change over time and space. Analysis of the bottom temperature, salinity and density of water masses present in the summer Chukchi Sea revealed much intra- and interannual variability that was linked to the timing and exact location of the collections. One reason for the variability might be that even when samples were taken in July, e.g., 1990-Hokkaido, 1991-Hokkaido, 1992-Hokkaido, the location of the sample sites varied. In general, bottom water is still quite cold in July in the Chukchi Sea and warmer ACW and BSW have not moved northward as far as they will spread by late August and September. From 1983 through 2008, four bottom water masses were differentiated in the Chukchi Sea: Alaska Coastal Water, Bering Sea Water, Winter Water, and Resident Chukchi Water. These water masses were not all present in all collections, an observation which emphasizes interannual variability and relationship between time and location of cruise and apparent effect, or lack thereof, of abiotic factors on fish in this study.

Historical catches differed by not only by month and location of sampling, but also by the bottom trawl gear used. Statistical comparisons among and between samples were confounded because of changes in gear type, net mouth width and height opening dimensions, and mesh size (Meyer and Holladay, 2011). Making comparisons among similar gears eliminates some of the uncertainty. The apparent decrease in diversity in 1989–1992 may be attributable to the large trawl nets that were designed to catch large fish and have correspondingly large mesh (Appendix E). The 83-112 eastern otter trawl tended to open higher off the bottom (Meyer and Holladay, 2011), which would explain the low richness and evenness and high catches of Arctic cod. However, in 1976 this net was used to sample Kotzebue Sound (Appendix E) and yielded higher diversity indices. Small mesh nets were used in 1973, 1977, 1989 and 2004–2008. While diversity indices were higher in 1973–1983, indicating that small size fishes captured by small mesh nets contributed to higher diversity, the values were still highest in 2004–2008. This supports the conclusions of low diversity in Lease Sale 193, the high diversity from Point Lay southward, and the increase in diversity in recent years. Direct comparisons of gear, especially between the 83-112 and the PSBT (Table II-1) that occurred in summer 2012, are needed to verify these findings.

Assessment of demersal fishes in the eastern Chukchi Sea is important because of the potential for changes to the ecosystem with changing climate and anthropogenic use of the region, e.g., oil and gas exploration, fisheries, and vessel use of the area. This collation of historical fish data from the Chukchi Sea establishes a baseline against which to measure the natural or anthropogenic changes in distribution of demersal fishes.

Through the multitude of assessments presented in this paper, several conclusions were derived about diversity, richness and evenness of fishes in the Chukchi Sea from 1959 through 2008. However, all conclusions must be treated with caution. Over the 50-year time span there have many confounding variables that affected the collections of fishes. While caveats were listed in other parts of this discussion, it is prudent to summarize them again. First and foremost, when the type of gear was not consistent among collections, effort could not be standardized. In cruises where the same type of trawl was used, it was often modified to fish differently or the time of tow was altered. Prior to the 1990's GPS was not available; therefore distance of tow could not be estimated. Substrate influences how effectively a trawl fishes or if it is possible to tow in a specific location. Trawls are not towed intentionally where large rocks and boulders are present. Local, i.e., tow-length scale, conditions of substrate, depth, temperature and salinity define the habitat suitability of a location for some species of fish while eliminating for other. Large-scale spatial variability appeared to affect diversity and must be considered carefully because it is but one in a nest of interwoven factors. Temporal variability from small scale day-night through interannual can be complicating. Sampling is usually achieved to maximize available ship time, which means some work is performed 12 hr/da and other work is 24 hr/da. Depending on the interdisciplinary nature of the cruise, fishing may be relegated to night because bird and mammal transects are conducted during the day. All fish trawling is performed in the open-water season, but oceanographically speaking, all summer months are not equal in the Arctic in terms of ambient conditions or accessibility. As demonstrated in this analysis, sampling during July has often prevented fish collections in northern parts of the Chukchi shelf that are not yet ice free, but that does not mean that the same temperatures and salinities are encountered. Water masses are characterized by temperature and salinity and, while they can be portrayed generally (Figure II-1), interannual conditions, compounded with time and location of sampling, portray a very different picture (Appendix D). The objective of the present research was to assess demersal fish data available over 50 years to determine if changes to fish distributions have occurred with changing climate and to establish a base against which to compare future collections.

The insights gained from these past collections can be used to design future studies in Lease Sale 193. The same trawl gear should be used each time to allow comparisons in the future and with as many past studies as possible. The most consistently used trawls were the small mesh PSBT used since 2004 and the

83-112 eastern otter trawl used in 1990–1991 (Chapter I). The apparent variability in fish diversity in the eastern Chukchi Sea over 50 years demonstrates the need to focus future studies in space and time. As a focal point of potential oil and gas exploration is the northeast part of the Chukchi Sea, an area from which there are the fewest fish collections, continued sampling should target the broad area within Lease Sale 193. Since 2009, BOEM-funded and industry-funded studies have directed sampling efforts throughout that area or have targeted specific lease sites. It would be desirable also to sample upstream, i.e., towards Bering Strait, because that is the source of water flowing into the Chukchi Sea and influx of boreal fish species, and there are historic fish data for qualitative comparisons. Unfortunately, monetary and time constraints on sampling made fish collections in the southern Chukchi Sea a lower priority. Although sampling in multiple seasons would be ideal to fully assess the area; practically one comprehensive cruise would be an effective assessment, preferably in late August – early September. This time frame should allow ice to melt and retreat so the northeast portion of Lease Sale 193 could be accessed. Comparisons would be most valid statistically if sample depths were restricted to <70 m, i.e., not to include Barrow Canyon or the slope. The deeper depths provide different habitats, with potentially different fish species, than the continental shelf; bottom temperature would confound interpretation of fish collections at depth. In summary, all variables cannot be controlled, but a good base monitoring plan can be designed. Once a baseline is established, Lease Sale 193 should be sampled every 3–4 years. Additional fish collections outside of Lease Sale 193 could be made in off years, but a core group of stations within the 193 should be included each time to ensure validity of interannual and interdecadal comparisons.

In the past, sampling for fishes in the Chukchi Sea has been episodic; however this project provided the background and impetus for additional collections of fish in this area. In the last nine years, Norcross and Holladay collected fish during 13 cruises in the Chukchi Sea, many of which were in Lease Sale 193: 2004 – 1; 2007 – 2; 2008 – 1; 2009 – 4; 2010 – 2; 2011 – 1; 2012 – 2. Of those, three (2004, 2009 and 2012) sampled in Russian as well as Alaskan waters; four (2009–2010) were solely in the northeast in offshore waters; two (2010–2011) were in nearshore waters; and the three (2007–2008) new collections supported by this study were in Lease Sale 193 and further south.

II.5. Chapter II Conclusions

1. Using smaller mesh nets to collect fish in the eastern Chukchi Sea produces greater richness and diversity indices; i.e., more fish taxa are collected because small taxa are retained.

2. There has been an apparent increase in fish diversity in recent years. Although collections during 2004–2008 were all from small-mesh nets, the diversity was greater compared to collections from similar nets in 1973–1983.

3. Low indices of richness and evenness, which typify low-stability communities, have been observed in the northern region of Lease Sale 193. These low indices may, in part, be due to the few samples collected here.

4. Fish diversity is highest at and straight north of Bering Strait, including the southwest portion of Lease Sale 193. High indices of richness and evenness in this area are indicative of high community stability.

5. Variability in year, month and location of collections over 50 years confounds interpretation of effect on fish in this study of physical environment factors, i.e., temperature, salinity, depth and water mass.

6. Fish collections 1959–2008 are not directly comparable because various trawl nets were used to collect fish, and therefore these conclusions should be considered with caution.

7. Direct comparisons of gear, especially the 83-112 eastern otter trawl and the 3 m plumb staff beam trawl (Table II-1), are needed to verify these findings.

8. Caution should be exercised when interpreting all results because of small and large scale spatial and temporal variability in historical fish collections.

9. Based on this study, we recommend that a consistent monitoring of fish and associated oceanographic variables in Lease Sale 193 be conducted with the same trawl gear, in late August every 3–5 years.

Table II-1. Overview of scientific fish surveys in the offshore eastern Chukchi Sea during 1959–2008. We assigned a CDF (Chukchi Demersal Fish) Cruise as a unique identifier for each cruise and gear combination. The vessel and year are indicated if there was no official cruise name. Gear is abbreviated: OT = otter trawl; PSBT = plumb staff beam trawl. Replicate gears that were deployed more than once with identical methods are indicated (A, B, or C). X indicates data are in the CDF database, -- indicates no data available, est indicates parameter was estimated. Substrate code D indicates descriptive data and % indicates grain size data. CDF Cruises analyzed in Chapter II of this report are indicated.

CDF Cruise	Cruise or Vessel-Year	Month & Year	Headrope, Fishing Gear, Smallest Mesh	Rep Gear	# Fished Stations	Distance	Swath	Presence	Count	Biomass	Fish Length	Depth	Temp.	Salin.	Substrate	Vouchers Examined	Ch. II
1959-Alverson	John N. Cobb 43	Aug 1959	21.6 m 400 eastern OT, 38 mm		51	--	X	X	X	--	--	X	X	--	D	X	X
1970-Quast	WEBSEC-70	Sep 1970	3 m OT, 38 mm		1	--	--	X	--	--	--	X	X	X	--	X	
1973-Morrow	Alpha Helix-1973	Jul-Sep 1973	4.9 m OT, 6 mm	A[1]	17	--	--	X	[2]	--	[2]	X	X	--	--	X	
1976-Wolotira	MF-76-B	Aug-Oct 1976	25.2 m 83-112 eastern OT, 33 mm	B	93	X	est	X	X	X	X	X	X	--	--	X	X
1977-Frost	Glacier-1977	Aug-Sep 1977	4.9 m & 5.8 m OT, 6 mm		10	--	--	X	X	X	--	X	--	--	D	X	X
1983a-Fechhelm	Discoverer-1983	Aug-Sep 1983	7.6 m OT, 13 mm		18	X	--	X	X	--	X	X	X	X	--	--	X
1983b-Fechhelm	Zodiac-1983	Aug-Sep 1983	2.7 m OT, 19 mm		6	X	--	X	X	--	X	X	--	--	--	--	X
1989-Barber	HX130	Sep 1989	6.1 m OT, 35 mm		25	--	--	X	X	--	--	X	X	X	--	X	X
1990-Barber	OH902	Aug-Sep 1990	25.2 m 83-112 eastern OT, 33 mm	B	48	X	X	X	X	X	--	X	X	X	--	X	X
1990-Hokkaido	OS33	Jul-Aug 1990	43 m OT, 90 mm		10	--	--	X	X	X	--	X	X	X	--	X	X
1991a-Barber[3]	Responder-1991a	Jul 1991	4.9 m OT, 5 mm	A[1]	[3]	--	--	--	--	--	--	--	--	--	--	--	
1991b-Barber[3]	Responder-1991b	Aug 1991	4.9 m OT, 5 mm	A[1]	[3]	--	--	--	--	--	--	--	--	--	--	--	
1991c-Barber	OH91	Aug-Sep 1991	25.2 m 83-112 eastern OT, 33 mm	B	15	X	est	X	X	X	--	X	X	X	--	X	X
1991d-Barber[3]	Responder-1991c	Sep 1991	4.9 m OT, 5 mm	A[1]	[3]	--	--	--	--	--	--	--	--	--	--	--	
1991-Hokkaido	OS38	Jul 1991	43 m OT, 90 mm		19	--	--	X	X	X	--	X	X	X	--	X	X
1992-Hokkaido	OS44	Jul 1991	43 m OT, 45 mm		17	--	--	X	X	X	--	X	X	X	--	X	X
2004-Mecklenburg	RUSALCA-2004	Aug 2004	7.1 m OT, 37 mm		4	X	--	X	X	--	[2]	X	X	X	D, %	X	
2004-Norcross	RUSALCA-2004	Aug 2004	3 m PSBT, 4 mm	C	5	X	X	X	X	--	X	X	X	X	D, %	X	X
2007-Hokkaido	OS180	Aug 2007	43 m OT, 45 mm		5	--	--	X	X	X	--	X	X	X	--	--	
2007a-Norcross	OS180	Aug 2007	3 m PSBT, 4 mm	C	16	X	X	X	X	X	X	X	X	X	D, %	X	X
2007b-Norcross	OD0710	Sep 2007	3 m PSBT, 4 mm	C	23	X	X	X	X	X	X	X	X	X	D, %	X	X
2008-Hokkaido	OS190	Jul 2008	43 m OT, 45 mm		7	--	--	X	--	X	--	X	X	X	--	--	
2008-Norcross	OS190	Jul 2008	3 m PSBT, 4 mm	C	16	X	X	X	X	X	X	X	X	X	D, %	X	X
count = 23	20					10	8	20	17	12	7	20	18	15	7	16	15

[1] Gears described as 4.9 m OT with smallest mesh of 5 or 6 mm are virtually identical

[2] Data collected but not yet reported by investigators, and therefore not included in CDF Database.

[3] Samples were lost and no catch data are available.

Table II-2. Potential density ranges for the bottom water masses assigned from the eastern Chukchi Sea during each cruise. # Stations is count over which density is expressed (# stations where fish presence is reported).

CDF Cruises	Water mass	# Stations	Potential density	Temperature (°C)	Salinity
1983a-Fechhelm &	Alaska Coastal Water	n=21(12)	21.3−23.8	4.5−7.5	27.0−30.5
1983b-Fechhelm	Bering Sea Water	n=17(7)	24.2−25.5	2.3−6.7	30.6−32.0
	Winter Water	n=6(1)	25.4−26.1	-0.8−1.6	31.7−32.6
1989-Barber	Alaska Coastal Water	n=15(9)	21.6−24.3	7.4−9.7	27.9−31.3
	Bering Sea Water	n=20(14)	24.3−25.2	5.2−7.5	30.7−32.0
	Resident Chukchi	n=1(1)	22.2	2.4	27.8
1990-Barber	Alaska Coastal Water	n=10(10)	22.4−23.9	5.7−12.7	29.5−30.4
	Bering Sea Water	n=27(27)	24.1−26.0	-0.2−7.1	30.8−32.6
	Winter Water	n=4(4)	26.2−26.8	-1.2 to -0.6	32.6−33.3
1990-Hokkaido	Alaska Coastal Water	n=4(1)	23.6−24.5	5.7−8.1	30.4−31.1
	Bering Sea Water	n=17(9)	24.8−26.0	0.6−4.9	31.3−32.5
1991c-Barber	Alaska Coastal Water	n=1(1)	23.1−23.1	7.1−7.1	29.5−29.5
	Bering Sea Water	n=2(2)	24.6−25.5	1.5−4.2	31.0−31.8
	Winter Water	n=14(12)	25.9−27.0	-1.7−0.4	32.2−33.5
1991-Hokkaido	Alaska Coastal Water	n=6(6)	24.5−25.4	0.7−4.4	30.7−32.0
	Bering Sea Water	n=8(8)	25.8−26.4	-1.3−1.2	32.2−32.8
	Winter Water	n=3(3)	26.6−26.9	-1.7 to -1.6	33.1−33.4
1992-Hokkaido	Alaska Coastal Water	n=4(3)	24.6−25.0	4.0−5.2	31.0−31.7
	Bering Sea Water	n=12(4)	25.4−26.2	2.0−3.5	31.9−32.8
	Winter Water	n=19(10)	25.4−26.3	-1.7−0.1	31.6−32.6
2004-Mecklenburg	Alaska Coastal Water	n=2(3[2])	23.5−24.4	8.0−10.5	30.6−31.3
& 2004-Norcross[1]	Bering Sea Water	n=4(2)	25.2−26.0	2.8−4.4	31.7−32.6
2007a-Norcross	Bering Sea Water	n=30(16)	24.8−26.2	0.3−7.6	31.8−32.9
2007b-Norcrosss	Alaska Coastal Water	n=17(12)	23.6−25.5	4.6−10.7	30.9−32.2
	Bering Sea Water	n=21(9)	25.5−26.3	-0.5−5.0	32.2−33.0
2008-Norcross	Bering Sea Water	n=18(9)	25.4−26.3	-0.7−3.2	31.9−32.9
	Winter Water	n=14(7)	26.1−26.8	-1.7 to -0.6	32.5−33.4

[1] Water masses from 2004 are after Norcross et al. (2010).

[2] One fishing station during 2004 was assigned as Alaska Coastal Water although bottom temperature and salinity were not recorded.

Table II-3. Similarity (ANOSIM R) and significance between habitat physical parameters and fish species composition within each cruise. Presence, rather than proportion, of substrate was tested. Blanks indicate insufficient data with which to run ANOSIM. Asterisks indicate significant differences: * *P*<0.05, ** *P*<0.01.

CDF Cruises	Depth	Temperature	Salinity	Water Mass	Rock	Gravel	Shell	Sand	Mud
1959-Alverson	0.235 **	0.235 *							
1976-Pereyra	0.451 **	0.387 **							
1977-Frost	-0.007				0.266	0.172			0.266
1983a&b-Fechhelm	0.352 *	0.228	0.075	0.338 *					
1989-Barber	0.228 **	0.372	0.555	0.149 **					
1990-Barber	0.158 **	0.313 **	0. 256 **	0.210 **					
1990-Hokkaido	0.389	0.077	0.417	0.920					
1991c-Barber	0.667		0.926						
1991-Hokkaido	0.276			0.040					
1992-Hokkaido	-0.531		0.554	0.160					
2004-Mecklenburg & 2004-Norcross	0.071	0.504 **	0.504 **	0.332		0.609 **	0.461	0.032	0.461
2007a-Norcross	-0.132	0.076	-0.640			-0.052	-0.015	0.026	0.454 *
2007b-Norcross	0.156	0.165	0.324	0.014	0.099	0.021	-0.476	-0.456	0.141
2008-Norcross	-0.072	0.074	0.182	0.004	0.383 *	0.112	-0.024	0.319 *	0.498 **

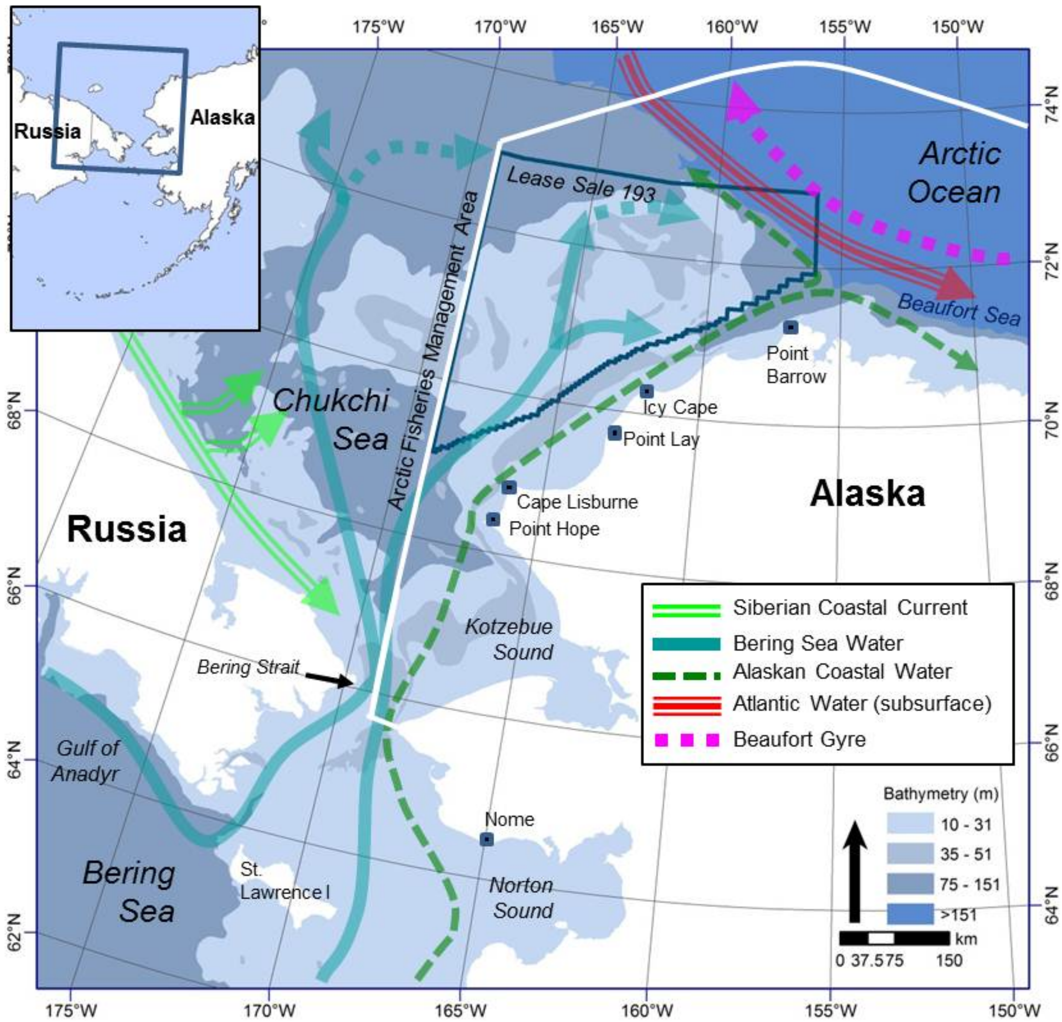


Figure II-1. Generalized positions of circulation and water masses in the Chukchi and adjacent seas (modified from Weingartner et al., 2008 and Day et al., In press).

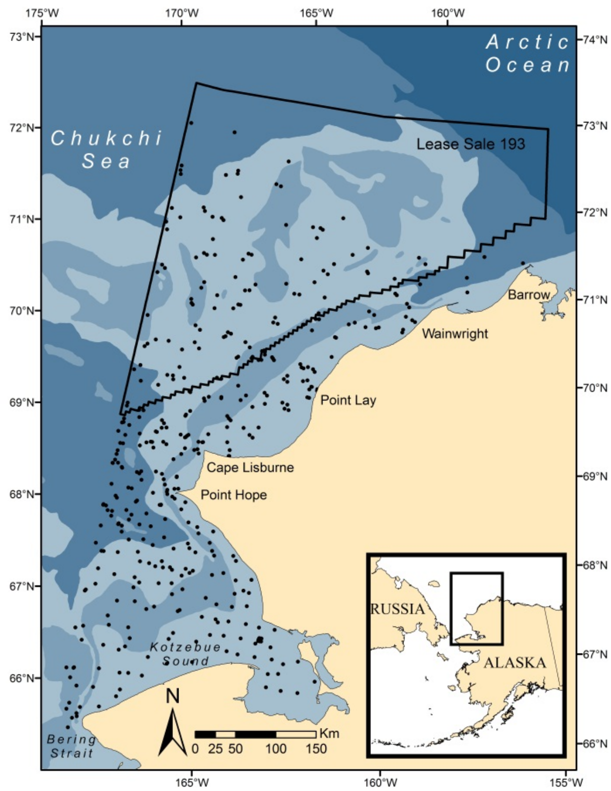


Figure II-2. Map of the eastern Chukchi Sea, Lease Sale 193, and fish sampling sites during 1959–2008 (dots).

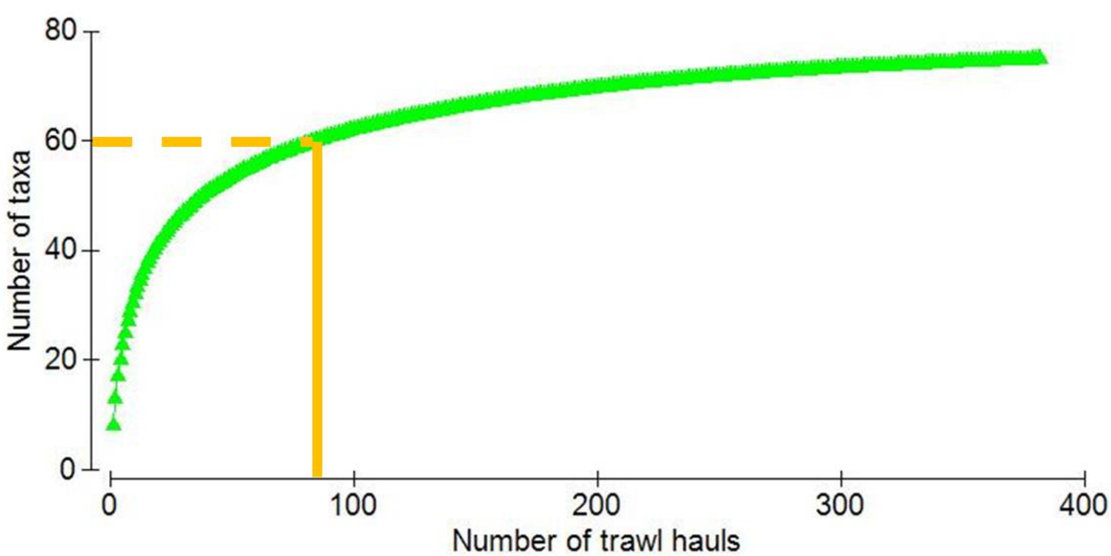


Figure II-3. Cumulative count of fish taxa captured in the Chukchi Sea in 1959–2008. 60% of taxa are captured in 84 hauls.

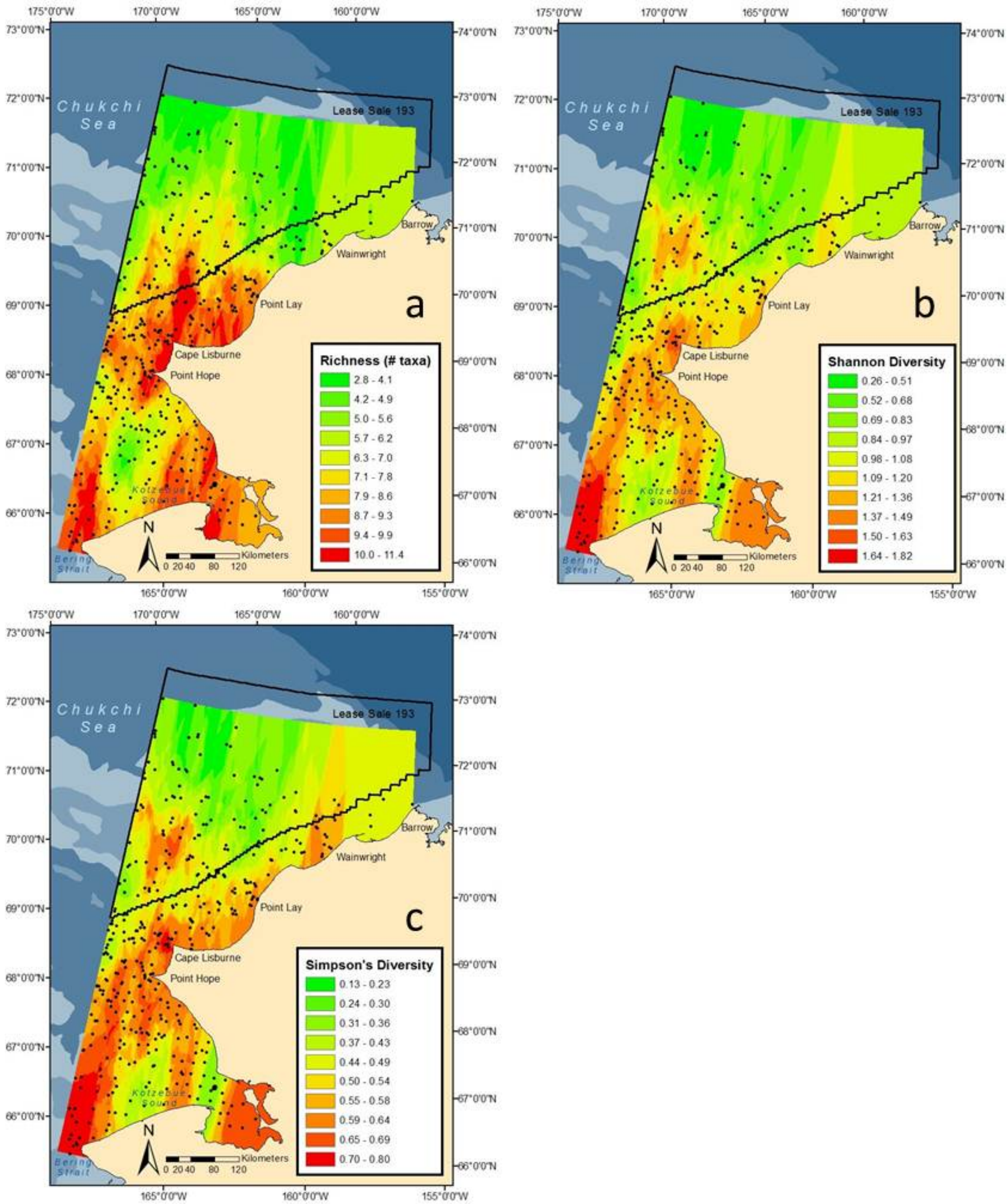


Figure II-4. Maps of fish presence data in the eastern Chukchi Sea, 1959–2008: a) taxa richness, b) Shannon diversity, and c) Simpson's diversity. Colors represent groupings of index values kriged. Black dots indicate haul locations. Fish collections used different survey methods.

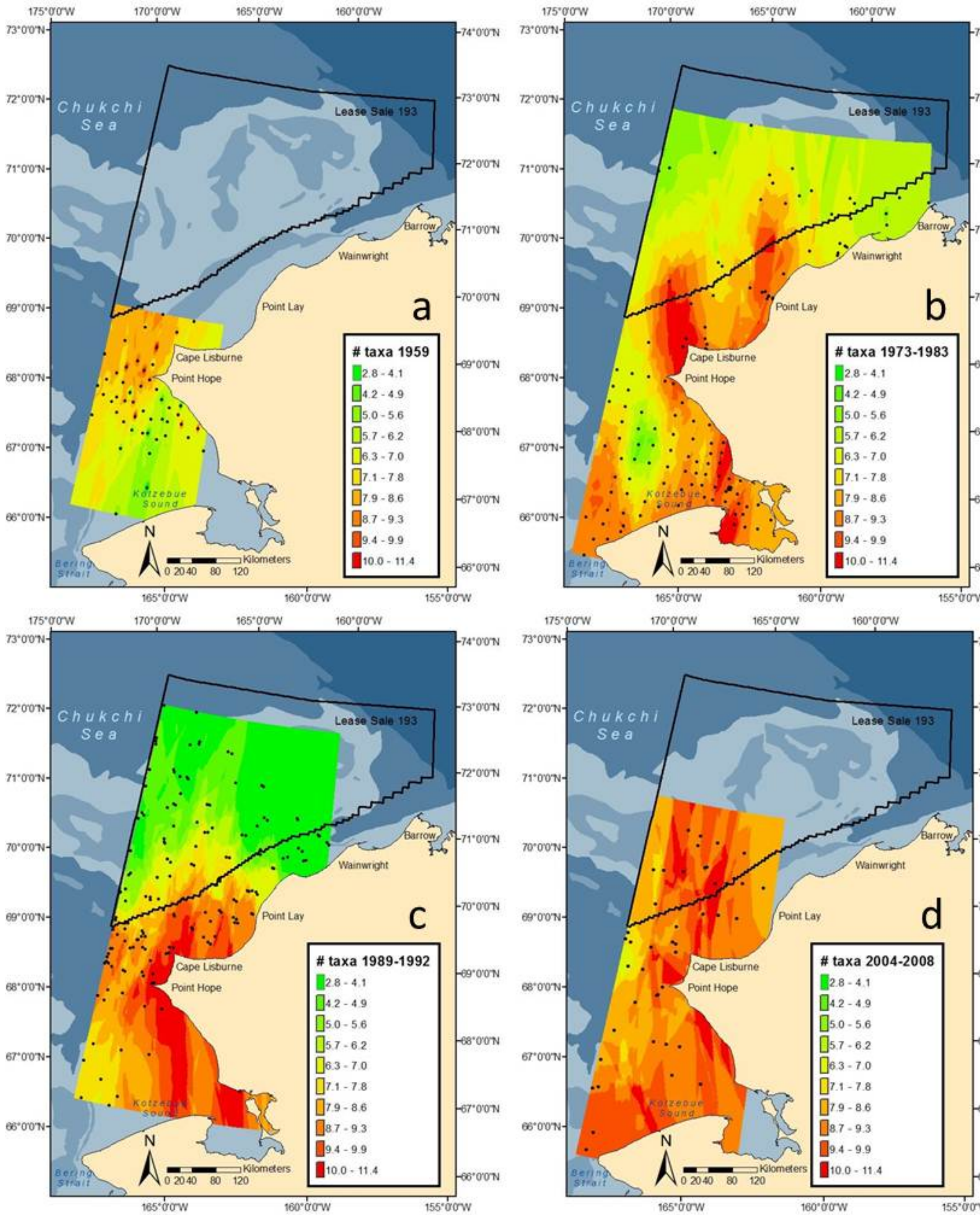


Figure II-5. Maps of taxa richness in the eastern Chukchi Sea by approximate decade: a) 1959, b) 1973–1983, c) 1989–1992, and d) 2004–2008. Colors represent groupings of index values kriged. Black dots indicate haul locations. Fish collections used different survey methods.

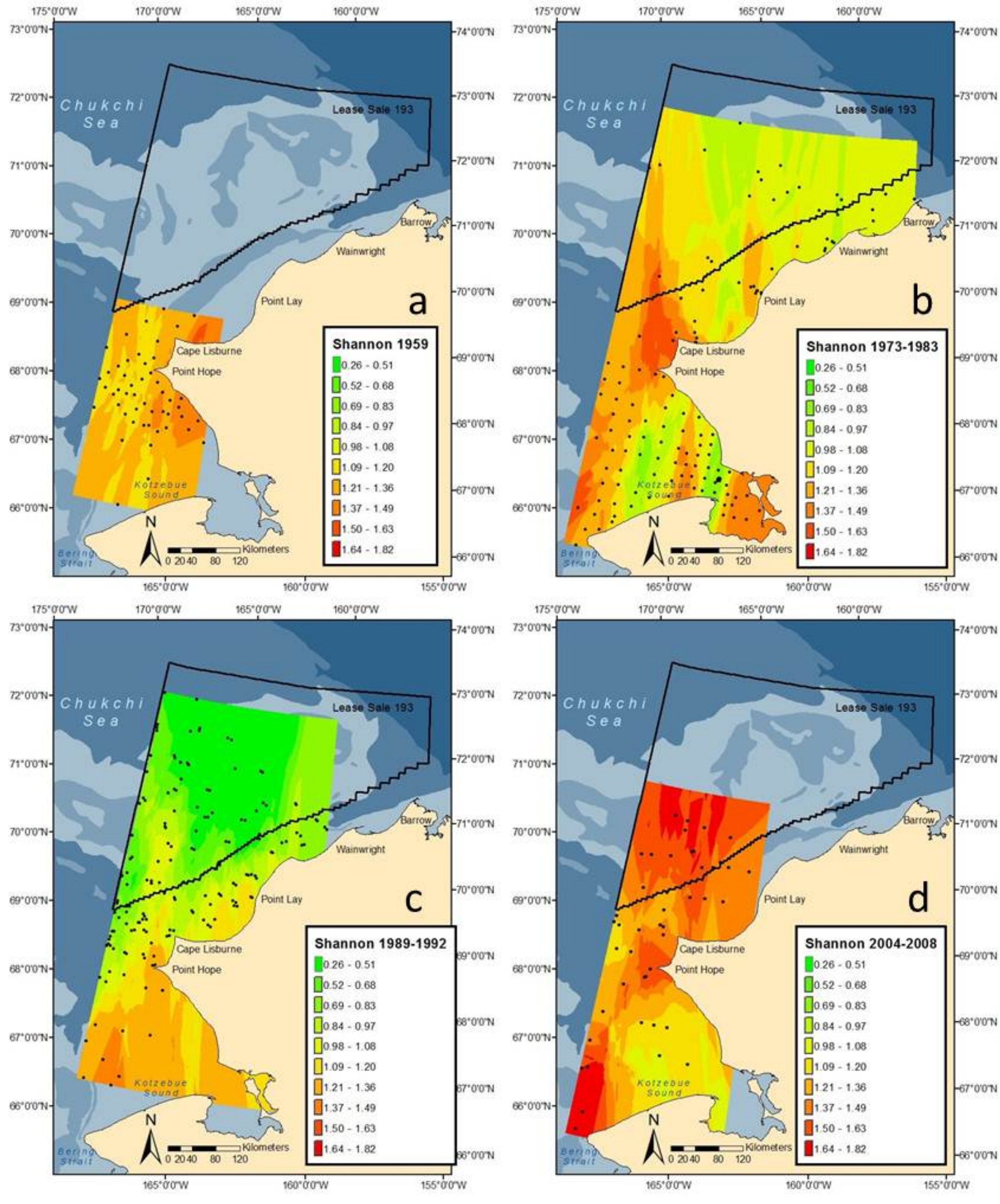


Figure II-6. Maps of Shannon diversity indices in the eastern Chukchi Sea by approximate decade: a) 1959, b) 1973–1983, c) 1989–1992, and d) 2004–2008. Colors represent groupings of index values kriged. Black dots indicate haul locations. Fish collections used different survey methods.

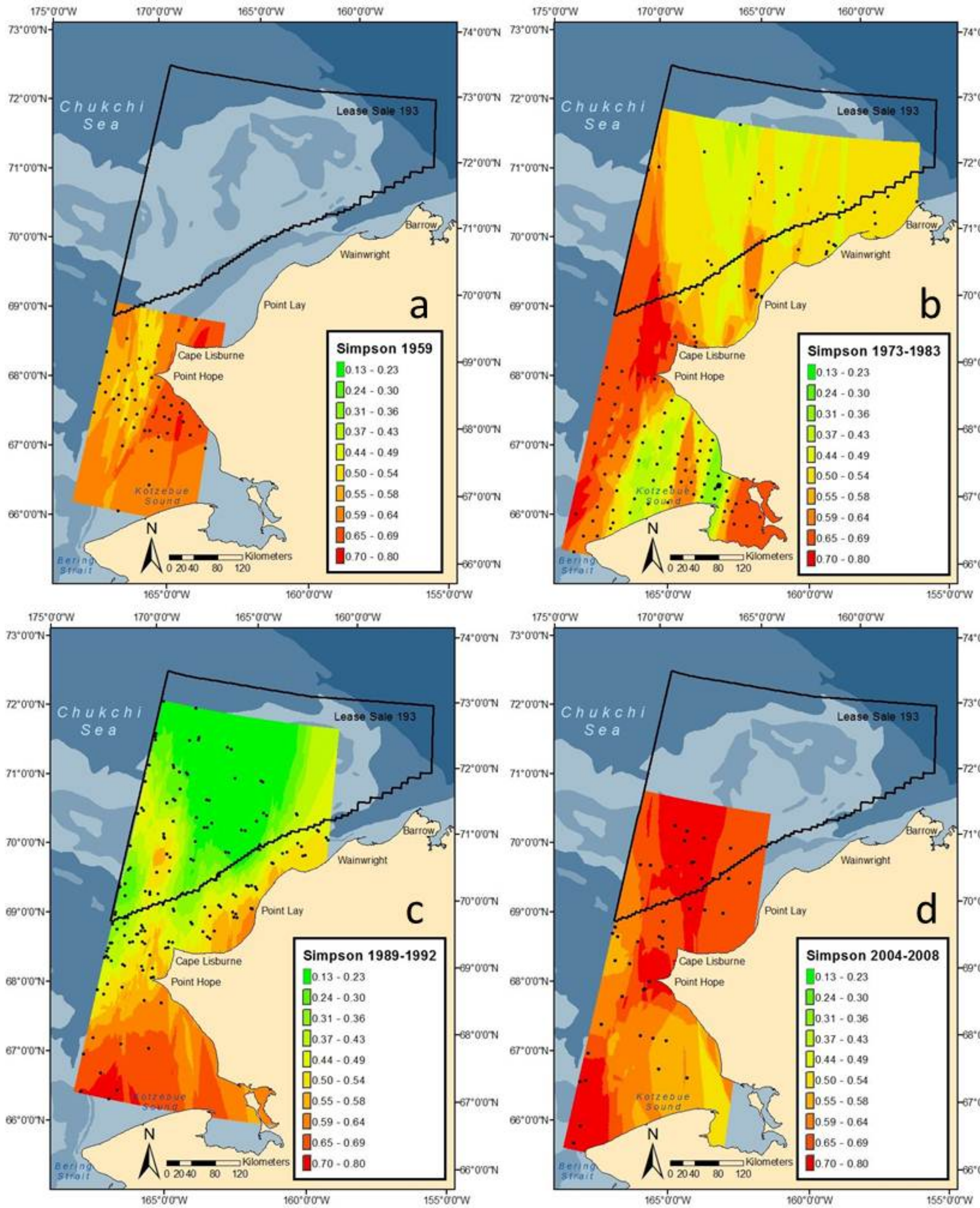


Figure II-7. Maps of Simpson's diversity indices in the eastern Chukchi Sea by approximate decade: a) 1959, b) 1973–1983, c) 1989–1992, and d) 2004–2008. Colors represent groupings of index values kriged. Black dots indicate haul locations. Fish collections used different survey methods.

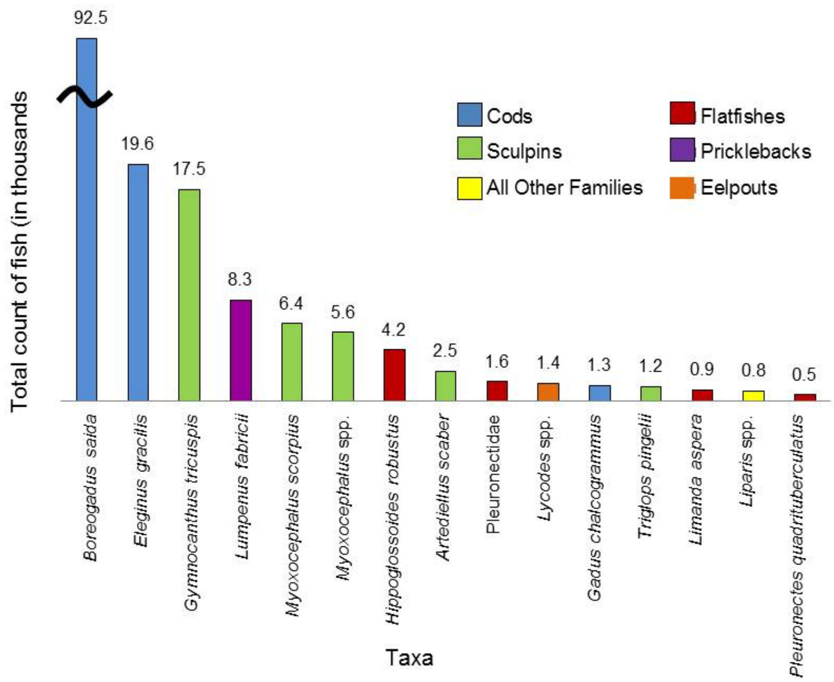


Figure II-8. The 15 most abundant fish taxa in the Chukchi Sea during 1959–2008. Taxa are color-coded by family.

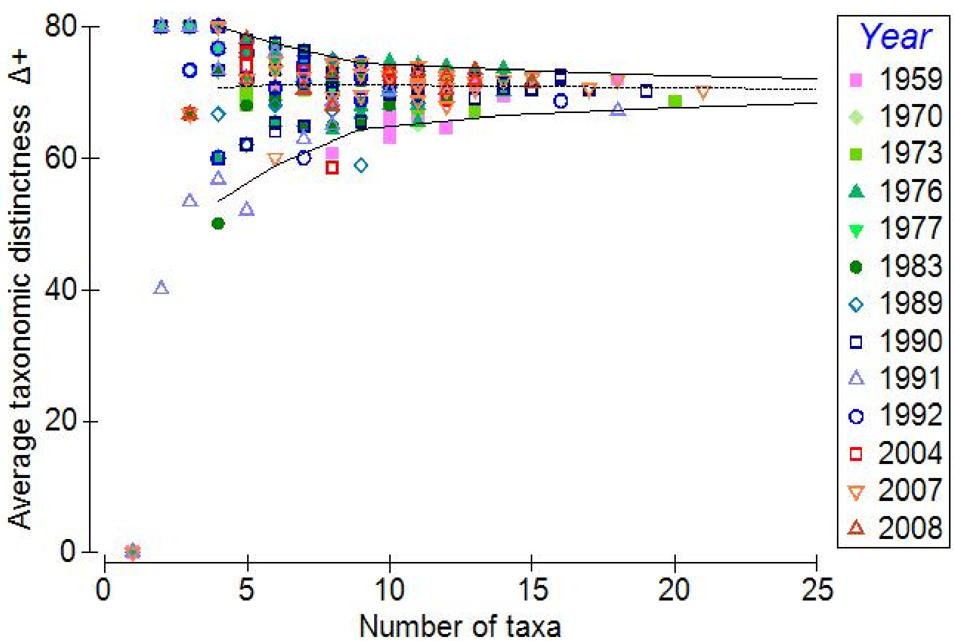


Figure II-9. Taxonomic distinctness of number of fish taxa captured during 1959–2008. Symbols for years indicate departure of individual hauls from the theoretical mean (straight line) of taxonomic distinctness (Δ+). Funnel shape represents 95% confidence limits, which cannot be accurately displaced for n<4 taxa.

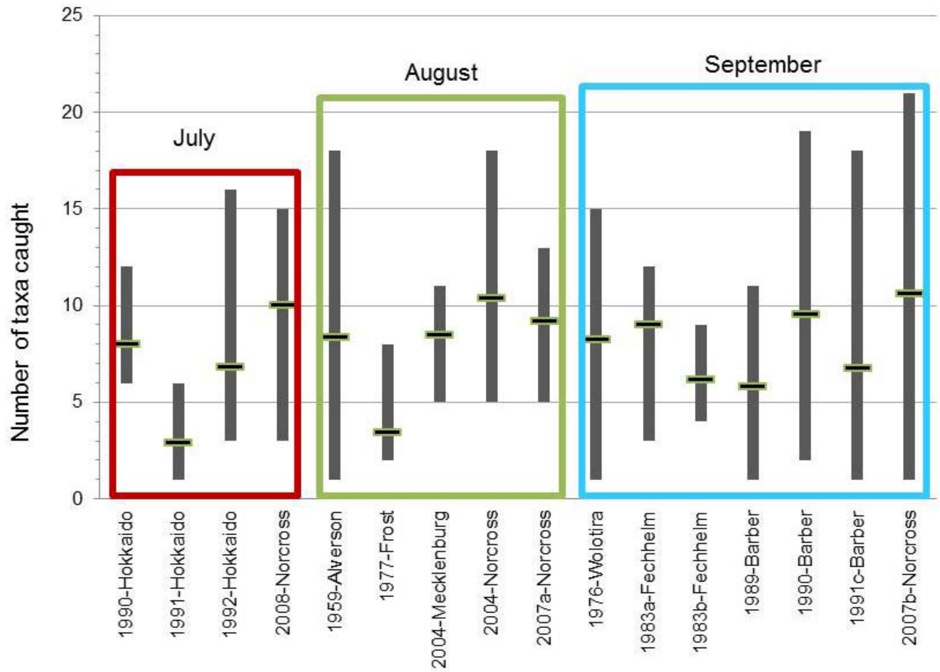


Figure II-10. Range and average number of fish taxa captured in the eastern Chukchi Sea during 1959–2008. X-axis is cruise grouped by month and year of collection.

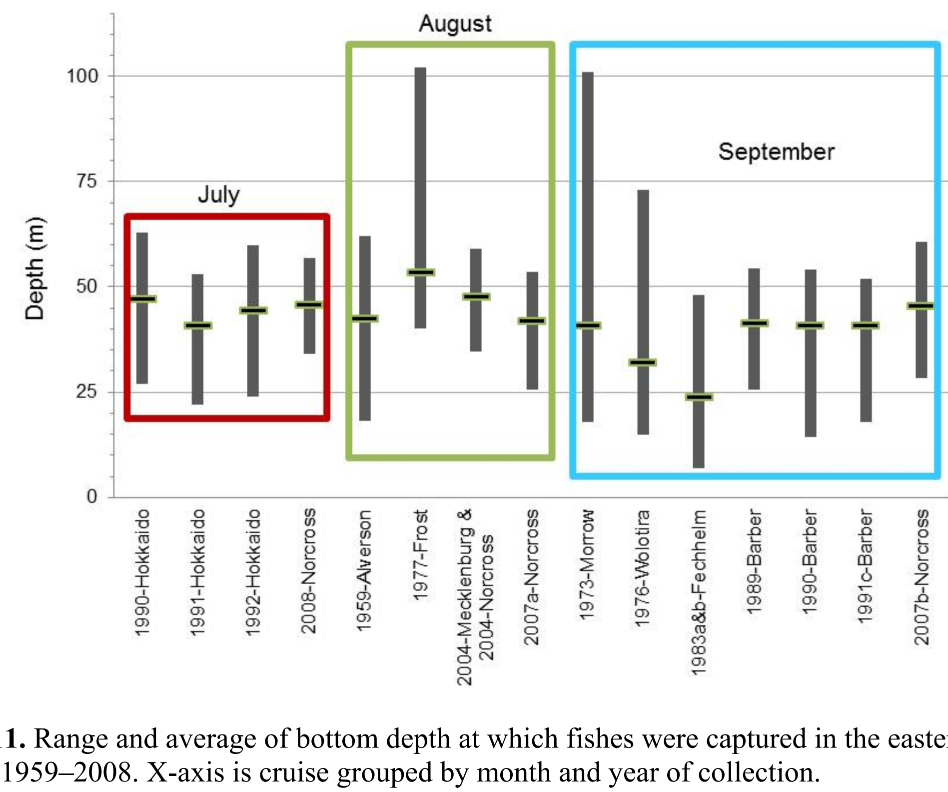


Figure II-11. Range and average of bottom depth at which fishes were captured in the eastern Chukchi Sea during 1959–2008. X-axis is cruise grouped by month and year of collection.

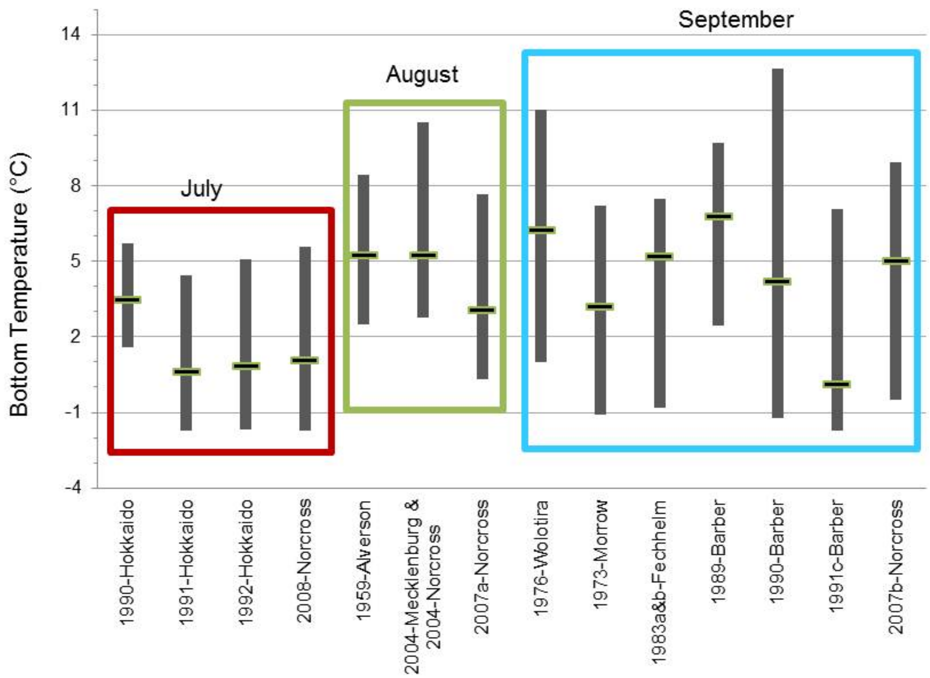


Figure II-12. Range and average of bottom temperature at which fishes were captured in the eastern Chukchi Sea during 1959–2008. No ranges are plotted when data were not collected. X-axis is cruise grouped by month and year of collection.

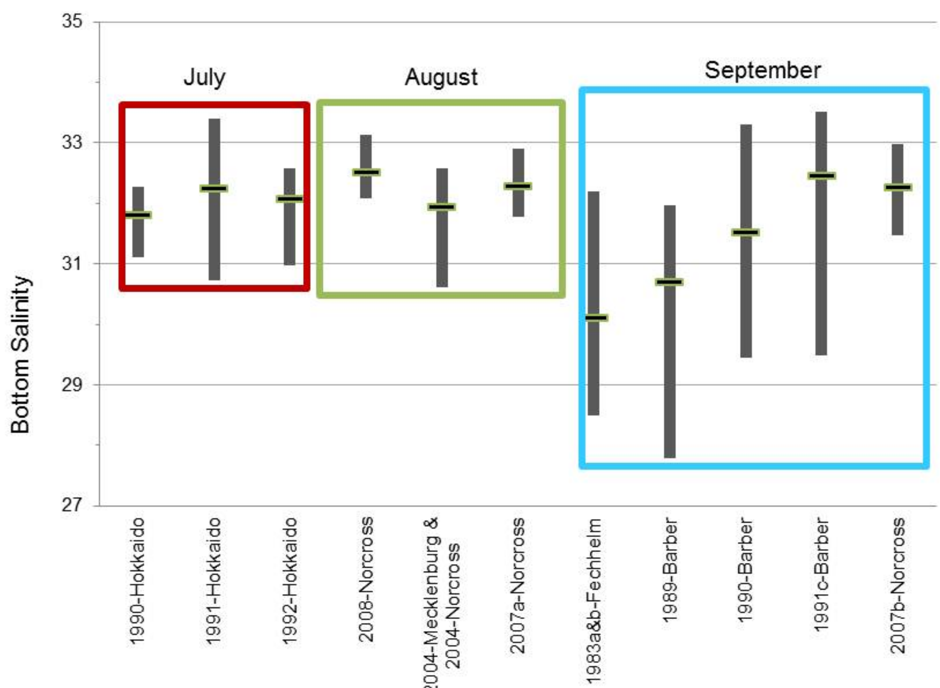


Figure II-13. Range and average of bottom salinity at which fishes were captured in the eastern Chukchi Sea during 1959–2008. No ranges are plotted when data were not collected. X-axis is cruise grouped by month and year of collection.

Acknowledgements

This project was funded primarily by the Coastal Marine Institute (CMI) of the University of Alaska, through Task Order M07AC12462 (previously M07AC13416) from the Bureau of Ocean Energy Management (BOEM). Vessel support for 2007 and 2008 sample collection aboard the T/S *Oshoro-Maru* cruises OS180 and OS190 was supplied by Hokkaido University Faculty of Fisheries, and vessel support aboard the R/V *Oscar Dyson* cruise OD0710 was provided by the Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA Fisheries. Mecklenburg's participation during OD0710fieldwork was funded by the Arctic Research Office (ARO/NOAA) through the Russian-American Long-term Census of the Arctic program (RUSALCA).The successful field collections during 2007–2008 were due largely to the generous help of colleagues and crew aboard these vessels. The CMI was one of several entities providing financial support for the verification of museum vouchers and development of the Arctic Marine Fish Museum Specimens Database; funding for this task was also provided by the Sloan Foundation through the Census of Marine Life program/Arctic Ocean Diversity (ArcOD), and the ARO/NOAA through the RUSALCA program. We appreciate the helpful reviews of earlier versions of this report by C. Coon, N. Deschu and M. Rasser (BOEM), L. Edenfield and B. Gray (IMS/UAF), and two anonymous reviewers. Thank you to L. Edenfield for assistance with figures of this report. This project contributes to the ArcOD Census of Marine Life and is a result, in part, of RUSALCA funding through NOAA Cooperative agreement NA08OAR4320870. Electronic project data are available through the Alaska Ocean Observing System (*www.aoos.org*).

Project Organization

B. L. Norcross was the lead investigator and manager of this project. Norcross wrote project reports and presented results at University of Alaska, state, national, and international meetings, including management agency meetings. B. A. Holladay led field collections during 2004–2008 and prepared a relational database of catches of demersal fishes and associated physical data in the eastern Chukchi Sea from assorted publications, project reports, and electronic data repositories. Holladay also prepared maps, assisted with preparation of reports and presentations, and presented results at an international workshop. C. W. Mecklenburg reviewed, and in some cases revised the identification of, museum specimens in the United States, Canada, Japan and Russia, which significantly increased the accuracy of species records in this project's database from original data reports. She also identified and preserved the recent voucher collections, at sea in 2004 and 2007 as PI for her own projects and from frozen collections of the *Oshoro Maru* cruises in 2007 and 2008. She suggested the creation of the catch records database (in 2006), obtained haul-catch records early in the project, and advised on interpretation and updating of the haul-catch records. Mecklenburg also assisted with preparation of project reports.

Study Products

Written Reports and Publications

Norcross, B. L., and B. A. Holladay. 2010. Current and Historic Distribution and Ecology of Demersal Fishes in the Chukchi Sea Planning Area. CMI Annual Report: September 2008 – December 2009, 11 p + Figures.

Bluhm, B.A., K. Iken, S. Mincks Hardy, B. I. Sirenko, and B. A. Holladay. 2009. Community structure of epibenthic megafauna in the Chukchi Sea. Aquatic Biology Vol. 7: 269–293. *doi: 10.3354/ab00198.*

Norcross, B. L., and B. A. Holladay. 2008. Current and Historic Distribution and Ecology of Demersal Fishes in the Chukchi Sea Planning Area. CMI Annual Report: May 2007 – September 2008, 17 p + Figures.

Oral Presentations

Norcross, B. L. 2011. Arctic cod dominate 50 years of demersal fishes in the Chukchi Sea. Fisheries Department, University of Alaska Fairbanks, Fairbanks, AK. May 2011.

Norcross, B. L., and B. A. Holladay. 2011. 50 years of demersal fishes in the Chukchi Sea. Alaska Marine Science Symposium, Anchorage, AK. January 2011.

Norcross, B. L., B. A. Holladay, and C. W. Mecklenburg. 2011. Distribution and ecology of demersal fishes in the Chukchi Sea over 50 years. Arctic Frontiers Conference, Trømso, Norway. January 2011.

Norcross, B. L., and B. A. Holladay. 2010. Demersal fishes in the northeastern Chukchi: 1959–2008. *Oshoro-Maru* IPY 2007–2008 Workshop, Hakodate, Japan. February 2010.

Holladay, B. A., B. Bluhm, S. M. Hardy, K. Iken, B. Sirenko. 2010. Epibenthos in the Chukchi Sea: Environmental influences on community structure. *Oshoro-Maru* IPY 2007–2008 Workshop, Hakodate, Japan. February 2010.

Norcross BL, Holladay BA (2010) Historic distribution of demersal fishes in the Chukchi Sea. Alaska Marine Science Symposium, Anchorage, AK. January 2010.

Norcross, B. L., and B. A. Holladay. 2009. Current and historic distribution and ecology of demersal fishes in the Chukchi Sea Planning Area – Year 2. Project report for CMI review, Fairbanks and Anchorage, AK. December 2009.

Norcross, B. L., and B. A. Holladay. 2009. Climate change, physics and demersal fishes in the Chukchi Sea. Alaska Chapter, American Fisheries Society Meeting, Fairbanks, AK. November 2009.

Norcross, B. L., and B. A. Holladay. 2009. Demersal fish of the Chukchi Sea. Fisheries Department, University of Alaska Fairbanks, Juneau, AK. October 2009.

Norcross, B. L., B. A. Holladay, and C. W. Mecklenburg. 2008. Current and historic distribution and ecology of demersal fishes in the Chukchi Sea Planning Area. Project report for CMI review, Fairbanks, AK. February 2008.

Mecklenburg, C. W. (2007) Russian-American Long-term Census of the Arctic (RUSALCA): Results of 2004 cruise to the Chukchi Sea and database of Arctic marine fish museum specimens. Hokkaido University, Hakodate, Japan. May 2007.

References Cited

ACIA (Arctic Climate Impact Assessment). 2004. Impacts of a warming Arctic. Cambridge University Press. New York, NY (*www.amap.no/acia*).

Alverson, D. L., and N. J. Wilimovsky. 1966. Fishery investigations of the southeastern Chukchi Sea. In: Wilomovski, N. J., and J. N. Wolfe (editors.), Environment of the Cape Thompson region, Alaska, p. 843–860. U.S. Atomic Energy Commission, Washington, DC.

Barber, W. E., R. L. Smith, M. Vallarino, and R. M. Meyer. 1997. Demersal fish assemblages of the northeastern Chukchi Sea, Alaska. Fisheries Bulletin (US) 95:195–209.

Byrkjedal, I., and Å. Høines. 2007. Distribution of demersal fish in the south-western Barents Sea. Polar Research 26:135–151.

Clarke, K. R., and R. N. Gorley. 2006. PRIMER v6: User Manual/Tutorial. PRIMER-E Ltd., Plymouth.

Clarke, K. R., P. J. Somerfield, and R. N. Gorley. 2008. Testing of null hypotheses in exploratory community analyses: similarity profiles and biota-environment linkage. Journal of Experimental Marine Biology and Ecology 366:56–69.

Clarke, K. R., and R. M. Warwick. 2001. Change in marine communities: an approach to statistical analysis and interpretation, 2nd edition. PRIMER-E, Plymouth.

Day, R. H., T. J. Weingartner, R. R. Hopcroft, L. A. M. Aerts, A. L. Blanchard, A. E. Gall, B. J. Gallaway, D. E. Hannay, B. A. Holladay, J. T. Mathis, B. L. Norcross, J. M. Questel, and S. S. Wisdom. In press. The offshore northeastern Chukchi Sea, Alaska: a complex high-latitude ecosystem. Continental Shelf Research (*http://dx.doi.org/10.1016/j.csr.2013.02.002*).

de Smith, M. J, M. F. Goodchild, and P. A. Longley. 2009. Geospatial Analysis—A Comprehensive Guide, 3rd edition, Web version, (*www.spatialanalysisonline.com*)

Doyle, M. J., K. L. Mier, M. S. Busby, and R. D. Brodeur. 2002. Regional variation of springtime ichthyoplankton assemblages in the northeast Pacific Ocean. Progress in Oceanography 53:247–281.

Eschmeyer, W. N. (editor). 2013. Catalog of Fishes. California Academy of Sciences. Electronic version accessed 1 Feb 2013, (*http://research.calacademy.org/research/ichthyology/catalog/fishcatmain.asp*).

Ellis, J. R., S. I. Rogers, and S. M. Freeman. 2000. Demersal assemblages in the Irish Sea, St George's Channel and Bristol Channel. Estuarine, Coastal and Shelf Science 51:299–315.

ESRI Inc. 2010 ArcMap GIS Desktop v. 10.0.

Fossheim, M., E. M. Nilssen, and M. Aschan. 2006. Fish assemblages in the Barents Sea. Marine Biology Research 2:260–269.

Frank, K. T., B. Petrie, N. L. Shackell, and J. S. Choi. 2006. Reconciling differences in trophic control in mid-latitude marine ecosystems. Ecology Letters 9:1096–1105.

Froese R., and D. Pauly (editors). 2011. FishBase. World Wide Web electronic publication., version December 2011, (*www.fishbase.org*).

Frosini, B. V. 2004/Rev.2006. Descriptive measures of ecological diversity, in: Environmetrics, Eds. Jana Jureckova, Abdel H. El-Shaarawi, in Encyclopedia of Life Support Systems (EOLSS), Developed under the Auspices of the UNESCO, Eolss Publishers, Oxford, UK, (*www.eolss.net*).

Frost, K. J., and L. F. Lowry. 1983. Demersal fishes and invertebrates trawled in the northeastern Chukchi and western Beaufort seas 1976–1977. U.S. Dep. of Commerce, NOAA Technical Report NMFS-SSRF-764, 22 p.

Grebmeier, J. M., L. W. Cooper, H. M. Feder, and B. I. Sirenko. 2006. Ecosystem dynamics of the Pacific influenced Northern Bering and Chukchi Seas. Progress in Oceanography 71:331–361.

Gunderson, D. R., and I. E. Ellis. 1986. Development of a plumb staff beam trawl for sampling demersal fauna. Fisheries Research 4:35–41.

Hillebrand, H., D. M. Bennett, and M. W. Cadotte. 2008. Consequences of dominance: a review of evenness effects on local and regional processes. Ecology 89:1510–1510.

Hokkaido University. 2008. The "*Oshoro-Maru*" cruise 180 to the northwest North Pacific Ocean, the Bering Sea, and the Chukchi Sea in July–August 2007. Pages 33–90 in: Data record of oceanographic observations and exploratory fishing No. 51. Faculty of Fisheries, Hokkaido University, Hakodate, Hokkaido, Japan.

Hokkaido University. 2009. The "*Oshoro-Maru*" cruise 190 to the northwest North Pacific Ocean, the Bering Sea, and the Chukchi Sea in June–July 2008. Pages 39–88 in: Data record of oceanographic observations and exploratory fishing No. 52. Faculty of Fisheries, Hokkaido University, Hakodate, Hokkaido, Japan.

Hunt, G. L., Jr., K. O. Coyle, L. B. Eisner, E. V. Farley, R. A. Heintz, F. Mueter, J. M. Napp, J. E. Overland, P. H. Ressler, S. Salo, and P. J. Stabeno. 2011. Climate impacts on eastern Bering Sea foodwebs: a synthesis of new data and an assessment of the Oscillating Control Hypothesis. ICES Journal of Marine Science 68:1230–1243.

Jaureguizar, A. J., R. Menni, C. Bremec, H. Mianzan, and C. Lasta. 2003. Fish assemblage and environmental patterns in the Rio de la Plata estuary. Estuarine, Coastal and Shelf Science 56:921–933.

Jenks, G. F. 1967. The Data Model Concept in Statistical Mapping, International Yearbook of Cartography 7: 186–190.

Matarese, A. C., A. W. Kendall Jr., D. M. Blood, and B. M. Vinter. 1989. Laboratory guide to early life history of Northeast Pacific fishes. NOAA Technical Report NMFS 80, Seattle, WA. 652 p.

Mecklenburg, C. W., and T. A. Mecklenburg. 2009. Arctic marine fish museum specimens, 2nd edition. Metadata report and database submitted to ArcOD, Institute of Marine Science, University of Alaska Fairbanks by Point Stephens Research, P.O. Box 210307, Auke Bay, AK 99821 USA (metadata report: *http://www.arcodiv.org/Database/Fish_datasets.html*)

Mecklenburg, C. W., T. A. Mecklenburg, and L. K. Thorsteinson. 2002. Fishes of Alaska. American Fisheries Society, Bethesda, MD. 1037 p.

Mecklenburg, C.W., T. A. Mecklenburg, B. A. Sheiko, and N. V. Chernova. 2006. Arctic marine fish museum specimens. Metadata report and database submitted to ArcOD, Institute of Marine Science, University of Alaska Fairbanks by Point Stephens Research, P.O. Box 210307, Auke Bay, AK 99821 USA (metadata report: http://dw.sfos.uaf.edu/rest/metadata/ArcOD/2007F1)

Mecklenburg, C. W., D. L. Stein, B. A. Sheiko, N. V. Chernova, T. A. Mecklenburg, and B. A. Holladay. 2007. Russian–American Long-term Census of the Arctic: benthic fishes trawled in the Chukchi Sea and Bering Strait, August 2004. Northwestern Naturalist 88:168–187.

Mecklenburg, C. W., B. L. Norcross, B. A. Holladay, and T. A. Mecklenburg. 2008. Fishes. Pages 65–79 in: Hopcroft R, B. Bluhm. R. Gradinger (editors). Arctic Ocean synthesis: Analysis of climate change impacts in the Chukchi and Beaufort Seas with strategies for future research. Final Report to the North Pacific Research Board. Fairbanks, AK, (*http://doc.nprb.org/web/05_prjs/503_final.pdf*).

Mecklenburg, C. W., P. R. Møller, and D. Steinke. 2011. Biodiversity of arctic marine fishes: taxonomy and zoogeography. Marine Biodiversity 41: 109–140 (*DOI 10.1007/s12526-010-0070-z*).

Mueter, F. J., C. Ladd, M. C. Palmer, and B. L. Norcross. 2006. Bottom-up and to-down controls of walleye pollock (*Theragra chalcogramma*) on the Eastern Bering Sea shelf. Progress in Oceanography 68:152–183.

Mueter, F. J., and M. A. Litzow. 2008. Sea ice retreat alters the biogeography of the Bering Sea continental shelf. Ecological Applications 18:308–320.

Meyer, R. M., and B. A. Holladay. 2011. Appendix 4: An evaluation of benthic trawls that have been used to sample demersal fishes in the northeastern Chukchi Sea, Alaska. Pages 1–26 in: A synthesis of diversity, distribution, abundance, age, size and diet of fishes in the lease sale 193 area of the northeastern Chukchi Sea, Final Report, prepared for ConocoPhillips Alaska, Inc., Shell Exploration & Production Company, and Statoil USA E & P, Inc., November 2011.

Nelson, J. S., E. J. Crossman, H. Espinosa-Pérez, L. T. Lindley, C. R. Gilbert, R. N. Lea, and J. D. Williams. 2004. Common and scientific names of fishes from the United States, Canada, and Mexico, Sixth Ed. American Fisheries Society Special Publication 29, Bethesda, MD. 386 p.

Nichol, D. G. 1998. Annual and between-sex variability of yellowfin sole, *Pleuronectes asper*, spring-summer distributions in the eastern Bering Sea. Fishery Bulletin 96:547–561.

Norcross, B. L., B. A. Holladay, M. S. Busby, and K. L. Mier. 2010. Demersal and larval fish assemblages in the Chukchi Sea. Deep Sea Research Part II: Topical Studies in Oceanography 57(1–2):57–70.

NPFMC (North Pacific Fisheries Management Council). 2009. Fishery Management Plan for Fish Resources of the Arctic Management Area, November, (*www.fakr.noaa.gov/npfmc/current_issues/Arctic/arctic.htm).*

Overholtz, W. J., and A. V. Tyler. 1985. Long-term responses of the demersal fish assemblages of Georges Bank. Fishery Bulletin 83:507–520.

Parmesan, C., S. Gaines, L. Gonzalez, D. M. Kaufman, J. Kingsolver, A. Townsend Peterson, and R. Sagarin. 2005. Empirical perspectives on species borders: from traditional biogeography to global changes. Oikos 108:58–75.

Perovich, D. K. 2011. The changing Arctic sea ice cover. Oceanography 24(3):162–173

Pickart, R. S., L. J. Pratt, D. J. Torres, T. E. Whitledge, A. Y. Proshutinsky, K. Aagaard, T. A. Agnew, G. Moore, and H. J. Dail. 2010. Evolution and dynamics of the flow through Herald Canyon in the western Chukchi Sea. Deep Sea Research Part II: Topical Studies in Oceanography 57(1–2):5–26.

Polyak, L., R. B Alley, J. T. Andrews, J. Brigham-Grette, T. M. Cronin, D. A. Darby, A. S. Dyke, J. J. Fitzpatrick, S. Funder, M. Holland, A. E. Jennings, G. H. Miller, M. O’Regan, J. Savelle, M. Serreze, K. St. John, J. W. C. White, and E. Wolff. 2010. History of sea ice in the Arctic. Quaternary Science Reviews 29:1757–1778.

RACE. 2010. ADP code book, v.March 2010. Resource Assessment and Conservation Engineering, National Marine Fisheries Service, Seattle WA. 162 p. *http://www.afsc.noaa.gov/RACE/groundfish/adp_codebook.pdf*

Rogers, S. I., K. R. Clarke, and J. D. Reynolds. 1999. The taxonomic distinctness of coastal bottom-dwelling fish communities of the North-east Atlantic. Journal of Animal Ecology 68:769–782.

Schlitzer, R. 2007. Ocean Data View, (*http://odv.awi.de*).

Shackell, N. L., and K. T. Frank. 2003. Marine fish diversity on the Scotian Shelf, Canada. Aquatic Conservation: Marine and Freshwater Ecosystems 13:305–321.

Somerfield, P.J., F. Olsgard, and M. R. Carr. 1997. A further examination of two new taxonomic distinctness measures. Marine Ecology Progress Series 154:303–306.

Smith, R. L., W. E. Barber, M. Vallarino, J. G. Gillespie, and A. Ritchie. 1994. Biology of the Arctic staghorn sculpin, *Gymnocanthus tricuspis,* from the northeastern Chukchi Sea. Chapter 5 in Fisheries oceanography of the northeast Chukchi Sea. Final report. OCS Study MMS-93-0051, Minerals Management Service, Alaska OCS Region, Anchorage, AK.

Therriault, T. W., and J. Kolasa. 1999. Physical determinants of richness, diversity, evenness and abundance in natural aquatic microcosms. Hydrobiologia 412:123–130.

Tyler, A. V., W. L. Gabriel, and W. J. Overholtz. 1982. Adaptive management based on structure of fish assemblages of northern continental shelves. Canadian Special Publication of Fisheries and Aquatic Sciences 59:149–156.

Weingartner, T. J. 1997. A review of the physical oceanography of the Northeastern Chukchi Sea. Pages 40–59 in: Reynolds J (editor), Fish ecology in Arctic North America. American Fisheries Society Symposium 19, Bethesda, MD.

Weingartner, T. J., S. Danielson, Y. Sasaki, V. Pavlov, and M. Kulakov. 1999. The Siberian Coastal Current: a wind- and buoyancy-forced Arctic coastal current. Journal of Geophysical Research 104(C12):29697–29713.

Weingartner, T., K. Shimada, F. McLaughlin, and A. Proshutinsky. 2008. Physical oceanography. Pages 6–17 in Hopcroft, R., Bluhm, B., Gradinger, R. (editors), Arctic Ocean synthesis: analysis of climate change impacts in the Chukchi and Beaufort seas, with strategies for future research. Report to the North Pacific Research Board, Anchorage, AK, by the Institute of Marine Sciences, University of Alaska, Fairbanks, AK.

Zwanenburg, K. C. T. 2000. The effect of fishing on demersal fish communities on the Scotian Shelf. ICES Journal of Marine Science 57:503–509.

Appendices: Table of Contents

Appendices: List of Figures and Tables

Appendix B Tables

Appendix C Figures

Appendix C Tables

Appendix D Figures

Appendix D Figures continued

Appendix D Tables

Appendix E Figures

Appendix E Figures continued

Appendix E Figures continued

APPENDIX A

Acronyms used in text of report, appendices and in Chukchi Demersal Fish Database

Acronym	Description
ABL	Auke Bay Laboratory, AFSC/NMFS/NOAA, Juneau AK
ACW	Alaskan Coastal Water; nearshore warm fresh water mass in the eastern Chukchi Sea
AFSC	Alaska Fisheries Science Center, NMFS/NOAA, Seattle WA or Juneau AK
AKMAP	Alaska Monitoring and Assessment Program; Chukchi fish surveys inshore of Lease Sale 193 (2010–2011); *http://dec.alaska.gov/water/wqsar/monitoring/AKMAP.htm*
AMFISH	Arctic Marine Fish Museum Specimens Database;
AOOS	Alaska Ocean Observing System, a data portal; *http://www.aoos.org/*
ArcOD	Arctic Ocean Diversity, a Census of Marine Life program; *http://www.arcodiv.org/*
Arctic Eis	Arctic Ecosystem Impact Survey; Chukchi fish surveys 2012; *www.commerce.state.ak.us/dca/planning/cciap/ArcticEcosystemIntegratedSurvey.htm*
ARCTOS	University of Alaska Museum of the North's Arctos database
ARLIS	Alaska Resources Library and Information Service, Anchorage AK; *www.arlis.org*
BASIS	Bering-Aleutian Salmon International Survey; Chukchi fish surveys 2007
BOEM	Bureau of Ocean Energy Management, previously Minerals Management Service (MMS: 1982–2010) and Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE: 2011)
BOEMRE	Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE: 2011); currently known as BOEM
BSW	Bering Sea Water; further offshore, cooler and saltier than ACW
CAS	California Academy of Sciences, San Francisco CA; site of Chukchi fish voucher collection
CDF Database	Chukchi Demersal Fish Database, prepared by this project for the Bureau of Ocean Energy Management (BOEM)
CMI	University of Alaska Coastal Marine Institute; *http://www.sfos.uaf.edu/cmi/*
CMN	Canadian Museum of Nature, Gatineau, Quebec; holds Chukchi fish collection
COML	Census of Marine Life
CPUE	Catch-per-unit-effort, e.g., count or biomass of fish per area or duration of haul
CSESP	Chukchi Sea Environmental Studies Program; Chukchi fish surveys 2009–2011; *www.chukchiscience.com*
CTD	Equipment that records conductivity, temperature, and density
EBS	Eastern Bering Sea
FISHBOL	Fish Barcode of Life genetics program; *www.fishbol.org*
FMP	Fishery Management Plan, e.g. adopted by North Pacific Fisheries Management Council (NPFMC)
GMT	Greenwich Mean Time; local time in the eastern Chukchi Sea is GMT minus 9 hours
GPS	Global Positioning System
GVF	Goodness of Variance Fit, a statistical term
HUMZ	Museum of Zoology, Hokkaido University, Hakodate, Japan; site of Chukchi fish voucher collection
IMS	Institute of Marine Science, UAF, Fairbanks AK; site of Chukchi fish voucher collection
IPY	International Polar Year. Coordinated international research surveying the Arctic and Antarctic Regions, which has occurred 1882–1884, 1932–1933, 1957–1958, and 2007–2008
MMS	Minerals Management Service (MMS: 1982–2010); known as BOEMRE during 2011; currently known as BOEM
MMSU	Museum of the Moscow State University, Russia; site of Chukchi fish voucher collection
NMFS	National Marine Fisheries Service

Acronym	Description
NOAA	National Oceanic and Atmospheric Administration
NODC	National Oceanographic Data Center
NPFMC	North Pacific Fisheries Management Council
OSCEAP	Outer Continental Shelf Environmental Assessment Program; Chukchi fish surveys 1989–1991
OT	Otter trawl
PSBT	Plumb staff beam trawl
PSR	Point Stephens Research, Auke Bay AK; site of Chukchi fish voucher collection
RACE	Resource Assessment and Conservation Engineering division, AFSC, NMFS
RACEBASE	RACE/AFSC/NMFS groundfish resource database
RCW	Resident Chukchi Water, a cold and saline offshore water mass
RUSALCA	Russian-American Long-Term Census of the Arctic; Chukchi fish surveys 2004, 2009, 2012; *http://www.arctic.noaa.gov/aro/russian-american*
SCC	Siberian Coastal Current, cold dilute current flowing southeastward along the eastern coast of Siberia
UAF	University of Alaska Fairbanks
UAMN	University of Alaska Museum of the North, Fairbanks AK; site of Chukchi fish voucher collection
UBC	University of British Columbia, Vancouver Canada; site of Chukchi fish voucher collection
USMN	National Museum of Natural History, Washington, DC; site of Chukchi fish voucher collection
UW	University of Washington, Seattle Washington; site of Chukchi fish voucher collection
WW	Winter Water, a very cold and salty subsurface water mass west of BSW
ZIN	Zoological Institute, St. Petersburg, Russia; site of Chukchi fish voucher collection

APPENDIX B

Chukchi Demersal Fish Database – design and structure

B.1 Summary

This study is a compilation of data from research fishing activities that targeted demersal fishes in the offshore eastern Chukchi Sea from 1959–2008. Data will be archived online at the Alaska Ocean Observing System (http://www.aoos.org) and was provided in electronic form to the Bureau of Ocean Energy Management as a Microsoft Access 2007 database, with tables additionally provided as Microsoft Excel workbook files.

Appendix B describes the design of this Chukchi Demersal Fish (CDF) Database. Table B.1-1 lists the Access database tables that compose the database; Excel workbook files were assigned the same names as the database tables.

Database: CDF_Database_1959-2008
From Project: Recent and Historical Distribution and Ecology of Demersal Fishes in the Chukchi Sea Planning Area
OCS Study BOEM 2012-073
University of Alaska Coastal Marine Institute; Bureau of Ocean Energy Management (BOEM) and the Institute of Marine Science, University of Alaska Fairbanks (IMS/UAF)

Contact for inquiries:

Brenda A. Holladay, Database Manager
baholladay@alaska.edu

Brenda L. Norcross, Principal Investigator
bnorcross@alaska.edu
(907) 474-7990

Institute of Marine Science
University of Alaska Fairbanks
P.O. Box 757220
Fairbanks, AK 99775-7220

Table B.1-1. List of tables in the CDF Database.

Table	Description
tbl_Cruise	Summary type of data input into CDF Database, one row for each unique cruise and gear of cruises that entered the northeastern Chukchi Sea
tbl_Haul	Details about deployment and environmental parameters, for each deployment of gear
tbl_Catch	One row for each taxon at each haul. Includes count, weight, multiplication factor to calculate catch per 1000 sq m, and extrapolated counts and weights per 1000 sq m
tbl_Catch_Presence_Stn	Presence of taxa reported at each station of each cruise, together with associated fields from tbl_Cruise and tbl_Haul, i.e., a flattened table of information relating to each haul; one row for each taxon present in each haul. Table is generated by Access query
tbl_Catch_CPUE_Stn	Catch-per-unit-effort at each station. One row for each demersal fish taxon, at taxonomic level recommended for long-term analysis, at each station that could be associated with area swept by bottom trawl gear. Count and weight are extrapolated per 1000 sq m, as an average over hauls at the station. Table is generated by Access query
tbl_Fish_Length_Wt	Length and weight for each fish, where data are available
tbl_Fish_Length_Increment	Count of each species, at each Haul_Unique_CDF, within each 10 mm increment of length. Includes data summarized from tbl_Fish_Length_Wt and data recovered from source as length increments
tbl_Fish_Names	Scientific and common names of species and family as included in CDF Database. Names are all species anticipated to occur in the Chukchi Sea, and other species as reported for the Bering and Beaufort Seas
tbl_Gear	Description of sampling gear used in fish collections reported in the CDF Database
tbl_Citations	Full length citations referenced in Appendices of Norcross et al. 2013 (OCS Study BOEM 2012-073) or in CDF Database
tbl_Acronyms	List of acronyms referenced in Norcross et al. 2013 (OCS Study BOEM 2012-073) or in CDF Database
tbl_CDF_Revisions	Table to track revisions to data reported in the CDF Database, e.g., additional data recovered, errors corrected

B.2 Database tables

Table B.2-1 tbl_Cruise. Summary type of data input into CDF Database; one row for each unique cruise and gear from research cruises that entered the northeastern Chukchi Sea.

Field_Name	**Data_Type**	**Description**
ID	Autonnumber	Unique identifier for each row (cruise)
Cruise_CDF	Text	Unique identifier for each cruise and gear combination; assigned in CDF Database as year of collection, letter indicating consecutive set of collections by researcher, and researcher
Cruise_Alt	Text	Alternate names identifying the cruise; if no name was reported by data source then Cruise_Alt is assigned for CDF Database as Vessel-Year
Regions	Text	Data in CDF Database collected in one or more of these regions: Chukchi Sea = 65.5-73°N and 169-156°W (western is west of and eastern is east of 169°W; Bering Sea = south of 66.5°N; Beaufort Sea = east of 156°W
Vessel	Text	Name of vessel from which fishing gear was deployed, e.g., R/V Oscar Dyson
Year	Number	
Date_Start	Date	Date of first deployment of Gear_Code; local date; mm/dd/yyyy
Date_End	Date	Date of last deployment of Gear_Code; local date; mm/dd/yyyy
Lat_And_Long_Comment	Text	E.g., onboard Global Positioning System, celestial navigation
Gear	Text	Abbreviated description of gear indicating headrope length in meters, fishing gear, smallest mesh in mm. OT is otter trawl; PSBT is plumb staff beam trawl. Gear is described more completely in tbl_Gear
Mesh_Smallest_mm	Number	Smallest mesh size in the gear in millimeters; usually from codend or codend liner
Fishing_Method	Text	Description of the typical fishing method for the cruise
Fishing_Gear_Other	Text	Additional gear that may have led to fish data other than the gear that was set on the seafloor; catch from Fishing_Gear_Other is not included in CDF Database
Duration_Reported	Text	Availability of haul duration: yes or no
Distance_Reported	Text	Availability of distance towed: yes or no
Swath_Reported	Text	Availability of horizontal opening of gear (width of haul track): yes or no
CPUE_Reported	Text	Availability of data on catch-per-unit-effort per area: yes or no
Presence_Reported	Text	Availability of data on presence of fish species: yes or no
Count_Reported	Text	Availability of data on count of fish species: yes or no
Biomass_Reported	Text	Availability of data on biomass of fish species: yes or no
Depth_Reported	Text	Availability of depth of haul: yes or no
Temperature_Reported	Text	Availability of bottom temperature data: yes or no
Salinity_Reported	Text	Availability of bottom salinity data: yes or no
Substrate_Reported	Text	Availability of substrate data: no, descriptive, or percent grain size
Citations_Main	Text	Source(s) of cruise data incorporated into CDF Database
Fish_Voucher_Collections	Text	Location of voucher collections; these museum acronyms are defined in tbl_Acronyms

n = 24 rows

Table B.2-2 tbl_Haul. Details about deployment and environmental parameters; one row for each deployment of gear.

Field_Name	**Data_Type**	**Description**
ID	Autonumber	Unique identifier for each deployment of gear (haul)
Haul_Unique_CDF	Text	Unique identifier for each cruise, gear, site, and haul combination
Region	Text	E.g., eastern Chukchi Sea, western Chukchi Sea, Beaufort Sea, Bering Sea
Cruise_CDF	Text	Unique identifier for each cruise and gear combination; assigned in CDF Database as year of collection, letter indicating consecutive set of collections by researcher, and researcher
Station_CDF	Text	Unique identifier for each cruise, gear, and site combination
Station	Text	Name or number identifying the site (location) of Haul_Unique_CDF; usually assigned during cruise
Haul	Text	Name or number identifying the gear deployment at the station; assigned as 1 if not assigned in source data, assigned as "m" if multiple hauls were collected but not differentiated in source data
Year	Number	
Month	Number	Month, e.g., January = 1, October = 10
Date	Date	Date of haul; local date unless data source did not indicate whether date was local or Coordinated Universal Time (UTC); mm/dd/yyyy
Time	Time	Time gear was fully deployed on the sea floor; local time unless data source did not indicate whether time was local or UTC; hh:mm
Duration_min	Number	Number of minutes the gear was towed on bottom
Gear	Text	Abbreviated description of gear indicating headrope length in meters, fishing gear, smallest mesh in mm. OT is otter trawl; PSBT is plumb staff beam trawl. Gear is described more completely in tbl_Gear
Net_Swath_m	Number	Effective horizontal opening of the gear, in meters
Latitude	Number	Latitude of vessel at start of haul in decimal degrees; if only one latitude was reported for the haul it is assigned in this field. xx.xxxx
Longitude	Number	Longitude of vessel at start of haul; negative decimal degrees indicate western hemisphere; if only one longitude was reported for the haul it is assigned in this field; xxx.xxxx
Latitude_End	Number	Latitude of vessel at the end of haul in decimal degrees; xx.xxxx
Longitude_End	Number	Longitude of vessel at the end of haul; negative decimal degrees indicate western hemisphere; xxx.xxxx
Distance_Towed_m	Number	Distance between start and end positions of haul in meters; calculated for CDF Database unless already reported by data source
Area_Towed_sq_m	Number	Area towed in square meters as reported by data source or calculated for CDF Database as Swath x Distance

Table B.2-2 tbl_Haul, continued.

Field_Name	**Data_Type**	**Description**
CPUE_Quality	Text	CPUE per area: catch data are quantitative per unit area and can be compared with hauls that used same gear. Catch per haul: count and/or weight per haul. Presence: analysis should be limited to taxon presence. Zero fish reported: gear deployed but no fish reported
CPUE_Multiplier_to_1000	Number	Value by which to multiply the catch to estimate catch per 1000 square meters of sea floor
Depth_Min_m	Number	Minimum depth of the haul in meters
Depth_Max_m	Number	Maximum depth of the haul in meters
Depth_m	Number	Depth of haul in meters; if data source reported Depth_Min and Depth_Max, then Depth is an average of those values unless data source reported mean depth
Temperature_Bottom	Number	Bottom temperature in degrees Celcius as reported in association with the haul, generally collected via vertical conductivity temperature density profiler (CTD) in the vicinity of the haul; x.xx
Salinity_Bottom	Number	Bottom salinity reported in association with the haul, generally collected via vertical conductivity temperature density profiler (CTD) in the vicinity of the haul; x.xx
Substrate_Decription	Text	Description of substrate reported in association with the haul
Gravel_percent	Number	Percent dry weight of gravel substrate (>2–64 mm); x.xx
Sand_percent	Number	Percent dry weight of sand substrate (0.07–2 mm); x.xx
Mud_percent	Number	Percent dry weight of mud substrate (<0.07 mm); x.xx
Comment	Text	E.g., indicates hauls that caught no fish; reasons that catch data are limited to taxon presence, etc.

n = 740 rows

Table B.2-3 tbl_Catch. Count, weight and multiplication factor to calculate catch per area fished, and extrapolated count and weight data per 1000 m^2; one row for each taxon at each haul.

Field_Name	Data_Type	Description
ID	Autonumber	Unique identifier for each row
Haul_Unique_CDF	Text	Unique identifier for each cruise, gear, site, and haul combination
Cruise_CDF	Text	Unique identifier for each cruise and gear combination; assigned in CDF Database as year of collection, letter indicating consecutive set of collections by researcher, and researcher
Station_CDF	Text	Unique identifier for each cruise, gear, and site combination, included here because multiple hauls are reported for some stations
Gear	Text	Abbreviated description of gear. Headrope length in meters, fishing gear, smallest mesh in mm; includes only gear deployed to assess demersal fish presence or abundance. OT is otter trawl; PSBT is plumb staff beam trawl. Gear is described more completely in tbl_Gear
Taxon_Analysis	Text	Taxonomic level recommended by CDF Database authors for analysis over long time scale, i.e., 20 years
Taxon_Most_Precise	Text	Most precise taxonomic identification of which CDF Database authors are confident
Taxon_Reported_Previously	Text	Taxon reported in earlier catch records
Difference_Taxon	Text	Explanation where Taxon_Analysis and Taxon_Reported_Previously differ
Demersal	Yes or No	Can the taxon be considered demersal?
Presence	Number	Field is set to 1 to indicate presence of taxon
CPUE_Quality	Text	One of three options: presence, catch per haul (count and or weight), CPUE per area
Count_per_Haul	Number	Count of individuals; if CPUE_Quality = presence, Count_per_Haul is blank
Gm_per_Haul	Number	Weight of taxon in grams
CPUE_Multiplier_to_1000_sq_m	Number	Quantity multiplied by Count_per_Haul and Gm_per_Haul to extrapolate catch to one square km
Count_per_1000_sq_m	Number	Count of individuals extrapolated over 1000 sq meters
Wt_per_1000_sq_m_g	Number	Weight of taxon extrapolated over 1000 sq m, in grams
Comment	Text	

Table B.2-4 tbl_Catch_Presence_Stn. Presence of taxa reported at each station of each cruise, together with associated fields from tbl_Cruise and tbl_Haul, i.e., a flattened table of information relating to each haul; one row for each taxon present in each haul. Table generated by Access query.

Field_Name	Data_Type	Description
ID	Autonumber	Unique identifier for each row
Station_CDF	Text	Unique identifier for each cruise, gear, and site combination
Cruise_CDF	Text	Unique identifier for each cruise and gear combination; assigned in CDF Database as year of collection, letter indicating consecutive set of collections by researcher, and researcher
Gear	Text	Headrope length in meters, fishing gear, smallest mesh in mm; includes only gear deployed to assess demersal fish presence or abundance. OT is otter trawl; PSBT is plumb staff beam trawl. Gear is described more completely in tbl_Gear
Latitude	Number	Latitude of vessel at Time_Start in decimal degrees; if only one latitude was reported for the haul it is assigned in this field. xx.xxxx
Longitude	Number	Longitude of vessel at Time_Start in negative decimal degrees to indicate western hemisphere; if only one longitude was reported for the haul it is assigned in this field. xxx.xxxx
Depth_m	Number	Average depth of haul in meters; if Depth_Min and Depth_Max were reported by data source then Depth_Avg is the mean of those values
Temperature_Bottom	Number	Bottom temperature in degrees Celcius as reported in association with the haul, generally collected via vertical conductivity temperature density profiler (CTD) in the vicinity of the haul
Salinity_Bottom	Number	Bottom salinity reported in association with the haul, generally collected via vertical conductivity temperature density profiler (CTD) in the vicinity of the haul
Substrate_Description	Text	Description of substrate reported in association with the haul
Mud_percent	Number	Percent of mud in dried substrate sample
Sand_percent	Number	Percent of sand in dried substrate sample
Gravel_percent	Number	Percent of gravel in dried substrate sample
Name_Scientific	Text	Calls from Taxon_Most_Precise
Name_Common	Text	Calls from Fish_Names
Presence	Number	Set to 1
Comment	Text	Indicates hauls that caught no fish; reasons that catch data are limited to taxon presence, etc.

Table B.2-5 tbl_Catch_CPUE_Stn. Catch-per-unit-effort at each station; one row for each demersal fish taxon, at taxonomic level recommended for long-term analysis, at each station that could be associated with area swept by bottom trawl gear. Count and weight are extrapolated per 1000 m^2 as an average over hauls at the station. Table is generated by Access query.

Field_Name	Data_Type	Description
ID	Autonumber	Unique identifier for each row (haul)
Station_CDF	Text	Unique identifier for each cruise, gear, and site combination
Cruise_CDF	Text	Unique identifier for each cruise and gear combination; assigned in CDF Database as year of collection, letter indicating consecutive set of collections by researcher, and researcher
Gear	Text	Abbreviated description of gear. Headrope length in meters, fishing gear, smallest mesh in mm; includes only gear deployed to assess demersal fish presence or abundance. OT is otter trawl; PSBT is plumb staff beam trawl. Gear is described more completely in tbl_Gear
Latitude	Number	Latitude of vessel at Time_Start in decimal degrees; if only one latitude was reported for the haul it is assigned in this field. xx.xxxx
Longitude	Number	Longitude of vessel at Time_Start in negative decimal degrees to indicate western hemisphere; if only one longitude was reported for the haul it is assigned in this field. xxx.xxxx
Depth_m	Number	Average depth of haul in meters; if Depth_Min and Depth_Max were reported by data source then Depth_Avg is the mean of those values
Temperature_Bottom	Number	Bottom temperature in degrees Celcius as reported in association with the haul, generally collected via vertical conductivity temperature density profiler (CTD) in the vicinity of the haul
Salinity_Bottom	Number	Bottom salinity reported in association with the haul, generally collected via vertical conductivity temperature density profiler (CTD) in the vicinity of the haul
Substrate_Description	Text	Description of substrate reported in association with the haul
Mud_percent	Number	Percent of mud in dried substrate sample
Sand_percent	Number	Percent of sand in dried substrate sample
Gravel_percent	Number	Percent of gravel in dried substrate sample
CPUE_Quality	Text	One of three options: presence, catch per haul (count and or weight), CPUE per area
Name_Scientific	Text	Calls from tbl_Catch, field Taxon_Analysis. Taxonomic level recommended by CDF Database authors for analysis over long time scale, i.e., 20 years
Name_Common	Text	Calls from Fish_Names
Count_per_1000_sq_m	Number	Count of individuals extrapolated to number per 1000 sq m
Wt_per_1000_sq_m_g	Number	Weight of taxon extrapolated to grams per 1000 sq m
Comment	Text	

Table B.2-6 tbl_Fish_Length_Wt. Length and weight for each fish; one row for each specimen that was measured or weighed.

Field_Name	Data_Type	Description
ID	Autonumber	Unique identifier for each row; one row for each fish from which a measurement of length or weight was recorded
Cruise_CDF	Text	Unique identifier for each cruise and gear combination; assigned in CDF Database as year of collection, letter indicating consecutive set of collections by researcher, and researcher
Haul_Unique_CDF	Text	Unique identifier for each cruise, gear, site, and haul combination
Date	mm/dd/yyyy	Date of haul; local date unless data source did not indicate whether date was local or Coordinated Universal Time (UTC)
Month	Number	Month, e.g., January = 1, October = 10
Gear	Text	Abbreviated description of gear. Headrope length in meters, fishing gear, smallest mesh in mm; includes only gear deployed to assess demersal fish presence or abundance. OT is otter trawl; PSBT is plumb staff beam trawl. Gear is described more completely in tbl_Gear
Name_Scientific	Text	Taxonomic nomenclature as per American Fisheries Society (Nelson et al. 2004)
Name_Common	Text	Common name of species as per American Fisheries Society (Nelson et al. 2004)
Length_Total_mm	Number	Straight-line measure from the tip of the snout to the tip of the longer lobe of the caudal fin; measured with the lobes compressed along the midline
Length_Fork_mm	Number	Straight-line measure from the tip of the snout to the end of the middle caudal fin rays; used in fishes in which it is difficult to tell where the vertebral column ends.
Length_Std_mm	Number	Straight-line measure from the tip of the snout, or of the lower jaw if projecting forward, to the base of the caudal fin.
Weight_g	Number	Wet weight of fish, in grams
Sex	Text	male; female; juvenile; blank = undetermined

Table B.2-7 tbl_Fish_Length_Increment. Length and weight summarized over 10 mm increments of fish length. This table contains data from more cruises than Table B.2-6; one row per 10 mm length increment of each species at haul.

Field_Name	Data_Type	Description
Haul_Unique_CDF	Text	Unique identifier for each cruise, gear, site, and haul combination
Cruise_CDF	Text	Unique identifier for each cruise and gear combination; assigned in CDF Database as year of collection, letter indicating consecutive set of collections by researcher, and researcher
Gear	Text	Headrope length in meters and brief description of fishing gear
Name_Scientific	Text	Taxonomic nomenclature as per American Fisheries Society (Nelson et al. 2004)
Name_Common	Text	Common name of species as per American Fisheries Society (Nelson et al. 2004)
Count	Number	Count of individuals measured of a species and length increment
Length_Total_mm	Number	Straight-line measure from the tip of the snout to the tip of the longer lobe of the caudal fin; measured with the lobes compressed along the midline. Number is the smallest of a 10 mm increment, i.e. 30 indicates lengths from 30 to 39 mm
Length_Fork_mm	Number	Straight-line measure from the tip of the snout to the end of the middle caudal fin rays; used in fishes in which it is difficult to tell where the vertebral column ends. Number is the smallest of a 10 mm increment, i.e. 30 indicates lengths from 30 to 39 mm
Length_Std_mm	Number	Straight-line measure from the tip of the snout, or of the lower jaw if projecting forward, to the base of the caudal fin. Number is the smallest of a 10 mm increment, i.e. 30 indicates lengths from 30 to 39 mm.
Sex	Text	male; female; juvenile; blank = undetermined
Comment	Text	

Table B.2-8 tbl_Fish_Names. Scientific and common names of all demersal fish taxa anticipated to occur in the Chukchi Sea, and other species as reported for the Bering and Beaufort Seas in the CDF Database.

Field_Name	Data_Type	Description
ID	Autonumber	Unique identifier for each row
Demersal	yes or no	Can the taxon be considered demersal?
Class	Text	Taxonomic class
Order	Text	Taxonomic order
Family	Text	Taxonomic family
Family_Common	Text	Common name for taxonomic family as per American Fisheries Society (Nelson et al. 2004)
Genus	Text	Taxonomic genus as per the American Fisheries Society (Nelson et al. 2004). Identification is less specific than genus, this field is the less specific identification followed by unidentified (unid.), e.g., a sculpin not identified to genus is listed as "Cottidae unid."
Name_Scientific	Text	Taxonomic nomenclature as per American Fisheries Society (Nelson et al. 2004)
Name_Common	Text	Common name of species as per American Fisheries Society (Nelson et al. 2004)
Comment	Text	E.g., note here if nomenclature has changed since Nelson et al. (2004)

n=124 rows

Table B.2-9 tbl_Citations. Full length citations referenced in CDF Database or in Appendices of Norcross et al. 2013 (OCS Study BOEM 2012-073).

Field_Name	Data_Type	Description
ID	Autonumber	Unique identifier for each row
Citation	Text	Citation as in text, e.g., Nelson et al. 2004
Citation_Detail	Memo	Full length citation

Table B.2-10 tbl_Acronyms. List of acronyms referenced in CDF Database, text or appendices of Norcross et al. 2013 (OCS Study BOEM 2012-073).

Field_Name	Data_Type	Description
ID	Autonumber	Unique identifier for each row
Acronym	Text	Acronyms used in report and Chukchi Demersal Fish database
Description	Text	Description of acronym; a website is listed if available

Table B.2-11 tbl_Gear. Description of sampling gear used in fish collections reported in the CDF Database.

Field_Name	Data_Type	Description
ID	Autonumber	Unique identifier for each row
Gear	Text	Abbreviated description of gear. Headrope length in meters, fishing gear, smallest mesh in mm; includes only gear deployed to assess demersal fish presence or abundance. OT is otter trawl; PSBT is plumb staff beam trawl. Gear is described more completely in tbl_Gear
Mesh_Smallest_mm	Number	Smallest mesh size in the gear in millimeters; usually from codend or codend liner
Horizontal_Opening_m	Number	Horizontal opening of the trawl while fishing, in meters
Vertical_Opening_m	Number	Vertical opening of the net while fishing, in meters
Description	Memo	Full description of gear

APPENDIX C

Reports on plumb staff beam trawl collections during recent cruises (2007–2008)

C.1 Cruise 2007a-Norcross (OS180)

This extended report on beam trawl collections by Brenda Holladay *baholladay@alaska.edu*
v. 15-Jan-2013

The summary cruise report of beam trawl activity, submitted at the end of cruise, is available online (*http://odyssey.fish.hokudai.ac.jp/IPY/data2007/CruiseReport-Summary_Leg2&3.pdf*)
The summary cruise report as revised after the cruise is published (Hokkaido University, 2008)

Official cruise name: OS180
Chief Scientist: Sei-Ichi Saitoh (Hokkaido University) *ssaitoh@salmon.fish.hokudai.ac.jp*
Vessel: T/S *Oshoro-Maru*
Cruise area: Northwest Pacific Ocean, Bering Sea, eastern Chukchi Sea
Beam trawl collections: OS180 Leg 3, Eastern Chukchi Sea
Depart Nome 3-Aug; arrive Nome 15-Aug-2007

Fish collections
Beam trawl scientific crew
Crew chief & Fishes: Brenda Holladay, IMS/UAF, Fairbanks AK
Fishes: S. Paige Drobny, IMS/UAF, Fairbanks AK
Epibenthic invertebrates: Sarah Mincks, IMS/UAF, Fairbanks AK
Dominic Hondolero, SFOS/UAF, Fairbanks AK
Otter trawl – Hokkaido University
Gill net – Hokkaido University
Salmon longline and hook-and-line – Hokkaido University

Additional gear deployed (partial list)
CTD deployed vertically
Plankton nets: NORPAC, MTD, Closing net, Bongo, SCOR, CalVET
Video camera towed on the sea floor

The primary objective of the beam trawl collections was to examine the distribution and abundance of demersal fishes and epibenthic invertebrates in the eastern Chukchi Sea.

Samples were collected by beam trawl at 16 stations (Table C.1-1, Figure C.1-1). Hauls at nine stations were quantitative for fish abundance per area swept; at six of these stations we also examined invertebrate abundance.

Gear was a plumb staff beam trawl of 7 mm mesh with a 4 mm codend liner and double tickler chain (after Gunderson and Ellis , 1986); we modified the net by seizing a lead-filled line and six inch sections of chain fastened at 6 inch intervals to the footrope, and by using a shorter (3.05 m) beam. The beam trawl was fished on the bottom for approximately five minutes at each site. Tow duration was measured as the time when the tow line was deployed until the start of retrieving the line; vessel position was recorded at these times and used to calculate distance towed. The net was towed in the direction of the current at approximately 1.5–2.0 kts, using a 400 m length of ½” double braided nylon line. The ratio of towing line to station depth was approximately 4:1. Reasons for a tow being considered as non-quantitative included gear damage, net being full beyond the codend, or a notable amount planktonic catch (i.e., water haul). During each quantitative haul, vibration of the towing line was observed as the net towed on the sea floor.

Fishes from both quantitative and non-quantitative hauls were identified. Fishes were enumerated, measured (total length, mm), and weighed from quantitative hauls. One weight was recorded in the field for each taxon, rather than for individual fishes. Weights were measured with hanging scales (5, 10, 40, 100, 250, 500 g). All fishes were identified prior to writing this report. Epibenthic invertebrates were identified, enumerated, and weighed from a subset of hauls. Substrate was observed only through visual analysis of towed video camera (stations C14 and C27) and from beam trawl contents; no grab was deployed on the sea floor. Vertical profiles of temperature and salinity were collected at each station.

Fish collections by Hokkaido University in the Chukchi Sea included an otter trawl and baited surface long line; gill net and baited-hook-and-line were deployed only south of the Chukchi Sea. The otter trawl fished by Hokkaido University had a 43 m headrope and a codend liner of 44 mm mesh. It was fished for 5–30 min at 3–4 kt. Weight, but not count, of fishes and invertebrates caught in the otter trawl are reported (Hokkaido University (2008). No fishes were caught by baited surface long line in the Chukchi Sea.

Specimens retained from beam trawl tows

A subset of fish specimens from both quantitative and non-quantitative hauls was frozen and returned to the UAF Fisheries Oceanography Laboratory to assess length/weight relationships and for potential analysis of diet, stable isotopes, age and trace elements chemistry.

Specimens of both rare and common fishes were provided to C.W. Mecklenburg for museum voucher collections, taxonomic study, and genetics for the Fish Barcode of Life initiative. Voucher specimens were deposited at the University of Alaska Museum of the North and California Academy of Sciences.

Sarah Mincks led the assessment of epibenthic invertebrate abundance and also collected epibenthic invertebrates (e.g., *Chionoecetes opilio, Ophiura sarsi)* to examine calorimetry, reproductive biology, and molecular phylogenetics.

Dominic Hondolero collected crabs and gastropods to test for differences in stable isotope ratios between frozen specimens and specimens preserved in 10% buffered formalin.

Ian Gleadell retained specimens of *Octopus* spp.

Fish catch data will be archived at project end by the Arctic Ocean Diversity project (ArcOD).

Acknowledgements

Brenda Norcross, Bodil Bluhm, Katrin Iken, and Sarah Mincks of IMS/UAF and Catherine W. Mecklenburg of Point Stephens Research/Auke Bay are additional investigators on this research. Funding for the beam trawl scientific crew's participation during OS180 was provided by the University of Alaska Coastal Marine Institute under the project "Current and historic distribution and ecology of demersal fishes in the Chukchi Sea Planning Area," the Cooperative Institute for Arctic Research's International Polar Year (IPY) Student Traineeship number S-8403, UAF's IPY Presidential Post-Doctoral Program, and the National Oceanic and Atmospheric Administration. We thank Dr. Sei-Ichi Saitoh (Hokkaido University) for inviting our participation on this cruise, and the officers and crew of the T/S *Oshoro-Maru* for their assistance with gear deployment. We greatly appreciate the assistance in sorting hauls provided by Ian Gleadell (Tohoku Bunka Gakuen University) and Kate Myers (University of Washington).

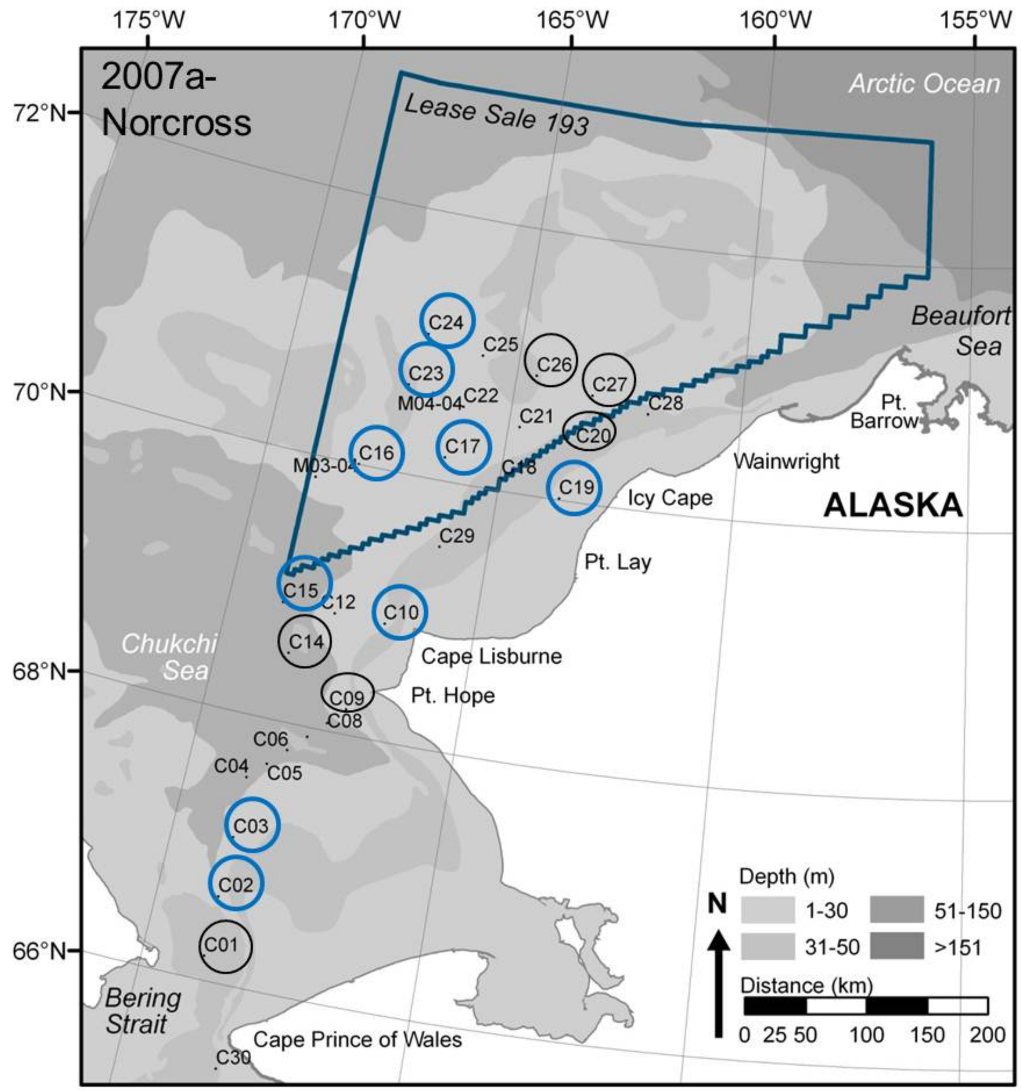


Figure C.1-1 2007a-Norcross: Map of station locations during leg 3 of cruise OS180. Beam trawl fishing stations are circled; stations with quantitative hauls are circled with blue. A CTD was deployed vertically at each station.

Table C.1-1 Beam trawl hauls during 2007a-Norcross (OS180). Quality indicates whether the catch of fishes was evaluated for catch-per-unit-effort (c) or presence (p), * indicates abundance of epibenthic invertebrates was evaluated. CPUE factor multiplied by catch = quantity per 1000 m^2.

Station	Haul	Quality	Date and time (local)	Duration (min)	Start Lat	Start Long	Depth (avg, m)	TowDist (m)	CPUE factor	Volume (gal)	Substrate	Tow comments
C01	1	p	05-Aug 22:24	5.3	66.1824	-168.8605	54	231	--	50	shell hash in net	gear damage
C02	2	c*	06-Aug 2:03	5	66.6405	-168.8645	41	234	1.897	50		
C03	3	c	06-Aug 5:32	5.2	67.0792	-168.8154	44	179	2.473	40	mud and small amount of shell hash in net	
C09	4	p	06-Aug 22:54	5.2	68.1821	-167.2338	44	234	--	80		full beyond codend
C10	5	c*	07-Aug 16:27	5	68.8628	-166.8186	40	204	2.172	4	medium sized shell hash & gravel in net	
C14	6	p	07-Aug 22:31	5.1	68.5109	-168.5759	49	175	--	6		gear damage; net clogged with algae
C14	7	p	07-Aug 22:57	5	68.5036	-168.5586	49	230	--	7	ROV observed sandy/muddy with no rocks	gear damage; net clogged with algae
C15	8	c*	08-Aug 14:18	5	68.8987	-168.9180	50	253	1.756	10		
C16	9	c*	09-Aug 3:25	5	70.0151	-167.9907	45	178	2.492	7	some smooth 1.5" gravel in net	
C17	10	c	09-Aug 14:40	5	70.1928	-166.2292	43	141	3.151	5	1-2" gravel in net	
C19	11	c*	09-Aug 20:53	5	70.0194	-163.7141	26	191	2.319	7		
C20	12	p	09-Aug 23:51	5	70.4183	-163.5009	32	222	--	100		codend and net full
C23	13	c	10-Aug 18:17	5	70.6807	-167.3083	51	190	2.329	6		
C24	14	c*	10-Aug 22:00	5	71.0787	-167.0801	43	224	1.978	8	mud & small amount of smooth gravel in net	
C26	15	p	11-Aug 4:34	5	70.8977	-164.5669	32	257	--	4		
C27	16	p	11-Aug 17:03	5	70.8112	-163.2785	42	231	--	5	ROV observed sandy/muddy	gear damage
C27	17	p	11-Aug 17:32	5	70.8087	-163.2400	42	209	--	15	ROV observed sandy/muddy	gear damage
C29	18	p	12-Aug 10:13	5	69.5147	-166.0089	35	84	--	2		gear damage
C29	19	p	12-Aug 10:33	5	69.5072	-166.0117	35	158	--	3		gear damage

Table C.1-2 Count of fishes caught during cruise 2007a-Norcross (OS180) by plumb staff beam trawl hauls. Haul_Unique_CDF is assigned in the Chukchi Demersal Fish (CDF) Database to include cruise, station, and haul. HaulQuality indicates whether the catch of fishes was evaluated for catch-per-unit-effort (c) or presence (p).

Haul_Unique_CDF	Quality	*Anisarchus medius*	*Artediellus scaber*	*Aspidophoroides monopterygius*	*Boreogadus saida*	*Eleginus gracilis*	*Enophrys diceraus*	*Eumesogrammus praecisus*	*Gymnelus hemifasciatus*	*Gymnelus viridis*	*Gymnocanthus tricuspis*	*Hemilepidotus papilio*	*Hippoglossoides robustus*	*Hypsagonus quadricornis*	*Icelus spatula*	*Limanda aspera*	*Liparis gibbus*	*Liparis* spp. unidentified	*Liparis tunicatus*	*Lumpenus fabricii*	*Lycodes mucosus*	*Lycodes palearis*	*Lycodes polaris*	*Lycodes raridens*	*Myoxocephalus scorpius*	*Nautichthys pribilovius*	*Podothecus veternus*	*Stichaeus punctatus*	*Trichocottus brashnikovi*	*Triglops pingelii*	*Ulcina olrikii*	Grand Total
2007a-Norcross-C01-1	p										1						5	1		3					2					1		13
2007a-Norcross-C02-2	c										6		2				13			16					5							42
2007a-Norcross-C03-3	c	16									4		3					2		91		1			1							118
2007a-Norcross-C09-4	p		8	3		5		1	9		13		2				1			2					3		1	24		3		75
2007a-Norcross-C10-5	c	3				5	1				23		28							2		9			157		4	1		1	1	235
2007a-Norcross-C14-7	p	49									4		60		1			1		3		1										119
2007a-Norcross-C15-8	c	18		3							3	1	106							7		3			1						4	146
2007a-Norcross-C16-9	c				1			1	8	1	1			1	1						3			1	3				1		5	27
2007a-Norcross-C17-10	c	1	6	6	1				1		2		5					1	1			3			6						3	36
2007a-Norcross-C19-11	c				63						39		2			1				19					10			1		1	5	141
2007a-Norcross-C20-12	p		1	2	5						25		4							3					1						1	42
2007a-Norcross-C23-13	c	5		1	19						1		28					1		6			2		5				1		3	72
2007a-Norcross-C24-14	c	7			2						5		64					2		3			4		7					1	1	96
2007a-Norcross-C26-15	p		12	1	2				2	1								2							3	2		1	3		2	31
2007a-Norcross-C27-17	p	1	3		11				8											3											2	28
2007a-Norcross-C29-19	p				116						6		32							53		1		2	26		2				6	244
Grand Total		100	30	16	220	10	1	2	28	2	133	1	336	1	2	1	19	10	1	211	3	18	6	3	230	2	7	27	5	7	33	1465

C.2 Cruise 2007b-Norcross (OD0710)

This extended report on beam trawl collections by Brenda Holladay *baholladay@alaska.edu*
v. 1-Sep-2012

Official cruise name: OD0710
Cruise mission: Bering-Aleutian Salmon International Survey (BASIS)
Vessel: R/V *Oscar Dyson*
Chief Scientist: Lisa Eisner, AFSC/Juneau AK *Lisa.Eisner@noaa.gov*
Cruise area: Eastern Chukchi Sea and Bering Sea
Beam trawl collections: OD0710 Leg 1, eastern Chukchi Sea and northern Bering Sea
Leg 1 Dates for beam trawl scientific crew:
depart Kodiak 30-Aug; arrive Nome 17-Sep 2007

Fish collections
Beam trawl – Crew chief / fishes: Brenda A. Holladay, Fisheries Oceanography Lab/IMS/UAF, Fairbanks AK *baholladay@alaska.edu*
Epibenthic invertebrates: Sarah Mincks, IMS/UAF, Fairbanks AK *smhardy@alaska.edu*
Surface trawl – Crew chief / fishes: Jim Murphy, AFSC/Juneau AK *Jim.Murphy@noaa.gov*
Fish taxonomy and genetics: Catherine W. Mecklenburg, Point Stephens Research, Auke Bay, AK *ptstephens@alaska.com*

Additional gear deployed (partial list)
CTD deployed vertically, twice per site
Zooplankton nets:
Paravet 150 micron hauled vertically,
Bongo 335 & 505 micron hauled oblique
Multi-net for phytoplankton

Cruise OD0710 was primarily a survey of Pacific salmon (*Oncorhynchus* spp.) and associated epipelagic fish species, zooplankton, ichthyoplankton, and oceanographic measurements within the eastern Chukchi Sea and eastern Bering Sea (EBS) aboard the NOAA Ship *Oscar Dyson*. It was considered part of the Bering-Aleutian Salmon International Survey (BASIS; *http://www.afsc.noaa.gov/ABL/OCC/ablocc_basis.htm*). The survey began 29-Aug-2007 in Kodiak, Alaska and ended 29-Sep-2007 in Dutch Harbor, for a total of 29 sea days (Legs 1 & 2). Fishing gear for the BASIS survey was a Cantrawl 400/601 surface trawl with 5 meter fixed-bail NETS mid-water doors and spectra bridals towed for 30 minutes.

The beam trawl fish collections were an invited effort that occurred only during Leg 1 (Kodiak to Nome). Three research projects auxiliary to the BASIS survey were supported by the beam trawl collections. Distribution and abundance of small demersal fishes were examined by Holladay, and specimens of the more common fish species were retained for potential laboratory analysis by the Fisheries Oceanography Laboratory, UAF (e.g., otoliths, diet, etc.). Specimens of both rare and common fishes were retained by Mecklenburg for museum voucher collections, taxonomic study, and genetics for the Fish Barcode of Life initiative. Abundance of epibenthic invertebrates was examined at some sites by Mincks, who also collected invertebrate tissues for research on genetics and maturity.

Beam trawl gear was deployed primarily at night and early morning. The surface trawl deployed by the BASIS fishing team was fished during the day, and the vessel was made available to the beam trawl fishing effort at night. Bottom trawling sites were selected by Holladay based primarily on location, with the goal of collecting samples in areas not previously fished by beam trawl gear, i.e., sites not occupied during cruise RUSALCA 2004 (August 2004 aboard the R/V *Professor Khromov*) or OS180 (August 2007 aboard the T/S *Oshoro-Maru*). Beam trawl locations were also guided by the location of the last surface haul of the day, and the first planned surface haul in the morning.

Demersal taxa were surveyed by 43 hauls at 32 stations (Figure C.2-1); there were 27 quantitative hauls at 25 stations; two quantitative hauls were collected at stations 5 and 47 (Table C.2-1). Gear was a plumbstaff beam trawl of 7 mm mesh with a 4 mm codend liner and double tickler chain (after Gunderson and Ellis, 1986); we additionally modified the net by seizing a lead-filled line and 6 inch sections of chain fastened at 6 inch intervals to the footrope, and by using a shorter (3.05 m) beam. The beam trawl was fished on the bottom for approximately five minutes at each site. Tow duration was measured as the time when the tow line was deployed until the start of retrieving the line; vessel position was recorded at these times and used to calculate distance towed. The net was towed in the direction of the current at approximately 1.5–2.0 kts, using a 400 m length of ½” double braided nylon line. The ratio of towing line to station depth was approximately 4:1. Reasons for a tow being considered as non-quantitative included gear damage, net being full beyond the codend, or a notable proportion of planktonic catch (i.e., water haul). During each quantitative haul, vibration of the towing line was observed as the net towed on the sea floor.

Most fishes were identified in the field and total length was measured to the nearest mm. One weight was recorded for each taxon, rather than for individual fishes. Weights were measured onboard with a Marel motion compensating 6 kg scale. All fishes were identified prior to writing this report (Table C.2.2). Invertebrates were identified and enumerated at seven hauls: 1, 4, 14, 18, 20, 24, and 33. Substrate was observed only through visual analysis of beam trawl contents; no grab or camera was deployed on the sea floor.

Specimens retained from beam trawl tows
A subset of fish specimens from both quantitative and non-quantitative hauls was frozen and returned to the UAF Fisheries Oceanography Laboratory to assess length/weight relationships and for potential analysis of diet, stable isotopes, age and trace elements chemistry.

Catherine W. Mecklenburg – fish tissues for genetics by Fish Barcode of Life Initiative (FishBOL); fish voucher specimens were archived by Mecklenburg at the California Academy of Sciences (San Francisco, CA), the University of Alaska Museum of the North (Fairbanks, AK), the Russian Academy of Sciences (Zoological Institute, St. Petersburg), and the Fisheries Oceanography Laboratory/University of Alaska Fairbanks

Sarah Mincks – epibenthic invertebrate vouchers; invertebrate tissues for genetics and maturity research

BASIS Program – subsample of abundant species from most hauls, for potential laboratory analyses

Bruce Wing, NMFS/Alaska Fisheries Science Center/Auke Bay – one saffron cod

Morgan Busby, NMFS/Alaska Fisheries Science Center/Seattle – early juvenile fish specimens for genetics, taxonomy, and teaching collection

Fish catch data will be archived at project end by the Arctic Ocean Diversity project (ArcOD).

Acknowledgements
Catherine W. Mecklenburg, Auke Bay, Alaska, collaborated with Holladay on identification, sorting, and recording the fish catch at sea, and resolved problematic identifications in the laboratory through analysis of morphological characters and DNA sequence results. Thanks to Jim Murphy, Lisa Eisner, and the BASIS program of the NOAA/Auke Bay Laboratory for inviting the participation of Holladay, Mecklenburg, and Mincks, accommodating our research during cruise OD0710, and for providing travel and shipping. Thanks also to the captain, science technicians, and vessel crew of the R/V *Oscar Dyson* for their helpful assistance with beam trawl collections.

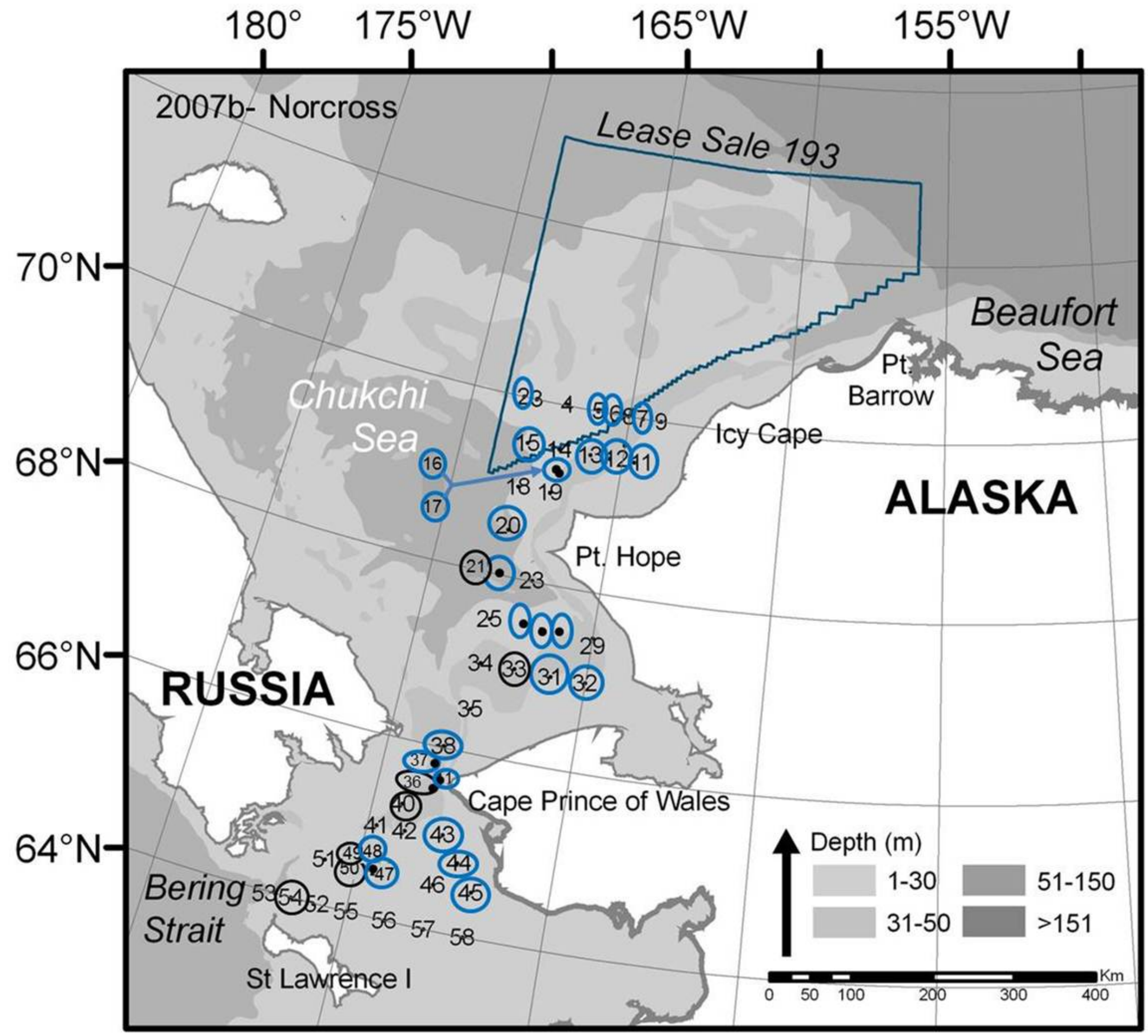


Figure C.2-1 2007b-Norcross: Map of station locations during leg 1 of cruise OD0710. Stations fished with the plumb staff beam trawl are circled; stations with quantitative hauls are circled with blue. A CTD was deployed vertically at each station.

Table C.2-1 Beam trawl hauls during 2007b-Norcross (OD0710). Quality indicates whether the catch of fishes was evaluated for catch-per-unit-effort (c) or presence (p), * indicates abundance of epibenthic invertebrates was evaluated. CPUE factor multiplied by catch = quantity per 1000 m^2.

Station	Haul	Quality	Date and time (local)	Duration (min)	Start Lat	Start Long	Depth (avg, m)	TowDist (m)	CPUE factor	Volume (gal)	Substrate observed in net	Tow comments
1	1	c *	4-Sep 06:29	5.55	65.6465	-168.4124	53	162	2.776	--	boulder and smooth gravel	
2	2	c	5-Sep 04:48	5.3	69.9988	-168.4050	45	208	2.162	4		
5	3	c	5-Sep 09:01	5.1	69.9743	-165.7547	43	204	2.200	3		
5	4	c *	5-Sep 09:41	5.32	69.9902	-165.7111	43	252	1.783	3		
6	5	p	5-Sep 23:29	5.23	69.9981	-165.2816	41	256	--	0		entire catch above codend
6	6	c	6-Sep 00:12	5.27	70.0170	-165.2604	41	256	1.755	<2		
7	7	p	6-Sep 02:55	5.48	70.0191	-164.5666	37	433	--	0		entire catch above codend
7	8	p	6-Sep 03:34	5.3	70.0365	-164.6079	38	267	--	6		gear damage
7	9	c	6-Sep 04:13	4.18	70.0485	-164.6410	39	205	2.198	8		
11	10	c	6-Sep 21:48	5.07	69.5143	-164.6308	30	350	1.285	5		
12	11	c	7-Sep 00:14	4.98	69.5108	-165.3997	35	225	1.997	5		
13	12	c	7-Sep 05:07	5.22	69.4935	-166.0077	40	239	1.882	6		
15	13	p	7-Sep 21:03	5	69.5070	-168.0173	51	325	--	3		net not consistently on bottom
15	14	c *	7-Sep 21:32	5.12	69.5039	-168.0250	51	254	1.774	4	cobble, gravel, sandy mud	
16	15	p	8-Sep 00:48	5.08	69.2375	-166.9884	44	217	--	7		gear damage
16	16	c	8-Sep 01:27	5.03	69.2233	-166.9999	44	257	1.752	15	some gravel	
17	17	c	8-Sep 03:46	5.18	69.0039	-167.0296	49	323	1.394	20	some gravel	
20	18	c *	8-Sep 20:50	4.97	68.5102	-167.9766	55	263	1.709	--	muddy net and large shell hash from gastropods	
21	19	p	9-Sep 01:05	4.17	68.0027	-168.7081	61	252	--	6		gear damage
22	20	c *	9-Sep 03:40	5.22	68.0101	-167.9942	56	359	1.254	3		
26	21	c	10-Sep 01:09	5.23	67.4969	-167.0078	48	255	1.764	20	muddy net	
27	22	c	10-Sep 03:31	4.73	67.4931	-166.5138	47	207	2.174	25	muddy net	
28	23	c	10-Sep 05:20	5.13	67.4945	-165.9988	43	157	2.867	5		
31	24	c *	10-Sep 23:16	5.02	67.0650	-166.0862	31	344	1.306	5		

Table C.2-1 Beam trawl hauls during 2007b-Norcross (OD0710), continued.

Station	Haul	Quality	Date and time (local)	Duration (min)	Start Lat	Start Long	Depth (avg, m)	TowDist (m)	CPUE factor	Volume (gal)	Substrate observed in net	Tow comments
32	25	c	11-Sep 02:11	5.07	67.0035	-164.9598	28	344	1.307	7		
33	26	p	11-Sep 06:54	5.15	67.0065	-167.0208	42	440	--	2 Tbsp		net not consistently on bottom
36	27	p	12-Sep 02:05	10.82	65.7083	-168.3235	55	1585	--	1/2		net not consistently on bottom
37	28	p	12-Sep 03:39	5.08	65.7322	-168.6114	53	649	--	50		gear damage; full beyond codend
37	29	c	12-Sep 04:58	3.7	65.8036	-168.5746	57	423	1.062	--	some cobble	
38	30	c	12-Sep 06:27	3.12	66.0080	-168.4831	55	331	1.359	40		
40	31	p	12-Sep 23:23	5.12	65.3053	-169.1846	48	266	--	5		net not consistently on bottom
43	32	p	13-Sep 22:51	4.98	65.1154	-168.0407	50	211	--	1		gear damage
43	33	c *	13-Sep 22:38	5.17	65.1232	-168.0663	50	565	0.795			
44	34	p	14-Sep 02:34	8.57	64.7894	-167.4896	34	495	--	1		undetermined time and distance on bottom
44	35	c	14-Sep 03:11	5.03	64.8036	-167.4497	31	451	0.997	2		
45	36	c	14-Sep 05:51	5.12	64.4993	-166.9908	29	351	1.282	5		
47	37	c	14-Sep 21:14	5.17	64.4985	-169.0239	44	237	1.894	1.5		
47	38	c	14-Sep 21:44	5.37	64.4939	-169.0632	45	253	1.777	2		
48	39	p	15-Sep 23:41	5.07	64.4892	-169.4886	42	293	--	2		gear damage
48	40	c	15-Sep 00:14	5.03	64.4759	-169.5029	40	180	2.496	2		
49	41	p	15-Sep 03:31	4.88	64.4923	-170.4410	47	279	--	40	boulders with barnacles	gear damage
50	42	p	15-Sep 17:21	5	64.4915	-169.9852	47	205	--	40	sand, boulders with barnacles	gear damage
54	43	p	15-Sep 22:54	3.82	64.0021	-171.3886	32	312	--	60	boulders with barnacles	gear damage

Table C.2-2 Count of fishes caught during cruise 2007b-Norcross (OD0710) by plumb staff beam trawl hauls. Haul_Unique_CDF is assigned in the Chukchi Demersal Fish (CDF) Database to include cruise, station, and haul. HaulQuality indicates whether the catch of fishes was evaluated for catch-per-unit-effort (c) or presence (p).

Haul_Unique_CDF	Quality	*Ammodytes hexapterus*	*Anarhichas orientalis*	*Anisarchus medius*	*Artediellus scaber*	*Aspidophoroides monopterygius*	*Boreogadus saida*	*Eleginus gracilis*	*Enophrys diceraus*	*Eumesogrammus praecisus*	*Eurymen gyrinus*	*Gadus macrocephalus*	*Gasterosteus aculeatus*	*Gymnelus hemifasciatus*	*Gymnelus* spp. unidentified	*Gymnelus viridis*	*Gymnocanthus tricuspis*	*Hemilepidotus papilio*	*Hippoglossoides robustus*	*Hippoglossus stenolepis*	*Hypsagonus quadricornis*	*Icelus spatula*	*Isopsetta isolepis*	*Lepidopsetta polyxystra*	*Leptoclinus maculatus*	*Limanda aspera*	*Limanda proboscidea*	*Liparis fabricii*	*Liparis gibbus*
2007b-Norcross-1-1	c						2							1					5			1							
2007b-Norcross-2-2	c						2			12				35		8	38		1						3				4
2007b-Norcross-5-3	c			26			61										33		20										
2007b-Norcross-5-4	c			9			24	2									46		20										
2007b-Norcross-6-5	p						2												2										
2007b-Norcross-6-6	c			15			25	1									22		12										
2007b-Norcross-7-7	p																												
2007b-Norcross-7-8	p		1		1			1									7		8										
2007b-Norcross-7-9	c				5	2	15	1									132		32										
2007b-Norcross-11-10	c	6					6	1									106	1	3							2			
2007b-Norcross-12-11	c						65	4							1		77		24							2			
2007b-Norcross-13-12	c						6	3									28		40						3				
2007b-Norcross-15-14	c			1			19	26						2			16		13										
2007b-Norcross-16-15	p				1																								
2007b-Norcross-16-16	c			1	8	7	8	1						2			14	1	4						1				1
2007b-Norcross-17-17	c	1		4		1	2										21		7										
2007b-Norcross-20-18	c			3			1										4		18										
2007b-Norcross-21-19	p							1											5										
2007b-Norcross-22-20	c			5		1	5	4									1		5										
2007b-Norcross-26-21	c			5			1										5		64										
2007b-Norcross-27-22	c							1									19		37										

Table C.2-2 2007b-Norcross catch, continued.

Haul_Unique_CDF	*Liparis* spp. unidentified	*Liparis tunicatus*	*Lumpenus fabricii*	*Lycodes mucosus*	*Lycodes palearis*	*Lycodes polaris*	*Lycodes raridens*	*Mallotus villosus*	*Myoxocephalus jaok*	*Myoxocephalus scorpius*	*Nautichthys pribilovius*	*Osmerus mordax*	*Pallasina barbata*	*Platichthys stellatus*	*Pleuronectes quadrituberculatus*	*Podothecus veternus*	*Pungitius pungitius*	*Reinhardtius hippoglossoides*	Stichaeidae	*Stichaeus punctatus*	*Theragra chalcogramma*	*Trichocottus brashnikovi*	*Triglops pingelii*	*Ulcina olrikii*	Grand Total
2007b-Norcross-1-1		3	1	1						4															18
2007b-Norcross-2-2				2						60	1											2		2	170
2007b-Norcross-5-3			11		5					136								1						11	304
2007b-Norcross-5-4			4		3					49								1					1	1	160
2007b-Norcross-6-5																									4
2007b-Norcross-6-6			12		3					23														1	114
2007b-Norcross-7-7																								3	3
2007b-Norcross-7-8							4																	3	25
2007b-Norcross-7-9			250				15			328						1								3	784
2007b-Norcross-11-10		1	77							182						5							1		391
2007b-Norcross-12-11		2	200						1	215						5		1	1				9	3	610
2007b-Norcross-13-12			359		13					164	1					4							1	4	626
2007b-Norcross-15-14			1							43														1	122
2007b-Norcross-16-15			9		2					7											6		1		26
2007b-Norcross-16-16		1	2633		12					1061	1									9		3	9	4	3781
2007b-Norcross-17-17			394		48					331						1				1			6	3	820
2007b-Norcross-20-18			3		2					3														2	36
2007b-Norcross-21-19			1							1															8
2007b-Norcross-22-20	3		29			1	1			9						1				1				1	67
2007b-Norcross-26-21			3		1																				79
2007b-Norcross-27-22		2	6		9					1						2								2	79

Table C.2-2 2007b-Norcross catch, continued.

Haul_Unique_CDF	Quality	*Ammodytes hexapterus*	*Anarhichas orientalis*	*Anisarchus medius*	*Artediellus scaber*	*Aspidophoroides monopterygius*	*Boreogadus saida*	*Eleginus gracilis*	*Enophrys diceraus*	*Eumesogrammus praecisus*	*Eurymen gyrinus*	*Gadus macrocephalus*	*Gasterosteus aculeatus*	*Gymnelus hemifasciatus*	*Gymnelus* spp. unidentified	*Gymnelus viridis*	*Gymnocanthus tricuspis*	*Hemilepidotus papilio*	*Hippoglossoides robustus*	*Hippoglossus stenolepis*	*Hypsagonus quadricornis*	*Icelus spatula*	*Isopsetta isolepis*	*Lepidopsetta polyxystra*	*Leptoclinus maculatus*	*Limanda aspera*	*Limanda proboscidea*	*Liparis fabricii*	*Liparis gibbus*
2007b-Norcross-28-23	c																4		59										
2007b-Norcross-31-24	c					1		132									2		30							2			
2007b-Norcross-32-25	c				1	1	1	64				1					87		35	2			1			19	1		
2007b-Norcross-33-26	p																		4										
2007b-Norcross-36-27	p												23						4								1		
2007b-Norcross-37-28	p						4			9				1		1					2								5
2007b-Norcross-37-29	c						4			1									2										1
2007b-Norcross-38-30	c						1							1			2		10		1				1				1
2007b-Norcross-40-31	p													1			3		2						2	1			
2007b-Norcross-43-32	p							15										1	1										
2007b-Norcross-43-33	c				2			18										1								1			
2007b-Norcross-44-35	c				5			13									5	8											
2007b-Norcross-45-36	c	1						28											2							4	1		
2007b-Norcross-47-37	c				1												2		6			1			1				
2007b-Norcross-47-38	c				1		1										4		7			1			1				
2007b-Norcross-48-39	p					1													1			2							
2007b-Norcross-48-40	c	1															1	2	6							7			
2007b-Norcross-49-41	p			2	1	3				8	1			7		6		1				3		1				1	3
2007b-Norcross-50-42	p															1			6			8		1					
2007b-Norcross-54-43	p	13					2		1								3							1					1
Grand Total		22	1	71	26	17	257	316	1	30	1	1	23	50	1	16	682	15	495	2	3	16	1	3	12	38	3	1	16

Table C.2-2 2007b-Norcross catch, continued.

Haul_Unique_CDF	*Liparis* spp. unidentified	*Liparis tunicatus*	*Lumpenus fabricii*	*Lycodes mucosus*	*Lycodes palearis*	*Lycodes polaris*	*Lycodes raridens*	*Mallotus villosus*	*Myoxocephalus jaok*	*Myoxocephalus scorpius*	*Nautichthys pribilovius*	*Osmerus mordax*	*Pallasina barbata*	*Platichthys stellatus*	*Pleuronectes quadrituberculatus*	*Podothecus veternus*	*Pungitius pungitius*	*Reinhardtius hippoglossoides*	Stichaeidae	*Stichaeus punctatus*	*Theragra chalcogramma*	*Trichocottus brashnikovi*	*Triglops pingelii*	*Ulcina olrikii*	Grand Total
2007b-Norcross-28-23			2		12					11		1				1				1					91
2007b-Norcross-31-24			920		1					117						4							1	3	1213
2007b-Norcross-32-25			922		24					105			2			16				1				2	1285
2007b-Norcross-33-26																									4
2007b-Norcross-36-27			1																						29
2007b-Norcross-37-28			2							1	1									1			1		28
2007b-Norcross-37-29			1	1																					10
2007b-Norcross-38-30	10	1	10	1						6						4				2	2		1	1	55
2007b-Norcross-40-31	1									1													1	1	13
2007b-Norcross-43-32	3		37								1										5			3	66
2007b-Norcross-43-33		1								1															24
2007b-Norcross-44-35										11	1											4	1		48
2007b-Norcross-45-36		2	34					1						1			1				1				76
2007b-Norcross-47-37	1																	1					1	13	27
2007b-Norcross-47-38	1			1						1													1	18	37
2007b-Norcross-48-39				1						1					1									3	10
2007b-Norcross-48-40			2												1	1								6	27
2007b-Norcross-49-41				1							1				1										40
2007b-Norcross-50-42	1			2							1													7	27
2007b-Norcross-54-43											1														22
Grand Total	20	13	5924	10	135	1	20	1	1	2872	9	1	2	1	3	45	1	4	1	16	14	9	35	101	11,359

C.3 Cruise 2008-Norcross (OS190)

This extended report on beam trawl collections by Brenda Holladay *baholladay@alaska.edu*
v. 15-Jan-2013

The summary cruise report of beam trawl activity, submitted at the end of cruise, is available online (*http://odyssey.fish.hokudai.ac.jp/IPY/data2008/CruiseReportSummary-2008.pdf*)
The summary cruise report as revised after the cruise is published (Hokkaido University, 2009)

Official cruise name: OS190
Cruise mission: Study on marine ecosystem responses to global climate change in the Bering and Chukchi Seas. *Oshoro-Maru* IPY Cruises 2007-2008
Chief Scientist (Leg 3): Toru Hirawake, Hokkaido Univ. *hirawake@salmon.fish.hokudai.ac.jp*
Vessel: T/S *Oshoro-Maru*
Cruise area: Northwest Pacific Ocean, Bering Sea, eastern Chukchi Sea
Beam trawl collections: OS190 Leg 3, Eastern Chukchi Sea
Depart Nome 6-Jul; arrive Dutch Harbor 17-Jul-2008

Fish collections
Beam trawl scientific team
Crew chief & Fishes: Brenda Holladay, IMS/UAF, Fairbanks AK
Fishes: Kirsten Baltz, SFOS, IMS/UAF, Fairbanks AK
Epibenthos: Luke Carrothers, IMS/UAF, Fairbanks AK
Jon Richar, SFOS/UAF, Fairbanks AK
Otter trawl – Hokkaido University
Gill net – Hokkaido University
Salmon longline and hook-and-line – Hokkaido University

Additional gear deployed (partial list)
CTD deployed vertically
Zooplankton nets: NORPAC, MTD, Closing net, Bongo, SCOR, CalVET

The beam trawl was deployed on the sea floor for 19 hauls at 16 stations (Figure C.3-1, Table C.3-1). Quantitative hauls were collected at 15 of these stations, i.e., all but station C01.

Gear was a plumbstaff beam trawl of 7 mm mesh with a 4 mm codend liner and double tickler chain (after Gunderson and Ellis , 1986); we additionally modified the net by seizing a lead-filled line and 6 inch sections of chain fastened at 6 inch intervals to the footrope, and by using a shorter (3.05 m) beam. The beam trawl was fished on the bottom for approximately five minutes at each site. Tow duration was measured as the time when the tow line was deployed until the start of retrieving the line; vessel position was recorded at these times and used to calculate distance towed. The net was towed in the direction of the current at approximately 1.5–2.0 kts, using a 400 m length of ½” double braided nylon line. The ratio of towing line to station depth was approximately 4:1. Those hauls that were full beyond the codend or constricted codend opening were considered non-quantitative; no hauls had notable gear damage or proportion of planktonic catch. During each quantitative haul, vibration of the towing line was observed as the net towed on the sea floor.

Most fishes were identified in the field and total length was measured to the nearest mm. One weight was recorded for each taxon, rather than for individual fishes. Weights were measured onboard with hand-held hanging scales.

Demersal fishes and epibenthic invertebrates were counted and weighed. Total length of fishes was recorded. Demersal fishes were frozen for subsequent analysis such as diet and aging studies. A subsample of each fish species was retained for voucher collection (California Academy of Sciences and University of Alaska Museum) and for genetic analysis (Fish BarCode of Life). Voucher specimens of each invertebrate species were retained or photographed. Specimens of octopuses and sea cucumbers were retained by First Officer Takagi for distribution to researchers; octopuses were retained for Ian G. Gleadall of Tohoku Bunka Gakuen University. Fish catches by the beam trawl will be archived at project end by the Arctic Ocean Diversity project (ArcOD).

Fish collections by Hokkaido University in the Chukchi Sea included an otter trawl and baited surface long line; gill net and baited-hook-and-line were deployed only south of the Chukchi Sea. The otter trawl fished by Hokkaido University had a 43 m headrope and a codend liner of 44 mm mesh. It was fished for 5–30 min at 3–4 kt. In order to capture live *Boreogadus saida* (Arctic cod), the net was fished on acoustic target in the water column in addition to dragging the bottom. Weight, but not count, of fishes and invertebrates caught in the otter trawl are reported (Hokkaido University, 2008). A single fish (*Myoxocephalus* sp.) was caught by baited surface long line in the Chukchi Sea.

Acknowledgements

Drs. Brenda L. Norcross, Katrin Iken, Bodil Bluhm, and Sarah Mincks of IMS/UAF/Alaska, and Catherine W. Mecklenburg of Point Stephens Research/Auke Bay/Alaska, are additional investigators on this research. Funding for the beam trawl scientific crew's participation during OS190 was provided by the University of Alaska Coastal Marine Institute under the project "Current and historic distribution and ecology of demersal fishes in the Chukchi Sea Planning Area." Vessel support was generously provided by Hokkaido University, Hakodate, Japan. We appreciate the cooperation and support of the officers and crew of the T/S *Oshoro-Maru*, and we thank our fellow researchers for their kind assistance with sorting tows and cleaning the deck. We thank Dr. Sei-Ichi Saitoh in particular for inviting our participation on this cruise, and Dr. Toru Hirawake for his service as Chief Scientist.

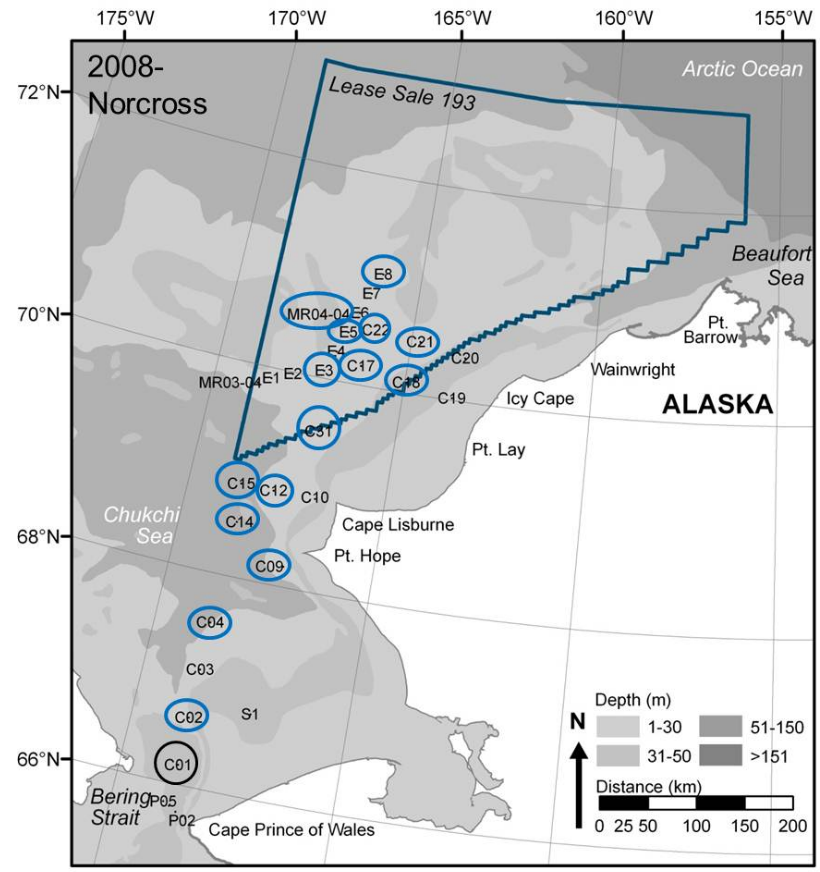


Figure C.3-1 2008-Norcross: Map of station locations during leg 3 of cruise OS190. Stations fished with the plumb staff beam trawl are circled; stations with quantitative hauls are circled with blue. A CTD was deployed vertically at each station.

Table C.3-1 Beam trawl hauls during 2008-Norcross (OS190). Quality indicates whether the catch of fishes was evaluated for catch-per-unit-effort (c) or presence (p), * indicates abundance of epibenthic invertebrates was evaluated. CPUE factor multiplied by catch = quantity per 1000 m^2.

Station	Haul	Quality	Date and time (local)	Duration (min)	Start Lat	Start Long	Depth (avg, m)	TowDist (m)	CPUE factor	Volume (gal)	Substrate	Tow comments
C1	1	p	07-Jul 7:16	5	66.1951	-168.6664	51			100	gravel, sand, cobble, 18" boulder	codend pinched; animals above codend
C1	2	p	07-Jul 7:51	5	66.2025	-168.6586	51			300	cobble, gravel, large shell hash	full beyond codend
C2	3	c*	07-Jul 12:57	5.4	66.6783	-168.6645	34	146	3.040	100	(assume sand or mud); few cobbles and large shells	
E3	4	c*	08-Jul 8:17	3.1	70.0598	-167.1639	44	108	4.115	15	silt, mud, sand, large gravel	
E5	5	c*	09-Jul 3:06	4	70.4813	-166.7525	45	186	2.375	6	mud, large gravel, cobble	
E8	6	c*	09-Jul 9:59	4	71.0850	-166.1296	41	230	1.927	7	sticky mud, shell hash	
M0404	8	c*	09-Jul 21:17	4.6	70.6323	-166.7440	45	150	2.950	4	mud, gravel, shell hash	
C22	9	p	09-Jul 23:54	5	70.5745	-166.0085	41			10	mud, shell	full beyond codend
C22	10	c*	10-Jul 0:26	3.1	70.5737	-165.9395	41	166	2.674	14	silty mud; shell	
C21	11	c*	10-Jul 2:56	4.3	70.4980	-164.7489	42	257	1.727	16	mud, shell	
C18	12	c*	10-Jul 17:18	5.1	70.0990	-164.9918	37	199	2.227	6	sand, mud, large shell hash	
C17	13	c*	10-Jul 21:08	4.8	70.1797	-166.2836	43	336	1.318	20	sand, large gravel, large shell hash	
C31	14	c	11-Jul 15:42	5.2	69.5014	-167.0220	44	167	2.646	6	sandy mud, shell hash	
C12	15	c*	12-Jul 5:41	5	68.8587	-167.8383	47	209	2.123	12	mud, shell, small amount of gravel	
C15	16	c*	12-Jul 9:47	4.8	68.8724	-168.6870	51	167	2.653	30	mud	
C14	17	c*	12-Jul 12:11	5	68.5104	-168.5749	50	267	1.658	30	mud	
C9	18	c*	12-Jul 19:22	5.2	68.1874	-167.1969	44	323	1.372	100	mud, large gravel, cobble	
C4	19	p	13-Jul 0:51	5.1	67.5414	-168.6197	46				mud, gravel	codend pinched; animals above
C4	20	c*	13-Jul 1:24	3.3	67.5452	-168.5580	46	161	2.747	20	mud, shell hash	

Table C.3-2 Count of fishes caught during cruise 2008-Norcross (OS190) by plumb staff beam trawl hauls. Haul_Unique_CDF is assigned in the Chukchi Demersal Fish (CDF) Database to include cruise, station, and haul. HaulQuality indicates whether the catch of fishes was evaluated for catch-per-unit-effort (c) or presence (p).

Haul_Unique_CDF	Quality	*Anisarchus medius*	*Artediellus scaber*	*Aspidophoroides monopterygius*	*Boreogadus saida*	*Eleginus gracilis*	*Eumesogrammus praecisus*	*Gymnelus hemifasciatus*	*Gymnelus viridis*	*Gymnocanthus tricuspis*	*Hippoglossoides robustus*	*Icelus spatula*	*Leptoclinus maculatus*	*Limanda sakhalinensis*	*Liparis gibbus*	*Liparis* spp. unidentified	*Liparis tunicatus*	*Lumpenus fabricii*	*Lycodes mucosus*	*Lycodes palearis*	*Lycodes polaris*	*Lycodes* spp. unidentified	*Myoxocephalus scorpius*	*Nautichthys pribilovius*	*Pholis fasciata*	*Podothecus veternus*	*Stichaeus punctatus*	*Triglops pingelii*	*Ulcina olrikii*	Zoarcidae unidentified	Grand Total
2008-Norcross-C1-1	p				2			2		2		1			1			2	2				1	1				3			17
2008-Norcross-C1-2	p				8	2		1	1	4	1	2	1		7			13	3				3				2	13			61
2008-Norcross-C2-3	c	2			1			2		56	4			1	2			26				3	26		1	2			2		128
2008-Norcross-E3-4	c		7		6			1		19								5					6					1	7		52
2008-Norcross-E5-5	c	2	1		3	1				15	13					1		15			2		2						8		63
2008-Norcross-E8-6	c	6			42		1			31	35							29					1						1		146
2008-Norcross-M0404-8	c				2					7	14							5											1		29
2008-Norcross-C22-9	p	3			1					2	19							12				1									38
2008-Norcross-C22-10	c	2	1	1	17	1		2		6	28							37		2			1						1		99
2008-Norcross-C21-11	c	15	10	1	18	1		2		8	20							19					7						4	10	115
2008-Norcross-C18-12	c	1		1	4					4	7					2	1	35				1	3			1			5		65
2008-Norcross-C17-13	c		29	1	27	1				31	1					2		58		4			5	1			1		13		174
2008-Norcross-C31-14	c	1									3							11													15
2008-Norcross-C12-15	c	5								4	15							51		5											80
2008-Norcross-C15-16	c	32								8	10							11		3						1	1				66
2008-Norcross-C14-17	c	56		1	5	2				1	21							558		2			3			1	1	1	1		653
2008-Norcross-C9-18	c	1	8		1	3		15		5	2							88					20	1		3	27	2			176
2008-Norcross-C4-19	p	7			48	1				17	10		3	1				35					8					1			131
2008-Norcross-C4-20	c	32			25					16	11							42					2								128
Grand Total		165	56	5	210	12	1	25	1	236	214	3	4	2	10	5	1	1052	5	16	2	5	88	3	1	8	32	21	43	10	2236

APPENDIX D

Incorporation of data into the Chukchi Demersal Fish Database

D.1 Historical and Recent Data

Objective 6 of this project was to develop a database of demersal fish catches and associated habitat parameters from research collections within Lease Sale 193 for use in assessment of long-term patterns in fish distribution, diversity, and abundance (Table D.1-1). The different trawl gears deployed in the Chukchi Sea 1959–2008 are described (Table D.1- 3). The Chukchi Demersal Fish (CDF) Database geographic coverage is comprehensive for available demersal fish data collected 1959–2008 in the offshore eastern Chukchi Sea, i.e., 65.5–73°N and 169–156°W. In addition to collections of demersal fishes within Lease Sale 193, the CDF Database includes all demersal hauls in the Chukchi Sea from cruises that entered the Lease Sale area, i.e., collections south, west and east (Figure D.1-1). It also includes all hauls in the Beaufort Sea from a cruise that entered the lease area (1977-Frost) and a 2-station cruise just west of Lease Sale 193 (1976-Frost). Two major historical collections from the Chukchi Sea were included in the CDF Database although all hauls were south of Lease Sale 193, i.e., 1959-Alverson and 1976-Wolotira. Data were not sought from cruises that were entirely inshore of Lease Sale 193, or from gear that was not deployed on the sea floor. Where a cruise reported in the CDF Database collected fishes with non-demersal gear, the gear types are noted (Appendix D-3).

Development of the CDF Database involved searches for published data in peer-reviewed literature, gray literature, and the internet. Unpublished data was sought from colleagues and institutional databases such as NOAA's RACEBASE groundfish resource database, the Institute of Marine Science database at the University of Alaska Fairbanks (UAF), the Alaska Ocean Observing System (AOOS), and the National Oceanographic Data Center (NODC). Searches for gray literature reports by the principal investigators were made online at the Alaska Resources Library and Information Service (ARLIS) and the Goldmine Library Catalog at UAF. Many data were not available electronically and were keyed into the database from paper reports and publications.

We included in the CDF Database all available data on fish presence, count, biomass, catch-per-unit-effort (CPUE), length, and weight from scientific fish collections in the Chukchi and Beaufort seas (Table II-1 of this report; additional descriptions in Appendix D). A considerable effort was made to find data, correct errors in transcription or taxonomy where necessary, and make the data reported in the CDF Database as accurate as possible. The tasks of acquiring, proofing, and reformatting the data to fit in the database structure that was agreed upon with BOEM were more labor intensive than anticipated. Difficulties were encountered in locating data that we know were collected, discrepancies between contract or study reports and electronic records, and discrepancies between voucher fish specimens and reported data. Specific examples are detailed in Appendix D.

Table D.1-1 Overview of scientific surveys of demersal fishes in the offshore eastern Chukchi Sea during 1959–2008 and associated environmental data archived in the Chukchi Demersal Fish (CDF) Database. We assigned CDF Cruise as a unique identifier for each cruise and gear combination. The vessel and year are indicated if there was no official cruise name. Gear types are abbreviated; OT = otter trawl; PSBT = plumb staff beam trawl. See Table D.1-2 for a full description of gear. Replicate gears that were deployed more than once with identical methods are indicated (A, B, or C). X indicates data are in the CDF database, -- indicates no data available, est indicates parameter was estimated. Substrate code D indicates descriptive data and % indicates grain size data. Cruises analyzed in Chapter II of this report are indicated.

CDF Cruise	Cruise or Vessel-Year	Regions	Month & Year	Headrope, Gear, Smallest Mesh	Rep Gear	# Fished Stations	#Hauls (E Chukchi)	Entered Lease Sale 193	Distance	Swath	Presence	Count	Biomass	Fish Length	Depth	Temp.	Salin.	Substrate	Vouchers Examined	Ch. II
1959-Alverson	John N. Cobb 43	eastern Chukchi Sea	Aug 1959	21.6 m 400 eastern OT, 38 mm		51	51(51)	no	--	X	X	X	--	--	X	X	--	D	X	X
1970-Quast	WEBSEC-70	eastern Chukchi Sea	Sep 1970	3 m OT, 38 mm		1	1(1)	no	--	--	X	--	--	--	X	X	X	--	X	--
1973-Morrow	Alpha Helix-1973	eastern & western Chukchi Sea	Jul-Sep 1973	4.9 m OT, 6 mm	A[1]	17	17(17)	yes	--	--	X	[2]	--	[2]	X	X	--	--	X	--
1976-Wolotira	MF-76-B	eastern Chukchi Sea	Aug-Oct 1976	25.2 m 83-112 eastern OT, 33 mm	B	93	260(93)	no	X	est	X	X	X	X	X	X	--	--	X	X
1976-Frost[4]	Glacier-1976	Beaufort Sea	Aug 1976	4.9 m & 5.8 m OT, 6 mm		2	2(0)	no	--	--	X	X	X	--	X	--	--	D	X	--
1977-Frost	Glacier-1977	Beaufort Sea, eastern Chukchi Sea	Aug-Sep 1977	4.9 m & 5.8 m OT, 6 mm		10	34(10)	yes	--	--	X	X	X	--	X	--	--	D	X	X
1983a-Fechhelm	Discoverer-1983	eastern Chukchi Sea	Aug-Sep 1983	7.6 m OT, 13 mm		18	19(19)	yes	X	--	X	X	--	X	X	X	X	--	--	X
1983b-Fechhelm	Zodiac-1983	eastern Chukchi Sea	Aug-Sep 1983	2.7 m OT, 19 mm		6	6(6)	no	X	--	X	X	--	X	X	--	--	--	--	X
1989-Barber	HX130	eastern Chukchi Sea	Sep 1989	6.1 m OT, 35 mm		25	50(50)	yes	--	--	X	X	--	--	X	X	X	--	X	X
1990-Barber	OH902	eastern Chukchi Sea	Aug-Sep 1990	25.2 m 83-112 eastern OT, 33 mm	B	48	95(95)	yes	X	X	X	X	X	--	X	X	X	--	X	X
1990-Hokkaido	OS33	eastern Chukchi Sea	Jul-Aug 1990	43 m OT, 90 mm		10	10(10)	no	--	--	X	X	X	--	X	X	X	--	X	X
1991a-Barber[3]	Responder-1991a	eastern Chukchi Sea	Jul 1991	4.9 m OT, 5 mm	A[1]	[3]	0(0)	no data	--	--	--	--	--	--	--	--	--	--	--	--
1991b-Barber[3]	Responder-1991b	eastern Chukchi Sea	Aug 1991	4.9 m OT, 5 mm	A[1]	[3]	0(0)	no data	--	--	--	--	--	--	--	--	--	--	--	--
1991c-Barber	OH91	eastern Chukchi Sea	Aug-Sep 1991	25.2 m 83-112 eastern OT, 33 mm	B	15	15(15)	yes	X	est	X	X	X	--	X	X	X	--	X	X
1991d-Barber[3]	Responder-1991c	eastern Chukchi Sea	Sep 1991	4.9 m OT, 5 mm	A[1]	[3]	0(0)	no data	--	--	--	--	--	--	--	--	--	--	--	--
1991-Hokkaido	OS38	eastern Chukchi Sea	Jul 1991	43 m OT, 90 mm		19	19(19)	yes	--	--	X	X	X	--	X	X	X	--	X	X
1992-Hokkaido	OS44	eastern Chukchi Sea	Jul 1991	43 m OT, 45 mm		17	17(17)	yes	--	--	X	X	X	--	X	X	X	--	X	X
2004-Mecklenburg	RUSALCA-2004	eastern & western Chukchi Sea	Aug 2004	7.1 m OT, 37 mm		4	27(8)	no	X	--	X	X	--	[2]	X	X	X	D, %	X	--
2004-Norcross	RUSALCA-2004	eastern & western Chukchi Sea	Aug 2004	3 m PSBT, 4 mm	C	5	19(6)	no	X	X	X	X	--	X	X	X	X	D, %	X	X
2007-Hokkaido	OS180	eastern Chukchi Sea	Aug 2007	43 m OT, 45 mm		5	19(19)	yes	--	--	X	X	X	--	X	X	X	--	--	
2007a-Norcross	OS180	eastern Chukchi Sea	Aug 2007	3 m PSBT, 4 mm	C	16	43(30)	yes	X	X	X	X	X	X	X	X	X	D, %	X	X
2007b-Norcross	OD0710	Bering Sea, eastern Chukchi Sea	Sep 2007	3 m PSBT, 4 mm	C	23	9(9)	yes	X	X	X	X	X	X	X	X	X	D, %	X	X
2008-Hokkaido	OS190	eastern Chukchi Sea	Jul 2008	43 m OT, 45 mm		7	7(7)	yes	--	--	X	--	X	--	X	X	X	--	--	--
2008-Norcross	OS190	eastern Chukchi Sea	Jul 2008	3 m PSBT, 4 mm	C	16	19(19)	yes	X	X	X	X	X	X	X	X	X	D, %	X	X
count = 24	21								10	8	21	18	13	7	21	18	15	8	17	15

[1] Gears described as 4.9 m OT with smallest mesh of 5 or 6 mm are virtually identical

[2] Data collected but not yet reported by investigators, and therefore not included in CDF Database.

[3] Samples were lost and no catch data are available.

[4] Cruise is not in the Chukchi Sea, but is included in the CDF Database because data were retrieved with 1977-Frost.

Table D.1-2 Descriptions of trawl gear used in the Chukchi Sea 1959–2008.

Gear	Mesh_Smallest_mm	Horizontal_Opening_m	Vertical_Opening_m	Description
2.7m OT: 19mm	19	<3		Otter trawl with 2.7 m headrope having 38 mm mesh and 19 mm codend mesh.
3m OT: 38mm	38	<3		Otter trawl with 3 .05 m headrope and 38 mm mesh.
3m PSBT: 4mm	4	2.257	1.2	Plumb staff beam trawl held open by a 3.05 m beam for an effective path width of 2.257 m. The vertical opening of the net has been observed by SCUBA divers as 1.20 m (JE Munk, AFSC/NMFS/Kodiak). The net body was of 7 mm and codend liner was of 4 mm mesh. A 3/8 inch leadline was fastened to the footrope, and 6 inch sections of chain were fastened at 6 inch intervals along the footrope. The net was rigged with a double tickler chain that consisted of a chain that was 0.5 m shorter than the foot rope and a second that was 0.9 m shorter than the foot rope. Net design was based after that of Gunderson and Ellis (1986).
4.9m OT: 6mm	6	<5		Otter trawl with 4.9 m headrope, 25 mm bar mesh in body, 6 mm mesh in codend, and 31 m bridle.
4.9m OT: 6mm or 5.8m OT: 6mm	6	<6		Otter trawls of 2 sizes reported for 1976-1977 study: 4.9 m and 5.8 m headropes with 32 mm web and 6 mm liner; no indication which net was fished at a particular haul (Frost et al. 1978, Frost and Lowry 1983).
6.1m OT: 35mm	35	<6		Otter trawl with 6.1 m headrope and 35 mm codend mesh.
7.1m OT: 37mm	37	<7		Otter trawl with 7.1 m headrope and 37 mm mesh codend; no codend liner
7.6m OT: 13mm	13	<7		Otter trawl with 7.6 m headrope having 38 mm mesh and 13 mm codend mesh
21.6m 400 eastern OT: 38mm	38	12.19	1.7	A 38 mm stretch mesh codend liner was added to this otter trawl to retain small animals (Alverson and Wilimovsky 1966). Remaining net specifications are for RACE Gearcode 20 with accessory 35, as described by RACE (2010). Gearcode 20: 400-mesh eastern trawl with 94 ft (28.6 m) footrope and 71 ft (21.6 m) headrope. 4 inch (102 mm) mesh (#36) in wings, square, and belly; 3.5 inch (89 mm) mesh (#60) in intermediate, and 3.5 inch (89 mm) mesh (#96) in codend. 11 to 15 deepsea floats of 8 inch (203 mm) diameter on headrope. Mean effective path width is 12.19 m. Mean vertical opening is 1.7 m; range is 1.4–1.8 m. Gear Accessory 35: 4 x 8 ft (1.2 x 2.4 m) doors, 120 m dandylines.

Table D.1-3 contiued

Gear	Mesh_ Smallest _mm	Horizontal _Opening _m	Vertical_ Opening _m	Description
25.3m 83-112OT: 32mm	32	17	2.3	This otter trawl net was fished with Scanmar equipment and actual net swath was recorded for each 1990-Barber haul; the average swath during that cruise was 15.3 m, which was applied to 1991c-Barber hauls. The mean swath reported for this gear by RACE (17.00 m) is applied to 1976-Wolotira hauls. The following net specifications are for RACE Gearcode 30 with accessory 32, as described by RACE (2010): Gearcode 30: 83-112 eastern otter trawl with 83 ft (25.3 m) headrope, 112 ft (34.1 m) footrope. 4 inch (10 mm) mesh (#49 thread because fished prior to 1984) in wings and body. 3.5 inch (89 mm) mesh (#95) in intermediate and codend. 41 floats on headrope of 8 inch (203 mm) diameter. Mean effective path width is 17.00 m; no range given (note that this mean swath is not reported in the CDF Database for 1990-Barber and 1991c-Barber). Mean vertical opening = 2.3 m; range is 1.9-2.7 m. RACE Gear Accessory 32: 7 x 10 ft (2.1 x 3 m) steel V-doors with 150 ft (45.7 m) dandylines and 1.25 inch (32 mm) mesh liner in codend.
43m OT: 45mm	45			Otter trawl with 43.3 m headrope and a 48.6 m footrope with roller gear but no tickler chain; codend lined with 45 mm mesh.
43m OT: 90mm	90			Otter trawl with 43.3 m headrope and a 48.6 m footrope with roller gear but no tickler chain. The smallest codend mesh was 90 mm; no codend liner.

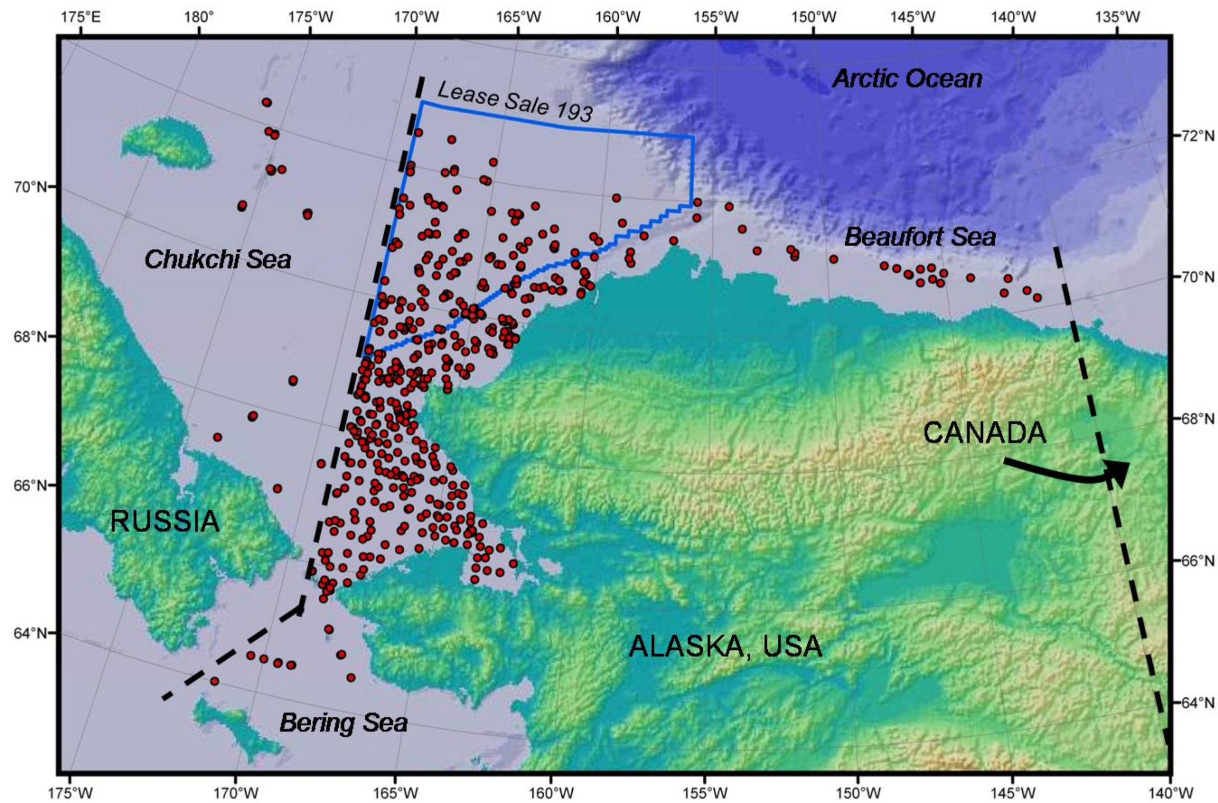


Figure D.1-1 Sites of scientific demersal fish collections during 1959–2008 that are included in the Chukchi Demersal Fish Database.

D.2 Methods of Examination of Collections of Fish Specimens

Providing an accurate characterization of northeastern Chukchi Sea fish species distribution and diversity and diversity meant that for this project we evaluated voucher specimens of fishes from the northeastern Chukchi Sea (Objective 1). While there is a lack of knowledge for many rare species, the taxonomy of many "common" species of North Pacific-Arctic fishes remains unsettled as well. Recent examination of museum specimens indicated that taxonomic problems exist with some Arctic species, and that misidentifications are common, even for the most common fish species.

Data and/or fish specimens were located from 21 different types of collections from 17 research cruises covering the 50 years from 1959 through 2008 (Table 1 in this report), of which C.W. Mecklenburg examined specimens from 15 of these collections. Thus to accomplish Objective I, Mecklenburg examined voucher specimens of fishes collected during 1959–2008 within and near Chukchi Sea Lease Sale 193. In some cases this led to increased accuracy with some loss of precision in the CDF Database. Following accurate and revised identification of fish specimens, we used the verified voucher specimens to certify the entire catch record of these past cruises. The accurate identification of these fishes was essential for preparation of the historical database and consequent comparison of species presence, abundance, and distribution over time.

A compilation of reliable records of occurrence of Chukchi Sea fish distribution can be found online in the database of Arctic Marine Fish Museum Specimens (AMFISH v.Apr-2009) (Mecklenburg and Mecklenburg, 2009; *http://www.arcodiv.org/Database/Fish_datasets.html*); revisions are noted in this report and will be incorporated in the next version of AMFISH . With funding from the CMI and other sources, C.W. Mecklenburg visited several voucher collections and confirmed or revised identifications of specimens of fishes collected during 1959–2008 within and near Chukchi Sea Lease Sale 193 with respect to present-day taxonomic rules. The review of vouchers was a time-consuming and travel-intensive task, and some museums were visited multiple times in the effort to evaluate and accumulate accurate historical records of fish presence in this region. Specimens with questionable identifications were examined, such as specimens collected from localities outside the species' published geographic ranges. Additionally, a more or less random sample of specimens of each species from each cruise or other collection activity was examined. Identifications were changed to correct misidentifications and to bring the taxonomic nomenclature up to date, i.e. changing an old name or junior synonym to the current name or senior synonym. Collections that were examined include vouchers archived at the University of Alaska Museum of the North (UAMN; Fairbanks, AK), Auke Bay Laboratory (ABL; Auke Bay, AK), University of Washington (UW; Seattle, WA), California Academy of Sciences (CAS; San Francisco, CA), Hokkaido University Museum of Zoology (HUMZ; Sapporo, Hokkaido, Japan), University of British Columbia (UBC; Vancouver, BC, Canada), and Canadian Museum of Nature (CMN; Ottawa, Ontario, Canada).

Species are reported in the CDF Database using nomenclature in the American Fisheries Society's most recent publication of scientific and common names (Nelson et al., 2004). Taxonomy of fishes is not a static science, and the AFS publication does not report the most recent taxonomic determination for every species. In particular, the rainbow smelt *Osmerus mordax* has since been reclassified as *O. dentex*, walleye pollock *Theragra chalcogramma* has been reclassified as *Gadus chalcogrammus*, and the Arctic alligatorfish *Ulcina olrikii* has been reclassified as *Aspidophoroides olrikii*. The more recent classifications are based on primary literature and reported in the California Academy of Science's Catalog of Fishes (Eschmeyer, 2013). We list the names under which fishes caught in the 1959–2008 cruises have previously been reported (Table D.2-1). Taxonomic redeterminations and changes to the names by which fishes were previously reported are indicated in the CDF Database tbl_Catch. Taxonomic verifications and redeterminations also contribute to a separate taxonomic database of Arctic fishes (Mecklenburg and Mecklenburg, 2009: AMFISH). Due to incorrectly identified voucher specimens or lack of voucher specimens of the less common species from some cruises, we recommended that for retrospective analyses some taxa be grouped at a lower taxonomic level, e.g. genus or family (Table D.2-3).

Incorrect identifications of some taxa, in the published literature going back to the late 1800s and in unpublished museum records, cannot be untangled without reexamination of specimens. Problems with the following taxa were recognized only recently, in part due to genetics analysis (Mecklenburg et al., 2011; C.W. Mecklenburg unpub. data). Resolution of the following problems and confirmation or revision of all identifications is not within the scope of this project, and is not possible for catch records without vouchers. These taxa include *Icelus* spp., Cottidae species A (*Microcottus sellaris* and *Trichocottus brashnikovi* complex), and *Liparis* spp. Two specimens of *M. sellaris* were confirmed by Mecklenburg from within the Lease Sale 193 area (Mecklenburg et al., 2011). It is difficult to distinguish among Liparis spp. <60 mm in length without microscopic analysis while fresh, or genetic analysis, and differentiating between *L. gibbus* and *L. bathyarcticus*, a newly described species in the Chukchi Sea, presently requires genetic analysis.

Table D.2-1 Current names of fish species that were reported using earlier taxonomic nomenclature in historical (1959–1992) collections in the Chukchi Sea. Nomenclature in the CDF Database follows the American Fisheries Society's most recent publication of scientific and common names (Nelson et al., 2004). Species whose names have been updated in scientific literature after that publication, as reported by the California Academy of Science's Catalog of Fishes (Eschmeyer, 2013), are indicated by footnotes.

Current name	Earlier names
Herrings (Clupeidae)	
Pacific herring *Clupea pallasii*	*C. harengus, C. harengus pallasii*
Smelts (Osmeridae)	
Capelin *Mallotus villosus*	*M. villosus socialis*
Rainbow smelt *Osmerus mordax* [1]	*O. dentex, O. mordax dentex*
Cods (Gadidae)	
Pacific cod *Gadus macrocephalus*	*G. ogac*
Walleye pollock *Theragra chalcogramma* [2]	
Sticklebacks (Gasterosteidae)	
Ninespine stickleback *Pungitius pungitius*	*Gasterosteus aculeatus*
Sculpins (Cottidae)	
Hamecon *Artediellus scaber*	*A. scaber beringianus*
Antlered sculpin *Enophrys diceraus*	*E. claviger*
Arctic staghorn sculpin *Gymnoanthus tricuspis*	*G. tricuspis orientalis*
Butterfly sculpin *Hemilepidotus papilio*	*Melletes papilio*
Belligerent sculpin *Megalocottus platycephalus*	*M. laticeps*
Arctic sculpin *Myoxocephalus scorpiodes*	*M. axillaris*
Shorthorn sculpin *Myoxocephalus scorpius*	*M. verrucosus; M. scorpius groenlandicus*
Ribbed sculpin *Triglops pingelii*	*T. beani; T. pingeli, T. pingeli pacificus*
Poachers (Agonidae)	
Alligatorfish *Aspidophoroides monopterygius*	*Aspidophoroides bartoni*
Arctic alligatorfish *Ulcina olrikii* [3]	
Eelpouts (Zoarcidae)	
Halfbarred pout *Gymnelus hemifasciatus*	*G. knipowitschi, G. platycephalus*
Fish doctor *Gymnelus viridis*	*G. barsukovi, G. bilabrus*
Wattled eelpout *Lycodes palearis*	*L. palearis arcticus*
Pricklebacks (Stichaeidae)	
Stout eelblenny *Anisarchus medius*	*Lumpenus medius*
Blackline prickleback *Acantholumpenus mackayi*	*Lumpenus mackayi*
Flatfishes (Pleuronectidae)	
Yellowfin sole *Limanda aspera*	*Pleuronectes asper*
Arctic flounder *Pleuronectes glacialis*	*Liopsetta glacialis*
Longhead dab *Limanda proboscidea*	*Pleuronectes proboscideus*

[1] Current status in Eschmeyer (2013) is *Osmerus dentex*

[2] Current status in Eschmeyer (2013) is *Gadus chalcogrammus*

[3] Current status in Eschmeyer (2013) is *Aspidophoroides olrikii*

Table D.2-2 Recommendations for grouping taxa for retrospective analyses of abundance.

Recommended grouping	Cruise_CDF	Taxon	Rationale
Icelus spp.	all	Spatulate sculpin *Icelus spatula* Thorny sculpin *Icelus spiniger* *Icelus* spp.	Taxonomists are now researching morphology to distinguish among juveniles of *Icelus spatula* and an undescribed species of *Icelus*, both of which are present in Lease Sale 193. These species are genetically distinct, and very similar in appearance
Cottidae sp. A	all	Brightbelly sculpin *Microcottus sellaris* Hairhead sculpin *Trichocottus brashnikovi*	Taxonomists are now researching morphology to distinguish among juveniles of *M. sellaris* and *T. brashnikovi*; these species are genetically distinct, and adults can bedistinguished by appearance
Eumicrotremus spp.		Pacific spiny lumpsucker *E. orbis* Pimpled lumpsucker *E. andriashevi*	Similar appearance; *E. orbi* s not verified from inside Lease Sale 193
Liparis spp.	all	Arctic seasnail *Liparis bathyarcticus* Gelatinous seasnail *Liparis fabricii* Variegated snailfish *Liparis gibbus* Kelp snailfish *Liparis tunicatus*	Misidentifications in many cruises. *L . bathyarcticus* has been identified from the eastern Chukchi Sea from a cruise after 2008; taxonomists are now researching morphology to distinguish among juveniles of *L. bathyarcticus* and *L. gibbus*; these species are genetically distinct, and adults can bedistinguished by appearance
Poachers (Agonidae)	*-Hokkaido	All taxa	Several misidentifications
Podothecus spp.		Veteran poacher *Podothecus veternus* Sturgeon poacher *P. accipenserinus*	Similar in appearance; *P. accipenserinus* not verified from inside Lease Sale 193
Eelpouts (Zoarcidae)	all	Halfbarred pout *Gymnelus hemifasciatus* Fish doctor *Gymnelus viridis* Saddled eelpout *Lycodes mucosus* Wattled eelpout *Lycodes palearis* Canadian eelpout *Lycodes polaris* Marbled eelpout *L. raridens* Arctic eelpout *L. reticulatus*	Misidentifications in most cruises; similar appearance
Flatfishes (Pleuronectidae)	*-Hokkaido	All taxa	Several misidentifications

D.3 Details of Data Collection, Specimen Verification, and Database Development

D.3.1 1959-Alverson

Researchers: Alverson D.L., Wilimovsky N.J. (NMFS)

Data sources: Alverson and Wilimovsky, 1966; RACEBASE, 2008

Alternate cruise: John N. Cobb 43

Vessel: M/V *John N. Cobb*

Sites: Figure D.3.1

Fishing dates: 6–30 August 1959; date was taken from Alverson and Wilimovsky (1966: Table 1, p. 851), Start time from RACEBASE (2008), which had reported Greenwich Mean Time (GMT), was converted for the CDF Database to local time (GMT-9 hr).

Demersal fishing gear: 400 eastern OT. **Details:** 400 eastern otter trawl with 21.6 m headrope, 90 mm stretch mesh in body, 32 mm stretch mesh codend liner; gear originally described by Greenwood (1958); RACEBASE reports as AFSC gearcode = 20 with accessories code = 435. The average opening of this net is 15.1 m wide x 4 m high (RACE, 2010).

Demersal fishing method: Approx. 30 min haul; vessel speed not reported

Source – catch data: RACEBASE (v.2008 courtesy of J. Orr, NMFS/AFSC/RACE/Seattle)

Source – area towed: Latitude and longitude were taken from celestial bearings, radio bearings, radar fixes, or dead reckoning. The CDF database incorporated haul latitude and longitude reported in Alverson and Wilimovsky (1966: Table 1). Distance and area towed were not reported.

Source – habitat data: Depth, bottom temperature and sediment descriptions were incorporated from Alverson and Wilimovsky (1966: Table 1). Substrate grabs were collected at each dredge & otter trawl site. A particular search was undertaken for salinity data in the chapters of Wilimovsky and Wolfe (1966) and in publications by researchers of this cruise. Although salinity was a factor in fish distribution (Alverson and Wilimovsky, 1966), no mention was found of gear that would have collected water to measure salinity or of actual values of salinity; we suggest that the reference to salinity likely indicated proximity to freshwater input rather than actual measurements.

Other fishing gear (not in CDF Database): Bottom dredge, shrimp trap, beach seine, midwater herring trawl, gill net

Fish voucher collections: Fishes from this collection were not examined for this project. However, C.W. Mecklenburg advises that the original identifications for Project Chariot were almost all correct, having been made by Norman J. Wilimovsky who was very familiar with the regional fishes. Vouchers are located at ABL, CAS, UBC, USNM, and UW.

Resolution of catch data: According to RACEBASE query results, data were limited to bottom trawl (code 20). It is likely that data present in RACEBASE v.2008 were entered from the field data sheets from the 1959-Alverson cruise, which were not recovered by this project; RACEBASE appeared to combine catches from multiple gears/site, i.e., did not differentiate between catches by gear type. There were several discrepancies in quantity of fishes reported by RACEBASE and AMFISH, such as the following two examples. Discrepancies where the count of vouchers examined are larger than the count of fish reported by RACEBASE are noted in Table CatchPerHaul Field DifferenceTaxonLevels. RACEBASE v.2008 reported biomass of each taxon at each haul as 0.045 kg, i.e. no biomass data were recovered.

> HaulUniqueCDF = 1959-Alverson-32-1: n=1 *Myoxocephalus* sp. (RACEBASE v.2008) and n=5 voucher specimens of Myoxocephalus scorpius were identified (AMFISH v. Apr-2009).

HaulUniqueCDF = 1959-Alverson-50-1: n=1 Liparidinae (RACEBASE, 2008) and n=6 voucher specimens identified as *Liparis tunicatus* (AMFISH v.Apr-2009).

The CDF Database excluded those stations that Alverson and Wilimovsky (1966) reported without bottom trawls, i.e., stations 38, 53–55, 62–72. It included in the Haul table those hauls where RACEBASE v.2008 did not report fish taxa caught at the site: i.e., stations 1 and 4.

Additional: Additional searches were made for catch and associated habitat data through NODC, ARLIS, journals, gray literature, and articles authored by the primary researchers.

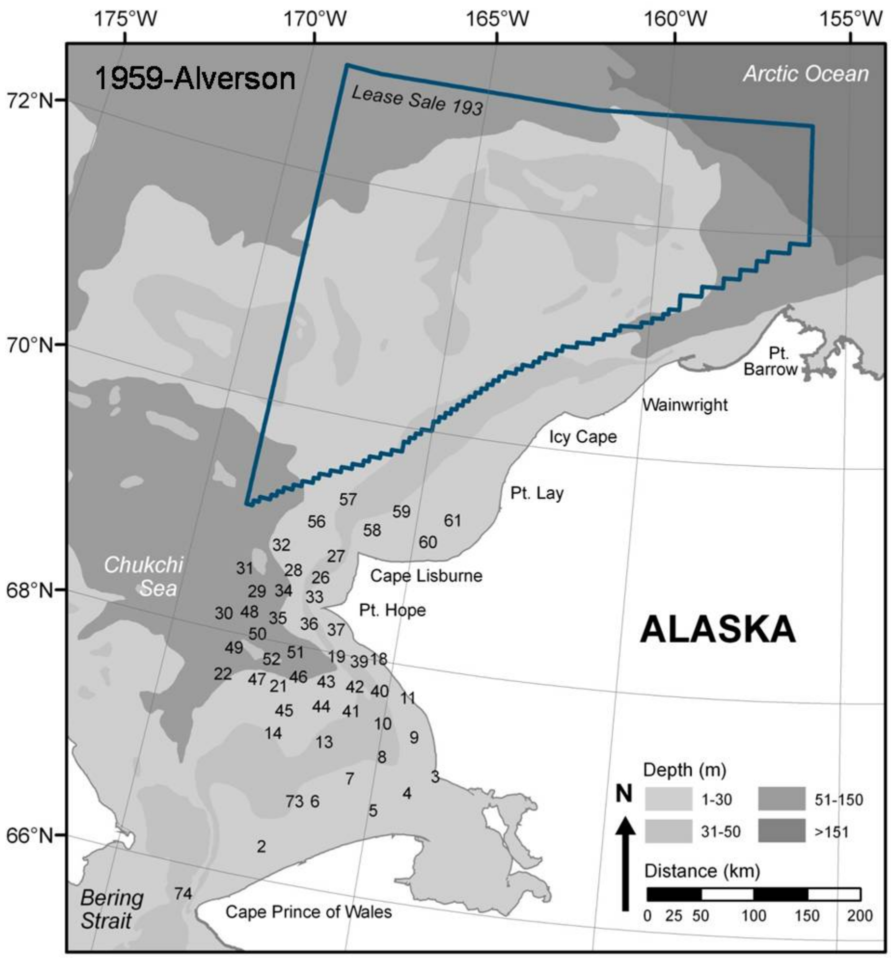


Figure D.3-1 1959-Alverson: Map of station locations.

D.3.2 1970-Quast (National Marine Fisheries Service)

Researcher: Quast J.C.

Data source: Quast, 1972

Alternate cruise: WEBSEC-70

Vessel: USCGC *Glacier*

Sites: Figure D.3.2

Fishing dates: 25-Sep-1970

Demersal fishing gear: 3mOT. **Details**: 3.05 m otter trawl with 38 mm mesh.

Demersal fishing method: Approximately 30 min haul; speed was not reported (Quast, 1972)

Source(s) – catch data: Presence/absence data were reported from the single otter trawl haul during WEBSEC-70 (station 8); number of fish per site were not reported (Quast, 1972).

Source – area towed: None.

Source – habitat data: Quast (1972: Figures 9 and 12, respectively) indicate bottom temperature >3 ºC and bottom salinity <31. Although a sediment grab was deployed at the fishing site (station 8), substrate data from that site were not reported; Quast (1972: Table 1) reported %G, %S, %Silt, %Clay for other stations

Other fishing gear (not in CDF Database): 1.8 m Isaacs-Kidd midwater trawl with 76 mm web and 13 mm liner

Fish voucher collections: The following changes were made and incorporated in the CDF Database: *Podothecus accipenserinus* became *P. veternus*. The original *Myoxocephalus scorpioides, M. ensiger, and M. verrucosus* were changed to *M. scorpius*. *Liparis bristolense* became *L. tunicatus*. Voucher collections located at ABL, CAS, UBC, USNM, and UW.

Resolution of catch data: Taxa were revised for the CDF Database as noted in Fish Voucher Collections.

Additional: None

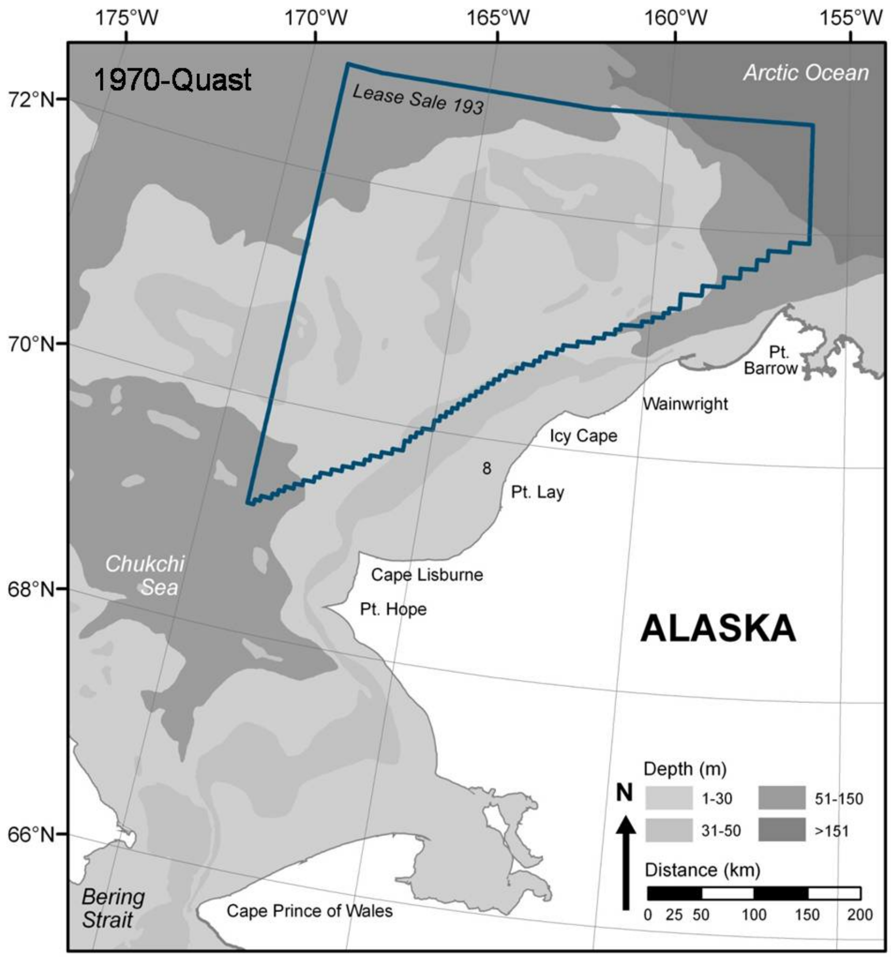


Figure D.3-2 1970-Quast: Map of location of the single station off Point Lay that was sampled for demersal fish.

D.3.3 1973-Morrow

Researchers: Morrow J., Mecklenburg C.W. (Collections by UAF)

Data sources: C.W. Mecklenburg, unpub. data

Alternate cruise: Alpha Helix-1973

Vessel: R/V *Alpha Helix*

Sites: Figure D.3.3

Fishing dates: 18 Aug – 7 Sep 1973

Demersal fishing gear: 4.9mOT. **Details:** 4.9 m otter trawl; 25 mm bar mesh in body; 6 mm mesh in codend; 17 fm bridle; warp was 3–6 x water depth

Demersal fishing method: Generally, two 10–20 minute replicate hauls were taken at each station (Stoker, 1985)

Source – catch data: Some, but not all, presence data, as described below

Source – area towed: None

Source – habitat data: As described below

Other fishing gear (not in CDF Database): Additional benthic sampling by 10 ft otter trawl (Elsner, 1975)

Fish voucher collections: Vouchers are located at UAMN and USMN, as described below

Resolution of catch data: As described below.

Additional: In 1973 a cruise was conducted in the western (Russian) and eastern Chukchi Sea and in the eastern Beaufort Sea. Dr. James Morrow of UAF was the fisheries scientist. Short records of fishing operations (Morrow, 1975) and associated cruises activities (e.g., Elsner, 1975; Stoker, 1975) were written. Fishes were preserved and shipped to the University of Alaska Museum of the North (UAM) for permanent storage, and no record of these fishes was ever published. However, C.W. Mecklenburg discovered approximately 300 jars containing the fishes in UAM collection. Presence of some, but not all, of the fishes caught in the eastern Chukchi Sea during this cruise are included in the CDF Database (as in AMFISH v. Apr-2009), however identification of all the fishes was beyond the scope of this project. Complete presence, abundance, and habitat records from all demersal fishing stations during 1973-Morrow will be reported by Mecklenburg et al. (in prep.). Because there is not a full record of fish collections as yet, it is only possible to list fish from this cruise as “present”, i.e., we do not know where they were “absent.” Accompanying data are limited to information written on sample labels about latitude, longitude, bottom temperature, and depth.

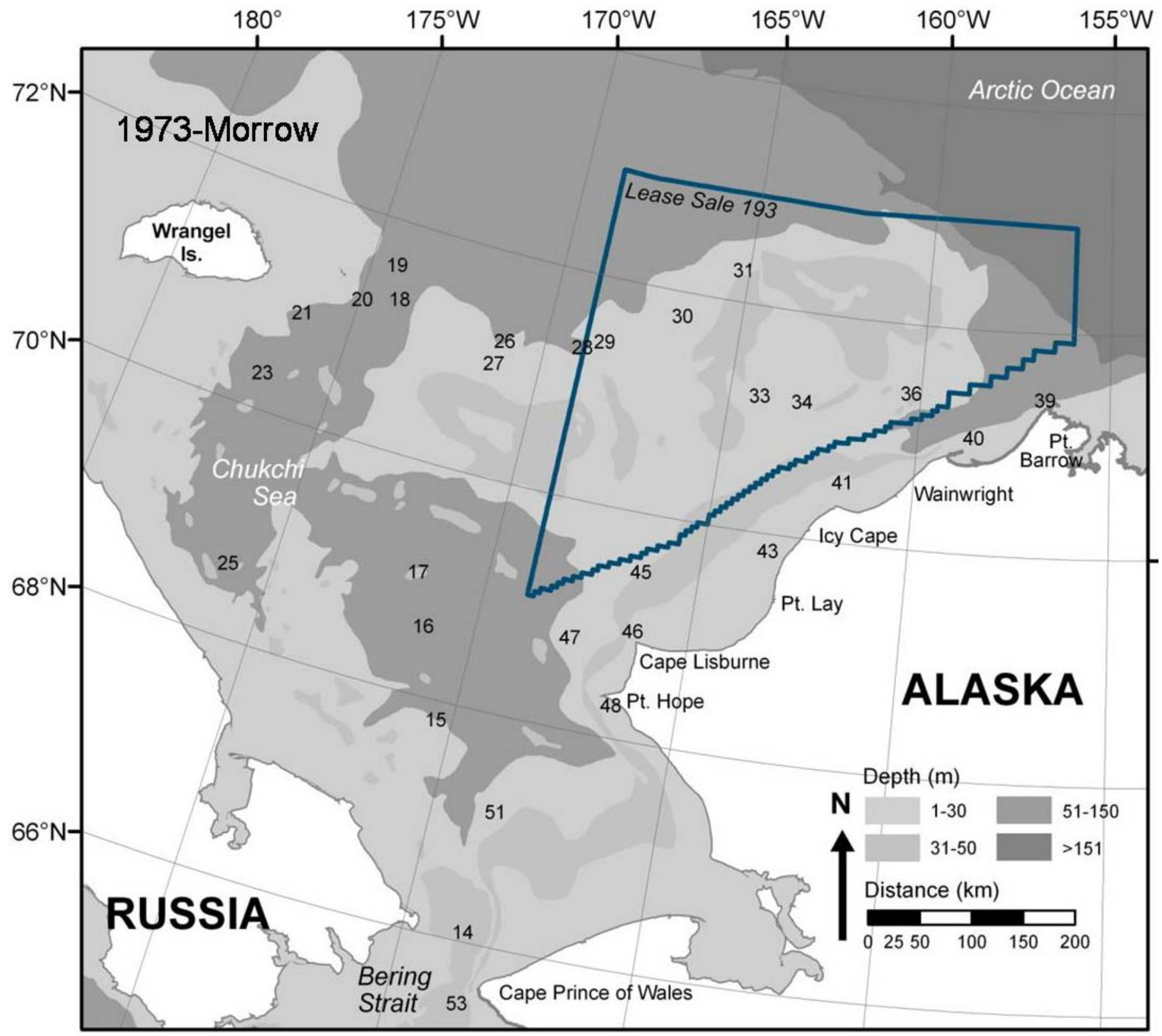


Figure D.3-3 1973-Morrow: Map of bottom trawl station locations occupied during the cruise.

D.3.4 1976-Wolotira

Researchers: Wolotira Jr R.J., Pereyra W.T., Sample T.M., Morin Jr M. (National Marine Fisheries Service)

Data sources: NODC track number TR067; RACEBASE v.2008

Alternate Cruise: MF-76-B

Vessel: R/V *Miller Freeman*

Sites: Figure D.3.4

Fishing dates: 2 Sep – 9 Oct 1976

Demersal fishing gear: NMFS 83-112. **Details:** NMFS 83-112: 25.6 m headrope, 34.1 m footrope, 90 mm mesh and 33 mm codend liner, tickler chain; RACE gear code = 30 with accessories code = 32; RACE (2010) reports this gear code as having an average swath of 17.0 m wide x 1.9–2.7 m (average = 2.3 m) vertical opening

Demersal fishing method: 30 min haul at average 3.5 kt towing speed; replicate (day-night) demersal sets

Source – catch data: Wolotira et al. (1977) summarized and analyzed catch data collected during this cruise, but did not publish counts or biomass of fishes; those data were taken from RACEBASE v.2008. Pereyra et al. (1976) reported species presence.

Source – area towed: AreaTowedSqKm was calculated for CDF Database by multiplying average net swath (RACE, 2010) by DistanceTowed per haul (RACEBASE v.2008).

Source – habitat data: Depth data were taken for the CDF Database from NOAA Navigational Chart 16005 rather than from the depth data reported in RACEBASE v.2008. RACEBASE sites north of Bering Strait were reported from 27 to 134 m, a maximum which is considerably greater than available in the sampled area. The incorrect depth data in RACEBASE were likely due to transcription error. Depth data were not found in the cruise report (RACE, 1976).

Bottom temperature was set to RACEBASE reported GEAR_TEMPERATURE. Although Pereyra et al. (1977) indicated an XBT was deployed at each trawl site, no bottom temperature data were found in that citation or in RACEBASE. Bottom salinity and substrate were not collected.

Other fishing gear (not in CDF Database): Gill net; BCF universal pelagic trawl (RACEBASE)

Fish voucher collections: Most of the taxon names in the CDF Database field TaxonReportedPreviously are from the sample jar labels or the UW online catalog. Most field identification errors were corrected as of the Wolotira et al. (1977) report. C.W. Mecklenburg confirmed what the previous investigators had concluded.

Several changes were made by Mecklenburg due to changes in classification and nomenclature of species and to misidentifications found by examination of the survey's voucher specimens. The following changes were made and incorporated in the CDF Database: *Clupea harengus pallasii = Clupea pallasii*, *Myoxocephalus scorpius groenlandicus = Myoxocephalus scorpius*, *Triglops pingeli = Triglops pingelii* (spelling), *Lumpenus mackayi = Acantholumpenus mackayi*, *Liopsetta glacialis = Pleuronectes glacialis*. The changes listed above are not misidentifications; they are merely taxonomic name changes.

Several misidentifications were found among the voucher specimens. *Artediellus uncinatus* was on the list but not found in the collections. *A. scaber* is abundant at times in the study area (e.g., Mecklenburg et al., 2007; Norcross et al., 2010), but there have been no records of *A. uncinatus* from Alaskan waters. It would be odd if *A. scaber* had not been found even at one station in such an extensive survey as the OCS survey. In the UW collection, several voucher specimens of *A. scaber* were found from this cruise, but no

A. uncinatus. Only one jar label had the name *A. uncinatus*, and the two specimens it contained were redetermined as *A. scaber* by Mecklenburg in March 2005.

The name *Chirolophis polyactocephalus* can be problematic because it has been used for more than one species, both of them occurring in the study area and both very similar looking*: C. decoratus* and *C. snyderi*. One voucher for *Chirolophis* was found in the UW collection. It had a field identification of *C. decoratus*, and was redetermined as *C. snyderi* by A.E. Peden in 1986; Mecklenburg confirmed as *C. snyderi* in March 2005. No specimens were found with the name *C. polyactocephalus*.

Hemilepidotus jordani is on the list, but is rare is the northern Bering Sea and not confirmed from the Chukchi Sea, whereas other species are more common in the area. Specimens identified as *H. jordani* were found to be *H. papilio*.

Eumicrotremus orbis is rare in the northern Bering Sea, whereas other lumpsucker species are relatively abundant. The one voucher specimen found for *E. orbis* was actually *E. andriashevi*.

The name *Agonus acipenserinus* is correct as Podothecus *accipenserinus*. However, both *P. accipenserinus* and *P. veternus* occur in the study area and are often mistaken for one another. The voucher specimens from the OCS survey were redetermined as *P. veternus* by B. A. Sheiko in 1997, confirmed as *P. veternus* by Mecklenburg.

In addition, seven species were found in the voucher collections that were not listed by Wolotira et al. (1977): *Microcottus sellaris*, *Myoxocephalus polyacanthocephalus*, *Trichocottus brashnikovi*, *Nautichthys robustus*, *Liparis tunicatus*, *Lycodes mucosus*, and *L. raridens*. The samples of *Microcottus sellaris* (1 specimen) and *Myoxocephalus polyacanthocephalus* (1 specimen) were correctly labeled. Perhaps the identifications were made after the 1977 report was prepared, but the records do not show who redetermined their identification. These specimens were examined by Mecklenburg in January and March 2005. *Trichocottus brashnikovi* (1 specimen) was found among the vouchers at UW for *Myoxocephalus* species in 1998 (Mecklenburg et al., 2002). The *Nautichthys robustus* lot (5 specimens) was previously identified as *N. pribilovius* and redetermined by A. Ankenbrandt in 1985. It is the northernmost record of *N. robustus* (Mecklenburg et al., 2002). The *Liparis tunicatus* specimens (3 lots, 1 specimen each) must be the "*Cyclopteridae* sp. Snailfish sp." on the list; K.W. Vogt identified them in 1995, confirmed as *L. tunicatus* by Mecklenburg in January 2005. *Lycodes mucosus* and *L. raridens* were misidentified as *L. turneri*; redetermined by Mecklenburg in November 2004.

Vouchers are located primarily at UW, with smaller collections at UAMN and USMN.

Resolution of catch data: Taxa were revised for the CDF Database as described in Fish Voucher Collections.

Additional: None

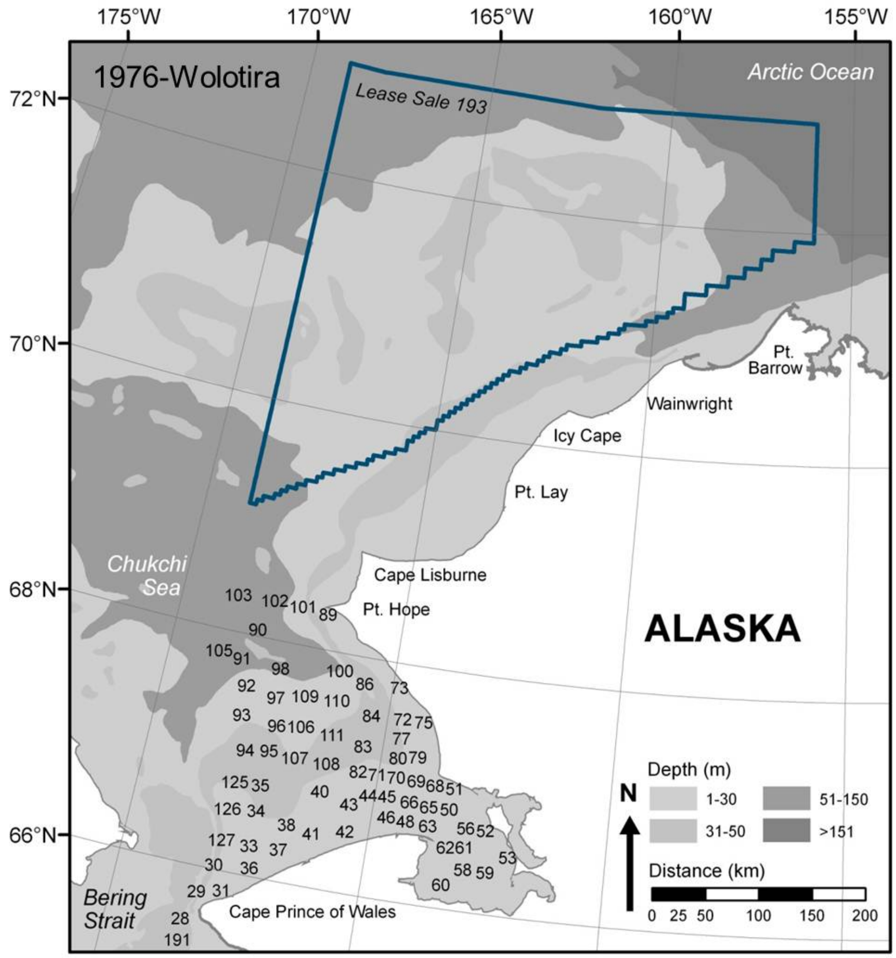


Figure D.3-4 1976-Wolotira: Map of station locations.

D.3.5 1976-Frost and 1977-Frost

Researchers: Frost K.J., Lowry L.F., Burns J.J. (Alaska Department of Fish and Game)

Data sources: Frost et al., 1978; Frost and Lowry, 1983

Alternate Cruise: Glacier-1976, Glacier-1977

Vessel: USCGC *Glacier*

Sites: Figure D.3.5

Fishing dates: 30–31 Aug 1976 (1976-Frost); 2 Aug – 3 Sep 1977 (1977-Frost)

Demersal fishing gear: 4.9mOT, 5.8mOT. **Details:** Gear included otter trawls of both 4.9 m and 5.8 m headrope length; both trawls had 32 mm web and 6 mm codend liner; neither report (no indication which net was fished at a particular haul (Frost et al., 1978, Frost and Lowry, 1983)

Demersal fishing method: 10–15 min haul at approx. 3–4 kt

Source – catch data: Presence of fish species during 1976 and 1977 was reported by Frost and Lowry (1983), and the count of fishes caught was reported by Frost et al. (1978).

Source – area towed: None

Source – habitat data: Data were incorporated from Alverson and Wilimovsky (1966: Table 1). Contents of the substrate grabs taken at each dredge & otter trawl site were described in that table.

Other fishing gear (not in CDF Database): None

Fish voucher collections: Specimens collected during 1976-Frost and 1977-Frost were examined by C.W. Mecklenburg at the University of Alaska Museum of the North (UAM), Fairbanks, from 2000 to 2006, and at the Canadian Museum of Nature (CMN), Gatineau, Quebec, in May 2008. Previous species identifications were from the museum jar labels or online databases of museum holdings, and were made by K.J. Frost and L.F. Lowry (those archived at UAM) and Canadian ichthyologist Don E. McAllister (CMN specimens).

The specimens that were archived were primarily those Frost and Lowry (1983) reported as possible extensions of known range. The CMN database lists 23 cataloged lots from Frost and Lowry's 1976 and 1977 sampling, and the University of Alaska Museum of the North's Arctos database lists 11. Most of the specimens were correctly identified. Exceptions were four lots identified as *Gymnelus viridis* which likely are *G. hemifasciatus*, as they have coloration and head pores matching *G. hemifasciatus* recently collected from the Chukchi Sea and verified by genetic analysis (C.W. Mecklenburg, unpub. data). *Lycodes rossi* was reported as present in the Beaufort Sea at a single site (Frost et al., 1983), but this is almost certainly a misidentification, judging from other specimens (non-Frost) from Alaska identified as this species and later found to have been misidentified. No specimens of *Lycodes rossi* were found in the collections of either museum, and therefore we recommend that it be reported in future as *Lycodes* sp.; vouchered specimens of other species of the *Lycodes* genus were correctly identified. Frost and Lowry opted for grouping all *Liparis* in *Liparis* spp., a caution with which we concur.

Vouchers are located at CMN, CAS, and UAMN.

Resolution of catch data: Taxa were revised for the CDF Database as described in Fish Voucher Collections.

Additional:
Cruises 1976-Frost and 1977-Frost were part of the Outer Continental Shelf Environmental Assessment Program (OCSEAP). The study was primarily focused on species known to be of trophic importance to marine mammals and other animals. The study was not designed to provide a quantitative estimate of biomass or abundance, and no record was found of which gear was deployed at the station.

Cruise 1976-Frost was two stations in the Beaufort Sea, and cruise 1977-Frost was in the Chukchi and Beaufort seas. The stations in the Beaufort Sea were included in the CDF Database because the taxonomic evaluation in this report was applicable to these stations as well as the stations within the Chukchi Sea.

Data on fish counts, weights, and total length range were entered from field data sheets that had been published in an OSCEAP annual report (Frost et al., 1978), and revised as per C.W. Mecklenburg's examination of voucher specimens.

One discrepancy was observed and researched, i.e. catches from 1976 reported in Frost & Lowry 1983 Appendix A listed those taxa caught at site A (site 1_76 in Frost et al., 1978) as caught at site B (site 2_76), and vice versa. We determined that the field notes attribute the catches to the correct sites, since site A / 1976-1 was 123 m and site B / 1976-2 was 40 m, and *Artediellus scaber* (presence reported at site A in Frost and Lowry, 1983, and abundance reported at 1976-2 in Frost et al., 1978) is only found to a maximum depth of 93 m (Mecklenburg et al., 2002). The field notes and abundance (Frost et al., 1978) are reported in the CDF Database in preference to the final report presence (Frost and Lowry, 1983).

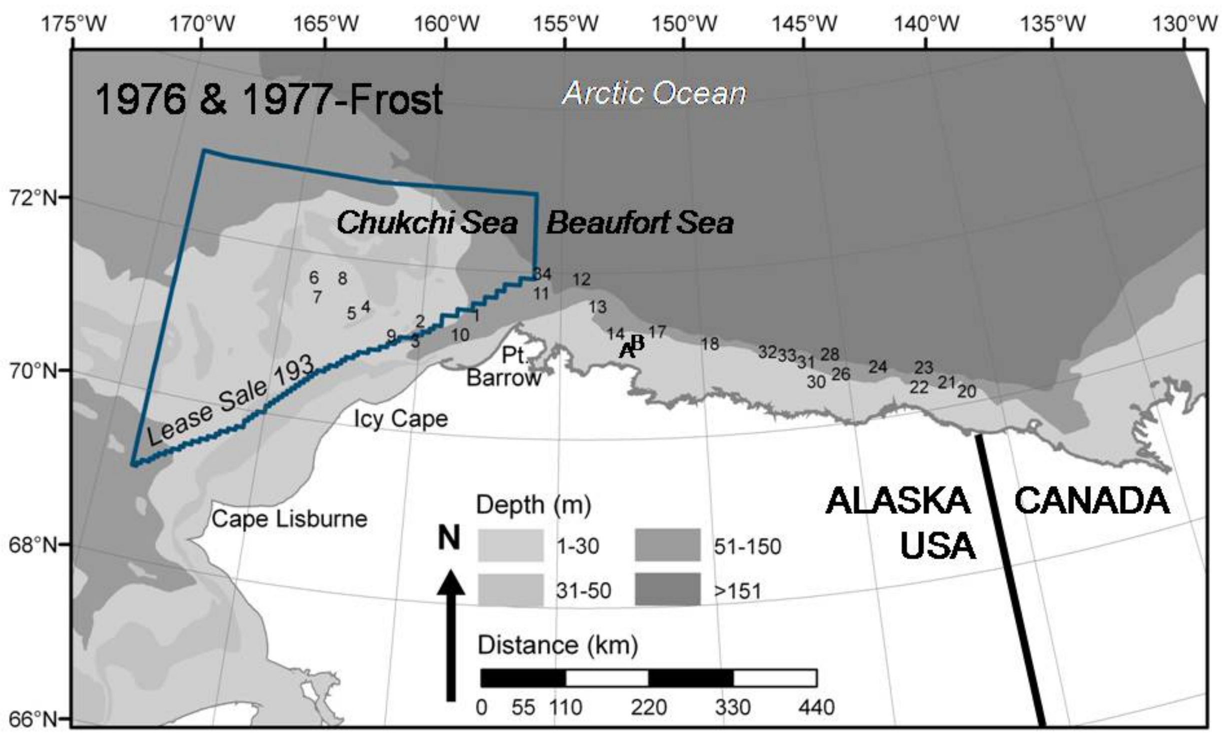


Figure D.3-5 1976-Frost and 1977-Frost: Map of station locations. Stations A and B were during 1976-Frost, and numbered stations were during 1977-Frost.

D.3.6 1983a-Fechhelm and 1983b-Fechhelm

Researchers: Fechhelm R.C., Craig P.C., Baker J.S., Gallaway B.J. (LGL Ecological Research Associates)

Data sources: Fechhelm et al., 1984

Alternate Cruises: Discoverer-1983, Zodiac-1983

Vessel: NOAA R/V *Discoverer* (1983a-Fechhelm); HMS Zodiac, a small unnamed vessel (1983b-Fechhelm)

Sites: Figure D.3.6

Fishing dates: 27 Aug – 12 Sep1983 (1983a-Fechhelm); 31 Aug – 11 Sep 1983 (1983b-Fechhelm)

Demersal fishing gear: 7.6mOT (1983a-Fechhelm); 2.7mOT (1983b-Fechhelm) **Details:** 7.6 m otter trawl with 38 mm mesh and 13 mm codend mesh was fished at deep sites (1983a-Fechhelm); 2.7 m headrope otter trawl with 38 mm mesh and 19 mm codend mesh was fished at shallow sites (1983b-Fechhelm); (Fechhelm et al., 1984)

Demersal fishing method: 15–30 min per haul (1983a-Fechhelm); 9–10 min per haul (1983b-Fechhelm)

Source – All data in the CDF Database were taken from Fechhelm et al., 1984). Data from 1983a-Fechhelm (Discoverer, track TT9401) and 1983-Fechhelm (HMS-Zodiac, track TT9402) were discovered in NODC Accession 8700139; that accession did not add data to those published by Fechhelm et al. (1984).

Catch data: Fechhelm et al. (1984: p. 170–171); Fechhelm et al. (1984: p. 19) indicate weight was measured of each species and gear, but we did not locate biomass per species per otter trawl haul, or weight of individual fish caught in bottom gear.

Source – area towed: Area towed was not reported; distance towed was reported (Fechhelm et al., 1984: p. 169)

Source – habitat data: Date, latitude, longitude, and depth are as reported by Fechhelm et al. (1984: Section 10.5, p. 168). Temperature was measured in the field with in-glass mercury thermometers. Bottom water collected via Van Dorn bottles and salinity was analyzed with YSI-33 Salinity/Conductivity meter. No substrate data were reported.

Other fishing gear (not in CDF Database): Gill net, fyke net

Fish voucher collections: No vouchers were discovered for this collection (Mecklenburg et al., 2007), thus no verifications were done.

Resolution of catch data: The actual count of fishes per haul was reported (Fechhelm et al., 1984: Section 10.5 pages 170–171). Where less than 100% of the haul was processed, those counts were extrapolated for the CDF Database by multiplying the counted fish by 100 * (% sorted). The resultant counts were similar, but not equal to those reported as summed over deep hauls in Fechhelm et al., 1984 (Table 5.5 column "Adjusted catch"), e.g., Arctic staghorn sculpin adjusted catch 10,699, sum over hauls 11,449; Arctic cod adjusted catch 4339, sum over hauls 4170; shorthorn sculpin adjusted catch 1608, sum over hauls 1708. We were unable to ascertain where the discrepancy arose from, and used in the CDF Database the number of fish counted at each site, adjusted to 100% of haul volume.

Although biomass of fishes at each haul was recorded, as evidenced by average values reported by Fechhelm et al. (1984: Table 5.5), those data were not reported for individual hauls, and are not available for the CDF Database.

Additional: Duration range of hauls during 1983b-Fechhelm was reported as 9–10 minutes; duration was not reported for individual hauls and therefore the CDF Database reports the mean, i.e., 9.5 minutes.

The word "Station" was assigned to more than one latitude, longitude vicinity (Fechhelm et al., 1984). Station in CDF Database is the Station reported on p. 132 in association with CTD data, latitude and longitude; Haul in CDF Database is the Station reported on p. 170–171 in association with fish count and on p. 168 in association with otter trawl depth, latitude and longitude. We compared latitude and longitude of the CTD Station and otter trawl Station, and assigned the otter trawl "Station" as a Haul at the CTD Station, i.e. both CTD Station and otter trawl Station are incorporated into the CDF Database's HaulUniqueCDF. There were otter trawl hauls that were not near any CTD stations, and those hauls are reported in the CDF Database with the Station field blank.

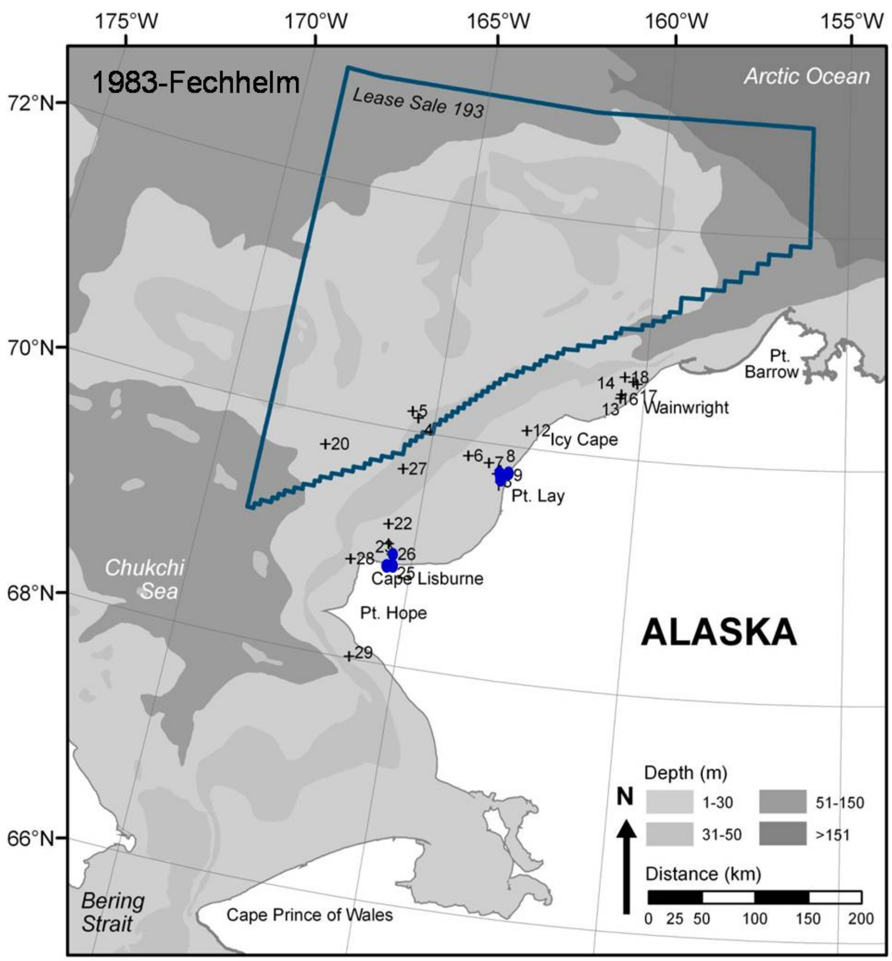


Figure D.3-6 1983a-Fechhelm and 1983b-Fechhelm: Map of station locations. The nearshore stations of 1983b-Fechhelm are indicated by blue filled circles (sites 9, 10, and 11 at Point Lay, and 23, 25, and 26 at Cape Lisburne).

D.3.7 1989-Barber

Researchers: Barber W.E., Smith R.L. (IMS/UAF)

Data sources: Barber et al., 1994

Alternate Cruise: HX130

Vessel: R/V *Alpha Helix*

Sites: Figure D.3.7

Fishing dates: 3–9 Sep 1989

Data sources: Barber et al. (1994); NODC

Demersal fishing gear: 4.9m OT: 35mm

Gear details: 6.1 m headrope otter trawl with 35 mm codend mesh (Barber et al., 1994)

Demersal fishing method: Two hauls at each site for approximately 30 min each at 2 kts (Barber et al., 1994)

Source – fish data: Counts of fish caught were entered for the CDF Database from Barber et al. (1994: Appendix 1-23). No electronic records of fish were discovered during searches of the AOOS, IMS, and NODC databases.

Source – area towed: None

Source – habitat data: One latitude and longitude was reported for each fishing station; positions were interpolated between satellite fixes, and LORAN C could not be used (Barber et al., 1994: Apx 1-4). Bottom depth, temperature and salinity were incorporated into the CDF Database from the CTD bottom datum as averaged over the multiple CTD casts per station, which were reported for Barber-1989 (Barber, 2004 via AOOS; these data are no longer hosted); the present project could not locate online data at AOOS or NODC 15 Jan 2013). Date, time, and bottom depth were not reported for fishing hauls by Barber et al. (1994). Date incorporated into the CDF Database is the date of the CTD cast, which was reported as GMT; since the start time of the HX130 tows was not available, it was not possible to calculate the local date. Substrate grain size data that Barber associated with fishing stations was collected during Cruise OC862 aboard the NOAA Ship Oceanographer during August and September 1986; we did not include substrate in the CDF Database because we were not certain which 1986 stations were associated with 1989 fishing hauls.

Other fishing gear (not in CDF Database): Isaacs-Kidd midwater trawl, Bongo plankton net

Fish voucher collections: Voucher specimens of 24 species were recovered from cruises 1989-Barber, 1990-Barber, and 1991c-Barber, and nine of these species (38%) were redetermined by C.W. Mecklenburg. Mecklenburg discovered sample jars in locations around the University of Alaska Fairbanks campus in addition to the UAMN; these samples have been assigned permanent specimen numbers and are now cataloged in UAMN's Arctos database. Specimens were generally in poor condition. Mecklenburg's examination of specimens revealed that *Myoxocephalus* sp. and *M. verrucosus* were incorrectly but consistently identified on sample labels; Mecklenburg redetermined these as *M. scorpius.* Eelpouts were not consistently identified to genus or to species; *Lycodes* and *Gymnelus* spp. were often misidentified (Mecklenburg et al., 2007). The voucher collection is at UAMN.

Resolution of catch data: Taxa were revised for the CDF Database as described in Fish Voucher Collections.

Additional: None

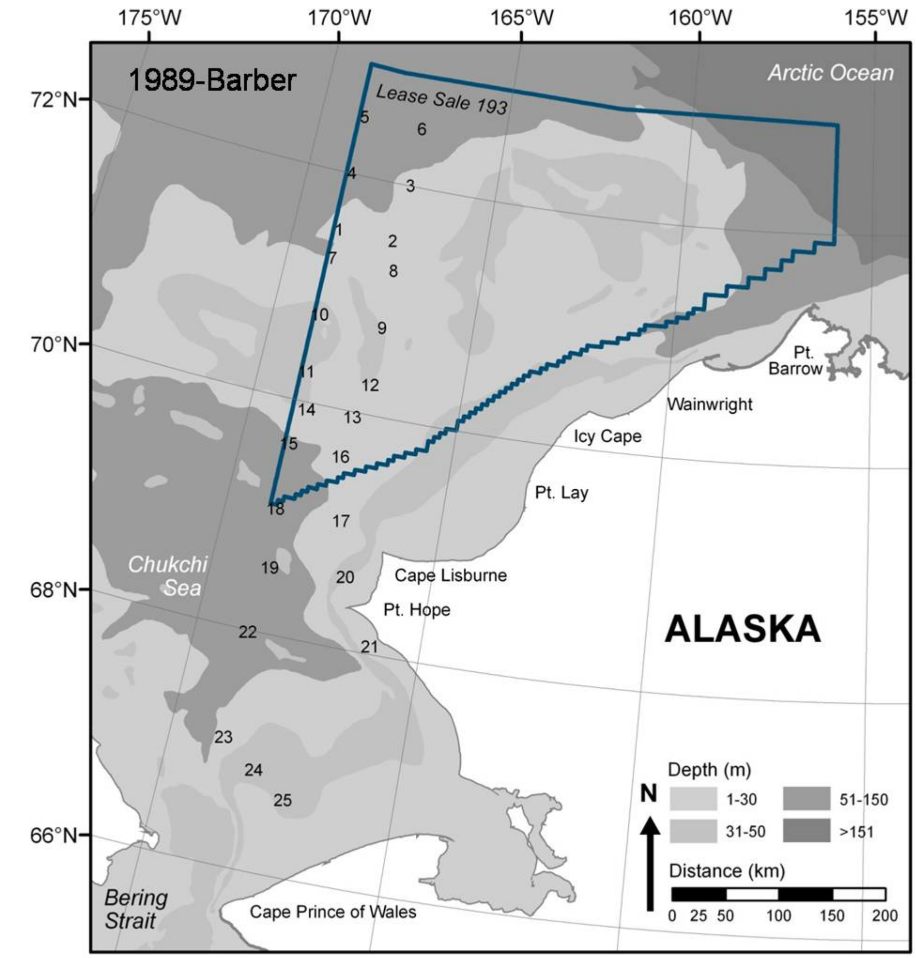


Figure D.3-7 1989-Barber: Map of station locations.

D.3.8 1990-Barber

Researchers: Barber W.E., Smith R.L. (IMS/UAF)

Data sources: Barber et al., 1994, 1997; AOOS; NODC

Alternate Cruise: OH902

Vessel: F/V *Ocean Hope III*

Sites: Figure D.3.8

Fishing dates: 16 Aug – 16 Sep 1990

Demersal fishing gear: NMFS 83-112; **Details:** NMFS 83-112 with 34.1 m footrope, 25.6 m headrope, 90 mm mesh, 33 mm codend liner, tickler chain (Barber et al., 1994: Appendix 5-2); identical trawl was used during 1990-Barber and 1991c-Barber. Trawl width at the wings and height of the headrope above the footrope were determined with a Scanmar™ electronic mensuration unit.

Demersal fishing method: Approx. 30 min per haul, two hauls per site at 2 kt (Barber et al., 1997). The CDF Database reports the duration of each haul, which ranged from 15 to 30 min (Barber, 2004 accessed via AOOS 1 Feb 2010). Method was identical to 1991c-Barber.

Source – catch data: Electronic count and biomass data for all taxa and hauls were recovered online from a site hosted by AOOS; these data are not presently hosted at AOOS. What appear to be the same catch data have since been discovered in the NODC database, i.e. NODC Accession 9400061 *http://www.nodc.noaa.gov/cgi-bin/OAS/prd/accession/details/9400061*. Although catch data were previously summarized (Gillispie et al., 1994, Barber et al., 1997, Smith et al., 1994a, 1994b), those data are not reported by the CDF Database for reasons explained below.

Source – area towed: Swath as recorded with Scanmar equipment, and distance per haul, are incorporated into the CDF Database as reported by Barber (Barber 1990 data accessed via AOOS website, 18 Dec 2009). Area towed is calculated for the CDF Database for each haul as swath x distance.

Source – habitat data: Date and time were taken from the AOOS source; date was the same as in Barber et al. (1994), however it was not clear from either source whether the reported date or time in AOOS were local or GMT. Time was not reported by Barber et al. (1994, 1997). Bottom temperature and salinity are from Barber et al. (1994: Chapter 5 Table 1, p. 5-2). Substrate grain size data that Barber associated with fishing stations was collected during Cruise OC862 aboard the NOAA Ship Oceanographer during August and September 1986; we did not include substrate in the CDF Database because we were not certain which 1986 stations were associated with 1989 fishing hauls.

Other fishing gear (not in CDF Database): Isaacs-Kidd midwater trawl, Bongo plankton net

Fish voucher collections: Described in Appendix D.3.7

Resolution of catch data: Five, sometimes conflicting, sources of fish count and biomass data were evaluated for the CDF Database (i.e., AOOS data portal; Barber et al., 1997; Gillispie et al., 1994; Smith et al., 1994a, 1994b).

Count and biomass per haul were incorporated into the CDF database as reported through the AOOS data portal, as corrected by taxonomic examination by C.W. Mecklenburg.

The abundance and biomass of a subset of species were reported at each site by Barber et al. (1994), i.e., combined data from multiple hauls at the site. The sum of haul 1 and haul 2 at site 1 does not equal the g/km^2 reported for the limited number of species reported by Barber et al. (1997); the abundances and biomasses are close in value, but are not exactly the same, nor are they consistently different.

Average station abundance and biomass of *Boreogadus saida* (Gillispie et al., 1994), *Gymnocanthus tricuspis* (Smith et al., 1994a: p. 5-2), and *Hippoglossoides robustus* (Smith et al., 1994b) are reported for the each haul sampled during 1990-Barber and 1991c-Barber. Due to the limited number of species, these data were not investigated further.

A subset of the 1990-Barber catch was reported by Barber et al. (1997). Abundance (fish/km^2) and biomass (g/km^2) for 1990-Barber were determined by area-swept method (Wakabayashi et al., 1985) and reported by Barber and others (1997) only for the most abundant 14 species, and only from the eight sites that were examined during both 1990-Barber and 1991c-Barber; catches were averaged over the multiple hauls at a station, and were reported as count and weight per square km.

Additional: None

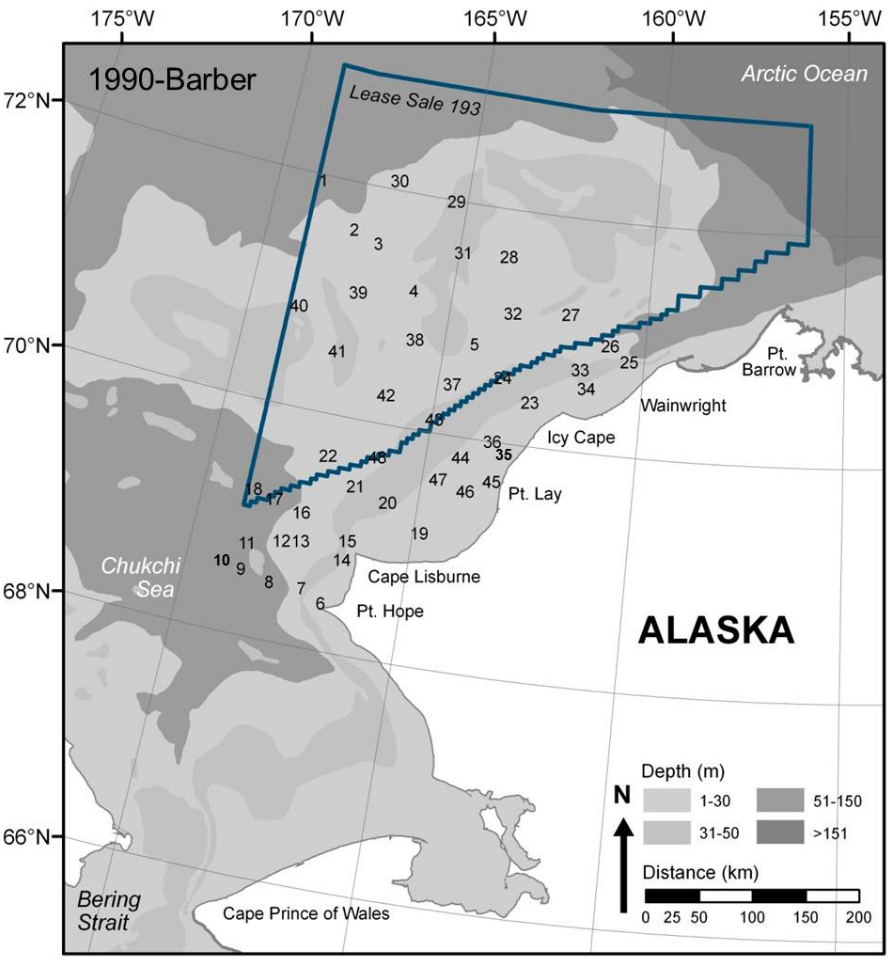


Figure D.3-8 1990-Barber: Map of station locations.

D.3.9 1990-Hokkaido

Researchers: Faculty of Fisheries, Hokkaido University

Data sources: Hokkaido University, 1991

Alternate Cruise: OS33

Vessel: T/S *Oshoro-Maru IV*

Sites: Figure D.3.9

Fishing dates: 29 Jul – 1 Aug 1990

Demersal fishing gear: 43m OT: 90 mm

Details: Otter trawl with 43.3 m headrope otter trawl with 48.6 m footrope with roller gear and 90 mm codend mesh, and without either codend liner or tickler chain (Barber et al., 1994: Appendix 4-2); identical trawl gear was used during 1990-Hokkaido and 1991-Hokkaido. The trawl used in 1990 and 1991 was modified for use prior to 1992-Hokkaido, and again modified before use during 2007-Hokkaido and 2008-Hokkaido.

Demersal fishing method: Approximately 60 minute hauls at 3–4 kt; actual speed and duration are reported (Hokkaido University, 1991: Table 10)

Source – catch data: Previously reported by Hokkaido University (1991: p. 163) and Barber et al. (1994)

Source – area towed: None

Source – habitat data: Haul name, date, time, duration, one position, and depth are as reported by Hokkaido University (1991: Table 10); bottom temperature was not taken from this table. Station name, bottom temperature, and bottom salinity are as reported from CTD data by Hokkaido University (1991: Table 2).

Other fishing gear (not in CDF Database): Baited longline deployed at surface; various plankton nets. Drift gillnet was deployed during the cruise but not in the Chukchi Sea.

Fish voucher collections:
Fish specimens from cruises 1990-Hokkaido, 1991-Hokkaido, and 1992-Hokkaido were archived at HUMZ, Hakodate, Hokkaido, Japan, and were examined there by C.W. Mecklenburg during May 2007. From talking to people at the museum, Mecklenburg concluded there was no systematic verification of identifications after fieldwork.

The cruise data records (Hokkaido University, 1991, 1992, 1993) list the species caught, number of individuals, and weight by station. The museum ledger lists 423 specimens archived from these cruises, of which 212 were examined in May 2007 by Mecklenburg; the remaining 211 archived specimens were missing, misshelved, or temporarily unavailable. Of the 212 specimens examined, 23% (49) were found to be misidentified. Most identifications as *Pleuronectes quadrituberculatus* were incorrect (91%; 20 of 22 specimens), confused with *Hippoglossoides robustus* and *Hippoglossus stenolepis.* Another of the most abundant species, *Myoxocephalus scorpius*, usually was correctly identified, although the field party called it *M. verrucosus*, the older name for a Pacific ecophenotype of *M. scorpius*. All *Podothecus veternus* (6) were misidentified as *P. accipenserinus* and *P. sachi*. Eelpouts were often confused with other species or were not identified to species; for instance, the only specimens of *Lycodes palearis* and *L. polaris* in the collection were misidentified as *L. turneri*, and *Gymnelus hemifasciatus* and *G. viridis* were identified only to genus. Several species caught in lowest abundance were also misidentified; for example, *Hippoglossoides elassodon* was misidentified as *H. robustus*, and *Glyptocephalus zachirus* was misidentified as *G. stelleri*. *Stichaeus ochriamkini* does not occur in the region, and although the one specimen listed in the data record as this species was not found, we assume it was misidentified. Other misidentifications involved *Mallotus villosus*, misidentified as *Osmerus mordax*; *Icelus spiniger, as I.*

cataphractus; Myoxocephalus polyacanthocephalus, misidentified as *M. verrucosus*; *Dasycottus setiger*, as *Eurymen gyrinus*; *Bathyagonus nigripinnis*, as *Aspidophoroides bartoni*; and *Eumesogrammus praecisus*, as *Bathymaster* sp.

Some of the taxonomic confusion, evidently, and as to be expected, was due to the field parties' greater familiarity with western Pacific species, many of which are very similar to northeastern Bering Sea and Chukchi Sea species. Some misidentifications were consistent, such as *Podothecus veternus*, which did not appear on the published catch records (Hokkaido University 1991, 1992, 1993) but was found in the voucher collection identified as *P. accipenserinus* and *P. sachi.* Some were inconsistent, such as *Lycodes palearis* often, but not always, being misidentified.

In addition to misidentifications, as with any museum collection, many of the names used were either old names no longer in use or junior synonyms. Both misidentifications and antiquated nomenclature were corrected.

For the purpose of constructing the CDF Database and conducting historical analysis, we made the following adjustments based on Mecklenburg's verifications. All flatfishes, except unique-looking *Glyptocephalus* were grouped as Pleuronectidae as they were not consistently identified either correctly or incorrectly. All *Podothecus* were assumed to be *P. veternus,* although *Leptagonus decagonus* occurs in the area and has occasionally been misidentified as *Podothecus* by other researchers. There was one misidentification of *Bathyagonus nigrippinis* as *Aspidophoroides*, leading to skepticism about *Aspidophoroides* identifications; therefore, poachers were treated as a group, i.e., Agonidae. Eelpouts of *Lycodes* and *Gymnelus* spp. were also grouped at the family level, i.e., Zoarcidae.

The majority of vouchers are located at HUMZ; a few samples are at UAMN.

Resolution of catch data: Catch data incorporated into the CDF Database are from Hokkaido University (1991: p. 163–165), as revised by identification of voucher specimens. Count data reported by Barber et al. (1994) were not used for the CDF Database. These data sources were not reviewed for discrepancies.

Additional:
A specific example of a difficulty encountered while incorporating data from the 1990-Hokkaido, 1991-Hokkaido, and 1992-Hokkaido cruises into the CDF Database was that fishing hauls were not assigned to the station names where the CTD was deployed to collect temperature and salinity data. Based on our (Norcross et al., 2010) and Barber's et al. (1997) research, salinity is an important environmental factor determining fish assemblages in the northeast Chukchi Sea. Temperature and salinity were associated in the Hokkaido reports with an Oshoro-Maru station name (e.g., OS91162), and temperature and fish data were associated with a trawl number (e.g., OST9103). The station name and trawl number were not associated, and the temperature data were recorded with two different instruments and are different. It was necessary to use latitude and longitude to detect which environmental data were associated with a trawl catch, i.e., a time-consuming but important task.

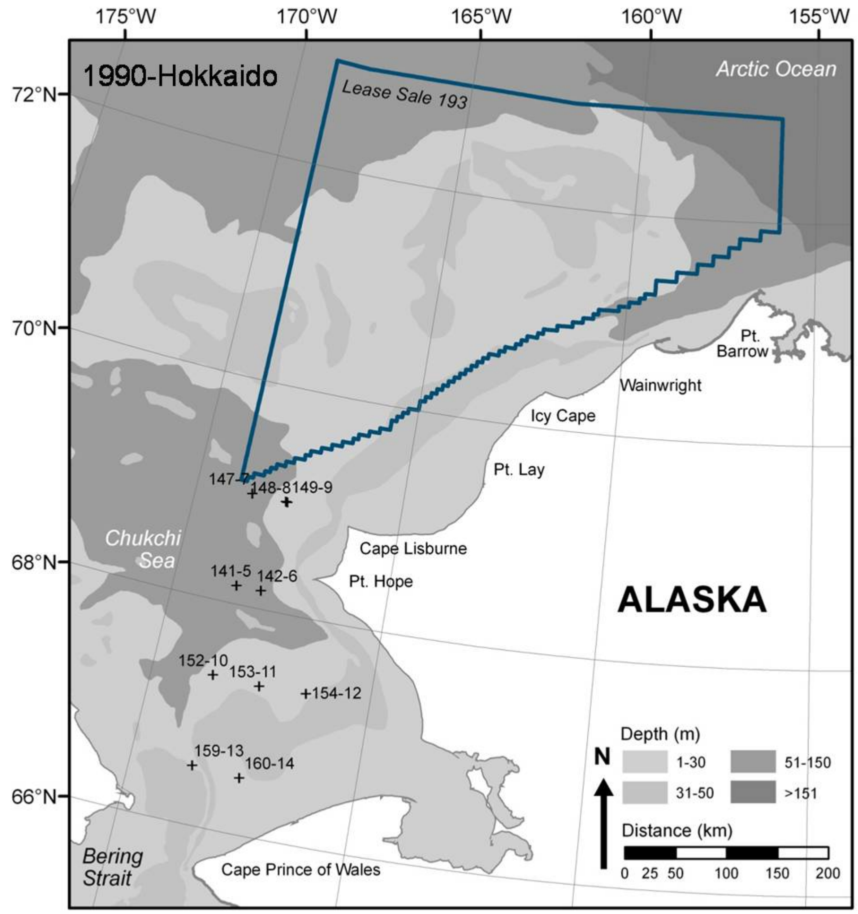


Figure D.3-9 1990-Hokkaido: Map of station locations sampled by bottom trawl. Although stations were occupied south of Bering Strait, they are not included in the CDF Database.

D.3.10 1991a-Barber, 1991b-Barber and 1991d-Barber

Researchers: Barber W.E., Smith R.L. (IMS/UAF)

Data sources: Barber et al., 1994

Alternate Cruise: Responder

Vessel: 10.9 m launch deployed from the oil company barge *Responder*

Sites: Figure D.3.10

Fishing dates: 24–29 Jul 1991 (1991a-Barber); 13–18 Aug 1991 (1991b-Barber); 28 Sep 1991 (1991d-Barber)

Demersal fishing gear: 4.9mOT; **Details:** 4.9 m headrope otter trawl with 5 mm mesh

Demersal fishing method: The launch was equipped with a detachable A-frame and diesel powered winch system. Various deployment methods were used (Barber et al., 1994: Appendices 3-5, 3-6, 3-7 & 3-11); methods are not detailed since catch data were not recovered.

Source – catch data: With the exception of the partial and qualitative summary given below (Additional), no field notes or additional information about the catch were recovered for the CDF Database, although several potential sources were investigated, i.e., personal communication with F.J. Mueter, R. Smith, M. Vallarino (SFOS/UAF), and R.M. Meyer (previously of MMS/Anchorage). Fish samples were collected but not quantified in the field; samples were lost in transit (Barber et al., 1994: Appendix 6-3), and thus no catch records are included in the CDF Database.

Source – area towed: None

Source – habitat data: None

Other fishing gear (not in CDF Database): IKMT; bongo zooplankton net; other zooplankton net

Fish voucher collections: Fishes from this collection were lost in transit and not examined for this project.

Resolution of catch data: None

Additional:
During 1991a-Barber and 1991d-Barber, four sites were sampled, and during 1991b-Barber, six sites were sampled, within Lease Sale 193. Field identification indicated that fish primarily consisted of *Boreogadus saida*, unidentified sculpins, *Eleginus gracilis*, and *Gymnocanthus* sp. (Barber et al., 1994: Appendix 6-2).

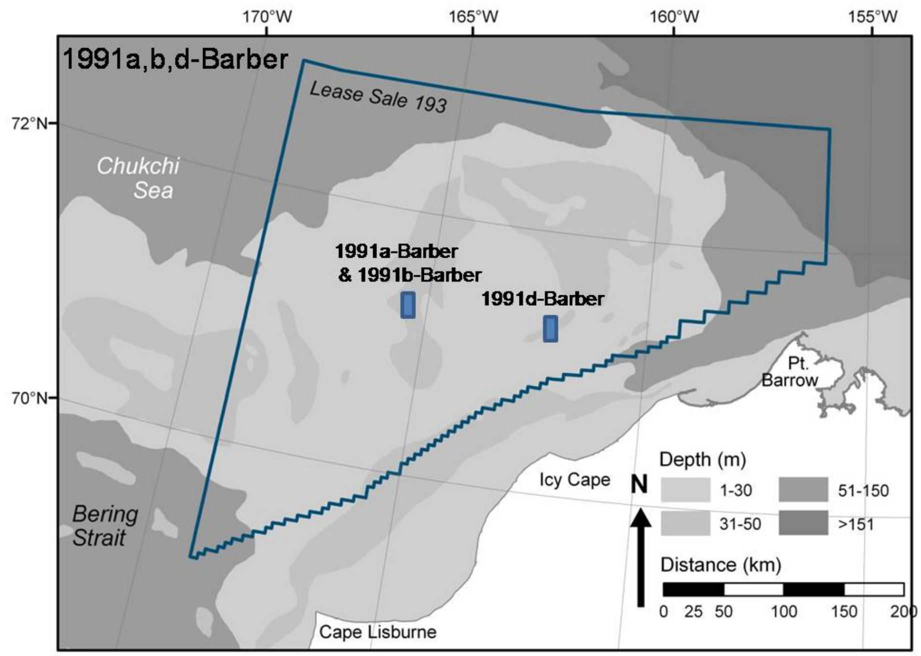


Figure D.3-10 1991a-Barber, 1991b-Barber and 1991d-Barber: Map of positions of the oil barge *Responder* from which the sampling boat was launched.

D.3.11 1991c-Barber

Researchers: Barber W.E., Smith R.L. (IMS/UAF)

Data sources: Barber et al., 1994, 1997; AOOS; NODC

Alternate Cruise: OH91

Vessel: F/V *Ocean Hope III*

Sites: Figure D.3.11

Fishing dates: 16 Aug – 16 Sep 1991

Demersal fishing gear: NMFS 83-112; **Details:** NMFS 83-112 with 34.1 m footrope, 25.6 m headrope, 90 mm mesh, 33 mm codend liner, tickler chain (Barber et al., 1994: Appendix 5-2); identical gear was used during 1990-Barber and 1991c-Barber. Scanmar mensuration equipment was deployed to measure horizontal and vertical net opening, but those data were not recovered for the CDF Database; the average net opening was assigned for the CDF Database as the average swath and headrope height of hauls during 1990-Barber, i.e., 15.3 m wide and 2.7 m high.

Demersal fishing method: Approx. 30 min per haul, two hauls per site at 2 kt (Barber et al., 1997). Method was identical to 1990-Barber)

Source – catch data: Electronic count and biomass data for all taxa and hauls were recovered online from a site hosted by AOOS; these data are not presently hosted at AOOS (Barber, 2004 via AOOS). What appear to be the same catch data have since been discovered in the NODC database, i.e. NODC Accession 9400061 *http://www.nodc.noaa.gov/cgi-bin/OAS/prd/accession/details/9400061*. Although catch data were previously summarized (Gillispie et al., 1994, Barber et al., 1997, Smith et al., 1994a, 1994b), those data are not reported by the CDF Database for reasons explained below.

Source – area towed: Although net mensuration equipment was deployed on the trawl, data were not reported (Barber, 2004 via AOOS; Barber et al., 1994, 1997); therefore trawl swath was assigned as the average of 1990-Barber hauls, i.e., 15.3 m. Although latitude and longitude were recorded at the start and end of each haul, haul distance was not reported (Barber, 2004 via AOOS; Barber et al., 1994, 1997).

Source – habitat data: Same as for 1990-Barber. Date and time were taken from the AOOS source; date was the same as in Barber et al. (1994), however it was not clear from either source whether the reported date or time in AOOS were local or GMT. Time was not reported by Barber et al. (1994, 1997). Bottom temperature and salinity are from Barber et al. (1994: Appendix p. 5-2). Substrate was not reported.

Other fishing gear (not in CDF Database): Isaacs-Kidd midwater trawl, Bongo plankton net

Fish voucher collections: Described in Appendix D.3.7

Resolution of catch data: The AOOS electronic data reported stations 97–123, and hauls 1– 2; these stations did not appear to be related to the station names listed in Barber et al. (1994, 1997). AOOS station names were not assigned in the order of consecutive gear deployments. The most likely scenario was that station was assigned in the AOOS data source after sorting the hauls by station name, haul number. For the CDF Database, we determined the closest geographic hauls using latitude and longitude (Barber, 2004 via AOOS) to the station position reported by Barber et al. (1994: Appendix 3, p. 3-3).

The AOOS source reported catch data as count and biomass per square km for each haul; the actual count of fishes caught per haul was not found in the following sources: AOOS, Barber et al. (1994, 1997).

Additional: None

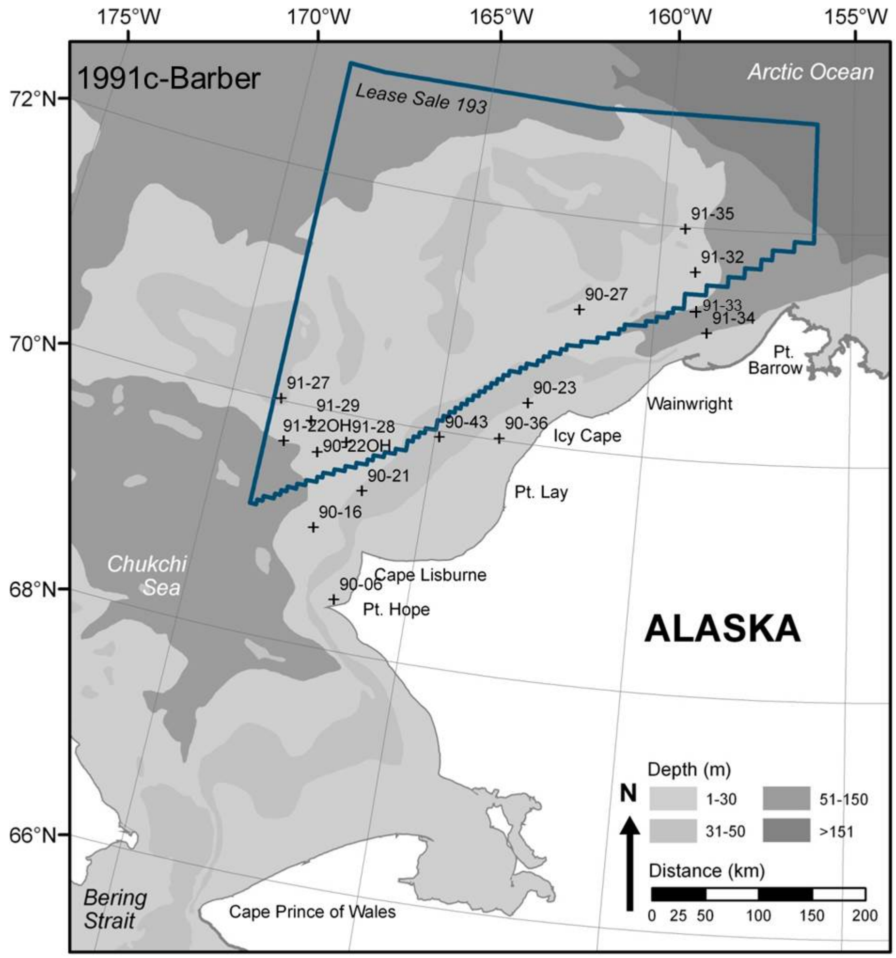


Figure D.3-11 1991c-Barber: Map of station locations.

D.3.12 1991-Hokkaido

Researchers: Faculty of Fisheries, Hokkaido University

Data sources: Hokkaido University, 1992

Alternate Cruise: OS38

Vessel: T/S *Oshoro-Maru IV*

Sites: Figure D.3.12

Fishing dates: 25–31 Jul 1991

Demersal fishing gear: 43m OT: 90 mm

Details: Otter trawl with 43.3 m headrope otter trawl with 48.6 m footrope with roller gear and 90 mm codend mesh, and without either codend liner or tickler chain (Barber et al., 1994: Appendix 4-2); identical trawl gear was used during 1990-Hokkaido and 1991-Hokkaido. The trawl used in 1990 and 1991 was modified for use prior to 1992-Hokkaido, and again modified before use during 2007-Hokkaido and 2008-Hokkaido.

Demersal fishing method: Approximately 60 minute hauls at 3–4 kt; actual speed and duration are reported (Hokkaido University, 1992: p. 162); identical method was used during 1990-Hokkaido and 1991-Hokkaido.

Source – catch data: Fish counts and biomass per haul were reported by Hokkaido University (1992: Table 11) and by Barber et al. (1994, not used for CDF).

Source – area towed: None

Source – habitat data: Haul name, date, time, duration, position, and depth are as reported by Hokkaido University (1992: Table 10). Station name, bottom temperature, and bottom salinity are as reported from CTD data by Hokkaido University (1992: Table 2). No substrate data were reported.

Other fishing gear (not in CDF Database): Baited longline deployed at surface; various plankton nets. Drift gillnet was deployed during the cruise but not in the Chukchi Sea.

Fish voucher collections: Detailed in Appendix D.3.9

Resolution of catch data: Fish counts and biomass per haul were incorporated into the CDF Database from Hokkaido University (1992: Table 11), as revised by our voucher examination.

Additional: None

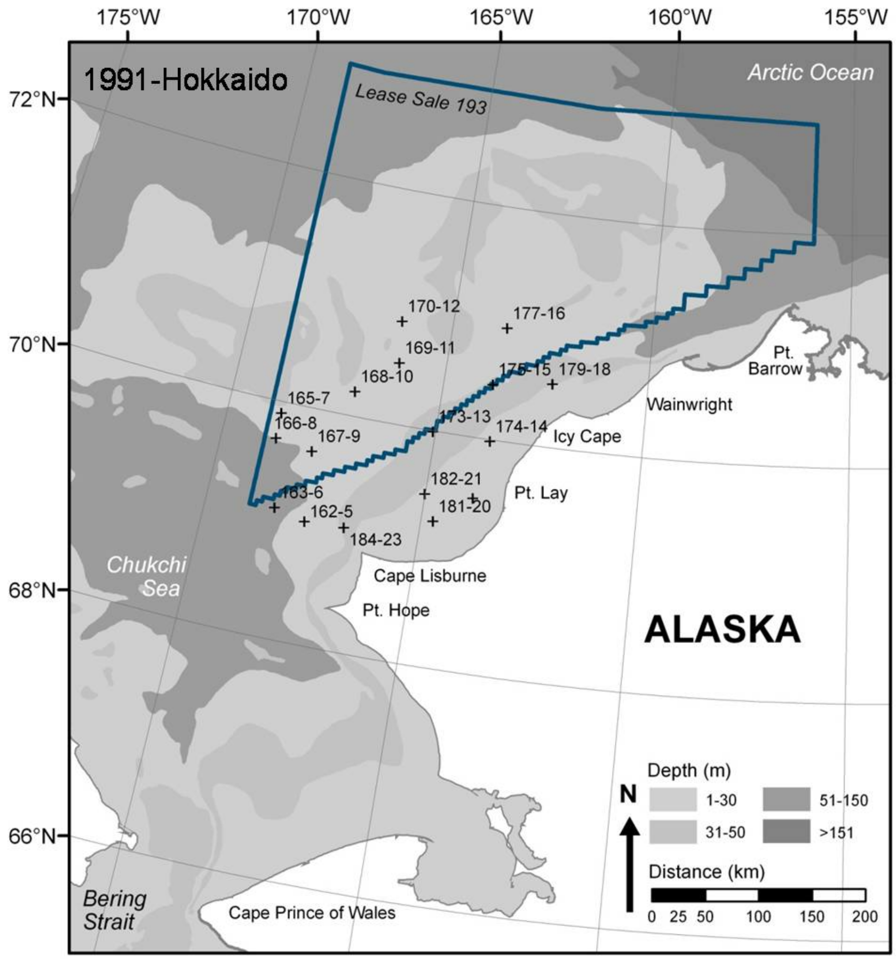


Figure D.3-12 1991-Hokkaido: Map of station locations in the Chukchi Sea sampled by bottom trawl. Labels are abbreviated station name and consecutive haul. i.e. 165-7 is station OS91165, haul 7. Although stations were occupied south of Bering Strait, they are not included in the CDF Database.

D.3.13 1992-Hokkaido

Researchers: Faculty of Fisheries, Hokkaido University

Data sources: Hokkaido University, 1993

Alternate Cruise: OS44

Vessel: T/S *Oshoro-Maru IV*

Sites: Figure D.3.13

Fishing dates: 25–31 Jul 1992

Demersal fishing gear: 43m OT: 45mm

Details: Otter trawl with 43.3 m headrope and 48.6 m footrope with roller gear but no tickler chain, 45 mm cod end liner; 1992-Hokkaido used the same trawl as used during 1990-Hokkaido and 1991-Hokkaido (43m OT: 90 mm), with the addition of a 45 mm codend liner (Barber et al., 1994: Appendix 4-2). The net was further modified for use during 2007-Hokkaido and 2008-Hokkaido by adding an additional pocket inside the mouth for the purpose of capturing live fish (B.A. Holladay, personal observation).

Demersal fishing method: Approximately 90 minute hauls at 3–4 kt; speed per haul is reported (Hokkaido University, 1993: Table 10).

Source – catch data: Count and biomass of fish per haul were reported by Hokkaido University (1993: Table 11); count of fish was also reported by Barber et al. (1994: not used for CDF).

Source –area towed (km^2): None

Source – habitat data: Haul name, one position, latitude, longitude, date, time, haul duration, and bottom depth were reported by Hokkaido University (1993: Table 10). Station name, bottom temperature, and bottom salinity were reported by Hokkaido University (1993: Table 2)

Other fishing gear (not in CDF Database): Baited longline deployed at surface; various plankton nets. A drift gill net was deployed during the cruise, but was not deployed in the Chukchi Sea.

Fish voucher collections: Detailed in Appendix D.3.9

Resolution of catch data: Count and biomass of fish per haul are incorporated into the CDF Database as reported by Hokkaido University (1993: p. 166–171), as revised by voucher examination.

Additional: None

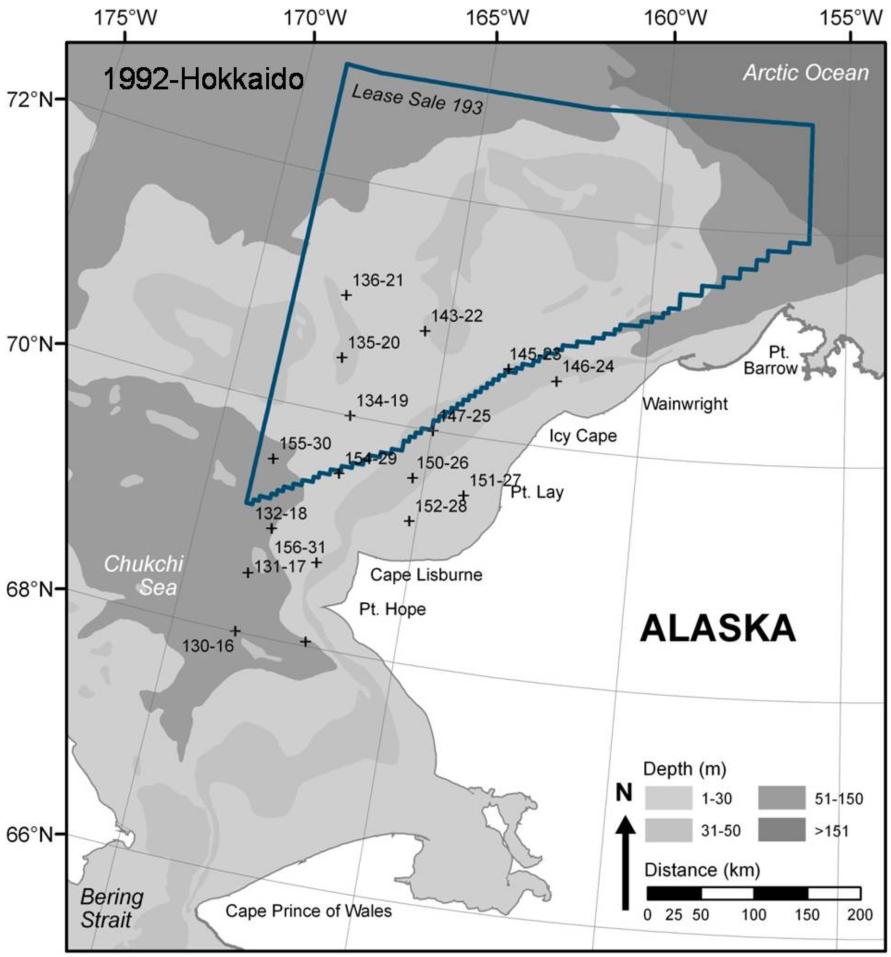


Figure D.3-13 1992-Hokkaido: Map of station locations in the Chukchi Sea sampled by bottom trawl. Stations are labeled with abbreviated station name and consecutive haul.

D.3.14. 2004-Mecklenburg

Researchers: Stein D.L. (Smithsonian Institution), Mecklenburg C.W. (Point Stephens Research), Sheiko B.A. and Chernova N.V. (ZIN)

Data sources: Mecklenburg et al., 2007; C.W. Mecklenburg, unpub. data

Alternate Cruise: RUSALCA-2004

Vessel: R/V *Professor Khromov*

Sites: Figure D.3.14

Fishing dates: 1–22 Aug 2004

Demersal fishing gear: 7.1mOT; **Details:** 7.1 m headrope otter trawl with 37 mm mesh (Mecklenburg et al., 2007); contrary to that article, the net was not lined

Demersal fishing method: Generally, two 9–20 minute hauls were collected at each station; towing speed was 3–3.5 kt.

Source – catch data: Presence of fish taxa at each station (Mecklenburg et al., 2007: Table 2); for some species, count of fish is reported by station in the text. The CDF Database is the first publication of complete catch data from this cruise. Fishes were not weighed.

Source – area towed: Haul distance was recorded; net swath was not observed.

Source – habitat data: Minimum and maximum depth were observed during haul. Bottom temperature and bottom salinity are reported by R. Pickart *(ftp://ftp.whoi.edu/pub/users/webpickart/khromov/)*. Substrate descriptions were from observations of trawl contents, and at some sites, from VanVeen grab contents, and are as reported by Mecklenburg et al. (2007). Percent grain size data are reported from the subset of fishing sites where substrate was collected (J. Grebmeier et al., pers. comm. Oct-2010; summarized in Grebmeier et al., 2006)

Other fishing gear in CDF Database: Norcross-2004 3mPSBT: 4 mm

Other fishing gear (not in CDF Database): 505 micron bongo net, various other plankton nets

Fish voucher collections: Fishes collected by the beam and otter trawls were verified by C.W. Mecklenburg at sea or in the laboratory immediately following the cruise. Identifications are as reported by Mecklenburg et al. (2007). Vouchers are located at CAS, IMS, PSR, UW, and ZIN.

Resolution of catch data: Species reported by Mecklenburg et al. (2007) as *Gymnelus* spp. are identified to species.

Additional: None.

D.3.15 2004-Norcross

Researchers: Norcross B.L., Holladay B.A. (IMS/UAF)

Data sources: Norcross et al., 2010; Abundance data have not been published prior to the present project's database.

Alternate Cruise: RUSALCA-2004

Vessel: R/V *Professor Khromov*

Sites: Figure D.3.14

Fishing dates: 1–22 Aug 2004

Demersal fishing gear: 3mPSBT; **Details:** plumb staff beam trawl of 7 mm mesh with a 4 mm codend liner and double tickler chain (after Gunderson and Ellis, 1986); the net was modified by seizing a lead-filled line and 6 inch sections of chain fastened at 6 inch intervals to the footrope, and by using a shorter (3.05 m) beam. The effective swath of this net is 2.26 m. Identical gear was used during 2004-Norcross, 2007a-Norcross, 2007b-Norcross, and 2008-Norcross.

Demersal fishing method: Hauls were approximately 2–5 min at 1–1.5 kt

Source – catch data: Presence of fish taxa was reported first by Mecklenburg et al. (2007); fish counts were reported by Norcross et al. (2010). Biomass was not measured. CPUE is first reported in the CDF Database.

Source – area towed: Net swath x distance towed

Source – habitat data: Identical to 2004-Mecklenburg

Other fishing gear in CDF Database: 2004-Mecklenburg 7.1mOT: 37 mm.

Other fishing gear (not in CDF Database): 505 micron bongo net, various other plankton nets

Fish voucher collections: Identical to 2004-Mecklenburg

Resolution of catch data: Species reported by Mecklenburg et al. (2007) as *Gymnelus* spp. are identified to species.

Additional: None

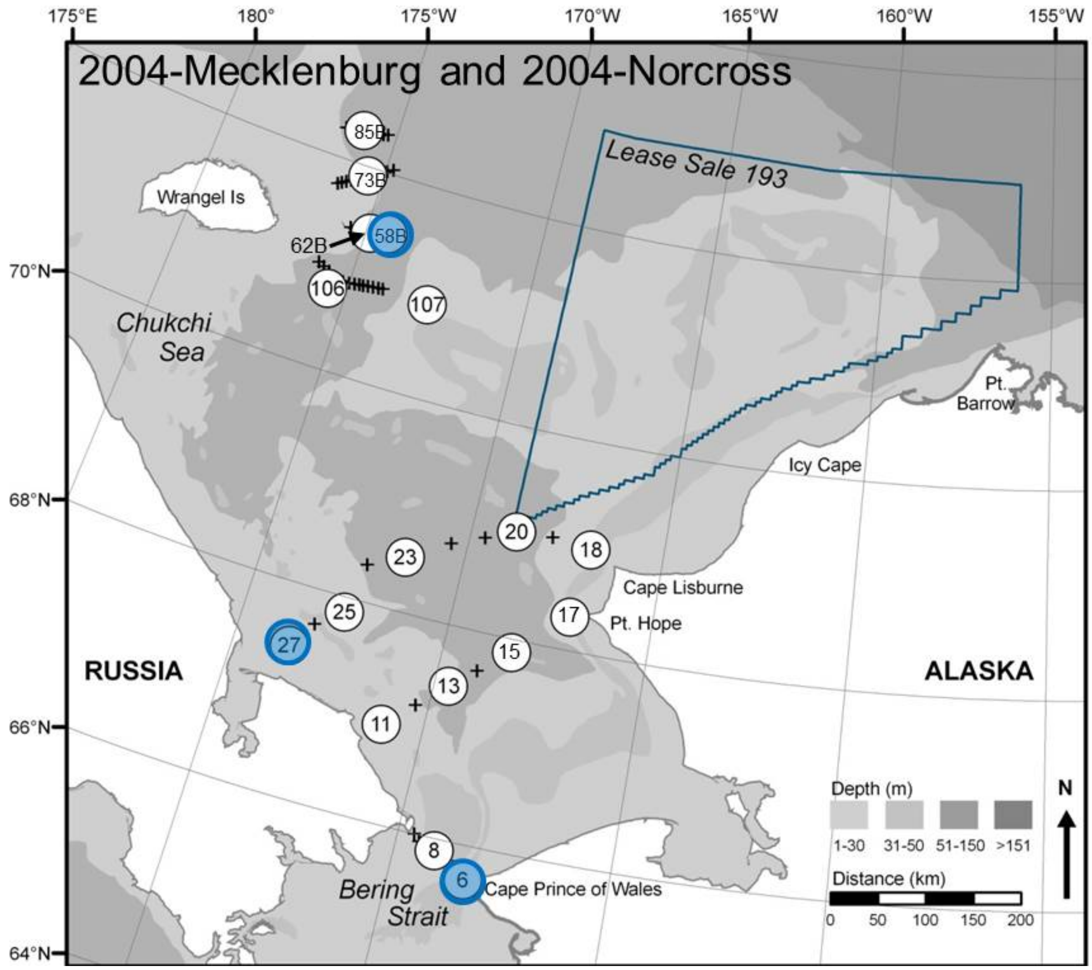


Figure D.3-14 2004-Mecklenburg and 2004-Norcross: Map of all station locations. 2004-Mecklenburg fishing stations are in white circles. 2004-Norcross fishing stations include all white and blue circles. Data from all fishing stations are included in the CDF Database.

D.3.16 2007-Hokkaido

Researchers: Faculty of Fisheries, Hokkaido University. Contact person: Atsushi Yamaguchi, *a-yama@fish.hokudai.ac.jp*

Data sources: Hokkaido University, 2008

Alternate Cruise: OS180

Vessel: T/S *Oshoro-Maru IV*

Sites: Figure D.3.15

Fishing dates: 26 Jul – 11 Aug 2007

Demersal fishing gear: 43m OT: 45 mm

Gear details: Otter trawl with 43.3 m headrope and 48.6 m footrope with roller gear but no tickler chain, 45 mm cod end liner; 1992-Hokkaido used the same trawl as used during 1990-Hokkaido and 1991-Hokkaido (43m OT: 90 mm), with the addition of a 45 mm codend liner (Barber et al., 1994: Appendix 4-2). The net was further modified for use during 2007-Hokkaido and 2008-Hokkaido by adding an additional pocket inside the mouth for the purpose of capturing live *Boreogadus saida* (B.A. Holladay, personal observation).

Demersal fishing method: 5–30 minutes per haul at 3.0–4.3 kt (Hokkaido University: Table 11)

Source – catch data: Field identifications and biomass per haul were reported by Hokkaido University (2008: Table 12); counts of fish were not reported. Where biomass was reported as "<0.1 kg," biomass in the CDF database was set to null and presence to "1."

Source – area towed: None

Source – habitat data: Data were reported by Hokkaido University (2008). Bottom depth and haul position were reported in Table 11 (page 64); bottom temperature and bottom salinity were reported in Table 2 (page 43).

Other fishing gear in CDF Database: 3m PSBT: 4mm (see Appendix D.3.17)

Other fishing gear (not in CDF Database): Hook and line; surface long-line, various plankton nets. Although a gill net was deployed during this cruise, all deployments were south of the Chukchi Sea.

Fish voucher collections: Fishes from this collection were not examined for this project, and we therefore recommend analyses using the field identifications be considered at the family level of taxonomy. After field collections, specimens were transported to Hakodate, Japan and are assumed to be incorporated into the fish voucher collection at HUMZ.

Resolution of catch data: Field identifications were revised as per Appendix Table D.2-3; because this was done without review of the vouchers, we recommend analyzing all but the most common and easily identified species at the level of family

Additional: Field identifications and biomass of invertebrates caught by bottom trawl were reported (Hokkaido University: Table 12)

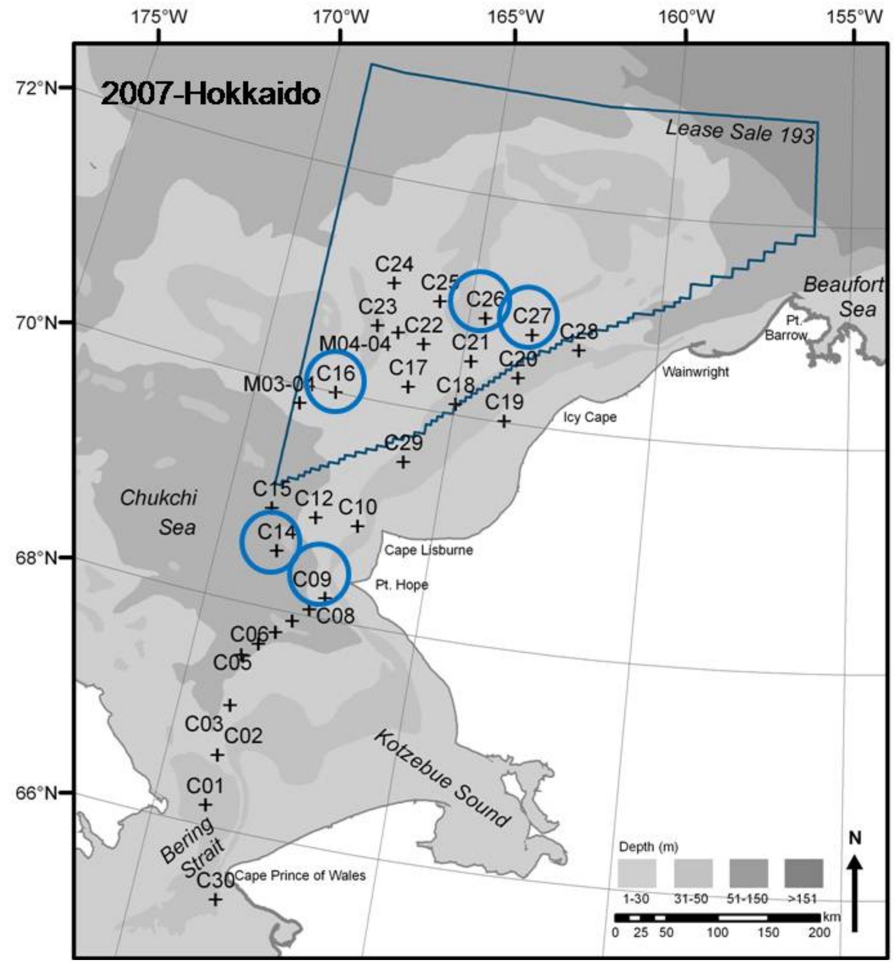


Figure D.3-15 2007-Hokkaido: Map of all stations in the Chukchi Sea and Bering Strait. Stations sampled by 43 m otter trawl are circled. A CTD was deployed vertically at each station. This cruise fished at stations south of Bering Strait and those data are not in the CDF Database.

D.3.17 2007a-Norcross

Researchers: Norcross B.L., Holladay B.A. (IMS/UAF)

Data sources: CDF Database: these data have not previously been published.

Alternate Cruise: OS180

Vessel: T/S *Oshoro-Maru IV*

Sites: Figure D.3.16

Fishing dates: 5–12 Aug 2007

Demersal fishing gear: 3m PSBT: 4mm; **Details:** plumb staff beam trawl of 7 mm mesh with a 4 mm codend liner and double tickler chain (after Gunderson and Ellis, 1986); the net was modified by seizing a lead-filled line and 6 inch sections of chain fastened at 6 inch intervals to the footrope, and by using a shorter (3.05 m) beam. The effective swath of this net is 2.26 m. Identical gear was used during 2004-Norcross, 2007a-Norcross, 2007b-Norcross, and 2008-Norcross.

Demersal fishing method: Hauls were approximately 2–5 min at 1–1.5 kt

Source – catch data: CDF Database is the first report of catch data. Count and biomass of each taxon was recorded at each haul.

Source – area towed: Trawl swath x distance towed

Source – habitat data: Minimum and maximum haul depth were observed during haul, and substrate was assessed from trawl contents. Other habitat data were reported by Hokkaido University (2008): bottom depth and haul position were reported on p. 70, bottom temperature and bottom salinity were reported on p. 58–60.

Other fishing gear in CDF Database: 43m OT: 45 mm, see Appendix D.3.16

Other fishing gear (not in CDF Database): Hook and line; surface long-line, various plankton nets. Although a gill net was deployed during this cruise, all deployments were south of the Chukchi Sea.

Fish voucher collections: Voucher specimens from this cruise were identified by C.W. Mecklenburg after the cruise. Genetic evaluation by FISHBOL helped to differentiate species with problematic morphologies.

Resolution of catch data: None

Additional: Additional details are available in the cruise report; see Appendix D.1.

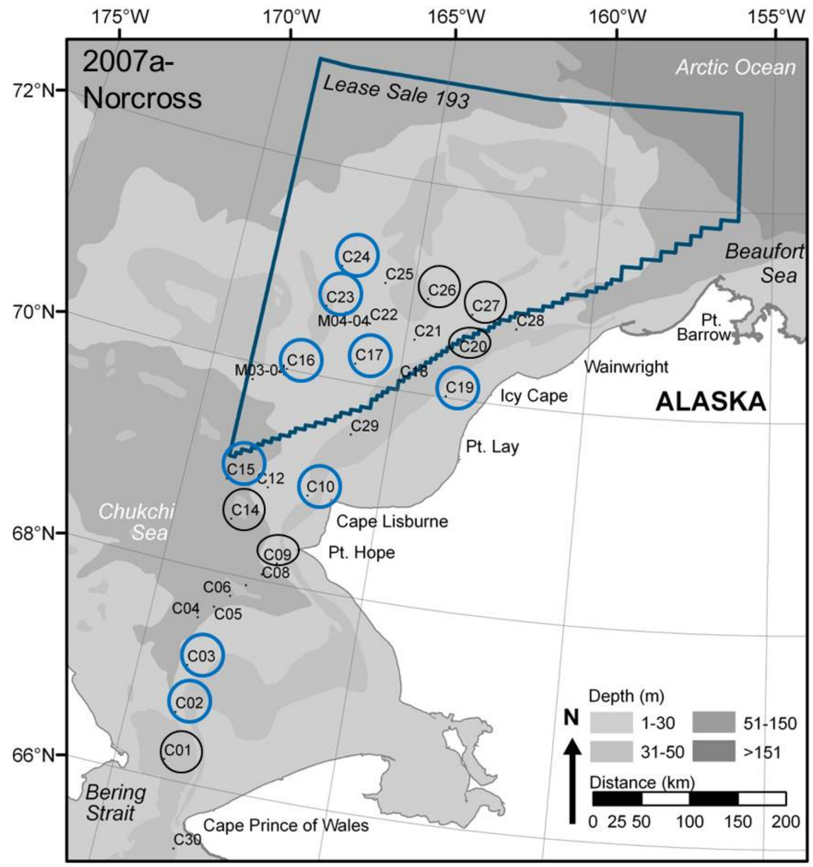


Figure D.3-16 2007a-Norcross: Map of all sampling stations in the Chukchi Sea and Bering Strait. Beam trawl fishing stations are circled; stations with quantitative hauls are circled with blue. A CTD was deployed vertically at each station.

D.3.18 2007b-Norcross

Researchers: Norcross B.L., Holladay B.A. (IMS/UAF)

Data sources: CDF Database; these data have not previously been published.

Alternate Cruise: OD0710

Vessel: R/V *Oscar Dyson*

Sites: Figure D.3.17

Fishing dates: 4–16 Sep 2007

Demersal fishing gear: 3mPSBT; **Details:** plumb staff beam trawl of 7 mm mesh with a 4 mm codend liner and double tickler chain (after Gunderson and Ellis, 1986); the net was modified by seizing a lead-filled line and 6 inch sections of chain fastened at 6 inch intervals to the footrope, and by using a shorter (3.05 m) beam. The effective swath of this net is 2.26 m. Identical gear was used during 2004-Norcross, 2007a-Norcross, 2007b-Norcross, and 2008-Norcross.

Demersal fishing method: Hauls were approximately 2–5 min at 1–1.5 kt

Source – catch data: CDF Database is the first report of catch data. Count and biomass of each taxon was recorded at each haul.

Source – area towed: swath x distance towed

Source – habitat data: Minimum and maximum haul depth were observed during haul, and substrate was assessed from trawl contents. Average bottom temperature and bottom salinity were calculated over the multiple deployments of the CTD at each station (pers. comm. L. Eisner NMFS/AFSC/Auke Bay).

Other fishing gear (not in CDF Database): Pelagic CANTRAWL, plankton nets of various designs and mesh sizes

Fish voucher collections: Fishes were verified at sea and during additional examination onshore by C.W. Mecklenburg. Genetic evaluation by FISHBOL helped to differentiate species with problematic morphologies.

Resolution of catch data: None

Additional: Additional details are available in the cruise report (Appendix D.2).

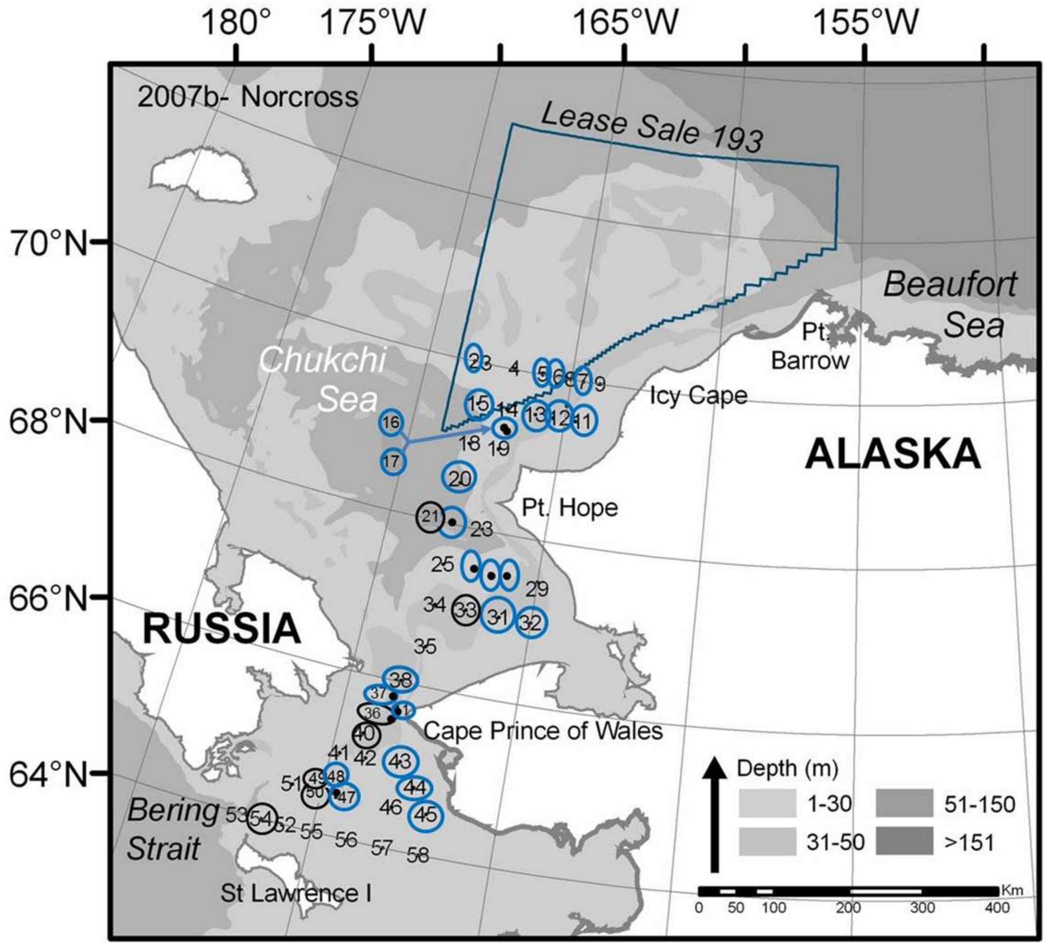


Figure D.3-17 2007b-Norcross: Map of station locations during leg 1 of cruise OD0710. Stations fished with the plumb staff beam trawl are circled; stations with quantitative hauls are circled with blue. A CTD was deployed vertically at each station.

D.3.19 2008-Hokkaido

Researchers: Faculty of Fisheries, Hokkaido University. Contact person: Atsushi Yamaguchi, *a-yama@fish.hokudai.ac.jp*

Data sources: Hokkaido University, 2009

Alternate Cruise: OS190

Vessel: T/S *Oshoro-Maru IV*

Sites: Figure D.3.18

Fishing dates: 25 Jun – 13 Jul 2008

Demersal fishing gear: 43mOT; **Details:** This trawl was modified from the trawl used during 1992-Hokkaido with an additional pocket inside the mouth with the goal of capturing live *Boreogadus saida*. Identical gear was used during 2007-Hokkaido and 2008-Hokkaido.

Demersal fishing method: 5–30 minutes reported per haul at 3.1–4.4 kt; speed per haul is reported (Hokkaido University, 2009: Table 12); trawl was deployed in the water column for a notable proportion of the haul time, with the goal of capturing live *Boreogadus saida* (observation by B.A. Holladay); fishing method was unlike other Hokkaido University cruises.

Source – catch data: Field identifications, count and biomass per haul were reported by Hokkaido University (2009: Table 13, page 72). Where biomass was reported in Table 13 as "unmeasurable," biomass in the CDF database was set to null.

Source – area towed: None

Source – habitat data: Data were reported by Hokkaido University (2009). Latitude, longitude, and bottom depth were in Table 12; bottom temperature and bottom salinity were in Table 2.

Other fishing gear in CDF Database: 3m PSBT: 4mm (see Appendix D.3.18)

Other fishing gear (not in CDF Database): Baited long-line deployed at the surface; various plankton nets. Although a gillnet was deployed during this cruise, all deployments of that gear were south of the Chukchi Sea.

Fish voucher collections: Fishes from this collection were not examined by this project; to our knowledge, vouchers have not been examined post-cruise. Located at HUMZ.

Resolution of catch data: None; because, to our knowledge the voucher specimens have not been examined post-cruise, we recommend that catch data be considered at the family level of taxonomy. Catches are not analyzed in the present report because the trawl was deployed mid-water as well as on the sea floor.

Additional: None

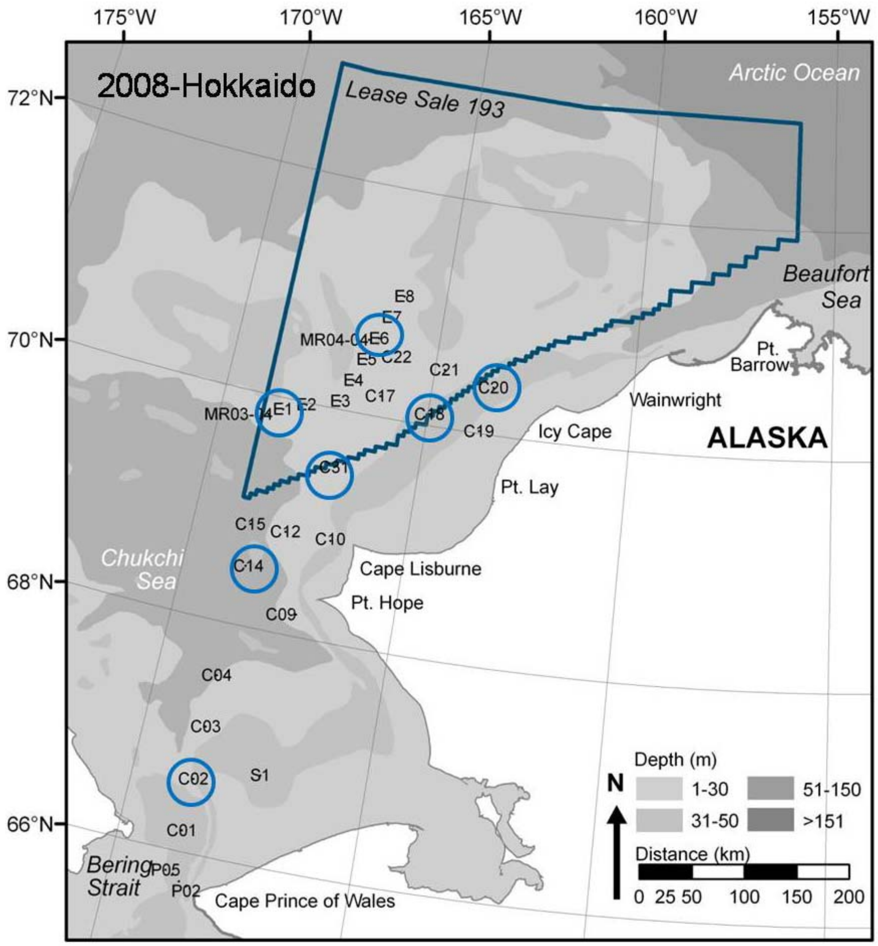


Figure D.3-18 2008-Hokkaido: Map of all sampling stations in the Chukchi Sea and northern Bering Sea. Stations sampled by 43 m otter trawl are circled. This cruise fished at stations south of Bering Strait and those data are not in the CDF Database.

D.3.20 2008-Norcross

Researchers: Norcross B.L., Holladay B.A. (IMS/UAF)

Data sources: CDF Database; these data have not previously been published.

Alternate Cruise: OS190

Vessel: T/S *Oshoro-Maru IV*

Sites: Figure D.3.19

Fishing dates: 7–13 July 2008

Demersal fishing gear: 3mPSBT; **Details:** plumb staff beam trawl of 7 mm mesh with a 4 mm codend liner and double tickler chain (after Gunderson and Ellis, 1986); the net was modified by seizing a lead-filled line and 6 inch sections of chain fastened at 6 inch intervals to the footrope, and by using a shorter (3.05 m) beam. The effective swath of this net is 2.26 m. Identical gear was used during 2004-Norcross, 2007a-Norcross, 2007b-Norcross, and 2008-Norcross.

Demersal fishing method: Hauls were approximately 2–5 min at 1–1.5 kt

Source – catch data: first reported in CDF Database

Source – area towed: swath x haul distance

Source – habitat data: Minimum and maximum haul depth were observed during haul, and substrate was assessed from trawl contents. Bottom temperature and bottom salinity were reported by Hokkaido University (2009: p. 58–60).

Other fishing gear in CDF Database: 43mOT, see Appendix D.3.19

Other fishing gear (not in CDF Database): surface long-line; various plankton nets

Fish voucher collections: Voucher specimens from this cruise were identified by C.W. Mecklenburg after the cruise. Genetic evaluation by FISHBOL helped to differentiate species with problematic morphologies.

Resolution of catch data: None

Additional: Additional details are available in the cruise report (Appendix D.3).

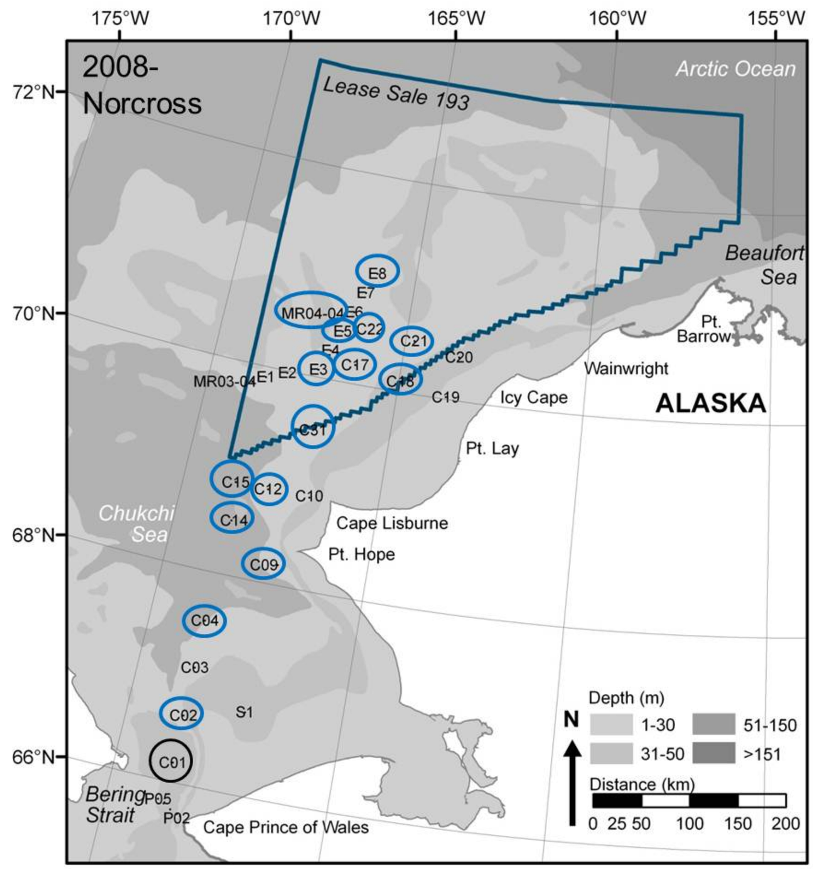


Figure D.3-19 2008-Norcross: Map of all sampling stations in the Chukchi Sea and northern Bering Sea. Beam trawl fishing stations are circled; stations with quantitative hauls are circled with blue. A CTD was deployed vertically at each station.

D.4 Literature Cited in Appendix D

Alverson, D. L., and N. J. Wilimovsky. 1966. Chapter 31. Fishery investigations of the southeastern Chukchi Sea. Pages 843–860 in: Wilimovsky N. J., and J.N. Wolfe (editors) Environment of the Cape Thompson region, Alaska. U.S. Atomic Energy Commission, Washington D.C.

Barber, W. E. 2004. *http://ak.aoos.org/data/archive/2007/0000021/01-version/data/EXB2007002/barber/ Access date 1-Feb-2010*.

Barber, W. E., R. L. Smith, and T. J. Weingartner. 1994. Fisheries oceanography of the northeast Chukchi Sea. Final report. OCS Study MMS-93-0051, Minerals Management Service, Alaska OCS Region, Anchorage, AK.

Barber, W. E., R. L. Smith, M. Vallarino, and R. M. Meyer. 1997. Demersal fish assemblages of the northeastern Chukchi Sea, Alaska. Fisheries Bulletin. 95:195–209.

Elsner, R. W. 1975. Bering and Chukchi Seas Expedition, July 20–September 15. Pages 57–61 in: Garey W. (editor) R/V *Alpha Helix* Research Program 1972–1974. Undated report, estimated 1975. University of California, San Diego.

Eschmeyer, W. N. (editor). 2013. Catalog of Fishes. California Academy of Sciences. Electronic version accessed 1 Feb 2013, (*http://research.calacademy.org/research/ichthyology/catalog/fishcatmain.asp*).

Fechhelm, R. C., P. C. Craig, J. S. Baker, and B. J. Gallaway. 1984. Fish distribution and use of nearshore waters in the Northeastern Chukchi Sea. LGL Ecological Research Associates, Inc. Bryan, TX. 178 p.

Frost, K, and L. F. Lowry. 1983. Demersal fishes and invertebrates trawled in the northeastern Chukchi and western Beaufort Seas, 1976–77. NOAA Tech. Rep. NMFS SSRF-764. 22 pp + Appendix.

Frost, K. J., L. F. Lowry, and J. J. Burns. 1978. Appendix 1. Offshore demersal fishes and epibenthic invertebrates of the northeastern Chukchi and western Beaufort seas. Pages 231–353 in: Environmental Assessment of the Alaskan Continental Shelf, Annual Reports of Principal Investigators for the Year ending March 1978. Volume I. Receptors – Mammals – Birds. US Dept. Commerce / US Dept. Interior / NOAA, Boulder, CO.

Gillispie, J. G., R. L. Smith, E. Barbour, and W. E. Barber. 1994. Distribution, abundance, and growth of Arctic cod (*Boreogadus saida*) in the Chukchi Sea. Chapter 7 in: Fisheries oceanography of the northeast Chukchi Sea. Final report. OCS Study MMS-93-0051, Minerals Management Service, Alaska OCS Region, Anchorage, AK.

Grebmeier, J. M., L. W. Cooper, H. M. Feder, and B. I. Sirenko. 2006. Ecosystem dynamics of the Pacific influenced Northern Bering and Chukchi Seas. Progress in Oceanography 71:331–361.

Greenwood, M. R. 1958. Bottom trawling explorations off southeastern Alaska, 1956–1957. US Fish and Wildlife Service, Commercial Fisheries Review 20(12):1–10.

Gunderson, D. R., and I. E. Ellis. 1986. Development of a plumb staff beam trawl for sampling demersal fauna. Fisheries Research 4:35–41.

Hokkaido University. 1991. The “*Oshoro-Maru*” cruise 33 to the northern North Pacific Ocean, the Bering Sea, the Chukchi Sea and the Gulf of Alaska in June–August 1990. Pages 161–165 in: Data record of oceanographic observations and exploratory fishing No. 34. Faculty of Fisheries, Hokkaido University, Hakodate, Hokkaido, Japan.

Hokkaido University. 1992. The "*Oshoro-Maru*" cruise 38 to the northern North Pacific Ocean, the Bering Sea, the Chukchi Sea and the Gulf of Alaska in June–August 1991. Pages 73–204 in: Data record of oceanographic observations and exploratory fishing No. 35. Faculty of Fisheries, Hokkaido University, Hakodate, Hokkaido, Japan.

Hokkaido University. 1993. The "*Oshoro-Maru*" cruise 44 to the northern North Pacific Ocean, the Bering Sea, the Chukchi Sea and the Gulf of Alaska in June–August 1992. Pages 73–188 in: Data record of oceanographic observations and exploratory fishing No. 36. Faculty of Fisheries, Hokkaido University, Hakodate, Hokkaido, Japan.

Hokkaido University. 2008. The "*Oshoro-Maru*" cruise 180 to the northwest North Pacific Ocean, the Bering Sea, and the Chukchi Sea in July–August 2007. Pages 33–90 in: Data record of oceanographic observations and exploratory fishing No. 51. Faculty of Fisheries, Hokkaido University, Hakodate, Hokkaido, Japan.

Hokkaido University. 2009. The "*Oshoro-Maru*" cruise 190 to the northwest North Pacific Ocean, the Bering Sea, and the Chukchi Sea in June–July 2008. Pages 39–88 in: Data record of oceanographic observations and exploratory fishing No. 52. Faculty of Fisheries, Hokkaido University, Hakodate, Hokkaido, Japan.

Mecklenburg, C. W., and T. A. Mecklenburg. 2009. Arctic Marine Fish Museum Specimens, Second Edition. v. April 2009 (*http://dw.sfos.uaf.edu/rest/metadata/ArcOD/2007F1*).

Mecklenburg, C. W., T. A. Mecklenburg, and L. K. Thorsteinson. 2002. Fishes of Alaska. American Fisheries Society, Bethesda, Maryland, 1037 p.

Mecklenburg, C. W., P. R. Møller, and D. Steinke. 2011. Biodiversity of arctic marine fishes: taxonomy and zoogeography. Marine Biodiversity 41: 109–140 (*DOI 10.1007/s12526-010-0070-z*).

Mecklenburg, C. W., D. L. Stein, B. A. Sheiko, N. V. Chernova, T. A. Mecklenburg, and B. A. Holladay. 2007. Russian-American Long-term Census of the Arctic: benthic fishes trawled in the Chukchi Sea and Bering Strait in August 2004. Northwest Naturalist 88:168–187.

Morrow, J. E. 1975. Fish collecting report, Bering and Chukchi Seas Expedition. Pages 59–60 in: Garey, W. (editor). R/V *Alpha Helix* Research Program 1972–1974. Undated report, estimated 1975. University of California, San Diego.

Nelson, J. S., E. J. Crossman, H. Espinosa-Pérez, L. T. Lindley, C. R. Gilbert, R. N. Lea, and J. D. Williams. 2004. Common and scientific names of fishes from the United States, Canada, and Mexico, Sixth Ed. American Fisheries Society Special Publication 29, Bethesda, MD. 386 p.

Norcross, B. L., B. A. Holladay, M. S. Busby, and K. L. Mier. 2010. Demersal and larval fish assemblages in the Chukchi Sea. Deep Sea Research Part II: Topical Studies in Oceanography 57(1–2):57–70.

Norcross, B. L., B. A. Holladay, and C. W. Mecklenburg. 2013. Recent and historical distribution and ecology of demersal fishes in the Chukchi Sea Planning Area. BOEM Final Contract Report, Task Order M07AC12462 (this report).

Pereyra, W. T., R. J. Wolotira Jr., T. M. Sample, and M. Morin Jr. 1977. Baseline studies of fish and shellfish resources of Norton Sound and the southeastern Chukchi Sea. RU 175. Pages 288–319 in: Environmental assessment of the Alaskan continental shelf. Volume 8. Receptors -- Fish, Littoral, Benthos. Outer Continental Shelf Environmental Assessment Program. Boulder, CO.

Quast, J. C. 1972. Preliminary report on the fish collected on WEBSEC-70. Pages 203–206 in: WEBSEC-70, an ecological survey in the eastern Chukchi Sea, September–October 1970. US Coast Guard Oceanography Report 50.

RACE. 1976. Cruise results Cruise No. RP-4-MF-76-B, NOAA Ship Miller Freeman, Norton Sound and Chukchi Sea Trawl Survey. Northwest and Alaska Fisheries Science Center – Division of Resource Assessment and Conservation Engineering. 6 pp + tables and figures *http://www.afsc.noaa.gov/RACE/surveys/cruise_archives/cruises1976 /results_1976_MF04B.pdf*

RACE. 2010. ADP code book, v.March 2010. Resource Assessment and Conservation Engineering, National Marine Fisheries Service, Seattle WA. 162 p. *http://www.afsc.noaa.gov/RACE/groundfish/adp_codebook.pdf*

RACEBASE. 2008. Alaska Fisheries Science Center survey database; Resource Assessment and Conservation Engineering Division. v.2008.

Smith, R. L., W. E. Barber, M. Vallarino, J. Gillespie, and A. Ritchie. 1994a. Biology of the Arctic staghorn sculpin, *Gymnocanthus tricuspis,* from the northeastern Chukchi Sea. Chapter 5 in Fisheries oceanography of the northeast Chukchi Sea. Final report. OCS Study MMS-93-0051, Minerals Management Service, Alaska OCS Region, Anchorage, AK.

Smith, R. L., M. Vallarino, E. Barbour, E. Fitzpatrick, and W. E. Barber. 1994b. Biology of the Bering flounder, *Hippoglossoides robustus,* from the northeastern Chukchi Sea. Chapter 6 in Fisheries oceanography of the northeast Chukchi Sea. Final report. OCS Study MMS-93-0051, Minerals Management Service, Alaska OCS Region, Anchorage, AK.

Stoker, S. W. 1975. Benthic investigations in the Bering and Chukchi Seas Expedition. Page 61 in Garey, W. (editor). R/V *Alpha Helix* Research Program 1972–1974. Undated report, estimated 1975. University of California, San Diego.

Wakabayashi K, R. G. Bakkala, and M. S. Alton. 1985. Methods of the U.S.-Japan demersal trawl surveys. Page 729 in: R. G. Bakkala and K. Wakabayashi (editors), Results of cooperative U.S.-Japan groundfish investigations in the Bering Sea during May–August 1979. International North Pacific Fisheries Comm. Bulletin 44.

Wilimovsky, N. J., and J. N. Wolfe (editors). 1966. Environment of the Cape Thompson region, Alaska. U.S. Atomic Energy Commission, Washington DC.

Wolotira Jr., R. J., T. M. Sample, and M. Morin Jr. 1977. Demersal fish and shellfish resources of Norton Sound, the Southeastern Chukchi Sea, and adjacent waters in the baseline year 1976. Northwest and Alaska Fisheries Center Processed Report October 1977. USDOC/NOAA/NMFS/NWAFC, Seattle WA. 292 p.

APPENDIX E

Historical (1959–1992) and recent (2004–2008) distributions of demersal fishes and water masses

E. 1 Summary

This appendix summarizes analyses of demersal fish data and physical variables from cruises in the offshore eastern Chukchi Sea that were not examined in detail in the report text. Analysis of water mass was considered particularly important because, in their analysis of demersal fish assemblages (presence/absence species composition) across the entire Chukchi Sea, Norcross et al. (2010) detected differences in demersal fish assemblages that were related to water mass. In the present report, both Chapter 1 which analyzed fish species abundance, and Appendix E, which analyzed fish species abundance and presence/absence, clarify that within the eastern Chukchi Sea, water mass does not consistently contribute in a significant way to the composition of fish assemblages.

For historic fish analysis in the Chukchi Sea (Chapter II of this report), we analyzed demersal fish presence/absence from 15 individual cruise-gear combinations that we had recovered from multiple sources and archived in the Chukchi Demersal Fish (CDF) database. Similar analyses were conducted for each cruise, as limited by availability of data. Each cruise is presented in Appendix E with one or more of the following figures: map of station locations (Appendix D), dendrogram of hierarchical clustering of stations with similar species composition, map depicting station clusters in the eastern Chukchi Sea, standard potential density plot, dendrogram of hierarchical clustering of stations with similar water mass properties, and map with water masses delineated.

Analysis of the historical temperature, salinity and density of bottom water masses present in the summer Chukchi Sea revealed much intra- and interannual variability that was linked to the timing and exact location of the collections. One reason for the variability might be that even when samples were taken at the same time frame, e.g., 1990-Hokkaido, 1991-Hokkaido, 1992-Hokkaido in July 1990, 1991 and 1992, the location of the sample sites varied. Statistical clusters distinguished among Chukchi water mass types as clearly as the standard physical oceanographic temperature and salinity (TS) diagrams. An example is 2004-Norcross, which examined Russian and U.S. waters of the Chukchi Sea (Norcross et al., 2010). Four bottom water masses in the Chukchi Sea were confirmed by R.S. Pickart (Woods Hole Oceanographic Institution, pers. comm.) and agreed closely with other interpretations of the region's physical oceanography (Weingartner, 1997; Pickart et al., 2010; Weingartner et al., 2005). The Alaska Coastal Water (ACW) and Bering Sea Water (BSW) flow northward from the Bering Strait. In the bottom as well as the water column, the warm, fresh ACW is isolated from the rest of the Chukchi Sea by a well-defined front ~50 km from the coast that extends northward from Bering Strait to the Lisburne Peninsula (Weingartner, 1997). Off Cape Lisburne, this flow might continue northward and spread westward (Weingartner et al., 2005), which explains the depth-integrated distribution of ACW. BSW originates from both the Bering Shelf water in the eastern Bering Sea and Anadyr Water that comes from the western Bering Sea; the former is warmer and less salty (>2.0º C, ~32.5; Weingartner et al., 2005) than the latter. BSW flowed northward through the Bering Strait and spread out across the Chukchi Shelf in 2004, which may be the typical flow pattern (Winsor and Chapman 2004). This water mass continues northward to enter the Arctic Ocean through three pathways, one of which is Herald Canyon (Weingartner et al., 2005).

Resident Chukchi Water intrudes into Lease Sale 193 on occasion. There is a discrepancy with terminology of Resident Chukchi Water (RCW), the name we used for a water mass that our bottom cluster analysis and TS diagram clearly identified as separate from WW. The RCW has been described as cold and fresh water and appears to be derived from the upper layers of the Arctic Ocean (Weingartner, 1997) or from shelf water transformed into a deep water mass in the previous winter and found offshore in the northern Chukchi Sea (Weingartner et al., 2005).The RCW water mass that we described for 2004 is not considered part of WW (Pickart et al., 2010), but rather is found in shallower water (<50 m) to the west of Herald Canyon. However, the extremely cold and moderately salty properties of the RCW in 2004 do not match descriptions from other years. The low salinity (28.0–<32.0) values found in 1993 were

similar to those in the RCW in 2004, yet the 2004 water temperature was much colder (-1.6 º C) than that which extended eastward (<0.0 º C) from Wrangel Island to Herald Canyon in 1993 (Weingartner et al., 2005). Conversely, in 1995 the water was very cold (<-1.0º C) and salty (~33.0; Weingartner et al., 2005), more closely related to WW, and not like the reduced salinity (~32) of the RCW in 2004.

It is not unusual to find the same or similar water masses in the Chukchi Sea called different names (Pickart et al., 2010). That may be, in part, because water masses do not have the same characteristics every year. Water mass modification depends on fall and winter winds and seasonal ice development. Interannual variations in Chukchi Sea masses may be attributable to properties of water flowing through the Bering Strait, as well as deviations in ice cover and polynya formation (Weingartner et al., 2005). The result could be interannual differences in winter temperature and salinity on the Chukchi shelf (Weingartner et al., 2005). Hence a water mass with the same name does not always have same temperature and salinity characteristics through time.

Composition of fish assemblages is dependent on time and location of sample collection. Fish assemblages and community structure were analyzed using cluster analyses that grouped stations according to species composition. Distinct assemblages of species presence occurred during two of the recent (2007–2008) and five of the historical (1959–2004) collections. Of those, all but one had only two groups of fishes; 1990-Barber was unique in that it had five significant assemblages. The unique results from 1990-Barber are most likely due to the high geographic sampling intensity, broad scale distribution of samples, seasonal timing of collections and interannual variability. Assemblage differences that we observed were not caused by taxonomic changes of fishes in the Chukchi Sea over time.

Fish assemblages tended to group by time and location of sample collection. The result was that characteristics of fish assemblages were not stable through time. It is unlikely that the location itself affected fish assemblages, but rather that the physical parameters associated with those locations were the driving factors. Temperature, salinity, and sediments determined demersal fish assemblages in the Chukchi Sea. These are factors that are likely to be affected by climate change. The composition of fish assemblages in the Chukchi Sea was often dominated by the same species. Over the historical collection period, >90% of the fish collected was composed of 10 species in 3 families: Cottidae (sculpins) – *Artediellus scaber*, *Gymnocanthus tricuspis*, *Myoxocephalus scorpius*; Gadidae (cods) – *Boreogadus saida*, *Eleginus gracilis*; Pleuronectidae (flatfishes) – *Hippoglossoides robustus*, *Limanda aspera*, *Pleuronectes quadrituberculatus*. However the dominant species differed among collections with place and time. Therefore, changes in distribution of individual fish species, as might be expected with influences of climate change, could restructure the species composition and spatial extent of fish assemblages.

E.2 Methods

To analyze fish assemblages, we used separate hierarchical clustering analyses (CLUSTER, PRIMER v. 6.1) for presence of species at stations using the Bray-Curtis dissimilarity coefficient because cluster analyses resolve inter-species associations, allowing an examination of community structure (as adapted from Doyle et al., 2002). A hierarchical cluster analysis for 1,000 permutations identified fish assemblages that grouped stations according to their species composition. The resulting dendrogram displays groupings of stations into smaller numbers of clusters containing more stations. The dendrogram that was produced for each cruise was used to establish station groups for demersal fishes. Station groupings were plotted on a map of the sample area to determine geographic distinctions for those cruises where significant groupings were found.

When employing cluster analysis the biological or environmental conditions that are being examined must be considered. Cluster analysis may find groups even if they are not relevant in nature, i.e., it is possible for random data to produce clusters. A Similarity Profile test (SIMPROF, PRIMER v.6.1) is a permutation test of the null hypothesis (Clarke and Gorley 2006), i.e., it tests that the stations will not be grouped because all distributions of fishes are equal. SIMPROF was used to test the significance of each grouping of fish presence that resulted from the cluster analysis. When the statistical test of clusters (SIMPROF) is not significant, it is inappropriate to consider further clustering (Clarke et al., 2008). However, it may be appropriate to group supersets of clusters. When cluster analysis results in only one of two stations, those might not be valid clusters (Clarke et al., 2008). Therefore we interpreted the results of the cluster analysis based on our accompanying knowledge of the fish and the environment in the Chukchi Sea.

For each historical fish collection (Table II-1 of this report, Appendix Table D.1-1) for which we had corresponding temperature and salinity data, we used both standard potential density plots and cluster analysis used to delineate water masses. Water masses were identified using a standard oceanographic technique, i.e., potential density plots (Ocean Data View v.2.3.3, Schlitzer 2007) and a technique that is described above and is commonly employed by biologists and ecologists, i.e., dendrograms. One thousand permutations of cluster analysis (CLUSTER, PRIMER v. 6.1) were used to delineate water masses from CTD records of temperature and salinity. Temperature and salinity data were normalized and Euclidean distances between stations were measured (Clarke and Gorley, 2006). Dendrograms were produced via group-averaged linkages. The deepest temperature and salinity from CTD collections at the station nearest to the fish collection were used to delineate water masses. We used Euclidean distance as input for the clustering as it is appropriate for physical data. For each cruise, maps of the bottom water masses were compared the plots of the station groupings of fishes produced.

We used PRIMER v.6.1, software that has robust non-parametric tests, to examine potential linkages between potential environmental drivers and observed fish assemblage patterns. The process was to first analyze biological samples with CLUSTER and SIMPROF, next analyze environmental samples with CLUSTER and SIMPROF, and then combine biological and environmental indices.

Graphs of non-metric multidimensional scaling results (MDS; Kruskal, 1964) were used to display patterns among sample groups. MDS ordination plots have no interpretable axes, are based on simple matching coefficients calculated between pairs of species, and describe the precise biotic relationships among samples (Clarke et al., 2008, Somerfield et al., 2008). Stations represented by points that are closer together in an MDS plot are more similar to each other; stations that are farther apart are less similar and correspond to different values, in this case, the fish species present at a station. A stress of <0.2 is considered to be a good fit. For each cruise, MDS ordination of fish species presence by station was used to visually portray the relationship of significant fish clusters with any physical variable for which a significant relationship was determined by ANOSIM (PRIMER v. 6.1). Because continuous variables would not show a pattern in MDS, bottom temperature, bottom salinity and depth values were grouped to create discrete variables. Bins of one unit were used for bottom temperature (ºC) and bottom salinity. Bottom depth bins were in 10 m increments with bin label being the lowest number in the bin, e.g., a depth bin of 10 m included all stations between 10 and 19.9 m. Only MDS plots with significant ANOSIM results and discernible patterns were displayed in the Appendices.

E.3 Results, by cruise.

E.3.1 1959-Alverson

Cluster analysis of fish presence/absence yielded six groups of station clusters of fishes at approximately 40% similarity (*P*<0.05) and 4, more significantly separated, groups at a similarity of approximately 30%, *P*<0.01 (Figure E.3-1). The two single-station clusters were combined with the stations physically surrounding them. The result was two groups of stations. Cluster A represented southern stations near the mouth of Kotzebue Sound and a few nearshore stations further north (Figure E.3-2). The largest group, B, encompassed the north and offshore stations, which were the majority of the sites sampled, and additionally encompassed a site in the Bering Strait. All these stations were in close proximity to each other. No patterns were apparent in the MDS plot.

A relationship between distribution of fish and physical attributes of the area sampled was found. Although bottom temperature data were available from this cruise, no salinity data were collected. Therefore, water masses could not be evaluated. No patterns appeared with bottom temperature bins, but the relationship between fish presence and bottom depth was significant (ANOSIM, R=0.235, *P*<0.003; Table 3 of this report). Depth bins 40, 50, and 60 m grouped in the MDS plot, while there was much more scatter in the 10, 20, and 30 m depth bins (Figure E.3-3).

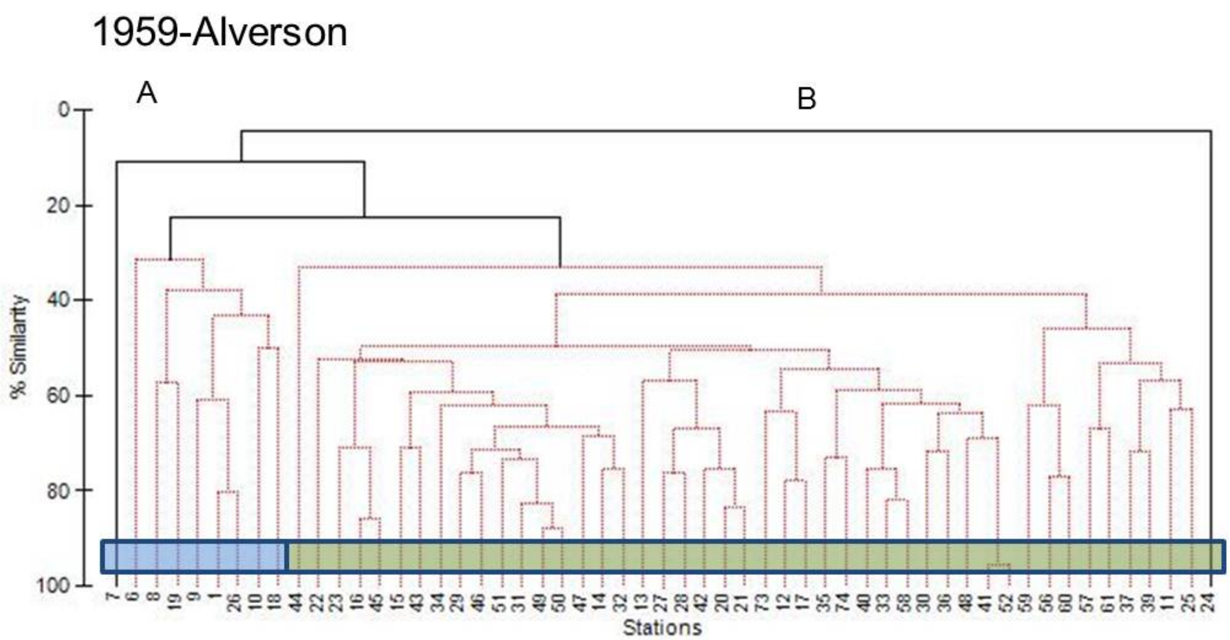


Figure E.3-1 1959-Alverson: Dendrogram of hierarchical clustering of stations with similar species composition (presence/absence). Black lines indicate significantly different clusters (*P*<0.01). Two fish-station groups, designated by colored blocks, were assigned.

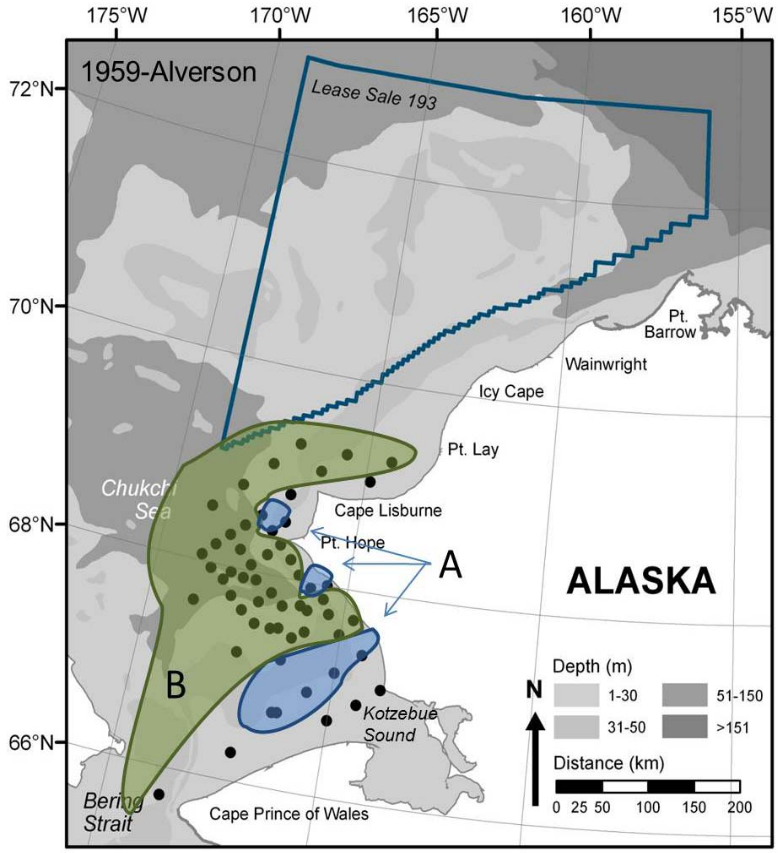


Figure E.3-2 1959-Alverson: Map depicting location of fish-station groups as determined in Figure E.3-1. No fish catch was reported at the sites excluded from polygons.

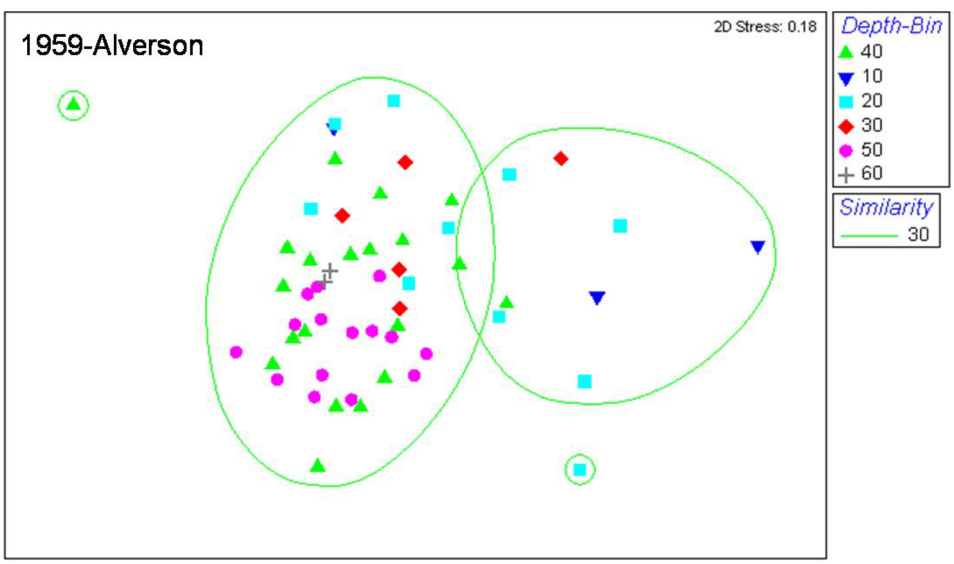


Figure E.3-3 1959–Alverson: Ordination of presence/absence of fish species by MDS (stress = 0.18). Colored symbols indicate 10 m depth bin increments, in which the number is the lowest value in the bin, with which species composition was related. Ellipses are based on the cluster analysis results (Figure E.3-1) using 30% similarity.

E.3.2 1976-Wolotira

A large number of stations were sampled within and near Kotzebue Sound. Five clusters (*P*<0.005) resulted from the analysis of fish taxon presence/absence (Figure E.3-4). Of those, four were single stations. The largest, Cluster A, represented the south and nearshore station into Kotzebue Sound (Figure E.3-5). Station 59, inside Kotzebue Sound, formed a single cluster. That station was the same depth as those surrounding it, but it only had three species of fish. We grouped it with the station surrounding it in Cluster A. Stations 34 and 35 formed a cluster separate from everything else. Those stations were unique in that Arctic cod (*Boreogadus saida*) was not caught and that only three species were caught at each station. It is likely that there could have been difficulty with fishing these hauls. However, the report (Wolotira et al., 1977) does not designate between quantitative and non-quantitative tows as we did for recent cruises; therefore the cause of this anomaly cannot be known. Those three species were also captured at the surrounding stations, therefore, these two stations were also included in Cluster A. Cluster B encompassed the north and offshore stations (Figure E.3-5). Stations 95 and 96 clustered separately, but were considered to be in the same group as Cluster B. These two stations had very few fish species, but those species were captured in the surrounding stations.

Physical data yielded some insight about the distribution of fishes. Although bottom temperature data were available from this cruise, no salinity data were collected. Therefore, water masses could not be evaluated. However, the depth bins seemed linked to the cluster groups in the MDS plot (Figure E.3-6). Fish presence was significantly related to depth (ANOSIM, R=0.441, *P*=0.001). There was no relationship (ANOSIM, *P*>0.05) with bottom temperature.

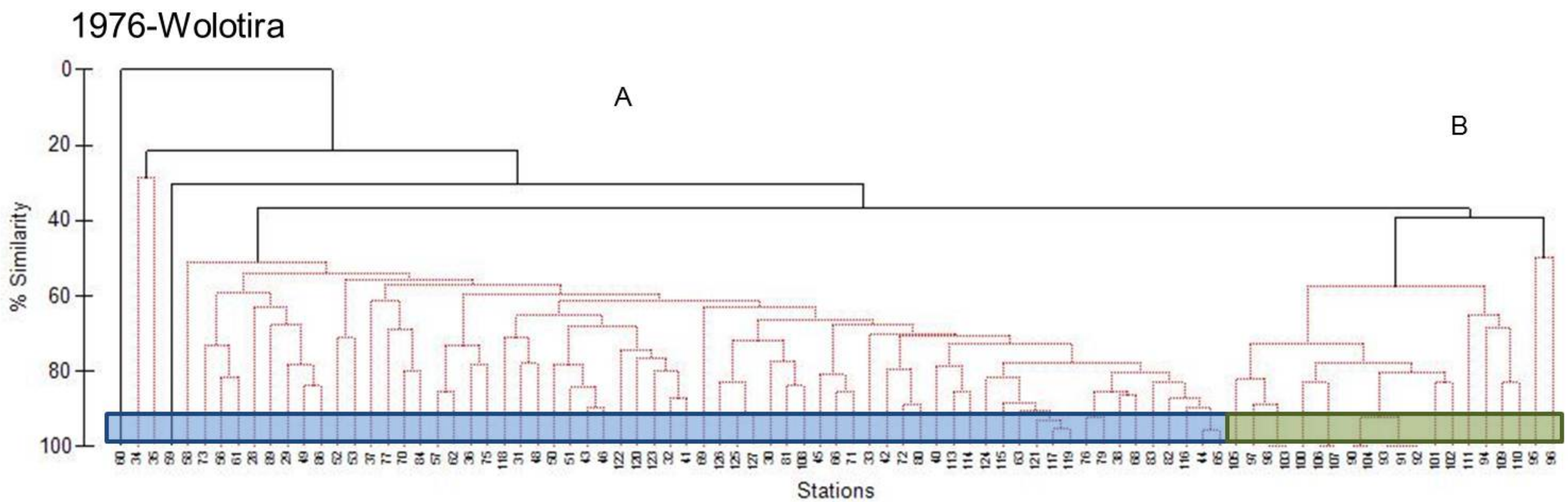


Figure E.3-4 1976-Wolotira: Dendrogram of hierarchical clustering of stations with similar species composition. Black lines indicate significantly different clusters (*P*<0.005). Two station groups, designated by colored blocks, were assigned.

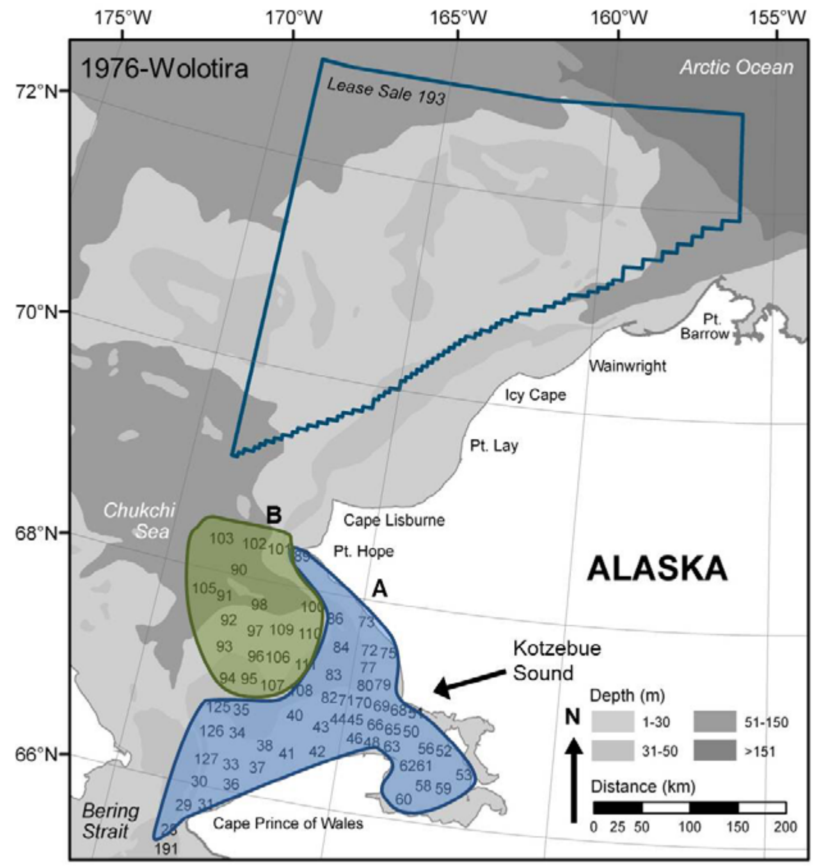


Figure E.3-5 1976-Wolotira: Map depicting location of fish-station groups as determined in Figure E.3- 4.

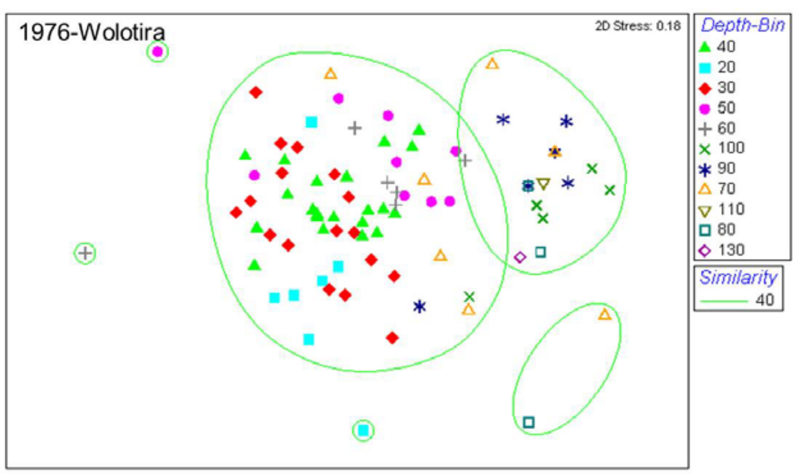


Figure E.3-6 1976–Wolotira: Ordination of presence/absence of fish species by MDS (stress = 0.18). Colored symbols indicate 10 m depth bin increments, in which the number is the lowest value in the bin, with which species composition was related. Ellipses are based on the clusters analysis results (Figure E.3-4) using 40% similarity.

E.3.3 1977-Frost

Analyses include only ten stations in the northeast Chukchi Sea and two stations slightly east of Barrow from cruise 1977-Frost, although additional hauls are in the CDF Database. There were no significant (*P*>0.05) clusters of fish presence/absence (Figure E.3-7) in the eastern Chukchi Sea (Figure E.3-8). No significant relationship was detected between species composition and depth or substrate type (ANOSIM, *P*>0.05; Table II-3 of this report). Because there were no relationships, no MDS plot is presented.

No bottom temperature data or salinity data were collected on this cruise. Therefore, water masses could not be evaluated.

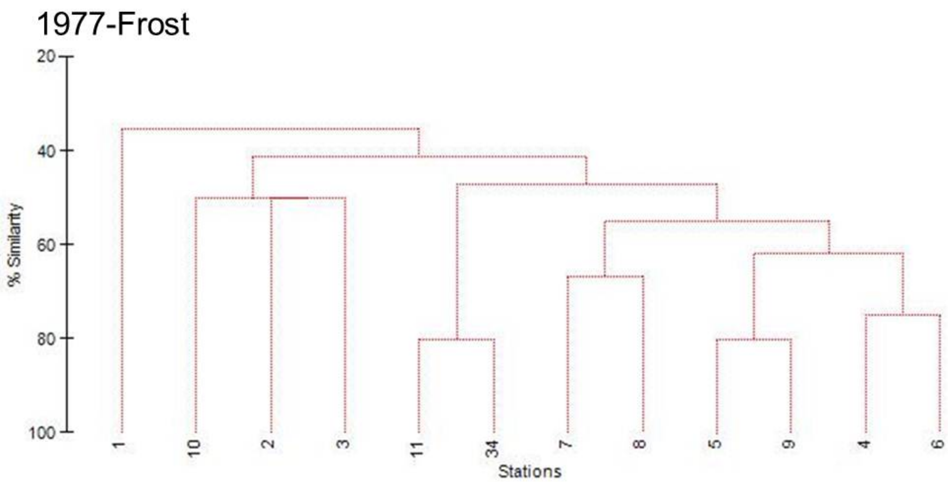


Figure E.3-7 1977-Frost: Dendrogram of hierarchical clustering of stations with similar species composition. No station groups significantly differed from others.

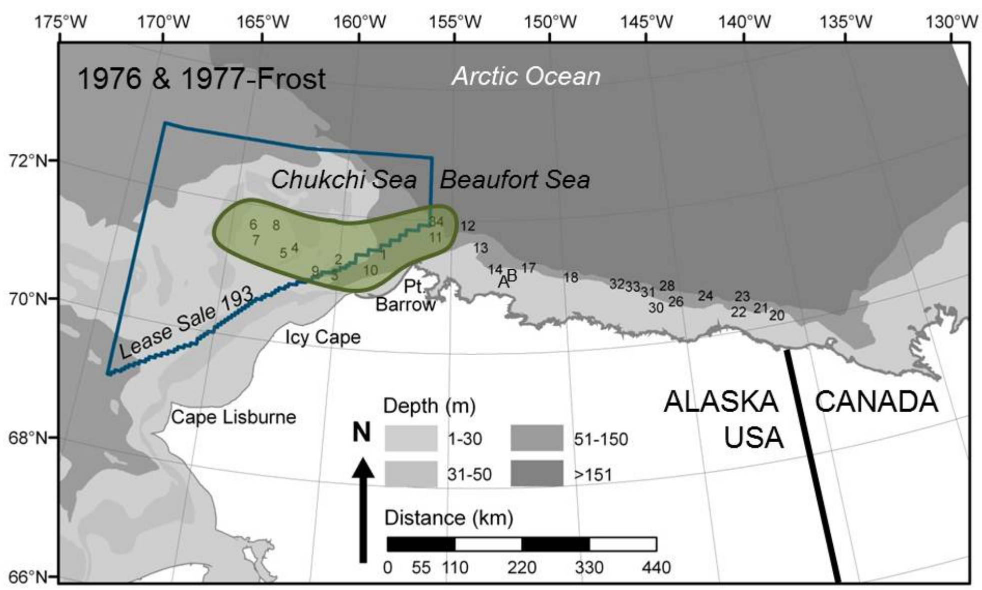


Figure E.3-8 1977-Frost: Map depicting location of stations examined in the species composition dendrogram depicted in Figure E.3-7. Stations examined outside of the Chukchi Sea are also shown.

E.3.4 1983a-Fechhelm and 1983b-Fechhelm

There were no significant (*P*>0.05) clusters for fish presence at stations on this cruise (Figure E.3-9), though a significant relationship was found between water mass and species presence (ANOSIM, R=0. 338, *P*=0.011). No relationship (ANOSIM, *P*>0.05) was observed between fish presence and bottom temperature or salinity (Table II-3 of this report). No MDS plot is presented since species composition was not different among stations (Figure E.3-10).

Cluster analysis of bottom temperatures and salinities averaged over replicate samplings at most stations during the 1983-Fechhelm collections resulted in four significantly (*P*<0.01) different groups (Figure E.3-9). However, though station 16 was statistically very distinct in the cluster, and somewhat separate in the standard potential density plot (Figure E.3-10), that station is at the mouth of the Kuk River, which likely caused the low salinity value. Therefore, station 16 was included in the Alaska Coastal Water. In late August and early September 1983, bottom water mass characteristics graded from nearshore to offshore. The ACW had a fairly narrow and cool range of temperature, 4.5–7.5º C, and extremely wide range of salinity 27–30.5. These characteristics yielded a wide range of densities for the ACW (Table II-2 of this report). That resulting water mass was confined to a thin band very near the coast (Figure E.3-11). Bering Sea Water had a wider range of relatively warm temperatures, 2.3–6.7º C, but a much narrower salinity range, 30.6–32.0. Winter Water was confined to the six stations furthest from shore and had cold temperature, -0.8 to 1.6º C, and higher salinities, 31.7–32.6.

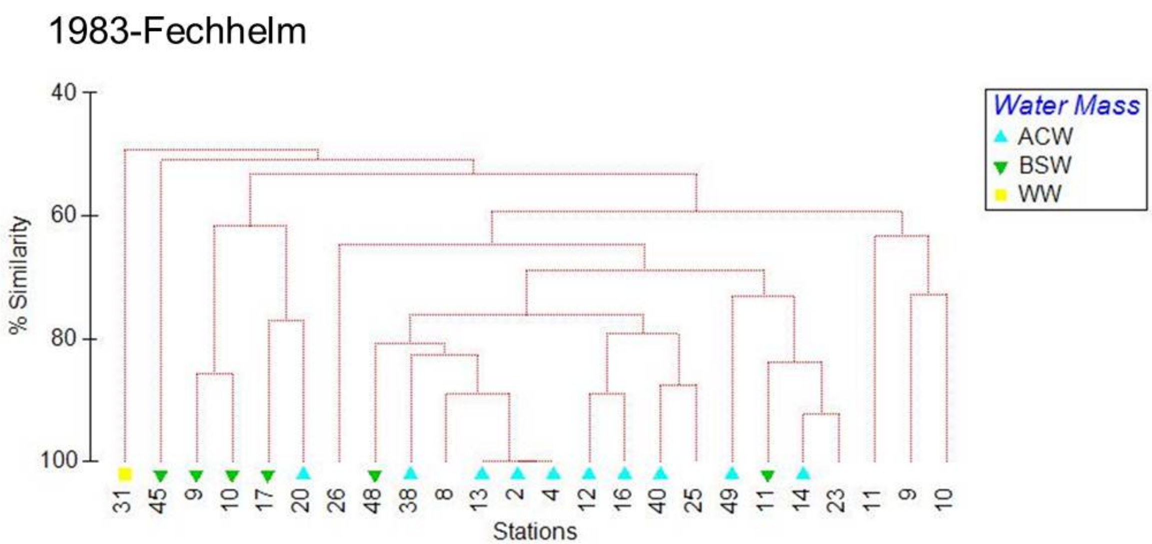


Figure E.3-9 1983a-Fechhelm and 1983b-Fechhelm: Dendrogram of hierarchical clustering of stations with similar species composition. No station groups significantly differed from others (*P*>0.05). Some stations were not assigned to a water mass. Locations of fish collections are indicated in Figure E.3-11.

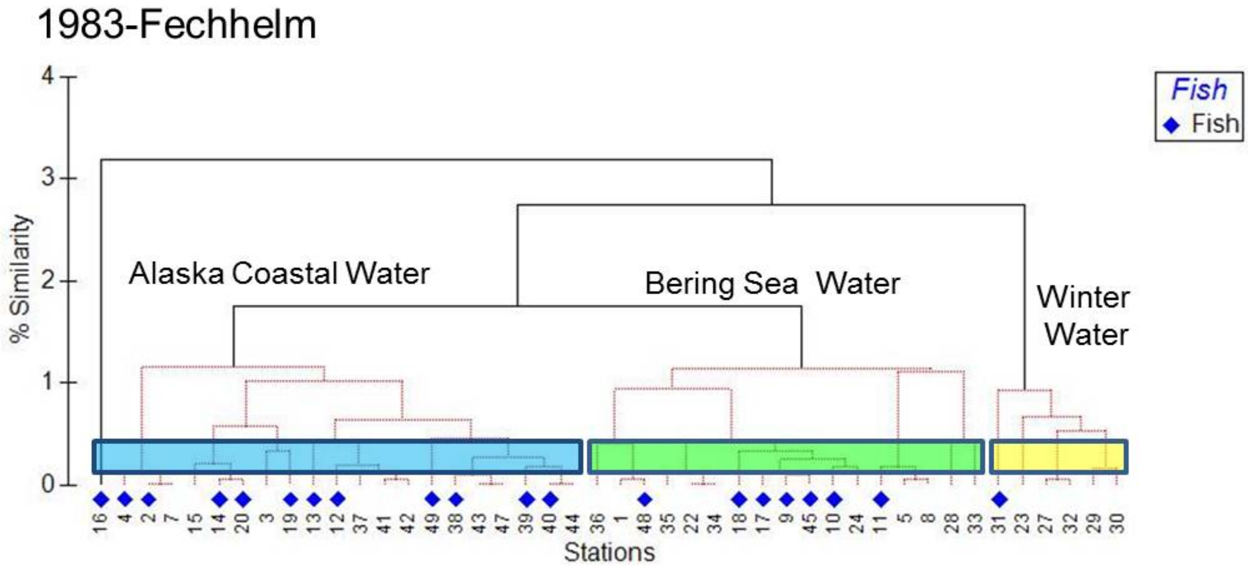


Figure E.3-10 1983a-Fechhelm and 1983b-Fechhelm: Dendrogram of hierarchical clustering of stations with similar water mass characteristics. Black indicates significantly different (*P*<0.01) clusters. Water masses were assigned based on these clusters and the standard potential density plot (Figure E.3-11). Fishing stations are indicated by blue diamonds.

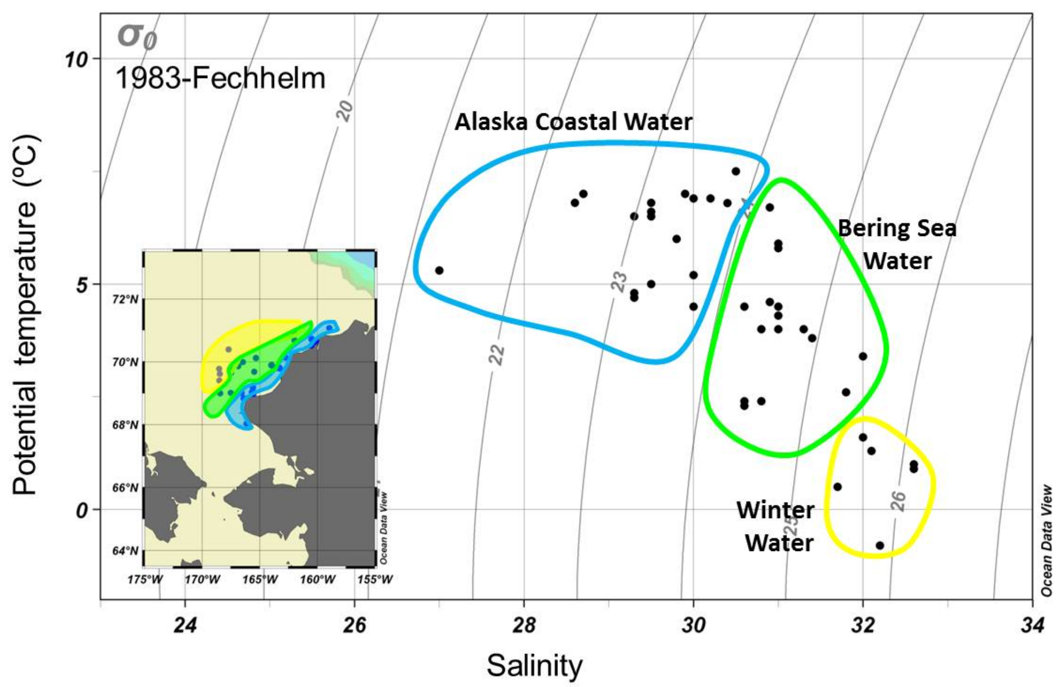


Figure E.3-11 1983a-Fechhelm and 1983b-Fechhelm: Water masses delineated by a standard potential density plot and depicted on a map showing station locations. Water mass designations and colors correspond to those in Figure E.3-10.

E.3.5 1989-Barber

There were no significantly different clusters for the fish presence/absence at stations on this cruise (*P*>0.05; Figures E.3-12 and E.3-13). However, species composition was significantly related to physical factors (Table II-3 of this report). There were significant relationships between fish presence and depth (ANOSIM, R=0.229, *P*=0.007), salinity (ANOSIM, R=0. 555, *P*=0.001), temperature (ANOSIM, R=0. 372, *P*=0.001), and water mass (ANOSIM, R=0.149, *P*=0.009). No bottom substrate data were available from these collections. No MDS is presented since there were no significantly different groups of species presence (Figure E.3-12).

Cluster analysis of bottom temperatures and salinities averaged over replicate samplings at most stations resulted in five significantly different groups (*P*<0.01; Figure E.3-14). ACW was classified by combining two closely aligned, yet statistically different groups, with one group of three stations that was more dissimilar. The three groups combined into the ACW had a fairly narrow, warm range of temperatures, 7.4–19.7ºC; however, they had an extremely wide range of salinity 27.9–31.3 (Figure E.3-15). The salinities caused clustering differences. That resulting water mass was confined to a thin band very near the coast. As with the ACW, Bering Sea Water had a wider range of relatively warm temperatures, 5.2–7.5º C, but had a much narrower salinity range, 30.7–32.0. These characteristics yielded a wide range of densities for the ACW and a narrow range for BSW (Table II-2 of this report). Station H5 was statistically very distinct in the cluster and very separate in the standard potential density plot (Figure E.3-15). The most northern and offshore station sampled, it had cold water (2.4°C) with low salinity (27.8), most likely derived from the upper layers of the Arctic Ocean (Weingartner, 1997) and therefore we classified it as Resident Chukchi Water.

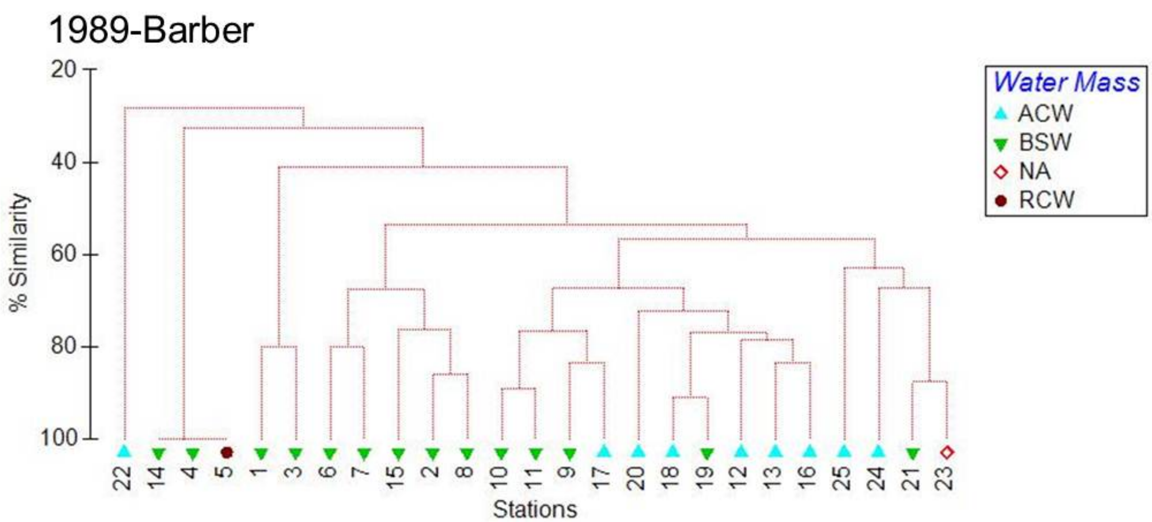


Figure E.3-12 1989-Barber: Dendrogram of hierarchical clustering of stations with similar species composition. No station groups significantly differed from others.

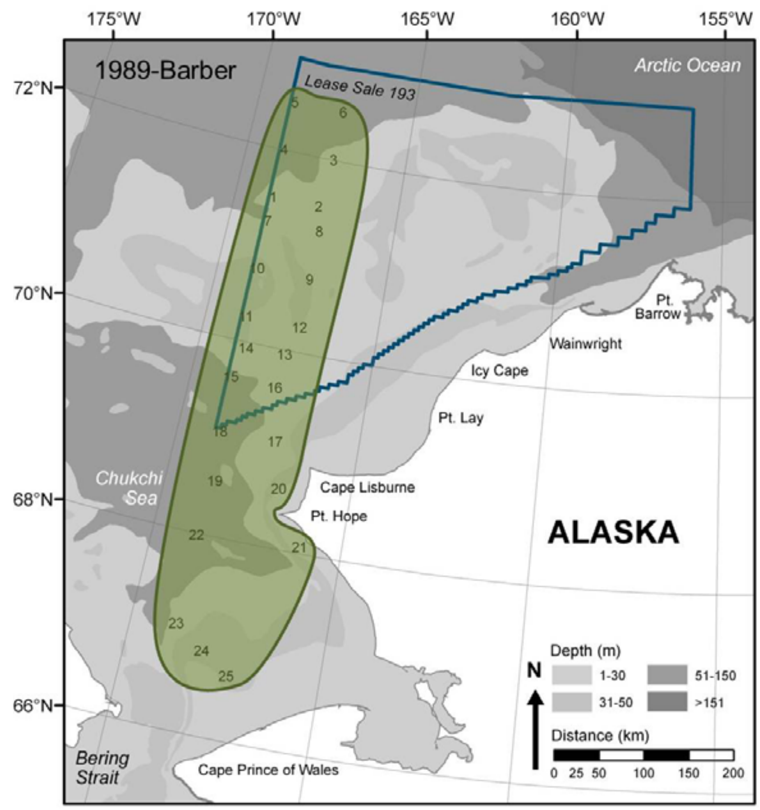


Figure E.3-13 1989-Barber: Map indicating location of stations examined in the species composition dendrogram (Figure E.3-12).

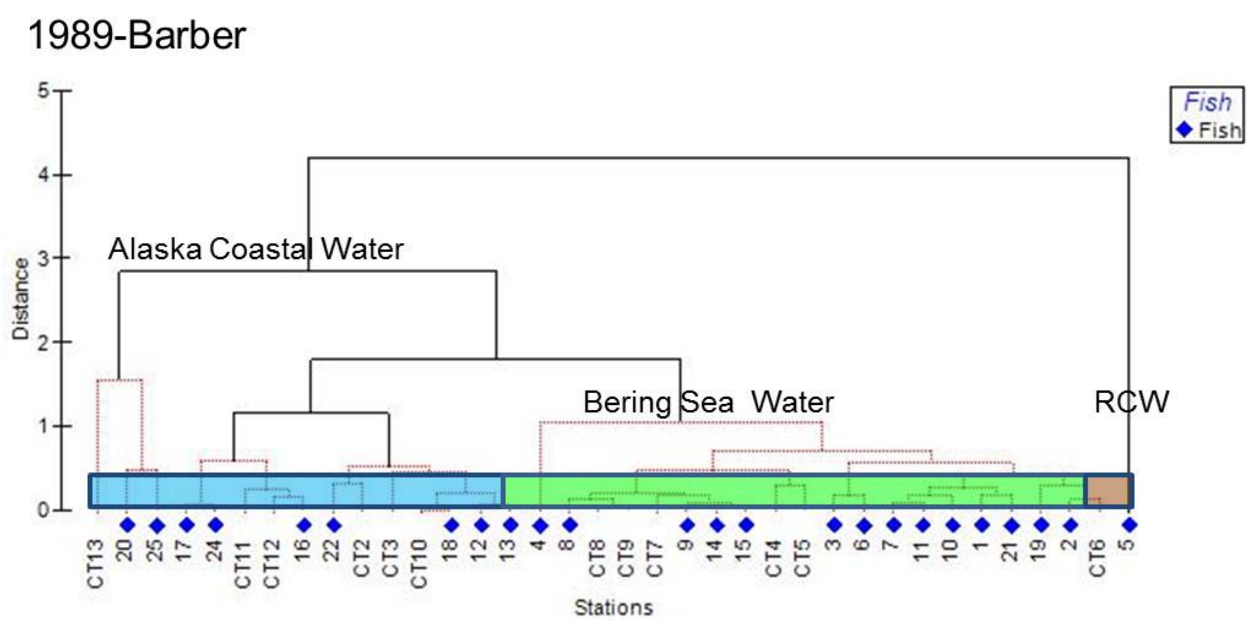


Figure E.3-14 1989-Barber: Dendrogram of hierarchical clustering of stations with similar water mass properties. Black indicates statistically significant (*P*<0.01) clusters. Fishing stations are indicated by blue diamonds. Water masses were assigned based on these clusters and the standard potential density plot (Figure E.3-15). RCW = Resident Chukchi Water.

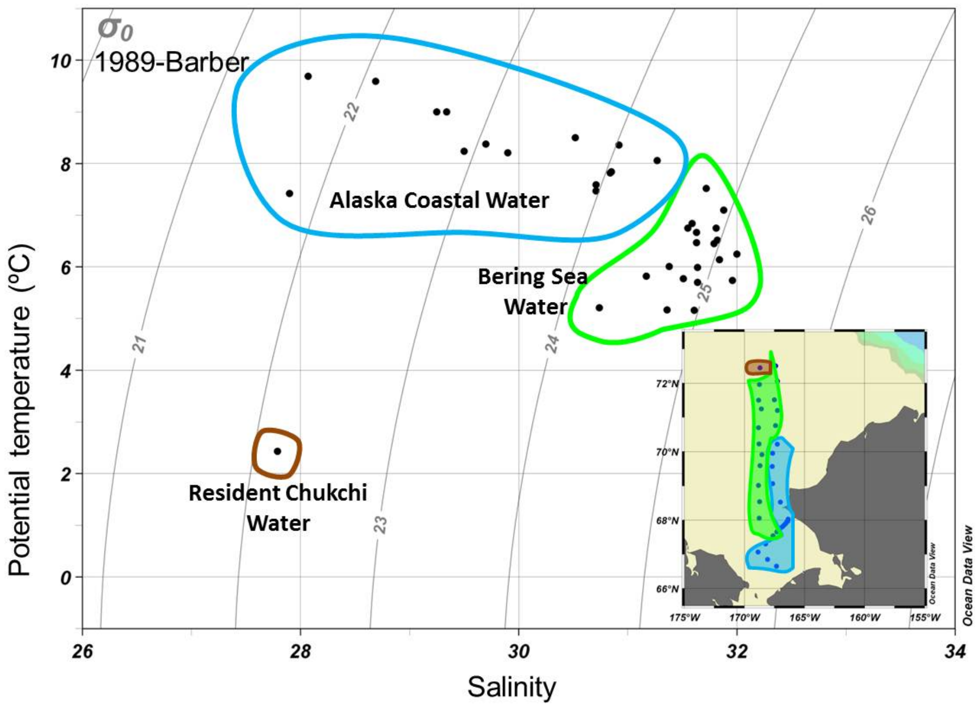


Figure E.3-15 1989-Barber: Water masses delineated by a standard potential density plot and depicted on a map showing station locations. Water mass designations and colors correspond to those in Figure E.3-14.

E.3.6 1990-Barber

Cluster analysis of fish presence/absence yielded five groups ($P<0.01$) of station clusters (Figure E.3-16: upper panel). Cluster A represented the south and nearshore station clusters (Figure E.3-17: upper panel). The largest group, B, encompassed the south and offshore stations and most stations of this cluster were in BSW. Cluster C contained north and offshore stations. Cluster D was a unique group of north and nearshore stations. Cluster E was formed of three stations that were surrounded by stations in Cluster D, with which it was most closely associated.

Cluster analysis of species abundance yielded 11 groups ($P<0.01$) of station clusters (Figure E.3-16: lower panel). We assigned these stations into 4 groups, of which Cluster 1990-abund-B was classified by combining 8 significantly different groups. Two southern nearshore stations formed Cluster 1990-abund-A (Figure E.3-17: lower panel). Offshore of Cluster 1990-abund-A and in the southern Lease Sale area, several stations formed Cluster 1990-abund-B. Cluster 1990-abund-C was further north and included a station nearshore off Wainwright. Offshore of Wainwright, the northernmost stations formed Cluster 1990-abund-D.

Several physical factors were significantly related to the fish distribution (Table II-3 of this report). There were significant relationships between fish presence and depth (ANOSIM, R=0. 158, P=0.003), salinity (ANOSIM, R=0. 256, P=0.008), temperature (ANOSIM, R=0. 13, P=0.002), and water mass (ANOSIM, R=0. 21, P=0.001). No bottom substrate data were available from these collections. The MDS plots did not show clear indications of relationships between water mass and species presence or abundance (Figure E.3-18).

Cluster analysis of bottom temperatures and salinities resulted in four significantly ($P<0.01$) different groups (Figure E.3-19). ACW was classified by combining statistically different groups. The two groups combined as the ACW had an extremely wide of temperatures, 5.7–12.7º C; however, they had a narrow range of salinity 29.5–30.4 (Figure E.3-20). That resulting water mass was very wide and distributed from the coast to far offshore. As with the ACW, Bering Sea Water had a wide range of relatively warm temperatures, -0.2–7.1º C, but had a much narrower salinity range, 30.8–32.6. These characteristics yielded a wide range of densities for the ACW and a rather narrow range for BSW (Table II-2 of this report). Winter Water was confined to four northeastern stations and had cold temperatures, -0.2 to -0.6º C, and higher salinities, 32.6–33.3.

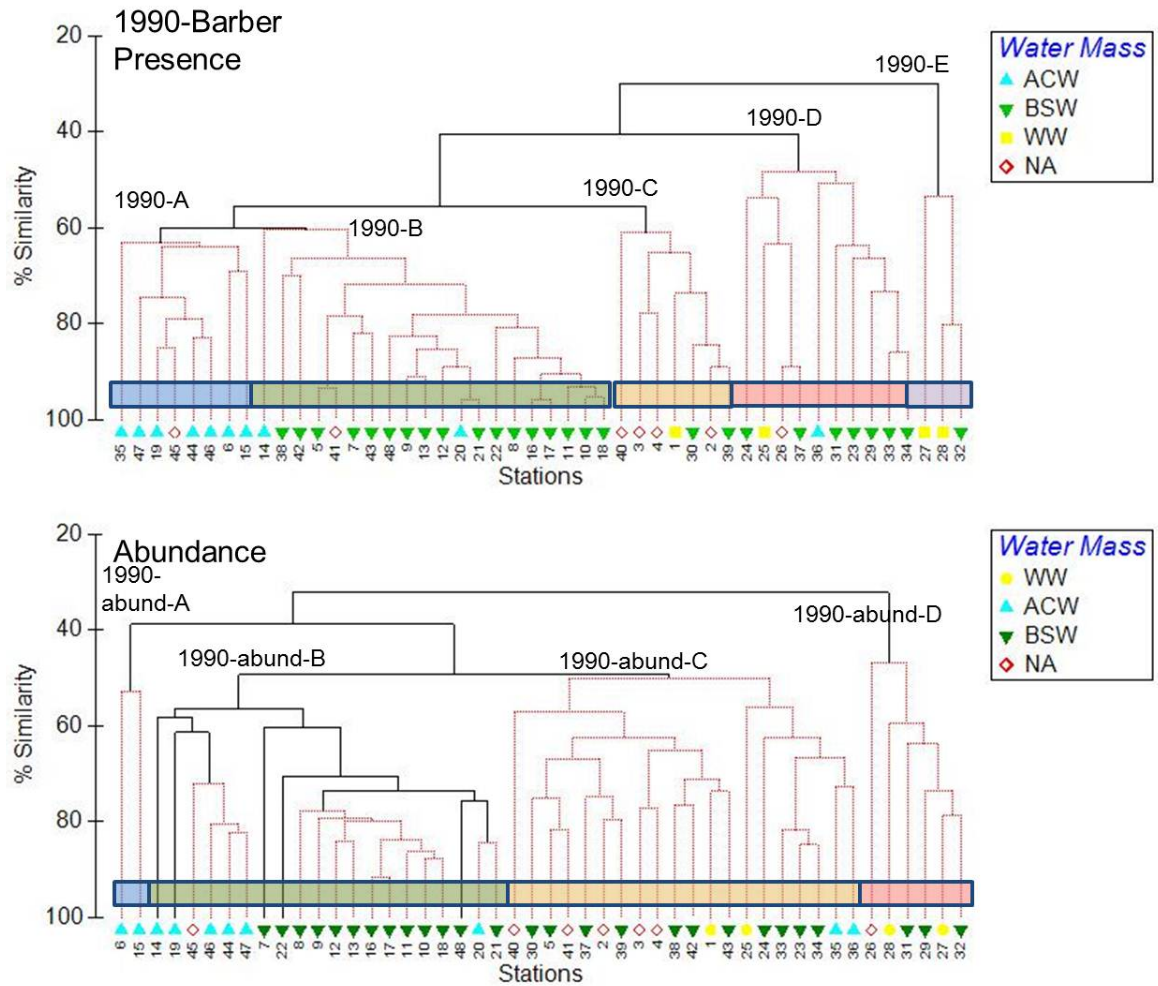


Figure E.3-16 1990-Barber: Dendrogram of hierarchical clustering of stations with similar species composition. Upper panel is presence; five station groups were assigned and are designated by colored blocks. Lower panel is abundance; 11 stations groups were observed, of which 8 were grouped as 1990-abund-B. In both panels, black lines indicate statistically significant (*P*<0.01) clusters.

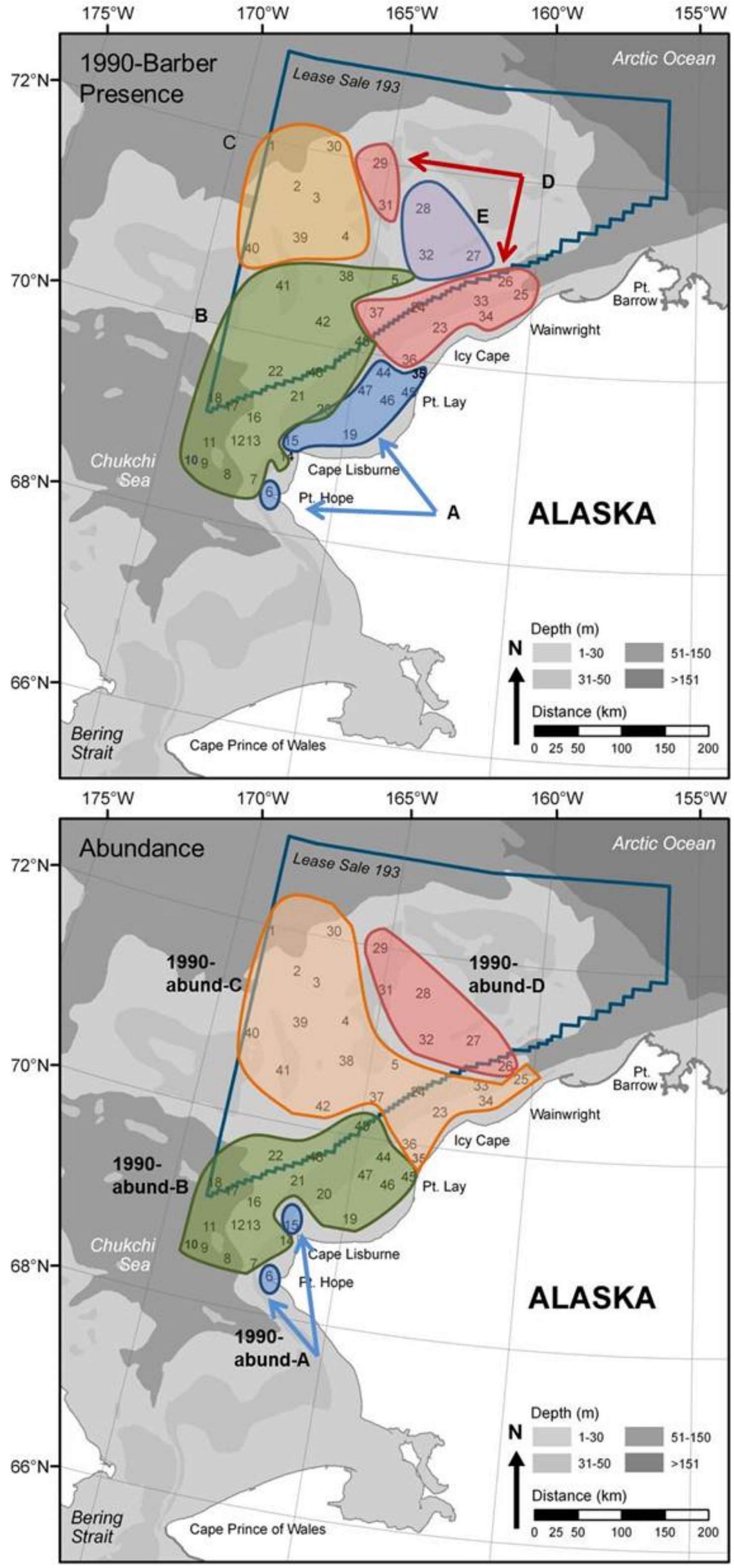


Figure E.3-17 1990-Barber: Maps depicting location of fish-station groups as determined in Figure E.3-16. Upper panel is species composition (presence/absence) and lower panel is species abundance.

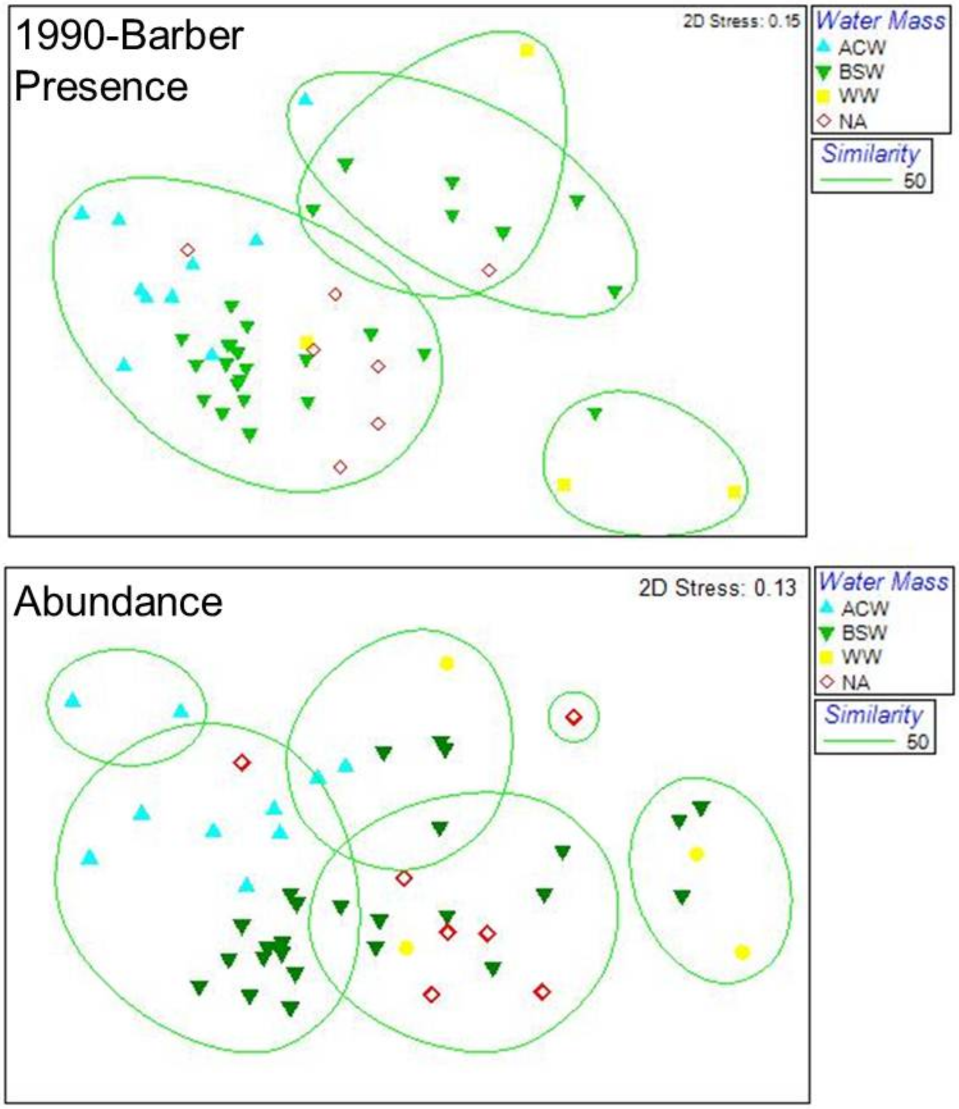


Figure E.3-18 1990-Barber: Ordination of presence/absence (upper panel) and abundance (lower panel) of fish species by MDS. Colored symbols indicate water mass, with which species composition, both presence/absence and abundance, were related. Ellipses are based on the clusters analysis results (Figure E.3-16) using 50% similarity.

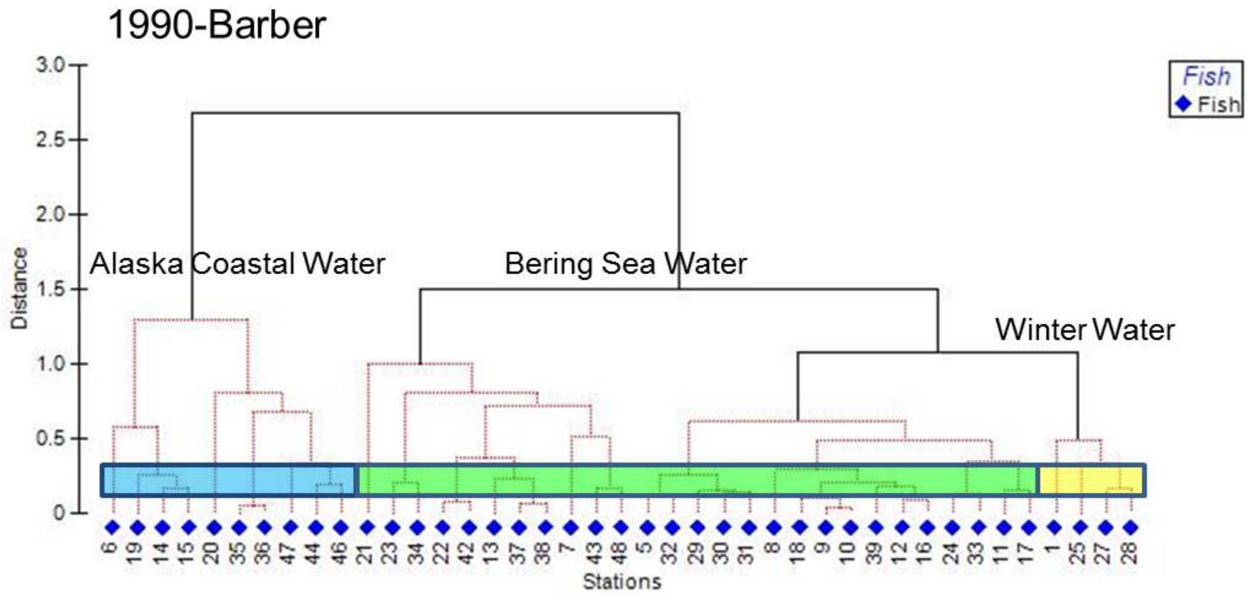


Figure E.3-19 1990-Barber: Dendrogram of hierarchical clustering of stations with similar water mass properties. Black indicates statistically significant (*P*<0.01) clusters. Fishing stations are indicated by blue diamonds. Water masses were assigned based on these clusters and the standard potential density plot (Figure E.3-20).

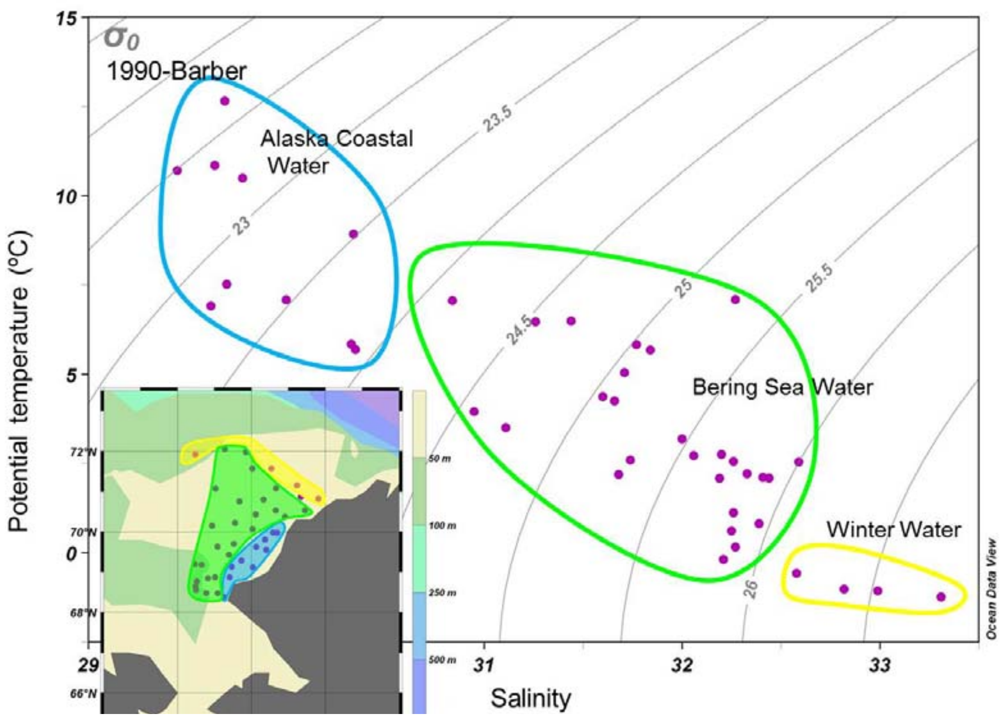


Figure E.3-20 1990-Barber: Water masses delineated by a standard potential density plot and depicted on a map showing station locations. Water mass designations and colors correspond to those in Figure E.3-19.

E.3.7 1990-Hokkaido

There were two significant (*P*>0.05) clusters for fish presence/absence at stations on this cruise (Figure E.3-21). The only fished station in the ACW was different from the other nine stations in the BSW (Figures E.3-21 and E.3-22). There were no significant (ANOSIM, *P*>0.05) relationships between fish and depth, bottom salinity, temperature, or water mass (Table II-3 of this report), and therefore no MDS plot is presented.

Cluster analysis of bottom temperatures and salinities resulted in 4 significantly (*P*<0.01) different groups (Figure E.3-23). Four stations with relatively warm temperatures (5.7–8.1^{o}) and relatively low salinities (30.4–31.1) were classified as ACW (Figure E.3-24). This water mass was seen in two spatially separated areas near the coast; no data exist between the areas to enable them to be connected. Bering Sea Water occupied most of the stations sampled. Bottom temperatures were 1.6–4.9º C and salinities were 31.3–32.5. Both ACW and BSW had fairly narrow density ranges (Table II-2 of this report).

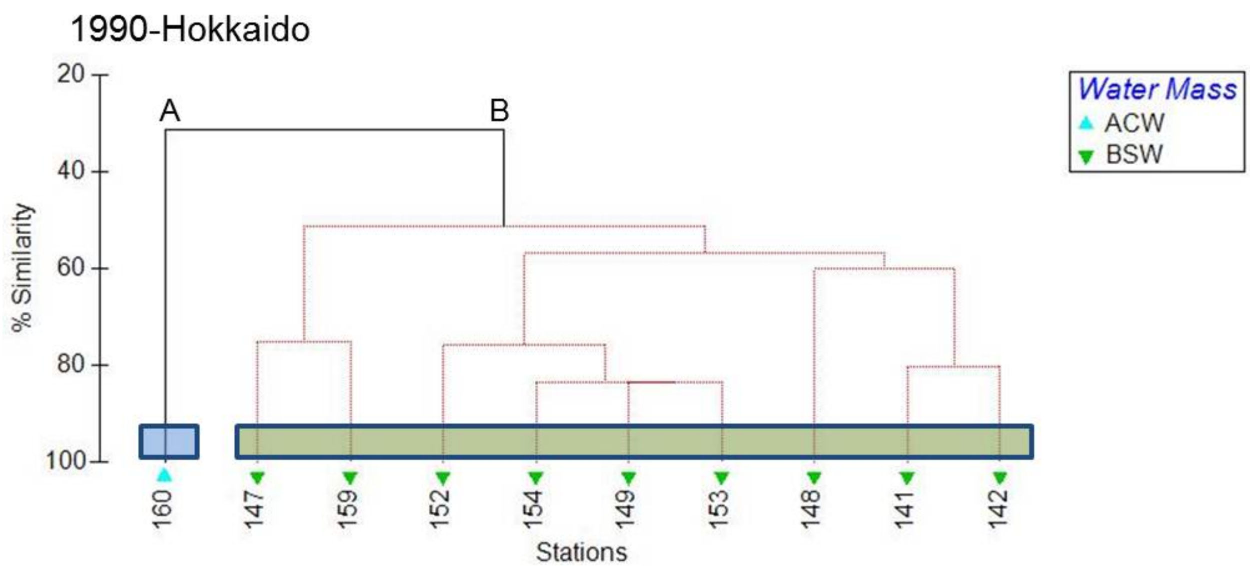


Figure E.3-21 1990-Hokkaido: Dendrogram of hierarchical clustering of stations with similar species composition. Black indicates statistically significant (*P*<0.05) clusters.

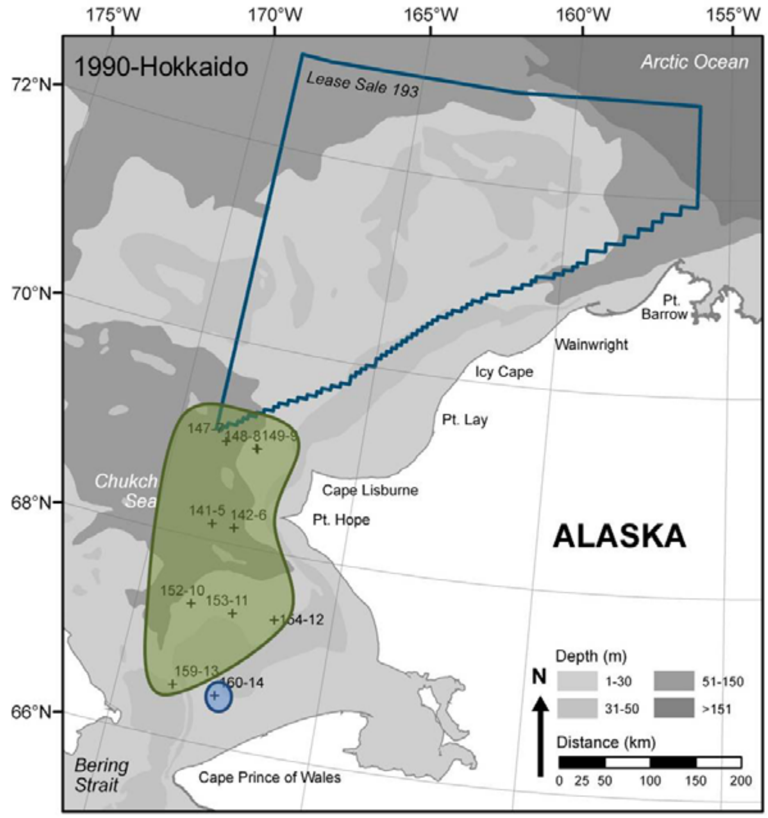


Figure E.3-22 1990-Hokkaido: Map depicting location of station clusters of species presence/absence as determined in Figure E.3-21.

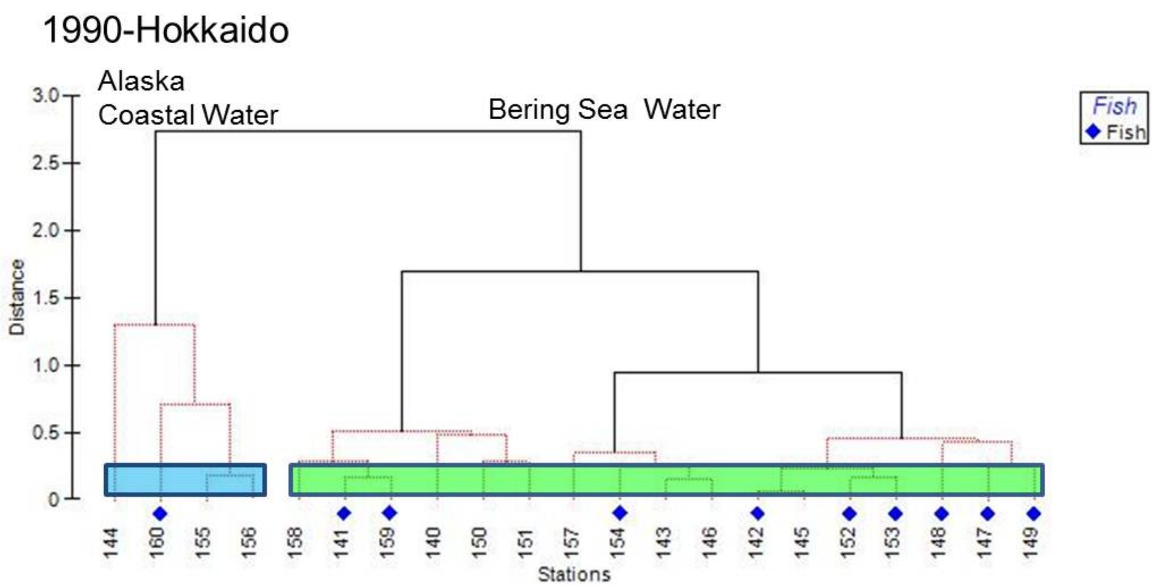


Figure E.3-23 1990-Hokkaido: Dendrogram of hierarchical clustering of stations with similar water mass properties. Black indicates statistically significant (*P*<0.01) clusters. Fishing stations are indicated by blue diamonds. Water masses were assigned based on these clusters and the standard potential density plot (Figure E.3-24).

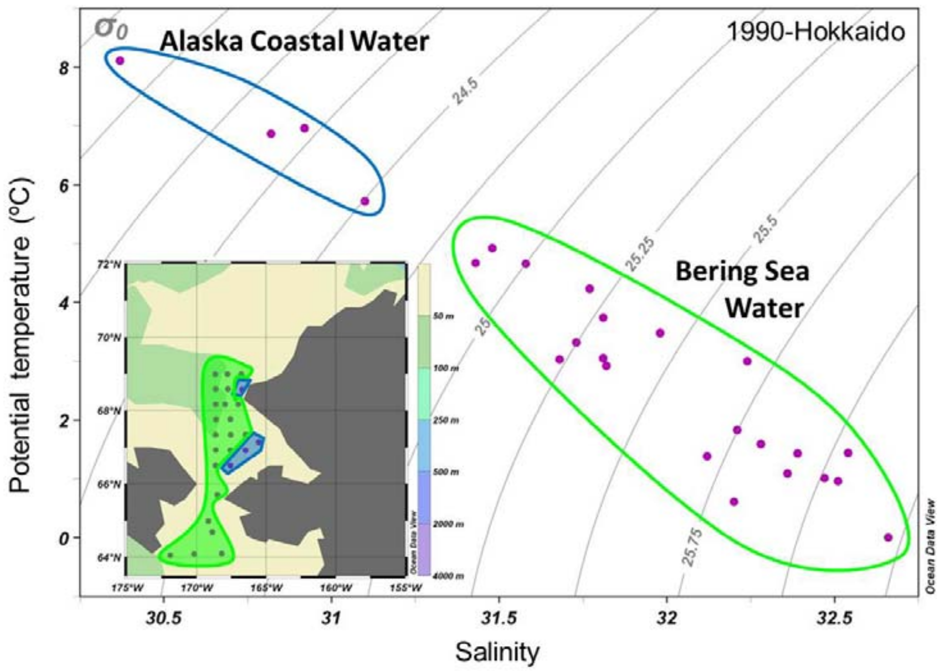


Figure E.3-24 1990-Hokkaido: Water masses delineated by a standard potential density plot and depicted on a map showing station locations. Water mass designations and colors correspond to those in Figure E.3-23.

E.3.8 1991c-Barber

There were no significant ($P<0.05$) clusters for fish presence/absence at stations on this cruise (Figures E.3-25 and E.3-26). There were no significant (ANOSIM, $P>0.05$) relationships between fish presence and physical factors (Table II-3 of this report), and therefore no MDS plot is presented.

Cluster analysis of bottom temperatures and salinities averaged resulted in three significantly ($P<0.01$) different groups (Figure E.3-27). The ACW was found at only one very nearshore station off Point Hope. It had a temperature of 7.1º C and a salinity of 29.5 (Figure E.3-28). BSW was limited to two stations just off Cape Lisburne. The temperatures ranged from 1.5 to 4.2º C, and salinity ranged 31.0–31.8. Winter Water was present at most of the stations sampled. WW has characteristically cold temperatures, -1.7–0.4º C, and higher salinities, 32.2–33.5. These characteristics yielded a wide range of densities for the WW (Table II-2 of this report).

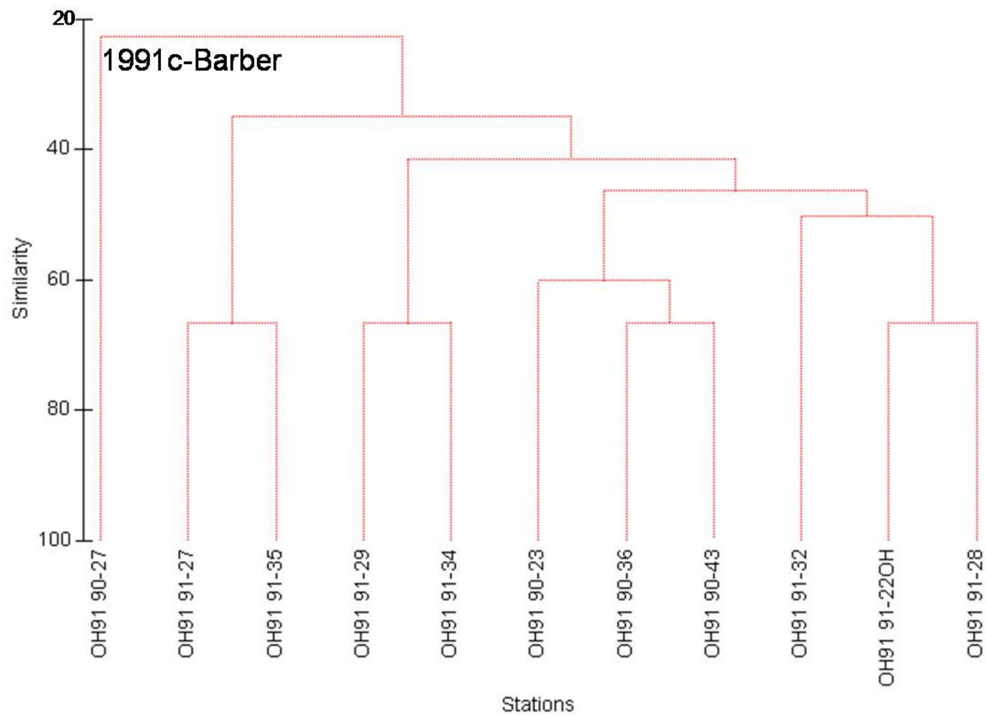


Figure E.3-25 1991c-Barber: Dendrogram of hierarchical clustering of stations with similar species composition. No station groups significantly differed from others.

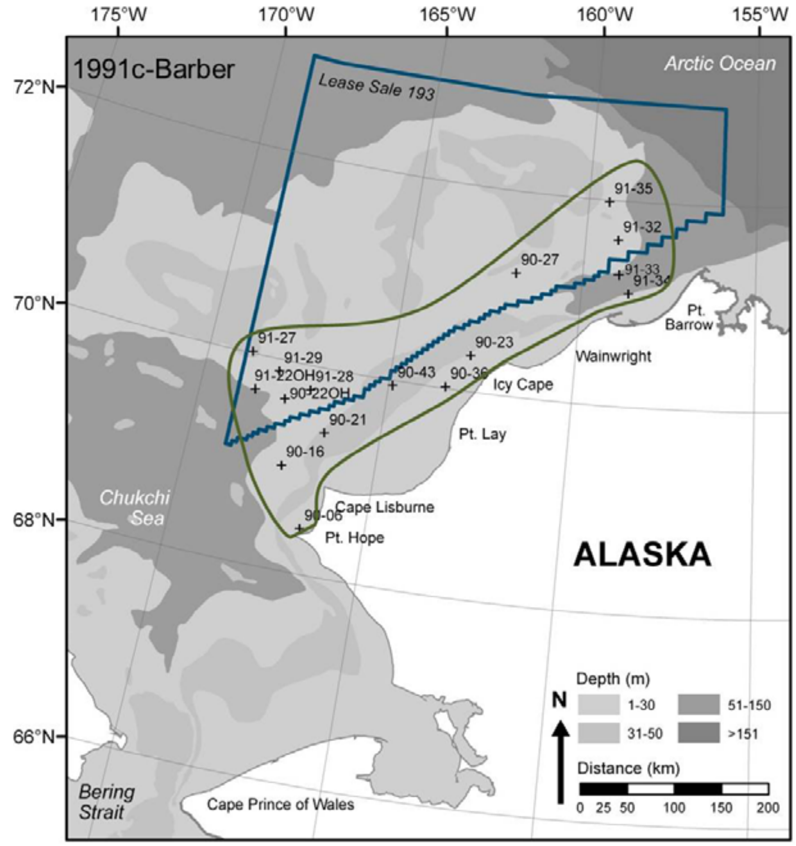


Figure E.3-26 1991c-Barber: Map depicting location of fishing stations, for which no stations were significantly different as determined in Figure E.3-25.

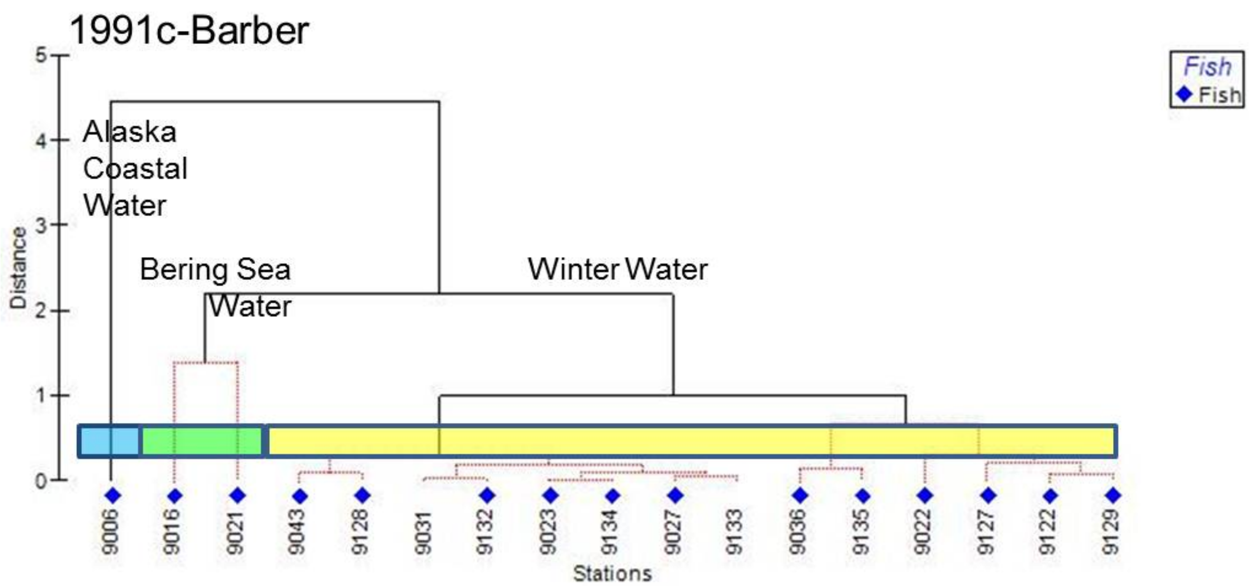


Figure E.3-27 1991c-Barber: Dendrogram of hierarchical clustering of stations with similar water mass properties. Black indicates statistically significant (*P*<0.01) clusters. Fishing stations are indicated by blue diamonds. Water masses were assigned based on these clusters and the standard potential density plot (Figure E.3-28).

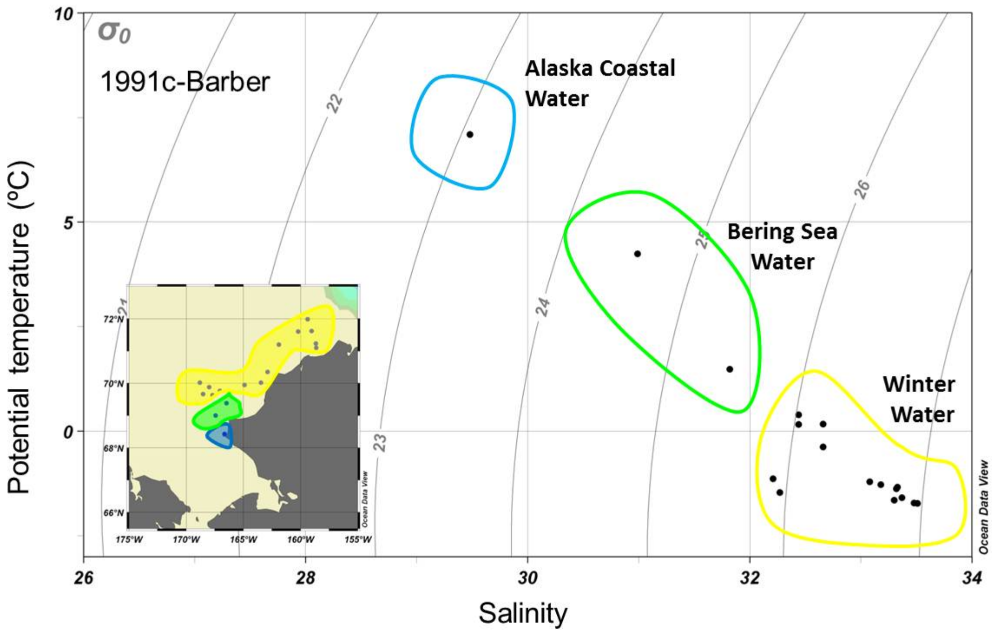


Figure E.3-28 1991c-Barber: Water masses delineated by a standard potential density plot and depicted on a map showing station locations. Water mass designations and colors correspond to those in Figure E.3-27.

E.3.9 1991-Hokkaido

There were no significant (*P*<0.05) clusters for fish presence/absence at stations on this cruise (Figures E.3-29 and E.3-30). There were no significant (*P*>0.05) relationships between fish presence and physical factors (Table II-3 of this report), and therefore no MDS plot is presented.

Cluster analysis of bottom temperatures and salinities resulted in three significantly (*P*<0.01) different groups (Figure E.3-31). The Alaska Coastal Water had a wide of temperatures, -1.3–1.2º C and salinities 30.7–32.0 (Figure E.3-32). That resulting water mass was fairly wide and distributed from along the coast from below the Bering Strait to Icy Cape. Bering Sea Water temperatures were cool, -1.3–1.2º C, with salinities 32.2–32.8. These characteristics yielded a wide range of densities for the ACW and a narrower range for BSW (Table II-2 of this report). Winter Water was confined to offshore stations and had very cold temperatures, -1.7 to -1.6º C, and higher salinities, 33.1–33.4.

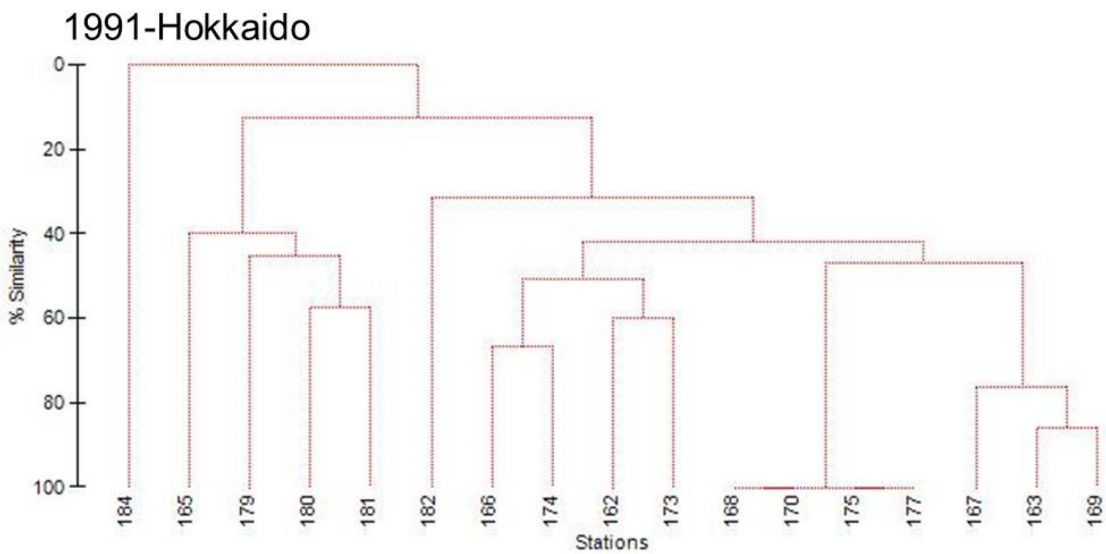


Figure E.3-29 1991-Hokkaido: Dendrogram of hierarchical clustering of stations with similar species composition. No station groups significantly differed from others.

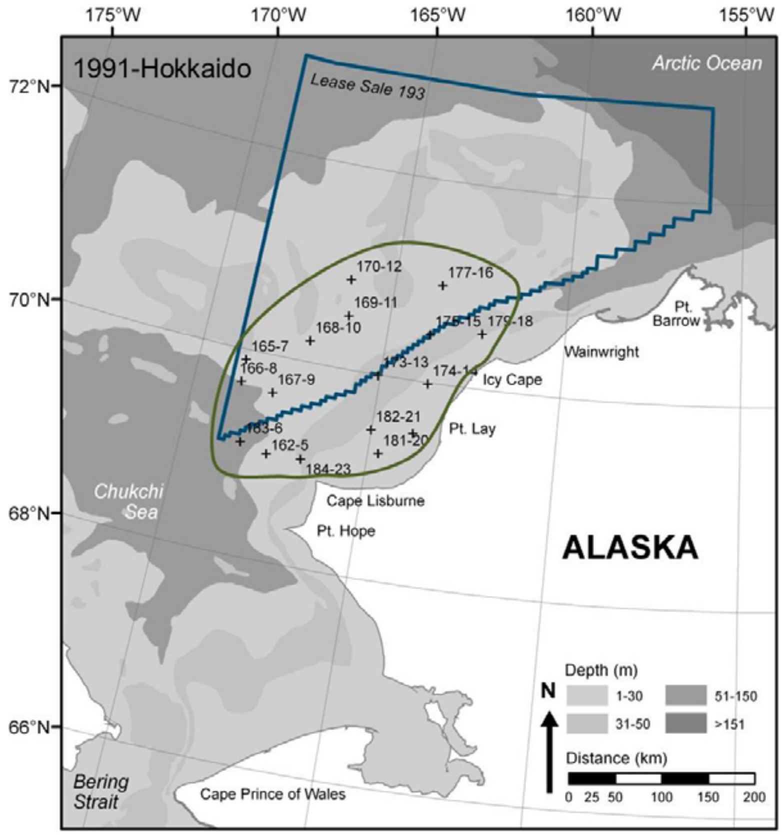


Figure E.3-30 1991-Hokkaido: Map depicting location of fishing stations, for which no stations were significantly different as determined in Figure E.3-29.

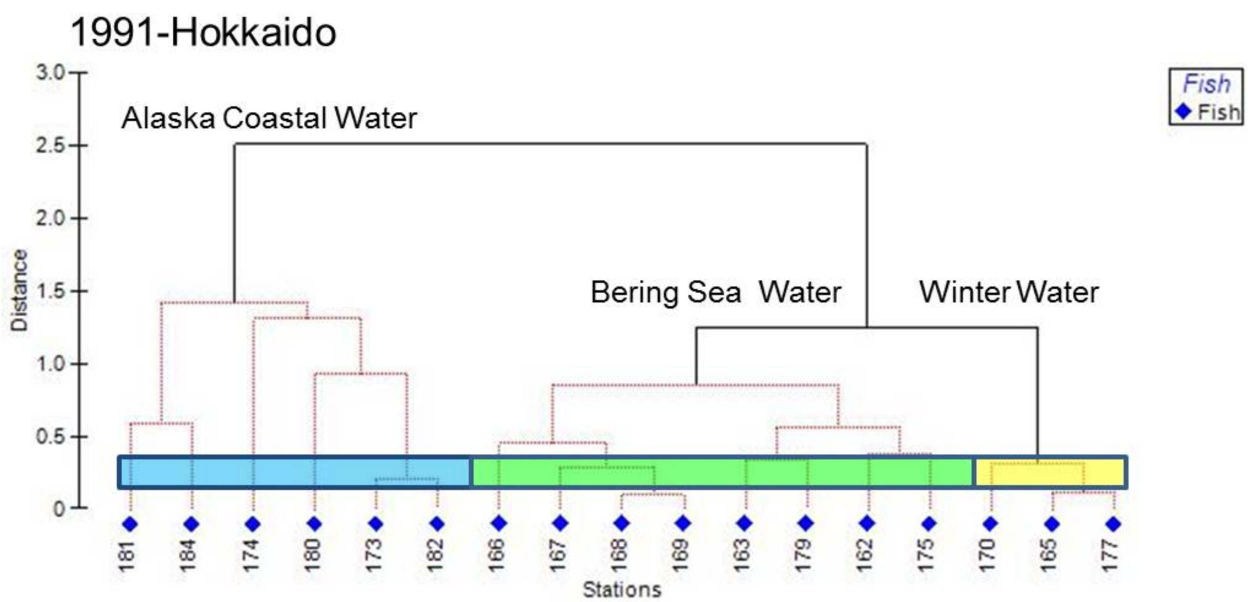


Figure E.3-31 1991-Hokkaido: Dendrogram of hierarchical clustering of stations with similar water mass properties. Black indicates statistically significant (*P*<0.01) clusters. Fishing stations are indicated by blue diamonds. Water masses were assigned based on these clusters and the standard potential density plot (Figure E.3-32).

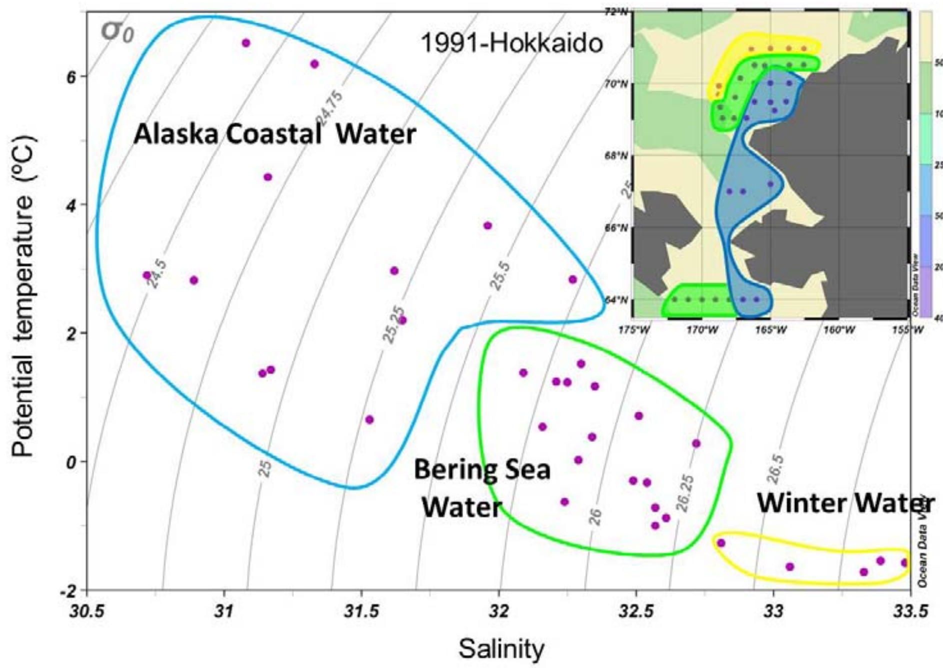


Figure E.3-32 1991-Hokkaido: Water masses delineated by a standard potential density plot and depicted on a map showing station locations. Water mass designations and colors correspond to those in Figure E.3-31.

E.3.10 1992-Hokkaido

There were no significant ($P<0.05$) clusters for fish presence/absence at stations on this cruise (Figures E.3-33 and E.3-34). There were no significant ($P>0.05$) relationships between fish presence and physical factors (Table II-3 of this report), and therefore no MDS plot is presented.

Cluster analysis of bottom temperatures and salinities resulted in three significantly ($P<0.01$) different groups (Figure E.3-35). Alaskan Coastal Water had temperatures of 4.0–5.2º C and salinities 31.0–31.7 (Figure E.3-36). The ACW was distributed along the coast from Point Hope to Point Lay. Bering Sea Water temperatures were cooler, 2.0–3.5º C, with salinities 31.9–32.8. The BSW was broadly distributed in the southern part of the sample range. Winter Water was found at the northern part of the sample range. Winter Water was composed of three separate clusters that had very cold temperatures, -1.7–0.1º C, and a narrower range of salinities, 31.6–32.6. These values yielded characteristic ranges of densities for BSW and WW and a narrow range for ACW (Table II-2 of this report).

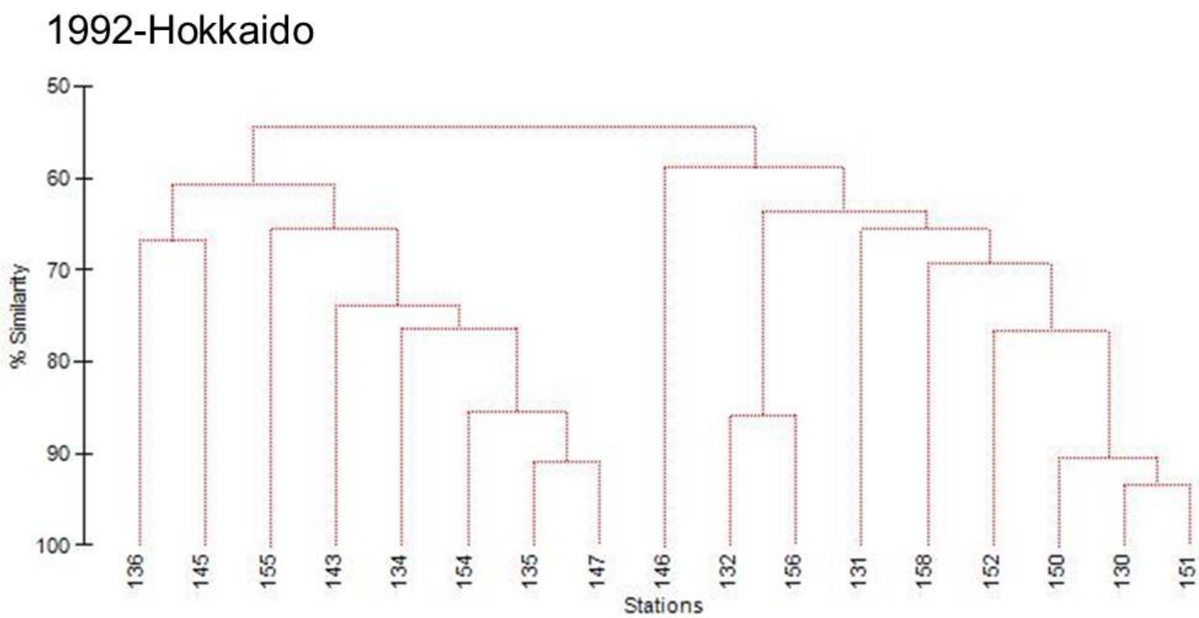


Figure E.3-33 1992-Hokkaido: Dendrogram of hierarchical clustering of stations with similar species composition. No station groups significantly differed from others.

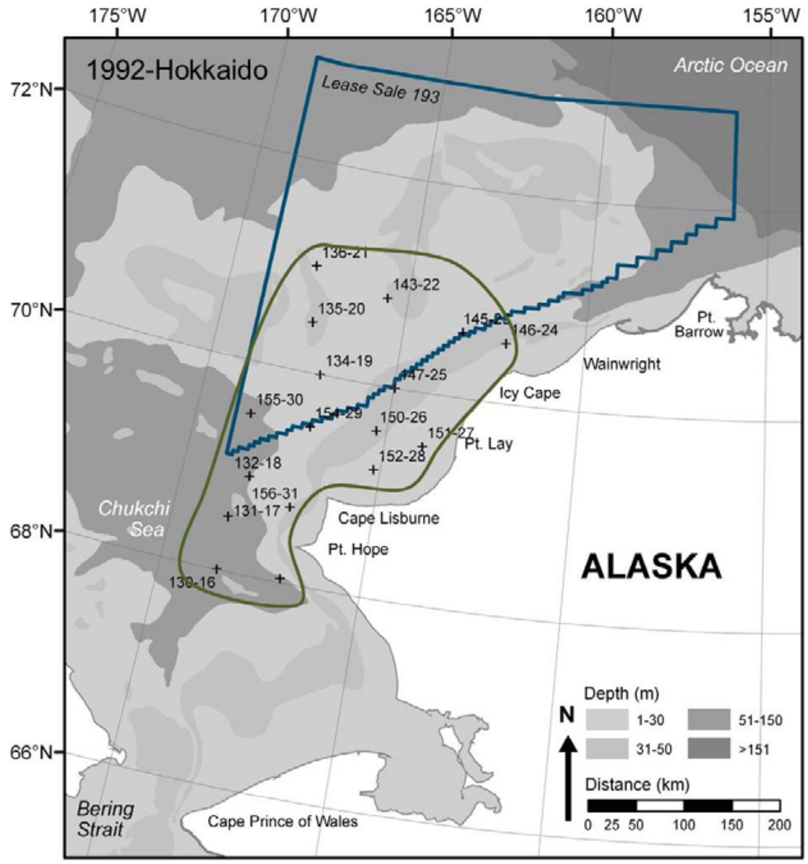


Figure E.3-34 1992-Hokkaido: Map depicting location of fishing stations, for which no stations were significantly different as determined in Figure E.3-33.

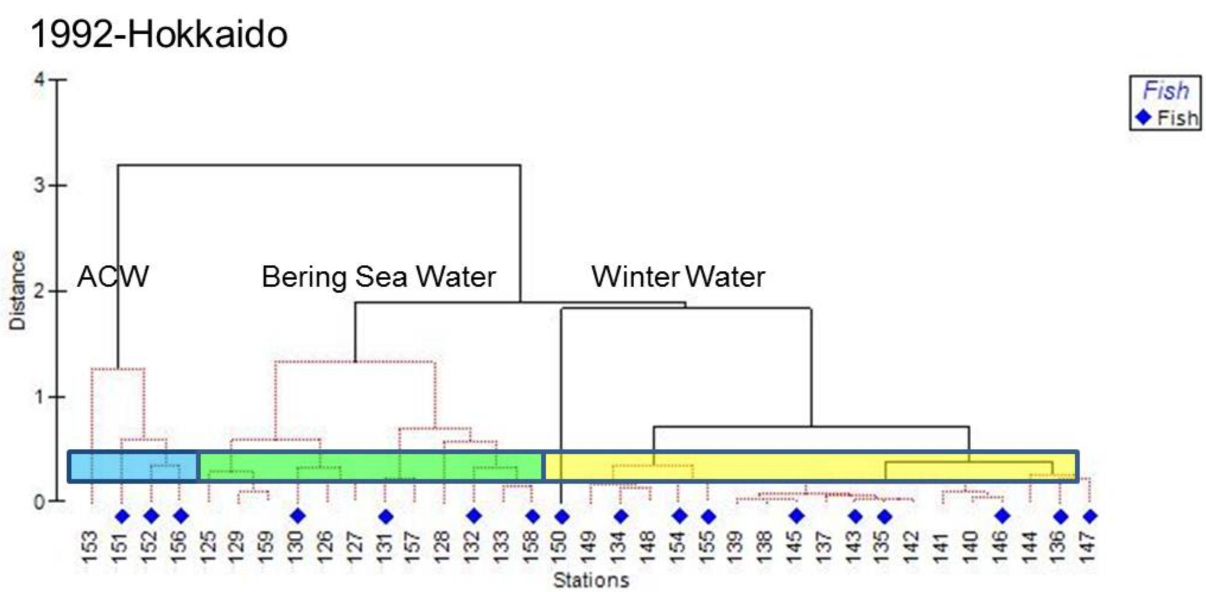


Figure E.3-35 1992-Hokkaido: Dendrogram of hierarchical clustering of stations with similar water mass properties. Black indicates statistically significant (*P*<0.01) clusters. Fishing stations are indicated by blue diamonds. Water masses were assigned based on these clusters and the standard potential density plot (Figure E.3-36). ACW = Alaska Coastal Water.

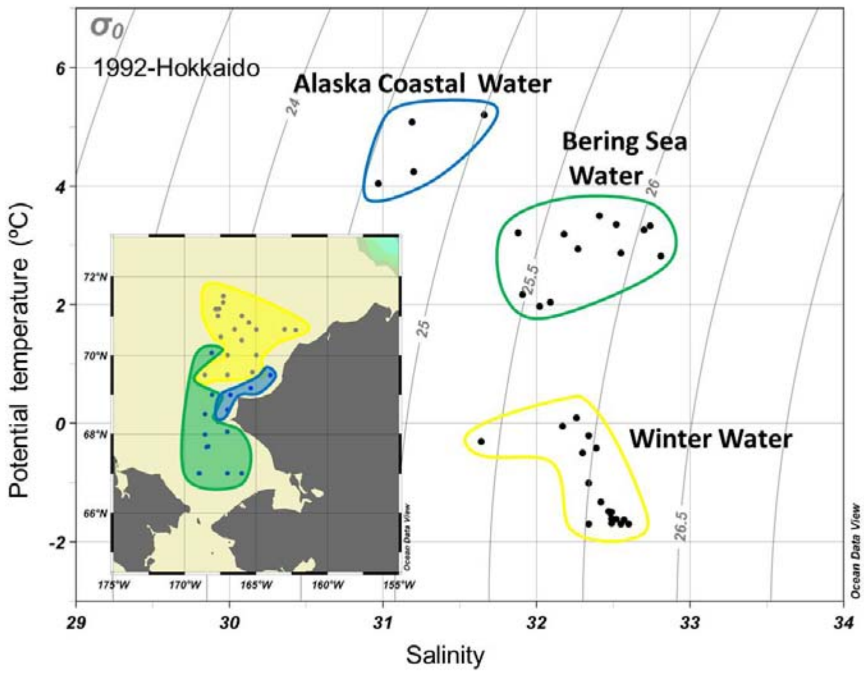


Figure E.3-36 1992-Hokkaido: Water masses delineated by a standard potential density plot and depicted on a map showing station locations. Water mass designations and colors correspond to those in Figure E.3-35.

E.3.11 2004-Mecklenburg and 2004-Norcross

On the RUSALCA-2004 cruise (Russian-American Long-term Census of the Arctic), fishes were captured with the same type of plumb staff beam trawl (Norcross et al., 2010) that was used in recent trawls in 2007 and 2008, i.e., 2004-Norcross and with a larger otter trawl, i.e., 2004-Mecklenburg (Mecklenburg et al., 2007). Cluster analysis of fish presence/absence from these two gears within the eastern Chukchi Sea yielded two significantly different fish-station groups (P<0.01; Figure E.3-37: upper panel). Cluster analysis of fish abundance using the plumb staff beam trawl during 2004-Norcross placed yielded the same pattern, although station 15 was omitted since CPUE was not calculated there (P <0.01; Figure E.3-37: lower panel). Clusters 2004-A and 2004-abund-A were made up of two stations in the south and nearshore (Figure E.3-38). Three stations north and offshore formed Cluster 2004-B; the two furthest north stations at which quantitative plumb staff beam trawl hauls were collected formed Cluster 2004-abund-B.

Several physical factors were significantly related to the fish species distribution (Table II-3 of this report). There were significant relationships between fish presence and salinity (ANOSIM, R=0. 504, P=0.01), temperature (ANOSIM, R=0. 504, P=0.01), and gravel (ANOSIM, R=0. 609, P=0.01). There was a weak relationship between water mass and fish presence as indicated by the pattern in the MDS plot (Figure E.3-39). No physical parameters were significantly related to fish abundance (Table I-4 of this report).

Cluster analyses of bottom temperatures and salinities from six CTD stations collected in the eastern Chukchi Sea differentiated (P<0.01) two groups (Figure E.3-40). The Alaska Coastal Water was at the stations closest to the Alaska coast. Although no CTD data were collected from station 17 on the Point Hope transect, we included this station in ACW because no other water mass was expected to be entrained at the coast in that location, and because stations to its north and south were grouped under the ACW designation. Temperatures ranges in the ACW were 8.0–10.5º C and salinity ranges were 30.6–31.3. Bering Sea Water had an extensive geographical range in the central Chukchi Sea (Norcross et al., 2010), and within the eastern Chukchi Sea was offshore of the ACW (Figure E.3-41). Bottom temperatures in the BSW were 2.8–4.4º C and salinities were 31.7–32.6. These values yielded a characteristic range of densities for ACW and BSW (Table II-2 of this report).

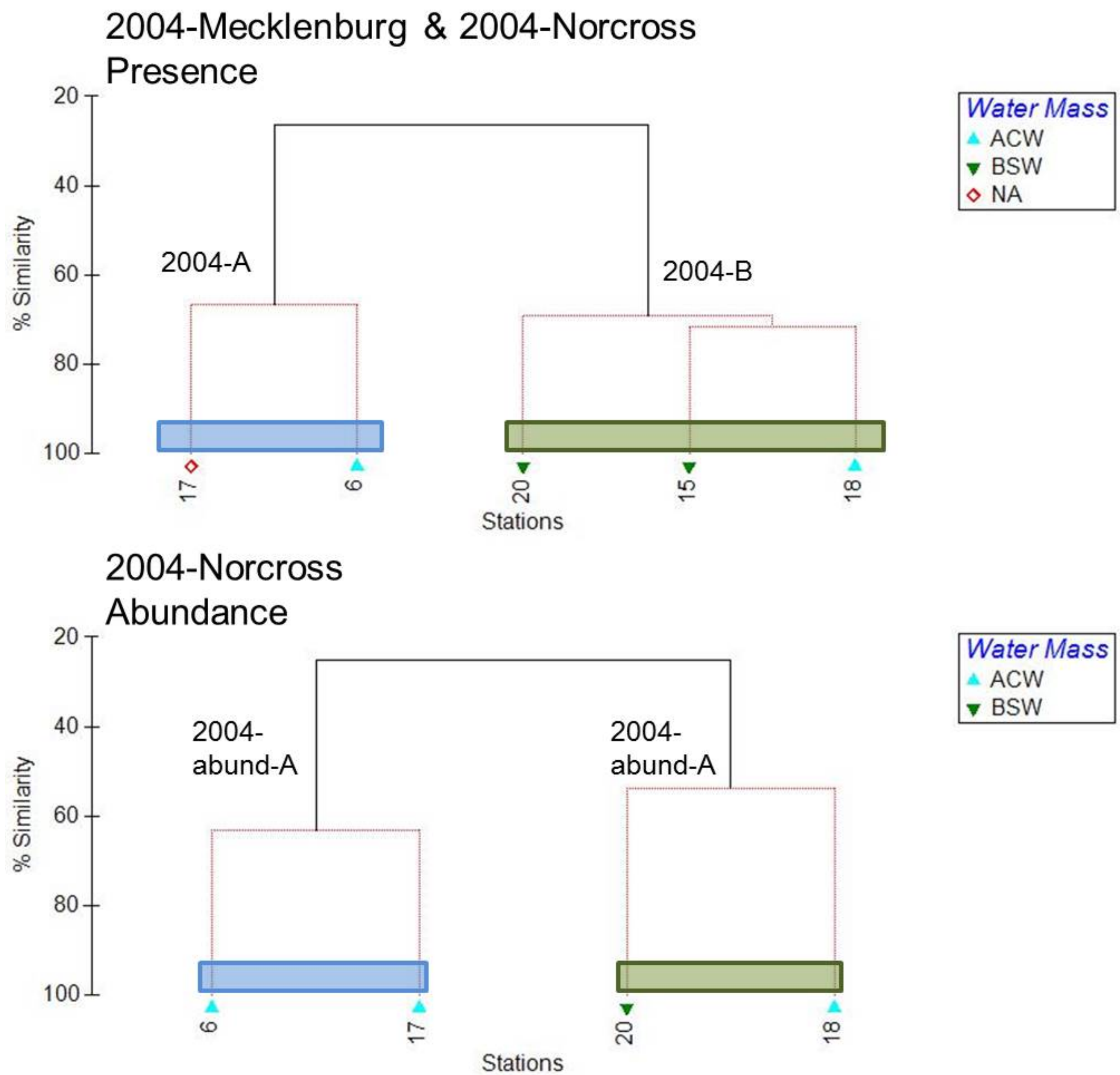


Figure E.3-37 2004-Mecklenburg and 2004-Norcross: Dendrogram of hierarchical clustering of stations in the eastern Chukchi Sea with similar species composition. Upper panel is presence/absence over both cruises. Lower panel is abundance during 2004-Norcross. Black indicates two statistically significant (*P*<0.01) clusters in each panel, and colored blocks designate different station groups.

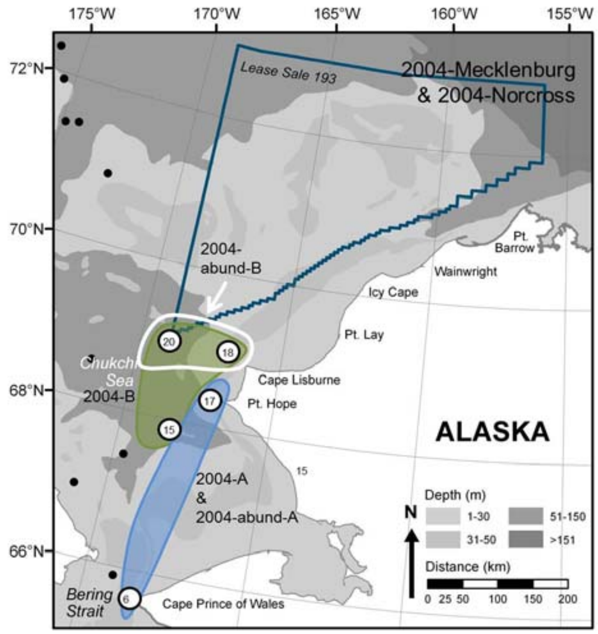


Figure E.3-38 2004-Mecklenburg and 2004-Norcross: Map depicting location of fish-station groups in the eastern Chukchi Sea as determined in Figure E.3 37: upper panel for species presence/absence, and in Figure E.3.37: lower panel for abundance during 2004-Norcross. Clusters 2004-A and 2004-abund-A are identical. Cluster 2004-abund-B is identical to 2004-B, with the exception of Station 15, which was not examined for fish abundance.

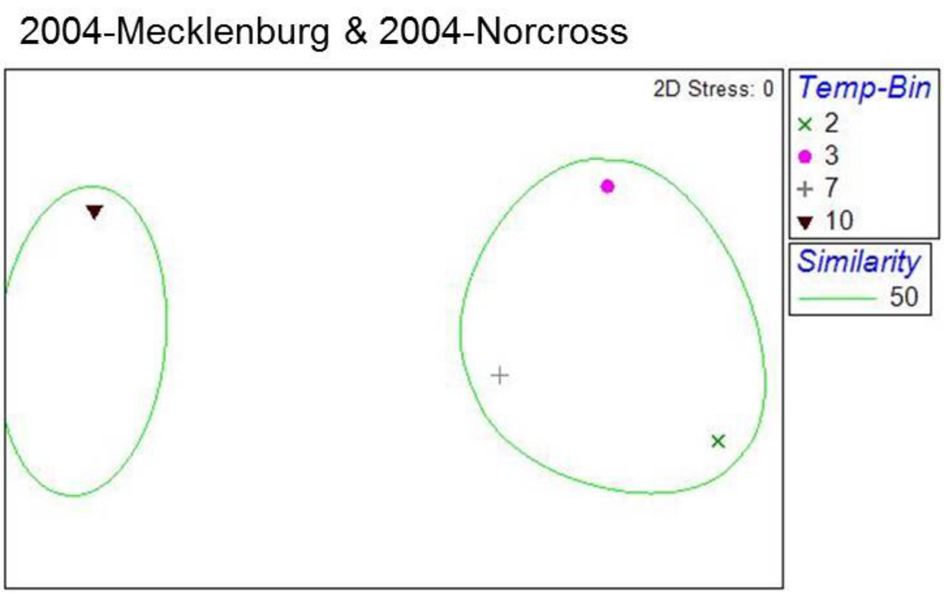


Figure E.3-39 2004-Mecklenburg and 2004-Norcross: Ordination of presence/absence of fish species by MDS. Colored symbols indicate bottom temperature, with which species composition was related.. Ellipses are based on the clusters analysis results (Figure E.3-37) using 50% similarity.

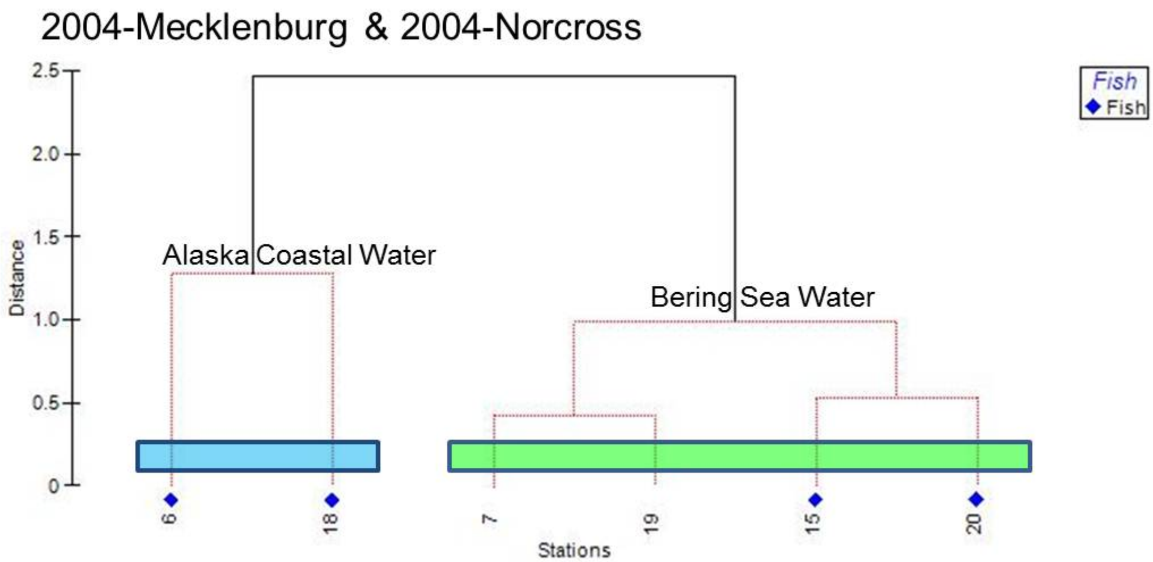


Figure E.3-40 2004-Mecklenburg and 2004-Norcross: Dendrogram of hierarchical clustering of stations with similar water mass properties. Black indicates statistically significant (*P*<0.01) clusters. Fishing stations are indicated by blue diamonds. Water masses were assigned based on these clusters and the standard potential density plot (Figure E.3-41).

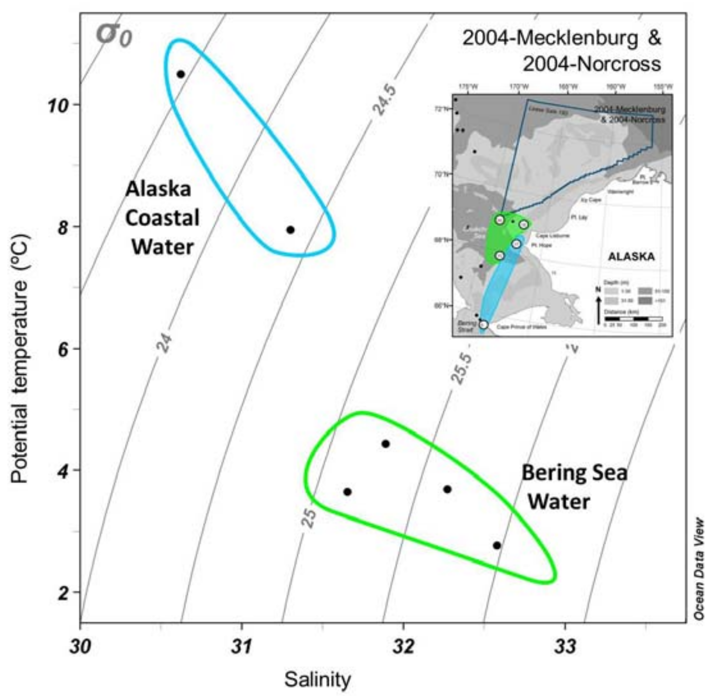


Figure E.3-41 2004-Mecklenburg and 2004-Norcross: Water masses delineated by a standard potential density plot and depicted on a map showing station locations; fishing stations are labeled. Water mass designations and colors correspond to those in Figure E.3-40. Figure is after Norcross et al. (2010).

E.3.12 2007a-Norcross

Sixteen and nine fishing sites were analyzed from cruise 2007a-Norcross for fish presence and abundance, respectively. Cluster analysis yielded three groups for fish presence, and two for fish abundance (*P*<0.05; Figure E.3-42). Station C16, in the southwest part of the Lease Sale area at ~70° N (Figure E.3-43), grouped by itself in both fish cluster analyses as it had species that were not found in the immediately surrounding stations. Fish presence at three stations in the eastern Lease Sale area grouped separately from the remaining stations; of these three stations, only C17 had a quantitative haul, and abundance there was not different from the other stations. There was a weak relationship between mud and fish presence as indicated by the pattern in the MDS plot (Figure E.3-44).

All stations that were sampled were classified as Bering Sea Water (Figure E.3-45). The bottom temperature range of these stations was broad, 0.3–7.6°C. The salinity and density ranges were not unusually wide (31.8–32.9 and 24.8–26.2, respectively (Table II-2). Fish presence was significantly related to the presence of mud (ANOSIM, *P*<0.05, Table II-3), while fish abundance was not significantly related to any measured physical variable (Table I-4).

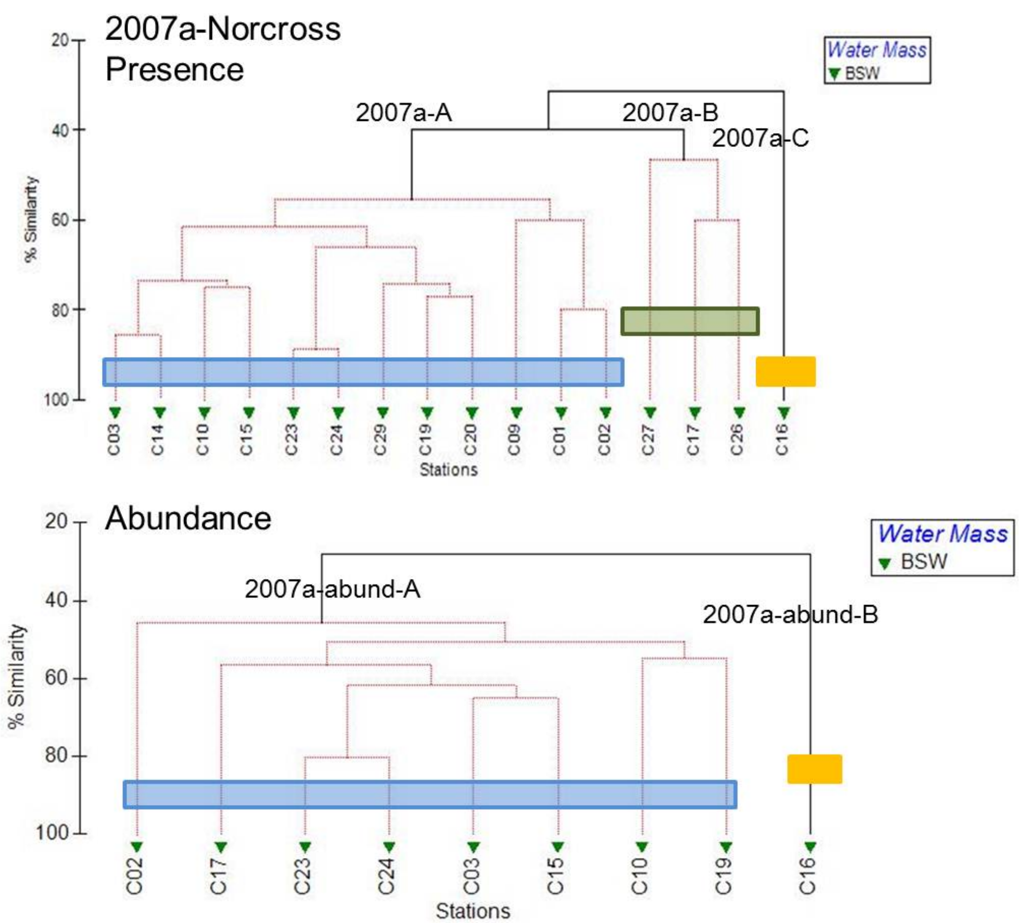
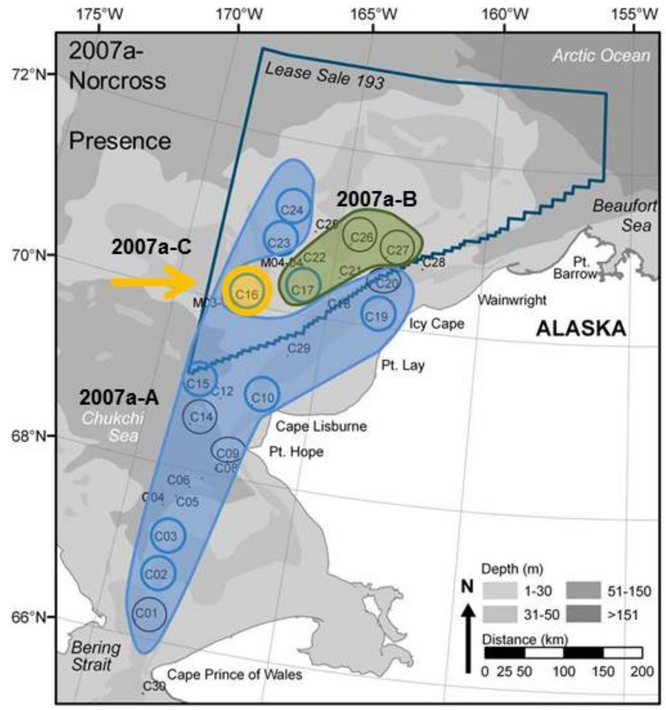


Figure E.3-42 2007a-Norcross: Dendrogram of hierarchical clustering of stations with similar species composition. Upper panel is presence; three station groups were assigned. Lower panel is abundance; two station groups were assigned. In both panels, black lines indicate statistically significant (*P*<0.05) clusters, and colored blocks designate different station groups; colored blocks in upper and lower panels are not equivalent to each other.



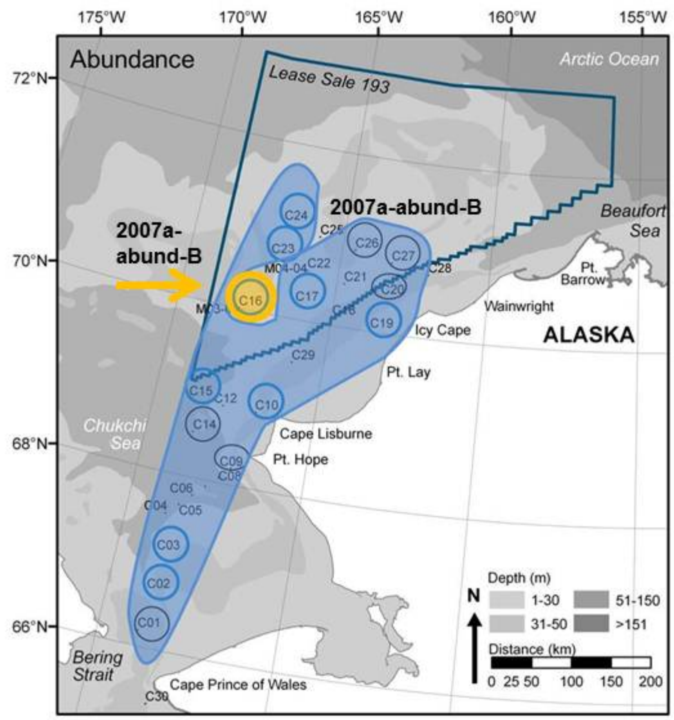


Figure E.3-43 2007a-Norcross: Maps depicting location of presence (upper panel) and abundance (lower panel) fish clusters. The station that was alone in both the presence and the abundance clusters (Figure E.3 42) is circled with orange.

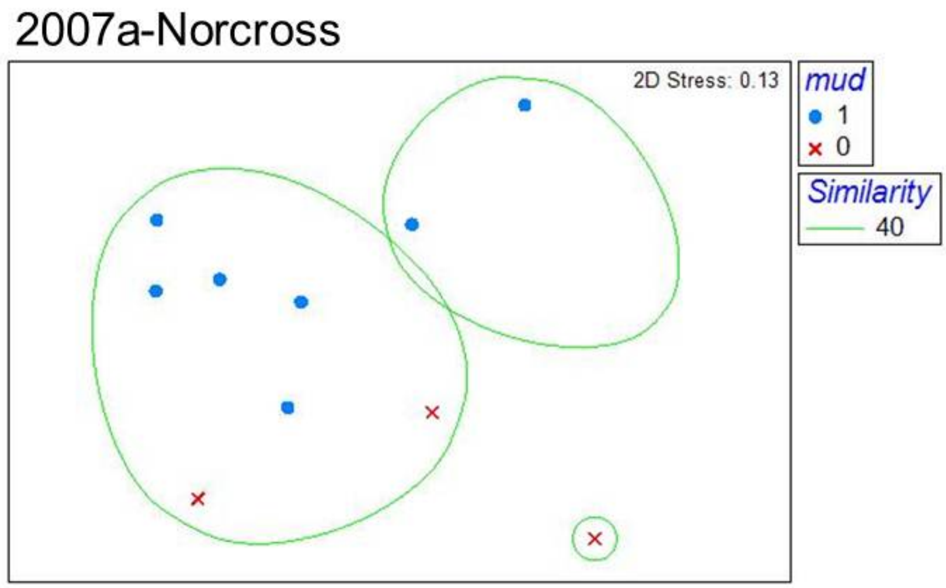


Figure E.3-44 2007a-Norcross: Ordination of presence/absence of fish species by MDS. Colored symbols indicate the presence (blue circle) or absence (red x) of mud. Ellipses are based on the clusters analysis results (Figure E.3-42) using 40% similarity.

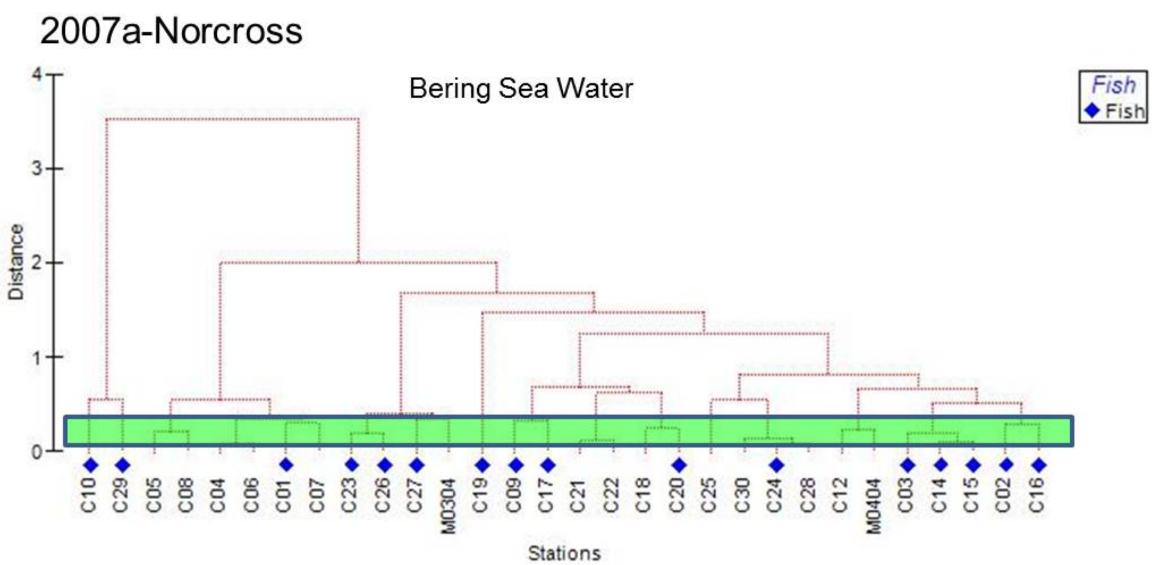


Figure E.3-45 2007a-Norcross: Dendrogram of hierarchical clustering of stations with similar water mass properties. Clusters were not significantly different (*P*<0.05).

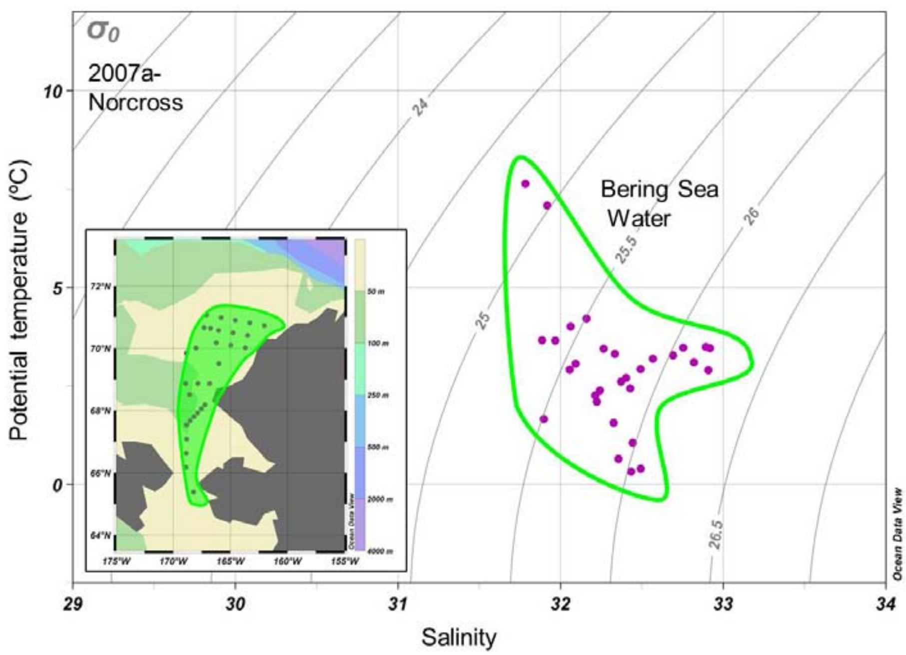


Figure E.3-46 2007a-Norcross: Water mass delineated by a standard potential density plot and depicted on a map showing CTD station locations. Water mass designation and color correspond to those in Figure E.3-45.

E.3.13 2007b-Norcross

Fish communities were examined at 21 stations during cruise 2007b-Norcross. Cluster analysis yielded significantly different groups for both species presence and species abundance (P<0.05). There were three groups of stations based on species presence (Figure E.3-47: upper panel). Station 33 grouped separately from other stations and was assigned as Cluster 2007b-C; it was located at approximately 68°N in BSW (Figure E.3-48: upper panel). Cluster 2007b-A was made up of two stations near Bering Strait and two stations north of Cape Lisburne; the northernmost of these was in BSW while the others were in ACW. The majority of stations were grouped as Cluster 2007b-B, including both nearshore and offshore stations north of 66.5°N. There were no significant (P>0.05) relationships between fish presence and physical factors (Table II-3 of this report), and no MDS plot is presented.

Fish abundance was assessed at 20 stations, and five significantly different station groups were formed based on species abundance (P<0.05; Figure E.3-47: bottom panel). The two stations in Bering Strait were assigned as 2007b-abund-A (Figure E.3-48: bottom panel). Cluster 2007b-abund-B was the single most northwestern station, while Cluster 2007b-abund-C was offshore in the southern Chukchi Sea. Cluster 2007b-abund-D was offshore of Cluster 2007b-abund-E and north of 65.5°N. Cluster 2007b-abund-E was more nearshore stations in southern Kotzebue Sound and in Ledyard Bay off of Cape Lisburne and Pt. Lay. Seven of these 8 nearshore stations were in the ACW. Species abundance was significantly related (P<0.05) to depth, bottom temperature and water mass (Table I-4 of this report). A weak relationship between water mass and fish abundance is indicated by the pattern in the MDS plot (Figure E.3-49).

Cluster analysis of bottom temperatures and salinities resulted in three significantly (P<0.01) different groups (Figure E.3-50). Alaska Coastal Water was classified by combining station 35, a statistically different, warm, fresh station with a large group of stations. The ACW had temperatures of 4.6–10.7°C and salinities 30.9–32.3 (Figure E.3-51). The ACW was divided into two coastal components above and below Point Hope. Bering Sea Water temperatures were cooler, -0.5–5.0°C, with salinities 32.2–33.0. The BSW was broadly distributed offshore. These values yielded a characteristic range of densities for BSW and a wider range for ACW (Table II-2 of this report).

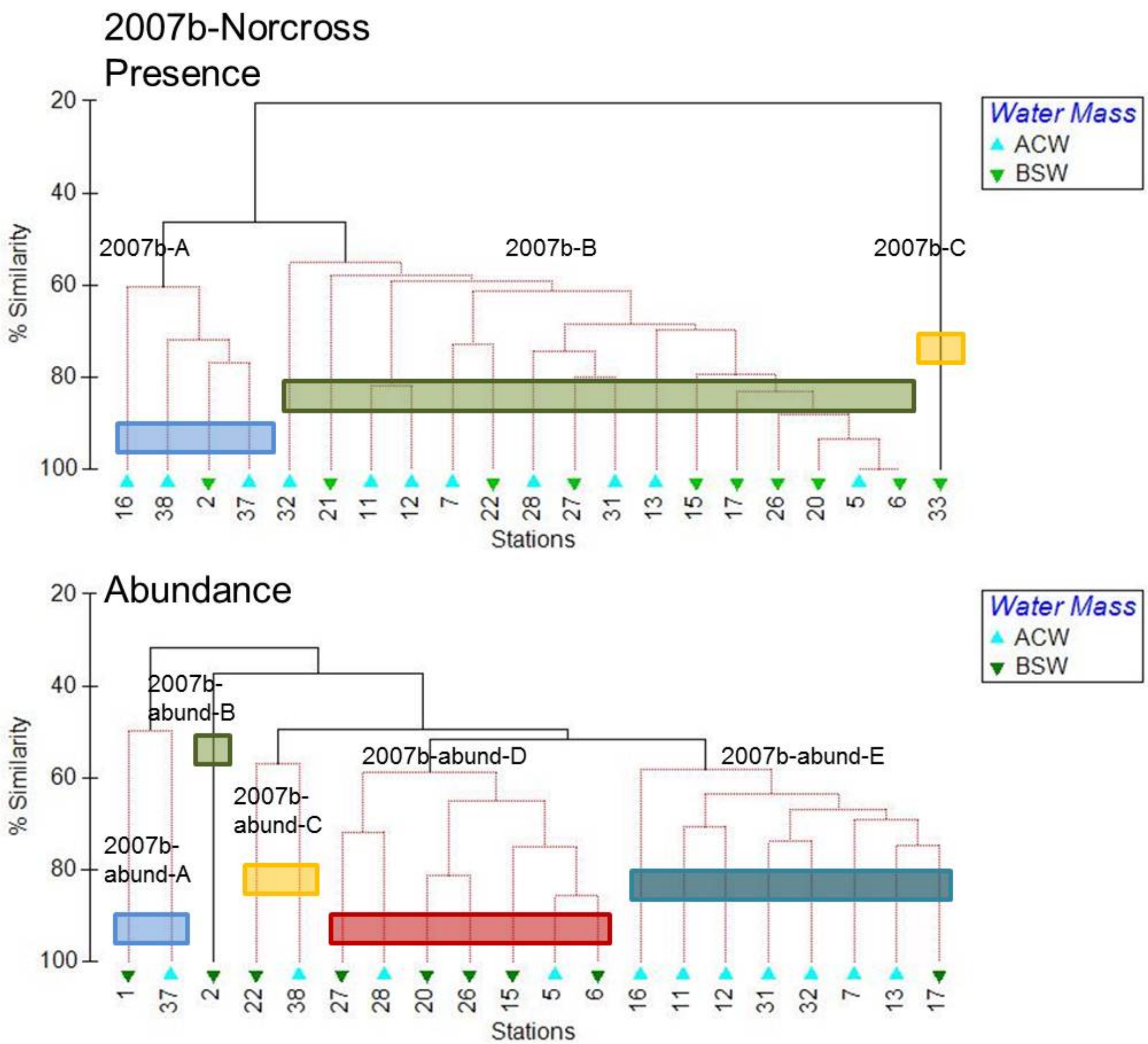


Figure E.3-47 2007b-Norcross: Dendrogram of hierarchical clustering of stations with similar species composition. The higher panel is presence, and three station groups were assigned. The lower panel is abundance, and five station groups are designated. In both panels, black lines indicate statistically significant (*P*<0.05) clusters, and colored blocks designate different station groups as depicted on the map in Figure E.3-48; colored blocks in upper and lower panels are not equivalent to each other.

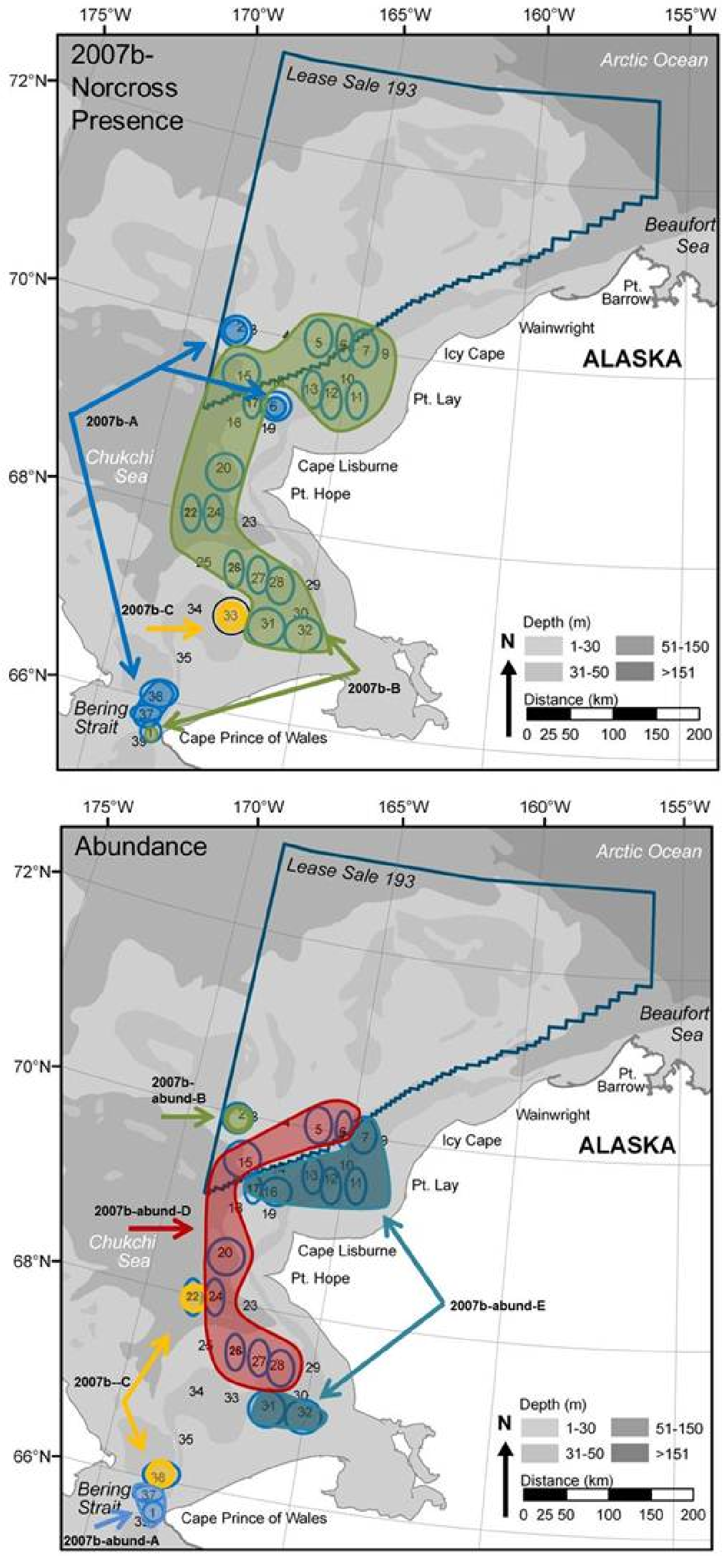


Figure E.3-48 2007b-Norcross: Maps depicting location of presence (upper panel) and abundance (lower panel) fish clusters. Clusters and colors correspond to those in Figure E.3-47; colored blocks in upper and lower panels are not equivalent to each other.

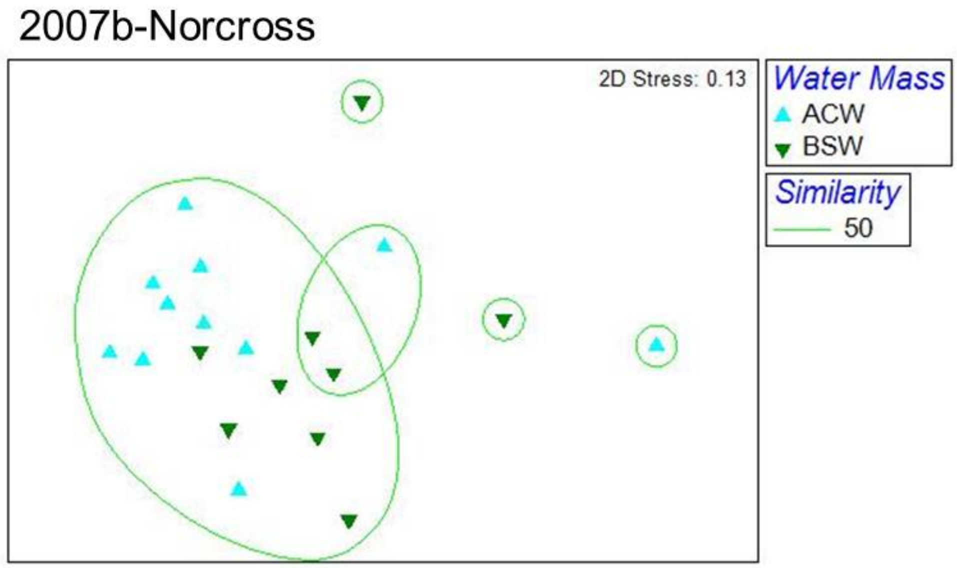


Figure E.3-49 2007b-Norcross: Ordination of fish abundance by MDS. Colored symbols indicate water mass, with which the fish species groups were related. Ellipses are based on the clusters analysis results (Figure E.3-47: lower panel) using 50% similarity.

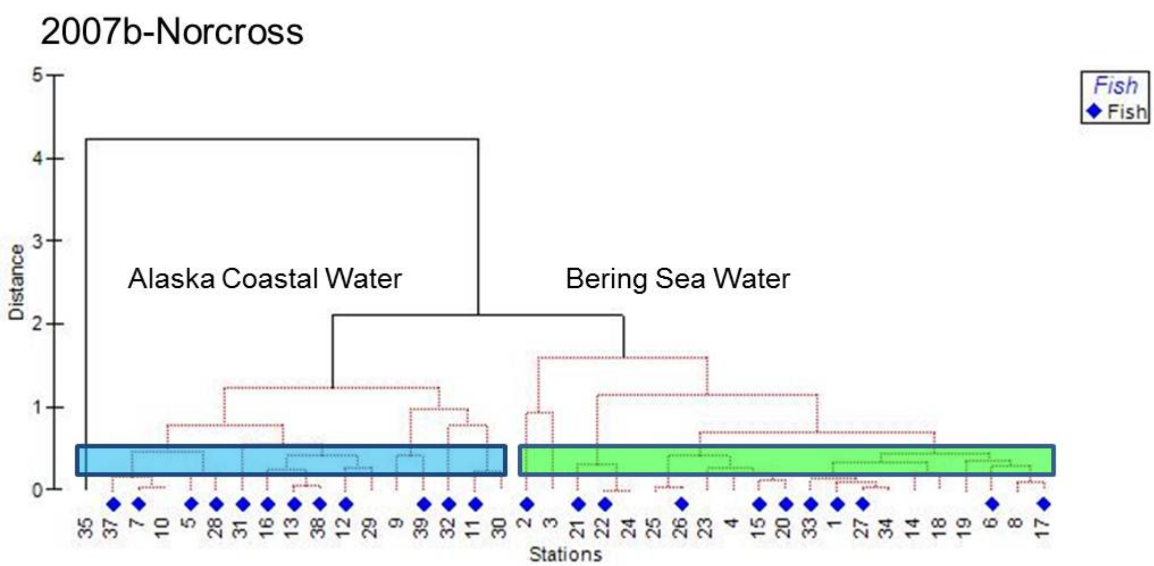


Figure E.3-50 2007b-Norcross: Dendrogram of hierarchical clustering of stations with similar water mass properties. Black indicates significantly different (*P*<0.01) clusters. Fishing stations are indicated by blue diamonds. Water masses were assigned based on these clusters and the standard potential density plot (Figure E.3-51).

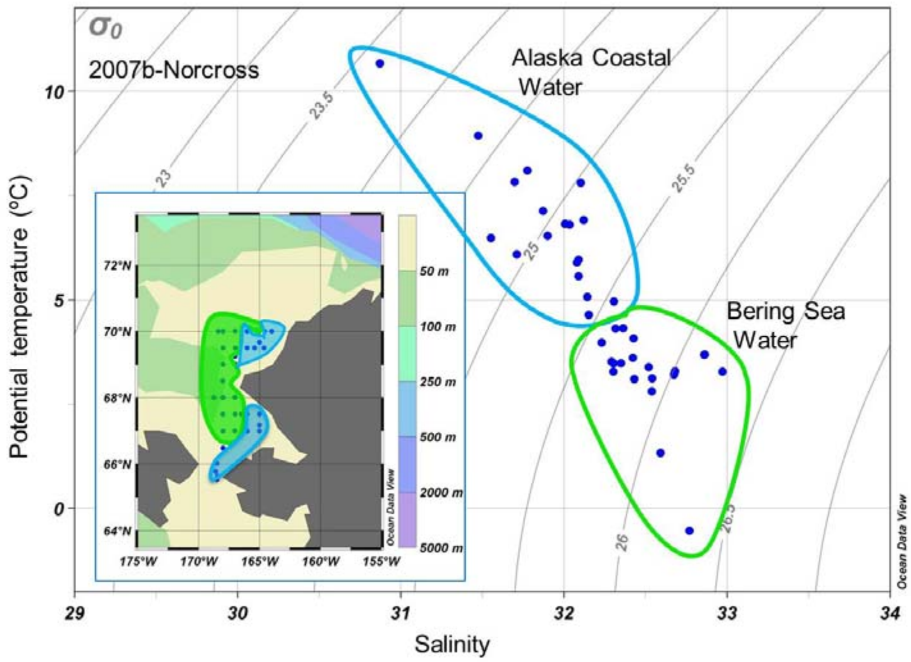


Figure E.3-51 2007b-Norcross: Water masses delineated by a standard potential density plot and depicted on a map showing station locations. Water mass designations and colors correspond to those in Figure E.3-50.

E.3.14 2008-Norcross

Fish communities were examined at 16 stations with species presence and 15 stations with species abundance during cruise 2008-Norcross. Cluster analysis detected no significant station groupings for species presence, and detected two groups for fish abundances ($P<0.05$; Figure E.3-52). Three stations offshore of Cape Lisburne and near the southern boundary of Lease Sale 193 grouped separately from other stations and were assigned as Cluster 2008-abund-A (Figure E.3-53). The remaining stations, both south and north of those three stations formed a separate group, Cluster 2008-abund-B. There were significant ($P<0.05$) relationships between presence of fish species and presence of rock or sand, and a stronger relationship ($P<0.01$) between presence of fish and presence of sand (Table II-3 of this report). No MDS plot is presented for fish presence since no groups were detected by cluster analysis. Bottom temperature was related to fish abundance ($P<0.05$; Table I-4 of this report). A weak relationship between bottom water temperature and fish abundance groups is indicated by the pattern in the MDS plot (Figure E.3-54).

Cluster analysis of bottom temperatures and salinities averaged resulted in three significantly different groups ($P<0.01$; Figure E.3-55). No ACW was identified. Bering Sea Water had a narrow range of cool temperatures, -0.7–3.2°C, and a narrow range of salinity, 31.9–32.9 (Figure E.3-56). The BSW was found at all the southern stations and was inshore of WW north of 69°N. Winter Water was classified by combining two statistically different groups. Winter Water occupied the northern-most stations. Compared with BSW, the WW had colder temperatures, -1.7 to -0.6°C, and slightly higher salinities, 32.5–33.4. These values were characteristic of densities for both BSW and WW (Table II-2 of this report).

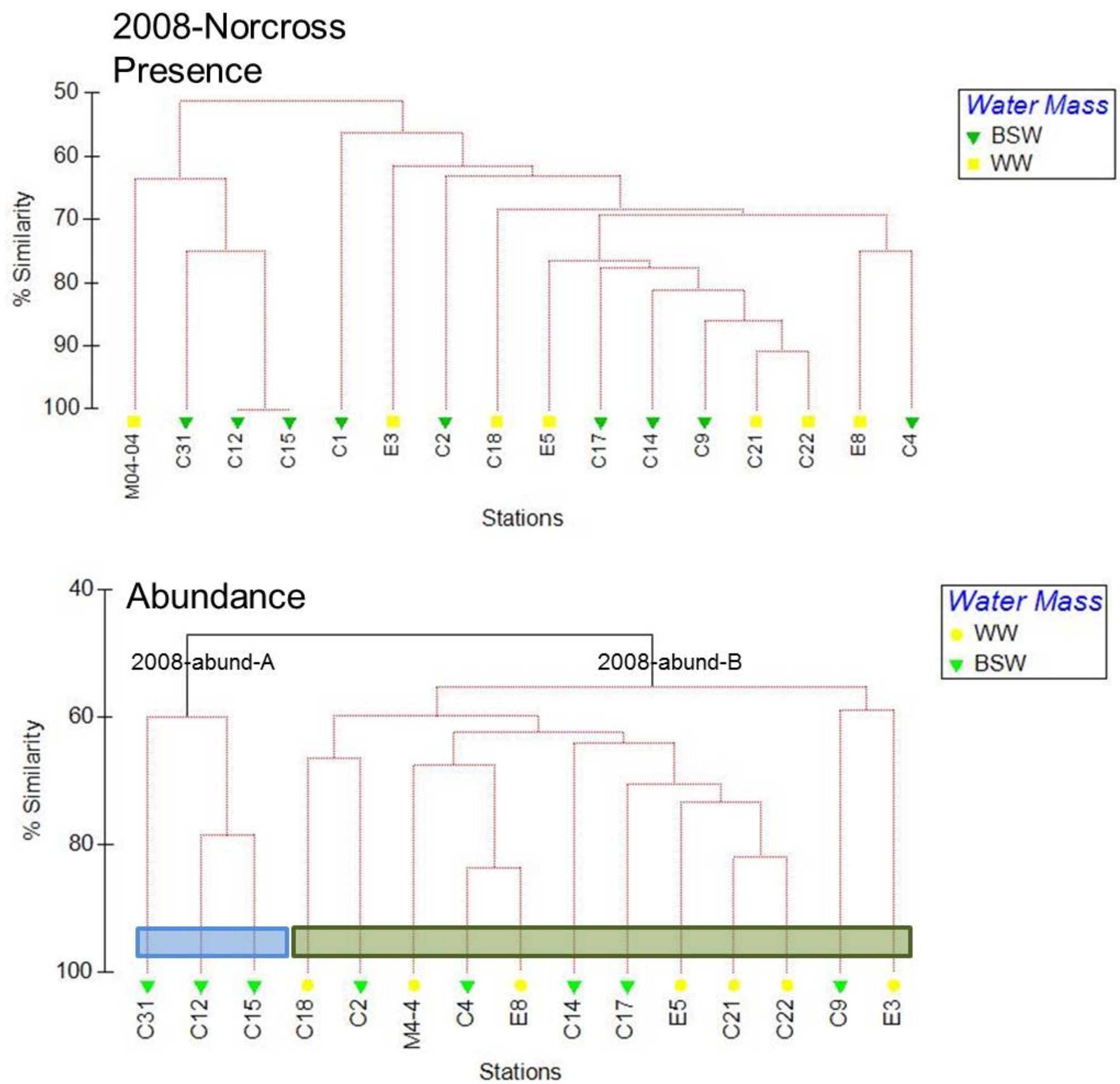


Figure E.3-52 2008-Norcross: Dendrogram of hierarchical clustering of stations with similar species composition. The upper panel is presence, and all stations were in one group. The lower panel is abundance, and two station groups are designated. In the lower panel, black lines indicate significantly different (*P*<0.05) clusters, and colored blocks designate different station groups, which are depicted on the map in Figure E.3-53.

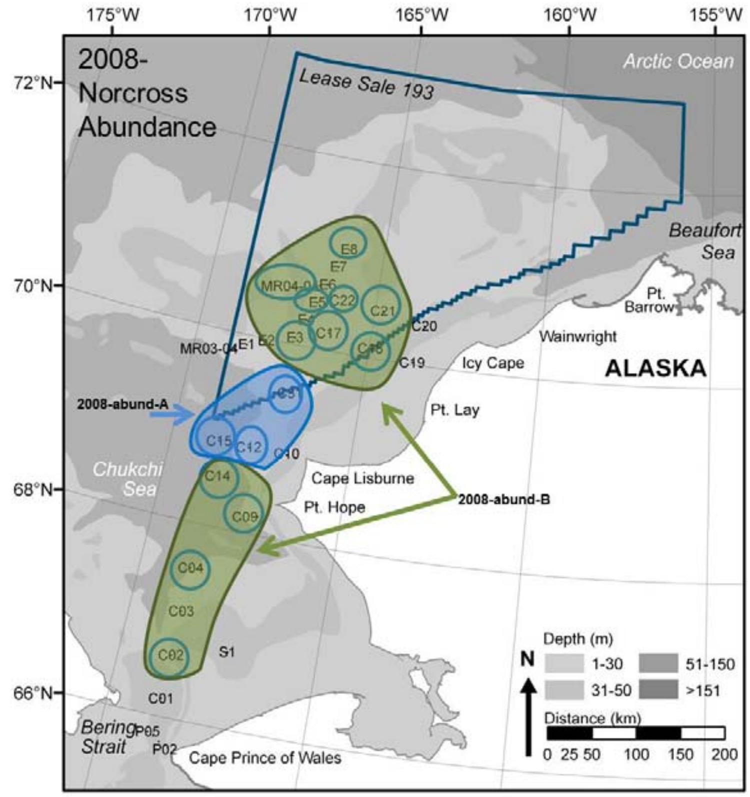


Figure E.3-53 2008-Norcross: Maps depicting location of abundance fish clusters. Colors correspond to those in Figure E.3-52.

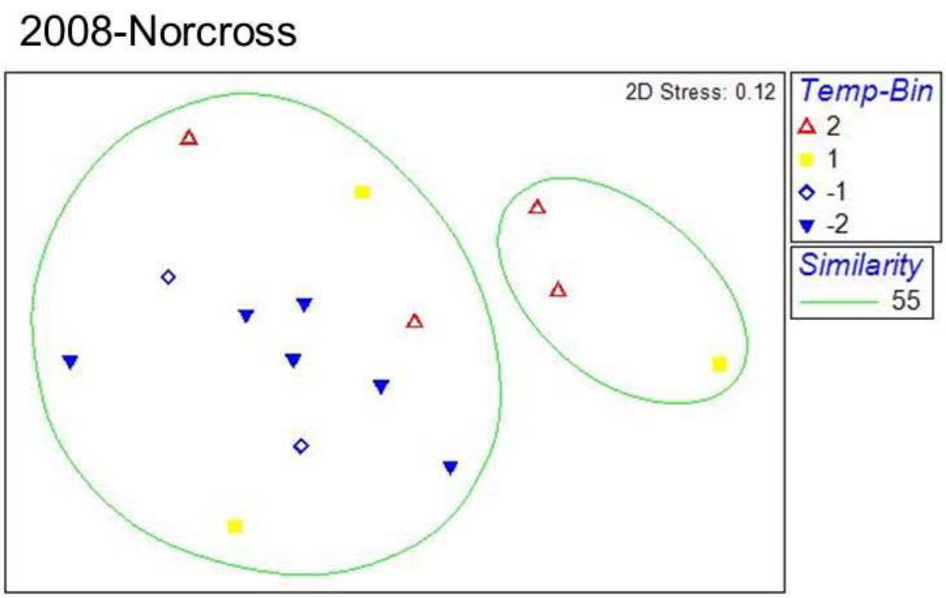


Figure E.3-54 2008-Norcross: Ordination of fish abundance by MDS. Colored symbols indicate 1°C bins of bottom temperature, with which the fish abundance was related. Ellipses are based on the clusters analysis results (Figure E.3-52: lower panel) using 55% similarity.

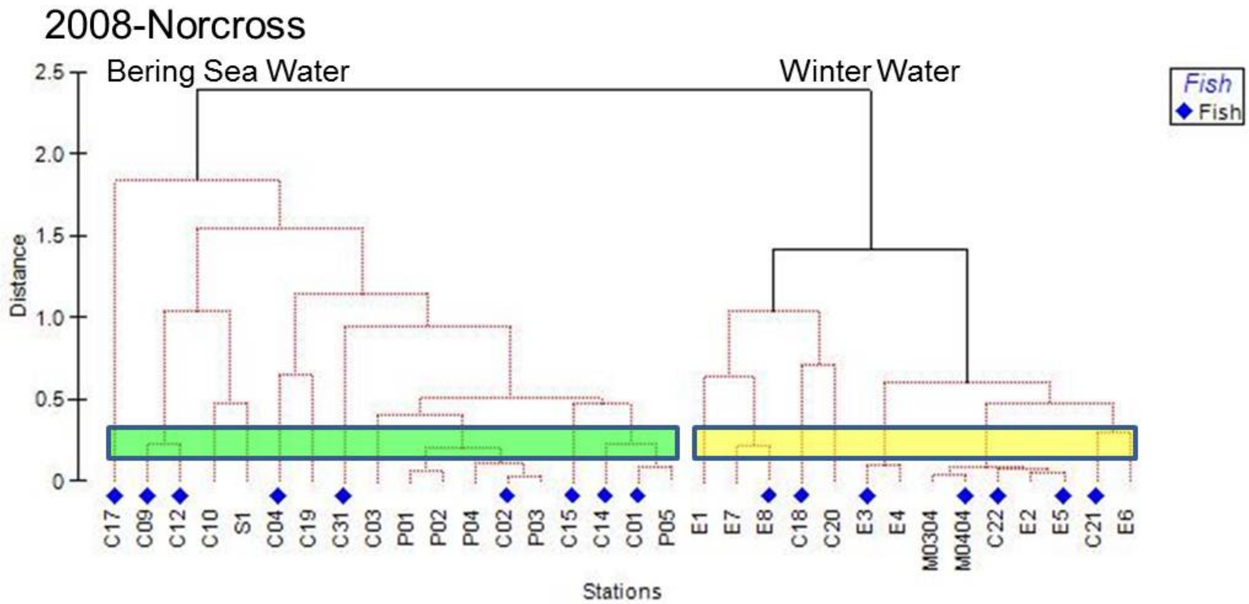


Figure E.3-55 2008-Norcross: Dendrogram of hierarchical clustering of stations with similar water mass characteristics. Black lines indicate significantly different clusters (*P*<0.01). Water masses were assigned based on these clusters and the standard potential density plot (Figure E.3-55).

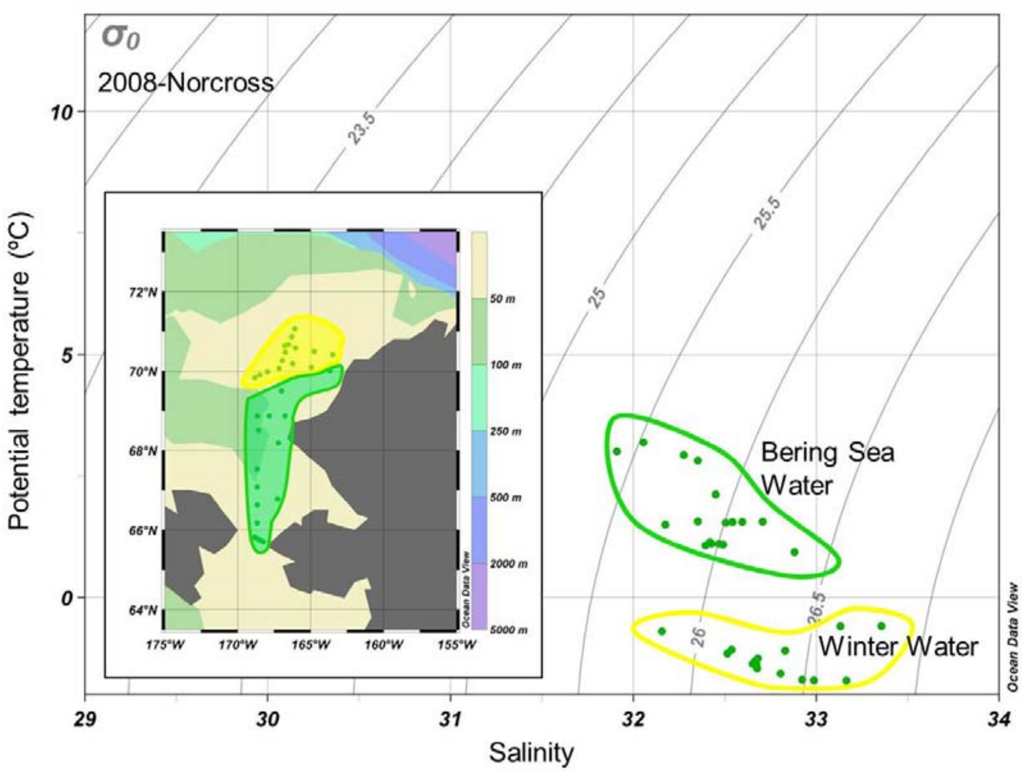


Figure E.3-56 2008-Norcross: Water masses delineated by a standard potential density plot and depicted on a map showing station locations. Water mass designations and colors correspond to those in Figure E.3-54.

E.4 Literature cited in Appendix E

Clarke, K. R., and R. N. Gorley. 2006. PRIMER v6: User Manual/Tutorial. PRIMER-E Ltd., Plymouth.

Clarke, K. R., P. J. Somerfield, and R. N. Gorley. 2008. Testing of null hypotheses in exploratory community analyses: similarity profiles and biota-environment linkage. Journal of Experimental Marine Biology and Ecology 366:56–69.

Kruskal, J. 1964. Nonmetric multidimensional scaling: a numerical method. Psychometrika 29(2):115–129.

Norcross, B. L., B. A. Holladay, M. S. Busby, and K. L. Mier. 2010. Demersal and larval fish assemblages in the Chukchi Sea. Deep Sea Research Part II: Topical Studies in Oceanography 57(1–2):57–70.

Pickart, R. S., L. J. Pratt, D. J. Torres, T. E. Whitledge, A. Y. Proshutinsky, K. Aagaard, T. A. Agnew, G. Moore, and H. J. Dail. 2010. Evolution and dynamics of the flow through Herald Canyon in the western Chukchi Sea. Deep Sea Research Part II: Topical Studies in Oceanography 57(1–2):5–26.

Somerfield, P.J., F. Olsgard, and M. R. Carr. 1997. A further examination of two new taxonomic distinctness measures. Marine Ecology Progress Series 154:303–306.

Weingartner, T. J. 1997. A review of the physical oceanography of the Northeastern Chukchi Sea. Pages 40–59 in: Reynolds, J. (editor), Fish ecology in Arctic North America. American Fisheries Society Symposium 19, Bethesda, MD.

Weingartner, T., K. Aagaard, R. Woodgate, S. Danielson, Y. Sasakic, and D. Cavalier. 2005. Circulation on the north central Chukchi Sea shelf. Deep-Sea Research II 52:3150–3174.

Winsor, P., and D. Chapman. 2004. Pathways of Pacific water across the Chukchi Sea: A numerical model study. Journal of Geophysical Research 109, C03002.

Wolotira Jr., R. J., T. M. Sample, and M. Morin Jr. 1977. Demersal fish and shellfish resources of Norton Sound, the Southeastern Chukchi Sea, and adjacent waters in the baseline year 1976. Northwest and Alaska Fisheries Center Processed Report October 1977. USDOC/NOAA/NMFS/NWAFC, Seattle WA. 292 p.

The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the sound use of our land and water resources, protecting our fish, wildlife and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island communities.

The Bureau of Ocean Energy Management

The Bureau of Ocean Energy Management (BOEM) works to manage the exploration and development of the nation's offshore resources in a way that appropriately balances economic development, energy independence, and environmental protection through oil and gas leases, renewable energy development and environmental reviews and studies.