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2011 Fish and Invertebrate Trawl Surveys in the Chukchi Sea Environmental Studies Program

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EXECUTIVE SUMMARY

We conducted a survey of fish and invertebrate resources in the northeastern Chukchi Sea from 24–31 August 2011 as part of the Chukchi Sea Environmental Studies Program (CSESP). The survey deployed pelagic and bottom trawls within a study area ~11,000 NM^2 in area, with higher sampling effort focused on three study-area boxes (Klondike, Burger, and Statoil) located within the Greater Hanna Shoal Study Area. The study area and oil lease blocks covered a region measuring ~200 NM southwest (offshore of Point Lay) to northeast (offshore of Pt. Barrow) and ~75 NM wide. A 60-ft steel trawler (F/V *Pandalus*) conducted pelagic trawling at 19 stations on 24–28 August, followed by bottom trawling at 19 stations on 29–31 August. Tow durations for the bottom- and pelagic-survey trawl gear were ~15 min and ~30 min, respectively.

The highest biomass estimates for the three most abundant species (snow crab *Chionoecetes opilio*, Arctic lyre crab *Hyas coarcticus*, and Arctic cod *Boreogadus saida*) caught in the bottom trawl (excluding brittle stars and other sea star species) were low ranging from about 2,000 to 65,000 metric tons (t) (0.5–17.5 kg/ha) within the study area. The density of fish and invertebrates was higher in the southwestern and central parts of the study area than in the northeastern part of the study area. Pelagic trawl catches were less diverse than were bottom trawl catches and indicated that the density of three small pelagic species – Arctic cod, Pacific sandlance, and capelin - was low, ranging from 0 to ~3,000 individuals/tow. The biomass from pelagic trawl tows was dominated by large jellyfishes. Catches from the bottom trawl showed lower densities of Arctic cod but more variety of demersal fish species, including sculpins, eelpouts, snailfishes, and wolffish. Of a few known Arctic flatfish species present in the area, only a few individuals of Bering flounder (*Hippoglossoides robustus*) were captured. Invertebrate catches from the bottom trawl were diverse and contained five shrimp species and three crab species. High densities of snow crab, especially in the southwestern part of the study area, were the only significant catches from the bottom trawl with current potential commercial value.

Estimates of total abundance and biomass of fish species encountered in the 2011 fish surveys were low. For invertebrates, jellyfishes, brittle stars, and other sea star species were prolific in catches but are excluded from reporting, with more focus on other invertebrate species. The catch rates of key species in the 2011 CSESP fish surveys are similar to or lower than other surveys conducted in or near the northeastern Chukchi Sea study area and are considerably lower than catch rates for surveys in adjacent areas (Arctic Ocean, northern Bering Sea). In addition, species diversity appears to be low, and individuals in catch were small and below normal sizes for commercial exploitation.

This report summarizes all survey activities and data collected from both trawl gears and includes details of total catch, CPUE, abundance and biomass estimates, species diversity, comparisons within the study area, and comparisons with other Chukchi Sea and adjacent arctic surveys.

INTRODUCTION

Recent sales of oil and natural gas (ONG) resource lease-sites in the Arctic have spurred exploration, research, and interest to access those resources. The development of infrastructure, drilling, and production is pending in the northeastern Chukchi Sea. The Chukchi Sea Environmental Studies Program (CSESP) has studied the ecology of the oil lease areas of interest since 2008, including fisheries surveys with benthic, pelagic, and acoustic collection methods. Natural Resources Consultants, Inc. (NRC) was contracted to conduct additional trawl surveys in 2011 in the general CSESP study area to assess the relative abundance of fish and invertebrate resources in oil and gas lease areas in the northeastern Chukchi Sea. These 2011 surveys were intended to build on prior research and to help clarify estimates of relative abundance and biomass, species composition, and biological information on marine fish and invertebrate communities within the study area. The NRC trawl survey methodology, equipment used, analyses, and reporting follows the established National Oceanographic and Atmospheric Administration (NOAA) procedures for conducting fish and invertebrate stock assessments on the U.S. West Coast and in Alaska.

Standardized surveys of marine resources follow systematic methods and procedures that include, among other things, extensive planning, defined research priorities and objectives, consistent sampling gear and data collection protocols, and data-summary methods – and importantly, funding for surveys that endure beyond one field season or collection year (Stauffer 2004). The CSESP fish surveys have been conducted since 2009 with a variety of collection gears and methods, and the scope of survey catches have proven to be very valuable to the overall Program objectives. Gear changes for these surveys, however, have highlighted some challenges to understanding trends in the data collected and have proven to influence results (Galloway et al. 2011). For this reason, methods described below in this report will include some details to understand the repeatability of the 2011 survey results and to facilitate the synthesis of results from NRC surveys with those of other surveys already conducted by the Program. Additionally, some relative comparisons within CSESP fish survey results (including NRC results) and with other arctic and northern Bering Sea survey results will be covered in the discussion. Lastly, the Results and Discussion of this report address accomplishing the survey objectives of the 2011 NRC trawl surveys as part of the CSESP fish surveys.

The objectives of this study are:

- To conduct fish and invertebrate trawl surveys within the study area using appropriate sampling gear and survey platform

- To sample fish and invertebrate species from the water column and near-bottom environment with pelagic and benthic survey trawls so that we can describe species-composition and standardized survey catches (CPUE) within the study area

- To estimate relative abundance and biomass by species at each trawl survey station and for the entire study area

- To analyze relationships between fish and invertebrate abundance in the trawl surveys and other environmental data recorded within the study area

METHODS

The following section describes the methods employed to conduct the NRC trawl surveys. As mentioned, these methods are based on the standardized NOAA/NMFS groundfish and crab trawl and pelagic resources survey procedures used on the U.S. West Coast and in Alaska for fish and crab stock assessment and on current cooperative research (NOAA/NMFS-industry) crab survey efforts in southeastern Bering Sea trawl surveys (Stauffer 2004, Hughes and Goodman 2008).

Trawl Survey Area and Sampling Density

The study area was defined around three study-area boxes (Klondike, Burger and Statoil) and encompasses approximately 11,068 NM^2 (Figure 1). Sampling density within the study area and lease sites was chosen to be at least as high (1 tow/400 NM^2) as in standardized NOAA Bering Sea surveys. NRC coordinated with CSESP research objectives to refine trawl survey station selection, and actual sampling density within the three study-area boxes was more than double the standard NOAA Bering Sea surveys (1 tow/180 NM^2). Final tow site selection and sampling density included 20 bottom trawl and 20 pelagic trawl tows in the Greater Hanna Shoal (GHS) Study Area[1], with five tows each planned for each study-area box and the remaining five at nearby stations (within the GHS Study Area but outside of the study-area boxes). The locations of pelagic trawl tows were planned to be opportunistic and based on areas with abundant pelagic fishes, as determined by split-beam sonar conducted aboard the R/V *Westward Wind*, another CSESP vessel, just prior to or during the trawl survey and could be located at or near the bottom trawl stations. Stations were chosen according to a standard grid within the overall study area, but not all grids included trawling stations. The distance between stations varied inside the study-area boxes from ~9 NM to ~12 NM. For the nearby stations outside the study-area boxes, the distance varied between stations from ~15 NM to ~40

[1] GHS Study Area in this report refers to the red outer polygon in Figure 1. The boundary coordinates of this polygon were provided by CSESP.

NM. Methods required lower sampling density for stations outside the study-area boxes but within the GHS Study Area (which covered 76% of the study area) because transit times to any of the closest of these stations could exceed 4 h. We planned 5 bottom trawl tows/day for 4 days and 5 pelagic trawl tows/day for an additional 4 days, for a total survey period of 8 days.

Chartered Survey Vessel

The 2011 surveys were conducted from the R/V *Pandalus* (Figure 2). The *Pandalus* proved to be an adequate vessel, and all of the proposed work in 2011 was completed. This boat is a converted steel-hulled fishing vessel similar to an Alaskan salmon purse seiner and measures ~60 ft (18.3 m) in length. The vessel is well suited to conduct surveys in near shore Alaska waters with mainly bottom trawl survey gear. The *Pandalus* is powered by a single main engine with 350 HP and has a single center-stern trawl drum (reel) mounted above a cutout at the stern bulwarks (no stern ramp). The vessel has no deck crane but several booms and winches that function to lift catches and equipment loads.

Bottom Trawl Survey Gear

The bottom trawl used in the 2011 surveys was a modified 400 Eastern survey trawl package. Most of the 400 Eastern survey bottom trawls owned and used in Alaska either are remaining NOAA survey trawls or new nets that match the design of the historical NOAA survey nets originally used for surveys in the eastern Bering Sea by NOAA (King, pers. comm. 2010)[2]. The net is a two-panel, semi-balloon design with a body constructed of 10.2 cm polyethylene mesh; the codend is lined with a 19 mm (0.75 in) mesh liner. The headrope is 21.7 m long, and the footrope is 28.7 m long. The trawl doors are V-style doors 1.5 × 2.1 m in size and weigh 364 kg each.

[2] Since 1982, NOAA surveys in the Bering Sea have used the 83-112 Northeastern bottom trawl. Prior surveys were conducted with the Eastern 400 bottom trawl.

Pelagic Trawl Survey Gear

The pelagic trawl used in the 2011 surveys was an older, discontinued pelagic rope trawl designed by Gourock[3]. The pelagic trawl had been used by the *Pandalus* during deeper water surveys conducted in the 1990s in southeast Alaska. The Gourock trawl measures 21 m wide × 15 m high and has 3.25 m (128 in) twine mesh forward, ~30–60 cm (~12-24 in) in the middle, and 5 mm (0.2 in) hexagonal poly stretch mesh at the codend and liner. The general dimensions of the Gourock trawl were headrope and footrope 48.8 m (160 ft), breastlines 34.8 m (114 ft), bridles 54.9 m (180 ft), and wing weights 40.8 kg (90 lb). The pelagic doors used for all tows with the Gourock net were 2 m (high) Jet double-foil, midwater doors that weighed 397 kg (875 lb) each. The normal wing weights for the Gourock trawl were more than 54 kg (120 lb), but, due to the shallow water in the study area, they were reduced to about 40.8 kg (90 lb) on each side.

Trawling Procedures

For each survey trawl tow, in addition to information from vessel instruments we recorded bottom temperature, salinity, and depth with a CTD (Seabird SBE 19) dropped to and retrieved from the seabed at a rate of 0.5-1.0 m/sec (fastcast). We deployed the bottom trawl net and towed it with locked winches for 15 min at a speed of ~2.5 kt; at this speed, an average trawl of 15 min would cover an area swept of ~0.004 NM^2 (1.4 ha). The survey net instrumentation recorded all trawl performance data possible during each tow for both the bottom trawl (BTR) and the pelagic trawl (PTR). Measurement of trawl geometry and function included wing spread (BTR), headrope height off the seabed (both), depth of the headrope in the water column (both), and footrope bottom contact with the seabed (BTR). Most net measurement data were transmitted via telemetry between the sensors and a hydrophone in a paravane deployed off a stabilizer boom. The bottom contact sensor collected data continuously during the bottom

[3] Gourock trawls were manufactured in Lynnwood, WA, but none have been manufactured in several years. The Gourock pelagic trawl is not used by NOAA but is similar dimensionally and in general design to the Nordic 264 rope trawl that currently is used for some NOAA pelagic surveys in Alaska.

trawl tows and recorded data were downloaded remotely via USB/PC connection after each tow. The location and speed over ground of the vessel were recorded continuously (1-sec intervals) during each trawl tow and were synchronized with a time stamp to the net measurement and bottom contact sensor data. Post-survey effort calculations applied a smoothing algorithm to the net mensuration and vessel position data to estimate accurately the geometry of the trawl net on the seabed, the distance fished (tow length), the average net spread (tow width), and the area swept.

After haulback, we dumped the codend contents into a sorting area and sorted, identified, counted, and weighed all captured fishes and invertebrates; we also took length-frequency (fishes) or carapace-width (crabs) measurements from high-volume or commercially important species. For tows with large total catch that prevented whole-haul processing (5 of 19 pelagic trawls and 11 of 18 bottom trawls), we followed a standard randomized subsampling procedure. First, we mixed the catch evenly in the sorting area and placed it in baskets that all were weighed to get a total haul weight. Second, we processed a subsample of randomly selected baskets in the same manner used for whole-haul processing, for later expansion of the count and weight of subsampled animals to the total haul weight. Sparsely represented animals or invertebrates (of any size) that were not appropriate for subsampling (evenly distributed within possible subsamples) were removed for separate whole-haul sampling. Any unidentifiable fish or invertebrate species were photographed, assigned a unique identifying specimen code, and either frozen or preserved in alcohol or formalin for later identification at the University of Alaska (Fairbanks) or University of Washington (Seattle).

We documented all catches with digital photos showing the station number, date, and time. At some stations, we videotaped the trawl survey operations and catch recording to document procedures employed. The time to complete trawling and all data recording at each station ranged from 60 to 90 min depending on the size of catch and the number of identifiable species.

The pelagic trawl was equipped with more limited net instrumentation that provided an estimate of the vertical opening of the net from the headrope to the footrope and the distances from the headrope to the seabed and the surface of the water. The pelagic trawl tow times were planned to be adjusted based on variable catches during the survey, with 30 min trawl durations anticipated. Pelagic tows were planned to be opportunistic because the objective of the pelagic trawling was to ground-truth information on schooling fishes observed with the split-beam sonar. In the event that the acoustically observed abundance of pelagic fishes was low or absent, we would conduct pelagic tows at or near the bottom trawl sites. Pelagic trawl catches were processed in a similar manner to bottom trawl catches, in that all fishes and invertebrates were identified to species, if possible, and many were measured for length. Because pelagic trawl surveys are intended to ground-truth acoustic survey data and no standardized methods exist for estimating area swept or volume swept for pelagic trawl tows[4], only the estimated length of trawl tow, set and haulback times, and GPS location were recorded for each pelagic tow. There was no directly calibrated hydroacoustic information logged or recorded onboard the *Pandalus* during the pelagic trawling. Methods to review pelagic fish hydroacoustic sign from data recorded on other CSESP research vessels was planned to be reviewed post-survey and included in reporting, if possible.

Data Analysis

Area-swept Calculations - Bottom Trawl

For the bottom trawl, we standardized catches for each species following the “area-swept technique” (Alverson and Pereyra 1969). This method relies on accurately estimating the area swept by the trawl from the distance fished and the average effective width (spread) of the trawl to calculate the density of animals per unit of seabed sampled (CPUE). When extrapolated to the total

[4] While standard NOAA survey methods for bottom trawl tows carefully measure the sampled area (area swept), pelagic trawl methods attempt only to verify species and general abundance of hydroacoustic data measured during acoustic surveying (NOAA 2009).

area of interest, the standardized catches are the basis of estimates of the absolute abundance (numbers) and biomass (weight) of each species of animals captured in the bottom trawl for the entire GHS study area. Abundance and biomass estimates from the bottom trawl survey are calculated by multiplying the average of all tow CPUEs by the area of the GHS study area.

The data from the trawl's acoustic sensors, the bottom-contact sensor, and the GPS unit were incorporated into a database utility for computing area swept per tow. For each tow, all sensor data were incorporated and reviewed graphically for the determination of on-bottom/off-bottom times and tow durations. Distance fished for bottom tows were calculated for three periods (winches paying scope, winches locked, and winches hauling back). For each tow when the trawl was on the bottom, the vessel's speed over ground was being recorded, and the speed of the net was adjusted by the winch rates – paying or retrieving wire scope. These methods are similar to NOAA protocols but are improved to provide more precise measurements of the distance fished/tow and the swept area per tow (Hughes and Goodman 2008).

Standardizing Catches - Pelagic Trawl

In contrast to the area-swept technique for the bottom trawl surveys, pelagic trawl survey methods in 2011 were used to complement acoustic monitoring conducted on the R/V *Westward Wind*. The pelagic trawl surveys attempted to verify the acoustic signal monitored during the survey at or near the bottom trawl stations. Instrumentation attached to the pelagic trawl was less than that for bottom trawls and was intended to allow the vessel/gear operator to know where the trawl was in the water column, rather than to measure and record trawl geometry precisely. Catches from the pelagic trawls were adjusted slightly by small changes in tow duration measured per tow to provide a general summary of catch per tow during the mid-water survey.

Relative and Absolute Abundance and Biomass

We calculated densities of animals caught with the bottom trawl by using the standard area-swept technique. Average densities (average CPUE; individuals/ha or kg/ha) for all major species were reported per study area box and for the entire GHS Study Area. We calculated the general summary of abundance and biomass (numbers and weight) from the area-swept densities with the standard statistical approach of multiplying mean area-wide densities of each species by the total area of interest. We then calculated both relative abundance (numbers of animals) among species and an estimate of absolute abundance (numbers) and biomass (weight) by species for each study area box and the nearby area outside the study area boxes but inside the GHS Study Area. These values provided the basis for a direct comparison between year-to-year survey results and for comparisons with other areas that have been surveyed with a similar methodology (e.g., Beaufort Sea, eastern Bering Sea, Aleutian Islands). For the pelagic trawl, we summarized the average CPUE (catch in numbers and weight/tow) for each major species for comparison between lease sites and to other survey areas.

Biological Analyses

We recorded and summarized length-frequency information for each major finfish species (Arctic cod, capelin, Pacific sandlance, sculpin spp.) encountered during the survey. We also recorded carapace widths by sex for snow crab (*Chionoecetes opilio*), the one commercially important crab species encountered during the survey. Finally, we recorded some maturity indices for gravid female snow crabs.

RESULTS

Operational Results

We completed the trawl survey within the chartered schedule. We completed 19 of the 20 bottom trawl tows planned, skipping the tow at station 20B/HF020 (transition station outside of study boxes) because of limited transit/charter time at the end of the survey. Of the 19 completed bottom trawl tows, 18 were successful tows and are included in results and analysis. However, the bottom trawl catch in 16B/HF010 contained ~750 kg of mud collected in 7.8 min (i.e., a shortened tow[5]) and was determined to be a poor-performance[6] tow that was excluded from summaries. All bottom trawl catches collectively totaled ~2,495 kg from 18 tows, with an average unsorted codend weight of 139 kg/tow. Bottom trawl durations averaged 16.5 min of total bottom time with an average net spread of 13.2 m during the tow. Total distance fished/bottom tow averaged 1,297 m, and the average tow speed was 2.4 kt.

We completed 19 of the 20 pelagic-trawl tows planned, skipping the tow at 20P/HF019 (transition station outside of study boxes) because it was believed to be too shallow to avoid bottom contact with the footrope of the pelagic trawl. Pelagic trawling was interrupted mid-survey when retrieval of the net at one station resulted in a significant backlash of the large meshes into the smaller meshes and chain rigging of the footrope. The net was successfully untangled with no significant damage after tending the net reel overrun. All pelagic trawl catches totaled ~710 kg from 19 tows, with an average unsorted codend weight of 37.4 kg/tow. Pelagic trawl durations averaged 30.4 min of total fishing time with the winches locked and an average tow speed of 3.5 kt. Estimated average spread of the pelagic trawl/tow was nearly 16 m, and the estimated vertical opening was between 11.0 and 14.6 m/tow.

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[5] Trawl instruments showed a spike in net spread as doors dug into mud and then an immediate collapsing of spread as the trawl loaded up with mud. Haulback began shortly after to avoid overloading the codend or damage to the net.

[6] Consistent with NOAA surveys' tow performance protocols, the geometry of the net was significantly changed by contact with something during the tow – in this case, a heavy catch of mud. The mud catch was dumped as one mass and washed/rinsed for nearly an hour to attempt to assess catch composition and clear the sorting area.

Total Catch

Catch results in numbers for total catch (number), CPUE (number/ha), and abundance (number for the entire study area) include all species for which counts of individuals could be made. Catch results in weight (kg), CPUE (kg/ha), and biomass (kg for study area) include all species for which weights of total species catch/tow could be taken. Importantly, some catch items have counts but no weights (e.g., hundreds of small larval eel blennies in aggregate were too light to weigh), and some have weights but no counts (e.g., 30 kg of brittle stars were too numerous to count). Consequently, all species results described below are in both numbers and weight whenever possible. Additionally, numerically dominant invertebrate catch items of jellyfishes, brittle stars, and other sea star species are not reported in detail.

The five most abundant fish species captured in both gear types combined were Pacific sandlance (6,650 individuals), Arctic cod (4,562), unidentified eel blennies (zoarcids; 655), capelin (268), and shorthorn sculpin (*M. scorpius*; 75); (Table 1). The most abundant invertebrates in both gear types combined were brittle stars (too many to count, but in the many thousands). The top five most abundant catch items other than fishes (with counts) were snow crabs (5,644 individuals), unidentified hermit crabs (pagurids; 1,027), unidentified snails (*Neptunia* spp.; 644), Arctic lyre crabs (470), and a pelagic amphipod (*T. libellula*; 439).

By weight, the most abundant species were invertebrates in both bottom and pelagic trawls. Jellyfishes (unidentified species; 712 kg) represented the most biomass in all pelagic trawls, and snow crabs (496 kg) represented the most biomass in bottom trawls. However, the high numbers of fish mentioned above almost exclusively represent small fishes (<15 cm); therefore, their aggregate biomass is low. The total catch weight for Arctic cod in both bottom and pelagic trawls combined was 14.1 kg. Most of the sandlance captured measured less than 60 mm total length (TL), so even in pelagic tows where sandlance catch was high, the aggregate weight of several hundred sandlance was too low to register on the motion-compensated deck scale. Biomass estimates from average CPUE in kg/ha presented below are for species with measured weights.

Catch Composition—Species Diversity

We recorded at least 20 species (14 identified to species and 6 identified to genus) of fishes from 10 families and at least 47 invertebrate species, of which 26 were identified to species (Table 1). The species diversity of fishes was 15% larger in bottom trawl catches (15 taxa; 75% of all taxa) than in the pelagic-trawl catches (12 taxa; 60% of all taxa; Figure 3); 7 taxa were recorded in both gear types. The species-diversity of invertebrates was much higher in the bottom trawl catches (41 taxa; 87% of all taxa) than in the pelagic-trawl catches (6 taxa; 13% of all taxa; Figure 4); 3 taxa were recorded in both gear types (basket stars, shrimp, and snow crabs[7]).

The biomass estimates from the most abundant three species (snow crab, Arctic lyre crab, and Arctic cod) caught in the bottom trawl still were low, ranging from about 2,000 t to 65,000 t for the entire study area. Catches from the pelagic trawl indicated low abundance of the three most abundant fish species of small species encountered – Arctic cod, Pacific sandlance, and capelin. Total catch of these species ranged from 0 to approximately 3,000 fish/tow. The biomass from pelagic trawl tows was dominated by large jellyfishes. Bottom trawl catches exhibited a lower abundance of Arctic cod than did pelagic catches and had a greater variety of demersal fish species, including sculpins, eelpouts, snailfishes, and wolffish.

Comparison of Areas and Spatial Analysis

Catch results varied by gear and species but in general show that the abundance of fish and invertebrates was higher in the southwestern and central parts of the

[7] One pelagic tow clearly contacted bottom and had basket stars entangled on the footrope and caught one large snow crab.

study area than in the northeastern part (Figure 5). For bottom trawl combined fish and invertebrate CPUEs[8], tows completed in the southwestern part of the study area (inside the Klondike study-area box) had more than 6 times the mean density for the 3 study-area boxes combined (477 individuals/ha in Klondike, 71 individuals/ha in Burger, and 79 individuals/ha in Statoil). Compared to the entire GHS study area combined fish and invertebrates mean CPUE (258 individuals/ha), Klondike was still nearly 2 times higher. For pelagic fish catches, there was more spatial variability in densities, in that the two highest fish catch tows occurred in Statoil; however, the highest mean catches occurred in the southwestern and central parts of the GHS study area. The general trend of both high CPUE (bottom trawl) and high total catch (pelagic trawl) in the southwestern and south-central parts of the GHS study area is shown in Figures 6 and 7 by summaries of total CPUE of 17 taxa of fish and invertebrates for bottom trawls and the three major species for pelagic trawls. Catches of major species by tow for both gears are plotted for each area in Figures 8 and 9.

In contrast to the pattern seen for all taxa combined, comparison of pelagic catches of the three major species caught (Arctic cod, Pacific sandlance, and capelin) indicates generally higher abundance in the central part of the GHS study area (Statoil and Burger) than in Klondike (Figure 6). Arctic cod in the pelagic trawl catch was highest in Statoil, averaging more than 4 times the mean catch of Arctic cod in all other pelagic tows combined. Statoil also had the highest average catch of Pacific sandlance from pelagic tows; however, one station (HF008) in the southern study area, due west of Klondike, numerically dominated the catch of sandlance, with more than 43% of the catch of all sandlance recorded there. With the exception of the high catch in HF008, sandlance catches were more evenly distributed than Arctic cod and capelin catches among study-area boxes, with all having at least one tow with a catch of >500 sandlance. Capelin catches in the pelagic trawl gear were much lower than those for Arctic cod and sandlance, with a mean catch rate of ~13 fish/tow.

[8] Combined fish and invertebrates mean CPUEs per study area include the 17 taxa shown in Table 2 and do not include brittlestars.

Klondike (22 fish/tow) had >2.5 times the mean catch of capelin in the other study block areas and had two tows with >50 capelin each.

The trend of higher abundance and biomass in the southern and south-central parts of the GHS study area was more apparent from the bottom trawl results (Figure 7). Bottom trawl density of Arctic cod was more than 10 times greater, on average, in the Klondike study area (56.37 fish/ha) than the other two study areas (5.50 fish/ha). Catches of snow crabs in Klondike (360.70 crab/ha) averaged more than 7 times greater than those in the other two study areas (50.88 crab/ha). For Arctic lyre crab, Klondike (26.62 crab/ha) also had the highest catch rates averaging >2.5 times catch rates for the other two study areas (10.57 crab/ha). Abundance and biomass estimates derived from bottom trawl area-swept catches provide more details below.

Abundance and Biomass Estimates

We expanded the CPUEs from bottom trawl tows to provide estimates of abundance (population size) and biomass in the GHS study area for 17 major taxa (Tables 2 and 3). The tables show the standardized catch (CPUE) for each taxon/tow within the lease or study area. Due to the small sample size for each study–area box (4–5 tows), the abundance and biomass estimates with 95% confidence intervals (bottom of tables) are calculated over the entire study area in aggregate (18 tows).

The three highest abundance estimates for fishes recorded in the bottom trawl are for Arctic cod (104.5 million), shorthorn sculpin (9.7 million), and capelin (3.2 million). Because of the low sampling effort, abundance estimates are imprecise, and confidence intervals (CIs) in most cases exceed 100%. Some reasons for the imprecision other than low sample sizes are described below in the Discussion. The most meaningful abundance estimates for invertebrates are for two crab species (snow crab and Arctic lyre crab) that were recorded in nearly every bottom trawl tow. The precision (95% CI) of both snow and lyre crab abundance estimates are ~±62.5% around the abundance point estimate.

With the exception of jellyfishes in the pelagic trawl catches and brittle stars in the bottom trawl catches (both were not rigorously quantified), the snow crab abundance estimate of 754 million crabs is the highest abundance of any species in the survey and represents an estimate of >66,000 t of biomass with similar level of precision (i.e., as a percentage around the estimate). Other biomass estimates generally are very low, primarily because of the small size of most fishes and invertebrates captured in the Chukchi study area.

Length-frequency of Key Species

We recorded lengths of several species during the 2011 trawl surveys. Efforts were taken to measure key species from each area, but due to low sample sizes and some on-deck logistics and timing, we weren’t able to measure some of the species of interest in some of the areas. Measured samples were high enough and lengths variable enough for Arctic cod, capelin and snow crab to show length modes and variation per study block area. Several Pacific sandlance were measured but there was little size or spatial variation and all samples were between 55 and 75 mm. Very few saffron cod were caught or measured and all were between 25 and 55 mm. Arctic cod sizes ranged from about 40 to 200 mm with a strong mode around 55 mm, and there was evidence of larger Arctic cod in the transition stations outside the study area blocks (Figure 10). Capelin measured during the 2011 surveys were between 55 and 115 mm with the strongest mode showing at about 85 mm in Klondike samples, although each area some small differences in size distribution (Figure 11). There were several hundred snow crab measured during the 2011 surveys although none were measured in Burger. Snow crab carapace widths ranged from 20 mm up to 82 mm for a few individuals and by far the most snow crab measured were from Klondike where a strong mode around 55 mm carapace width is evident (Figure 12). The sex ratio for snow crab measured was skewed, showing 77% males and no females were measured greater than 58 mm.

Environmental Relationships

All temperature and salinity data have been summarized and reviewed from the CTD casts made at each station. It is apparent from review of other temperature and salinity records taken during 2011 by other CSESP devices that some inconsistencies or problems may exist from the data collected by the CTD aboard the *Pandalus*. The basic summary of *Pandalus* CTD data is presented by tow in Table 4. The mean bottom-water temperature taken at trawl stations is +0.5 °C, with some readings <0.0° C and the highest approaching 4.0 °C. The mean salinity over the entire GHS study area was 29.6 ppt, with a high of 32.2 ppt and a low of 15.5 ppt. Three stations (nearest shore) in Burger appear to have lower recorded bottom temperatures and the lowest pelagic-trawl catches. Higher temperatures in the transition area (outside of study area boxes) between Statoil and Klondike and in the northern stations within Statoil also appear to correlate with higher pelagic catches. Further analysis of temperature and salinity records per tow along with any correlation to both benthic and pelagic fish catches may be included in future reporting that would corroborate with valid environmental data from 2011 surveys (summary report of 2011-2012 acoustic and environmental data).

DISCUSSION

Results from both gear types show that densities of fishes and invertebrates was higher in the southwestern and central parts of the GHS study area than in the northeastern part of it. Catches from the pelagic trawl were less diverse than catches from the bottom trawl and showed low densities of three small pelagic species – Arctic cod, Pacific sandlance, and capelin. Bottom trawl catches were most prolific for snow crabs, Arctic cod, and Arctic lyre crabs. Further details of results related to species observed, sampling gear used, and comparisons with other surveys are discussed below.

Expected Fish Catches and Commercial Species

Although the Chukchi Sea is not routinely surveyed, there have been enough surveys in or near the GHS study area to have a general idea for species expected to be seen in a trawl survey. Notably, among known Arctic flatfish species present in the area from a number of surveys, we caught only a few individuals of Bering flounder. Sculpin catches were substantially less diverse than expected and were limited to primarily three species (*G. tricuspis*, *M. scorpius*, and *A. scaber*). Additionally, we caught no commercially important fish species such as Pacific cod (*G. macrocephalus*) or Alaska pollock (*T. chalcogramma*). Invertebrate catches from the bottom trawl were diverse and contained five shrimp species and three crab species but only one commercial species (snow crab). Large catches of snow crabs, especially in the southwestern part of the GHS study area, were the only significant catches from the bottom trawl with current potential commercial value; in fact, this species dominated most bottom trawl catches by weight.

The average size of all species captured during the 2011 CSESP survey was small. Although snow crabs were the most commonly caught animals, there were less than 10 males that were larger than Alaska's legal minimal carapace width of 78 mm (3.1 in). In addition, male Bering Sea snow crabs are not harvested unless they measure at or above the market-preferred minimum carapace width of 102 mm (4.0 in). Both the reproductive condition of females and male chela-size measurements suggest that Chukchi Sea snow crabs of both sexes mature at smaller sizes than do snow crabs populations farther south.

Although a few individual Arctic cod were the largest fish observed, capelin were of the largest and most uniform mean size but were much smaller than capelin captured in other commercial capelin fisheries. For gadids, commercial production in Alaska requires the smallest fish (pollock and cod) to be >30 cm in length and >300 g in weight. The largest Arctic cod captured in the 2011 surveys was ~19 cm and weighed ~75 g. Hence, although some commercial species and similar species were present in catches, no commercial fishery could feasibly exploit the low densities of very small fishes and invertebrates recorded in the northeastern Chukchi Sea at this time.

Sampling Effort Within the Water Column

The gears employed during the 2011 CSESP survey covered a limited portion of the water column. It can be assumed that most benthic fishes on or near the bottom up to ~2 m off the bottom in the path of the 400 Eastern bottom trawl were captured. There are, however, other gear selectivity factors that could bring additional fish outside the estimated net path width into the net path (including herding by the doors or bridles) or exclude them from capture by the net such as escaping under the footrope or through meshes. The sampling efficiency of the Gourock pelagic trawl was more uncertain. The instrumentation on the headrope of the pelagic trawl indicated that the trawl was fishing with its headrope ~14.6–16.5 m below the surface down to the bottom in some tows (the footrope contacted the seabed at least once). The top of the trawl was sampling from ~14.6 m below the surface to ~29 m below it. The vertical opening of the pelagic trawl was estimated at about 11 m - so during the deepest pelagic tows the net would be fishing from 29 to 40 m below the surface, and during the shallowest pelagic tows the net would be fishing from 14.6 to 25.6 m below the surface. The goal to understanding the fishing geometry of the Guorock trawl and where it fishes in the water is to be able to ascertain what proportion of fish may be missed completely by being higher in the water column, unavailable to the net. Acoustic data summaries from the R/V *Westward Wind* recorded during the 2011 trawl surveys were reviewed to estimate what amount of acoustic signal might have been unavailable to the pelagic trawl. Preliminary results of that acoustic data suggest that ~37.5% of potential pelagic fish targets were at depths too shallow to be caught during pelagic tows – or stated in more positive terms for coverage during the pelagic survey, nearly 63% of pelagic fish were available to be caught and the pelagic survey trawl was covering most of the water column that it should have.

Comparison With Other Surveys

As overlapping surveys of the CSESP in the GHS study area – one with trawl gear and one with hydroacoustic instruments - a direct comparison of 2011 pelagic trawl catches can be made to 2011 acoustic data summaries by overlaying the data coverages. As we summarize in Figure 13, the correlation between the two measures of pelagic fish density do not consistently correlate. There appears to be higher catches from the pelagic trawl gear (numbers of Arctic cod, Pacific sandlance and capelin/tow) in the central and northern central GHS study area (Statoil and northwestern Burger) that correlate with some higher acoustic summary values (numbers of Arctic cod, Pacific sandlance and capelin/m^3) in that area. In other portions of the overlay, however, there are regions with high pelagic catch rates and low acoustic densities (north of Klondike at transition station and eastern edge of Klondike), and conversely, regions with low pelagic catch rates and high acoustic densities (southeast stations in Burger and transition station to northeast). It should be noted that the acoustic data summaries provided here may be revised in future CSESP reporting that may include re-summary of raw acoustic data using NMFS hydroacoustic methods directly. It is anticipated that in 2012, CSESP acoustic surveys will begin fully accessing NMFS hydroacoustic summary methods – which may include re-summary of historical data.

The relative catches of key species in the 2011 CSESP surveys appear to be similar to some previous surveys and quite different in others (species by species) when compared with other recent and historical Chukchi Sea surveys that have occurred in the general area (Galloway et al. 2011). It should be noted that interpreting these comparisons should be done with caution because of variation in survey methodologies and gear types. Interannual variation in the environment also may account for some of the differences, even when a rigorous, systematic survey methodology is in place. The changing conditions in the warming Arctic undoubtedly may influence the results of any survey of this type over time.

Synthesis summaries of several fish studies in the Chukchi Sea area of interest report mean CPUEs of Arctic cod as 2.2–30.9 individuals/1,000 m^2 (or 22-309 individuals/ha) captured during surveys with a variety of sampling gears (Galloway et al. 2011). The bottom trawl gear most similar to the 400 Eastern bottom trawl used in our 2011 surveys was the 83-112 Eastern (NMFS) survey trawl deployed in 1990–1991 Chukchi surveys; the mean Arctic cod CPUE in those surveys was 22 fish/ha (Barber et al. 1997). For comparison, our 2011 survey results for Arctic cod CPUEs ranged from 0.9 to 152.2 fish/ha and averaged 27.5 fish/ha. Three strata in NMFS northern Bering Sea surveys have at times shown substantial Arctic cod densities. Further comparison from this more rigorous , systematic but infrequently surveyed Arctic cod density of 0.26 kg/ha is available from the 2010 NMFS survey of the northern Bering Sea (Lauth 2011). In comparison, Arctic cod surveyed density from our 2011 surveys ranged from 0 to 2.47 kg/ha and average 0.49 kg/ha. While the comparison of one species catch rate across survey gears and years - even when temporal, spatial or sampling gear differences are minimized – may not highlight important biological trends, it does give a general indication of how consistent CPUE measures may be.

Few other historical fish data are available for comparison. For Arctic staghorn sculpin, Barber et al. (1997 – summarized in Galloway et al. 2011) report a mean CPUE of 0.2 fish/1,000 m^2 (2.0 fish/ha). In contrast, our surveys averaged 0.7 fish/ha in 2011. However, CIs for the 2011 surveys were >100% of the estimated mean densities (and Barber did not report precision of estimates), indicating no likely statistical difference between periods.

Catch rates of snow crabs from bottom trawls in the Chukchi Sea and surrounding arctic areas are not well documented. While bottom trawl surveys have been conducted in the area, they have mostly focused on fish species and standardized catch rates for snow crab and other invertebrates are not as well reported. The 2011 CPUE for snow crab in weight (kg/ha) ranged from 0.7 to 99.4 kg/ha and averaged 17.5 kg/ha over the entire GHS study area. The closest data on CPUEs for snow crabs for comparison is from the Beaufort Sea, where the mean CPUE in 2008 was 49.7 kg/ha (Rand and Logerwell 2011).

CONCLUSIONS

The summary of results from the NRC CSESP fish and invertebrate surveys from 2011 highlight a few key findings;

- Both total catches and standard catches differ among study areas.
- Bottom trawl abundance and biomass are higher in the southern and central parts of the GHS study area than in the northern parts of it.
- Pelagic trawl catches vary more than bottom trawl catches spatially and do not appear to correlate directly with acoustic data summaries from the GHS study area in 2011.
- Abundance and biomass of all fish and invertebrate species are low.
- Species diversity appears to be lower than in adjacent systematic surveys.
- Individuals of all species captured are small and well below normal commercial sizes for exploitation.

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Table 1. Summary of fish and invertebrate total catch by family and species for NRC CSESP 2011 fish surveys by gear (bottom trawl [BTR] and pelagic trawl [PTR]).

				Total Catch (#)		
Group	Family	Common/Unid.	Species	BTR	PTR	Total
Fish	Gadidae	Arctic cod	Boreogadus saida	822	3,740	4,562
		saffron cod	Eleginus gracilis	0	11	11
	Osmeridae	capelin	Mallotus villosus	25	243	268
	Ammodytidae	sandlance	Ammodytes hexapterus	0	6,650	6,650
	Stichaeidae	eel blenny	eelblenny unidentified	0	655	655
		slender eel blenny	Lumpenus fabricci	12	34	46
	Zoarcidae	polar eelpout	Lycodes polaris	5	0	5
		marbled eelpout	Lycodes raridens	4	0	4
		eelpout	Lycodes spp	3	0	3
	Pleuronectidae	Bering flounder	Hippoglossoides robustus	3	0	3
		flatfish	larval flatfish unidentified	1	8	9
	Agonidae	Arctic alligatorfish	Ulcina olrikki	2	41	43
		alligatorfish	Aspidophoroides monopterygius	0	2	2
	Cottidae	shorthorn sculpin	Myoxocephalus scorpius	75	0	75
		Arctic staghorn sculpin	Gymnocanthus tricuspis	21	0	21
		hamecon	Artediellus scaber	9	0	9
		sculpin	Myoxocephalus spp	1	0	1
		sculpin	Cottid unidentified	4	5	9
	Liparidae	snail fish	Liparis spp	13	2	15
	Anarhichadidae	wolf fish	Anarhichas orientalis	0	1	1

Table 1. continued…Summary of fish and invertebrate total catch by family and species for NRC CSESP 2011 fish surveys by gear (bottom trawl [BTR] and pelagic trawl [PTR]). [to be further finalized w/ nomenclature]

Group	Family	Common/Unid.	Species	Total Catch (#) BTR	PTR	Total
Invertebrates	Majidae	Arctic lyre crab	Hyas coarctatus	470	0	470
	Lithodidae	blue king crab	Paralithodes platypus	1	0	1
	Paguridae	hermit crab	hermit crab spp unidentified	1,027	0	1,027
	Hyperidae	amphipod	Themisto lebellula	0	439	439
	Ampeliscidae	amphipod	Ampelisca eschrichti	7	0	7
	Polynoidae	isopod	Eunoe nodosa	15	0	15
		isopod	scale worm unidentified	7	0	7
	Chaetilidae	isopod	Saduria entomon	1	0	1
	Euphausidae	krill	Thysanoessa raschii	0	32	32
	Crangonidae	shrimp	Argis dentata	189	0	189
		shrimp	Argis lar	11	0	11
	Pandalidae	shrimp	Pandalus goniurus	73	3	76
	Hippolytidae	shrimp	Lebbeus groenlandicus	5	0	5
	Oregonidae	snow crab	Chionoecetes opilio	5,643	1	5,644

Table 1. continued…Summary of fish and invertebrate total catch by family and species (or common grouping for minor taxa) for NRC CSESP 2011 fish surveys by gear (bottom trawl [BTR] and pelagic trawl [PTR]).

Group	Family	Common/Unid.	Species	Total Catch (#) BTR	PTR	Total
	mollusc	clam	Astarte borealis	360	0	360
	mollusc	clam	Clinocardium ciliatum	8	0	8
	mollusc	clam	Musculus niger	4	0	4
	mollusc	clam	clam unidentified	2	0	2
	mollusc	clam	Serripes groenlandicus	1	0	1
	mollusc	nudibranch	nudibranch unidentified	1	0	1
	mollusc	scallop	scallop unidentified (sm)	3	0	3
	mollusc	snail	snail unidentified	644	0	644
	mollusc	squid	Eogonatus tinro	0	3	3
	other inverts	brittlestar	brittle star unidentified	**	**	**
	other inverts	jellyfish	jellyfish unidentified	**	**	**
	other inverts	anemones	anemone unidentified	35	0	35
	other inverts	basket star	Gorgonocephalus eucnemis	44	0	44
	other inverts	bryozoan	bryozoan unidentified	0	0	0
	other inverts	chiton	chiton unidentified	98	0	98
	other inverts	sea cucumber	Ocnus glacialis	42	0	42
	other inverts	soft coral	Gersemia spp	32	0	32
	other inverts	starfish	Leptasterias polaris	399	0	399
	other inverts	starfish	star unidentified (5 leg/lg red)	168	0	168
	other inverts	starfish	Gorgonocephalus eucnemis	165	0	165
	other inverts	starfish	Crossaster papposus	92	0	92
	other inverts	starfish	Leptastarias arctica	72	0	72
	other inverts	starfish	cookie star unidentified	14	0	14
	other inverts	starfish	sea star unidentified (slime)	5	0	5
	other inverts	starfish	sea star unidentified	4	0	4
	other inverts	starfish	sea star unidentified (4 leg/lg)	1	0	1
	other inverts	tunicate	tunicate unidentified	230	0	230
	other inverts	tunicate	Boltenia ovifera	0	0	0
	other inverts	urchin	urchin unidentified	6	0	6
	other inverts	worm	sea worm unidentified	75	0	75
	other inverts	worm	Eunoe nodosa	4	0	4
	other inverts	worm	scale worm unidentified	2	0	2

* Noted high catches in bottom and pelagic trawl are not quantified in this table.

Table 2. Abundance of major fish and invertebrate species captured in the Eastern 400 bottom trawl during the 2011 NRC Chukchi Sea CSESP fish surveys. CPUE in fish/ha, abundance fish (mill).

ABUNDANCE		Fish										Invertebrates						
Bottom Trawl Only				Eelpout			Sculpin					Crab		Shrimp				Cucumber
		Arctic cod	capelin	Polar eelpout	Marbled eelpout	unid eelpout	Hamecon	Arctic staghorn	Shorthorn	unid Myox. spp	unid	Snow	Arctic Lyre					
Area	Haul	B. saida	M. villosus	L. polaris	L. raridens	Lycodes spp	A. scaber	G. tricuspis	M. scorpius		Cottid unid	C. opilio	Hyas coarctatus	Argis lar	A. dentata	L. groen-landicus	Pandalus goniurus	Ocnus glacialis
Statoil	02B	5.32	0.00	0.00	0.00	0.59	0.00	0.00	0.00	0.00	0.00	51.40	1.18	0.00	0.00	1.77	0.00	0.00
	03B	1.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	118.10	12.92	0.00	1.85	0.00	0.00	0.00
	04B	11.65	0.00	0.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	43.55	31.28	0.00	0.61	0.00	0.00	4.91
	05B	8.25	0.00	0.00	0.63	0.00	0.00	0.00	0.00	0.00	2.54	67.24	10.78	5.07	0.00	1.27	0.00	0.00
	06B	2.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.96	1.49	0.00	0.00	0.00	2.98
Burger	14B	7.30	0.00	1.83	0.00	0.00	0.00	0.00	3.65	0.00	0.00	113.18	20.08	0.00	10.95	0.00	0.00	10.95
	15B	6.59	0.00	0.00	0.00	0.00	0.00	0.00	2.03	0.00	0.00	22.32	6.09	0.00	1.01	0.00	0.00	1.01
	17B	2.67	0.00	0.00	0.00	0.00	0.53	0.00	0.53	0.00	0.00	19.74	5.87	0.00	16.00	0.00	0.00	0.00
	18B	2.92	0.00	0.49	0.00	0.00	0.49	0.00	0.49	0.00	0.00	22.42	0.97	0.00	2.92	0.00	0.00	0.00
Klondike	09B	70.87	0.62	0.00	0.00	0.00	0.00	0.62	0.00	0.00	0.00	380.45	6.22	0.00	3.73	0.00	3.73	0.00
	10B	27.87	0.00	0.00	1.09	0.00	0.00	2.19	0.00	0.00	0.00	189.05	12.02	0.00	1.09	0.00	1.09	0.00
	11B	152.22	2.36	0.00	0.00	1.18	0.00	2.36	0.00	0.00	0.00	228.92	2.36	0.00	11.80	0.00	28.32	0.00
	12B	11.53	0.00	0.00	0.00	0.00	0.00	5.43	5.43	0.00	0.00	955.34	21.71	0.00	16.28	0.00	0.00	0.00
	13B	21.14	2.49	0.00	0.62	0.00	4.35	2.49	14.30	0.00	0.00	49.75	90.80	0.00	46.02	0.00	7.46	0.00
Transition	01B	1.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	326.28	47.75	0.00	0.00	0.00	0.00	0.00
	07B	9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.64	0.00	185.09	20.57	0.64	2.57	0.00	2.57	0.00
	08B	151.07	9.79	0.00	0.00	0.00	0.00	0.00	19.57	0.00	0.00	783.20	0.00	0.00	0.00	0.00	0.00	0.00
	19B	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19.38	0.90	0.00	0.00	0.00	0.45	4.51
Statoil (5 tows/308,927 ha)																		
Total of CPUE		30.04	0.00	0.61	0.63	0.59	0.00	0.00	0.00	0.00	2.54	280.28	62.12	6.56	2.46	3.04	0.00	7.89
Average CPUE		6.01	0.00	0.12	0.13	0.12	0.00	0.00	0.00	0.00	0.51	56.06	12.42	1.31	0.49	0.61	0.00	1.58
Burger (4 tows/308,899 ha)																		
Total of CPUE		19.49	0.00	2.31	0.00	0.00	1.02	0.00	6.70	0.00	0.00	177.65	33.01	0.00	30.90	0.00	0.00	11.97
Average CPUE		4.87	0.00	0.58	0.00	0.00	0.26	0.00	1.68	0.00	0.00	44.41	8.25	0.00	7.72	0.00	0.00	2.99
Klondike (5 tows/308,936 ha)																		
Total of CPUE		283.63	5.47	0.00	1.71	1.18	4.35	13.08	19.73	0.00	0.00	1,803.51	133.11	0.00	78.93	0.00	40.61	0.00
Average CPUE		56.73	1.09	0.00	0.34	0.24	0.87	2.62	3.95	0.00	0.00	360.70	26.62	0.00	15.79	0.00	8.12	0.00
Trans. (4 tows/2,869,537 ha)																		
Total of CPUE		162.29	9.79	0.00	0.00	0.00	0.00	0.00	19.57	0.64	0.00	1,313.95	69.21	0.64	2.57	0.00	3.02	4.51
Average CPUE		40.57	2.45	0.00	0.00	0.00	0.00	0.00	4.89	0.16	0.00	328.49	17.30	0.16	0.64	0.00	0.76	1.13
Area Ttl (8 tows/3,796,299 ha)																		
Total of CPUE		495.46	15.26	2.93	2.35	1.77	5.37	13.08	46.00	0.64	2.54	3,575.39	297.45	7.21	114.85	3.04	43.63	24.36
Average CPUE		27.53	0.85	0.16	0.13	0.10	0.30	0.73	2.56	0.04	0.14	198.63	16.53	0.40	6.38	0.17	2.42	1.35
Std Dev. Of CPUE		48.00	2.36	0.45	0.31	0.30	1.03	1.47	5.52	0.15	0.60	268.94	22.32	1.22	11.38	0.50	6.75	2.88
Abundance Estimate (millions)		104.49	3.22	0.62	0.50	0.37	1.13	2.76	9.70	0.14	0.54	754.07	62.73	1.52	24.22	0.64	9.20	5.14
95% CI % of Estimate		80.6%	128.8%	128.4%	111.2%	142.6%	158.6%	93.6%	99.7%	196.0%	196.0%	62.5%	62.4%	141.3%	82.4%	136.5%	128.6%	98.4%
Lower 95 CI Limit		20.31	0.00	0.00	0.00	0.00	0.00	0.18	0.03	0.00	0.00	282.42	23.60	0.00	4.27	0.00	0.00	0.08
Upper 95 CI Limit		188.68	7.36	1.41	1.05	0.91	2.93	5.34	19.38	0.40	1.58	1,225.72	101.87	3.67	44.18	1.52	21.03	10.19

Table 3. Biomass of major fish and invertebrate species captured in the Eastern 400 bottom trawl during the 2011 NRC Chukchi Sea CSESP fish surveys. CPUE in kg/ha, biomass in metric tons (t).

BIOMASS		Fish										Invertebrates						
Bottom Trawl Only				Eelpout			Sculpin					Crab		Shrimp				Cucumber
		Arctic cod	capelin	Polar eelpout	Marbled eelpout	unid eelpout	Hamecon	Arctic staghorn	Shorthorn	unid	unid	Snow	Arctic Lyre					
Area	Haul	B. saida	M. villosus	L. polaris	L. raridens	Lycodes spp	A. scaber	G. tricuspis	M. scorpius	Myox. spp	Cottid unid	C. opilio	Hyas coarctatus	Argis lar	A. dentata	L. groen-landicus	Pandalus goniurus	Ocnus glacialis
Statoil	02B	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.76	0.21	0.00	0.00	0.00	0.00	0.00
	03B	0.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.82	1.26	0.00	0.59	0.00	0.00	0.60
	04B	0.28	0.00	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.46	0.91	0.00	0.21	0.00	0.00	0.24
	05B	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	2.07	1.99	0.25	0.00	0.00	0.00	0.26
	06B	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.30	0.80	0.01	0.00	0.00	0.00	0.01
Burger	14B	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	5.17	1.46	0.00	0.20	0.00	0.00	0.01
	15B	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.86	0.35	0.00	0.00	0.00	0.00	0.00
	17B	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.81	0.26	0.00	0.30	0.00	0.00	0.00
	18B	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.91	0.17	0.00	0.18	0.00	0.00	1.15
Klondike	09B	0.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	35.64	0.59	0.00	0.27	0.00	0.00	0.00
	10B	0.73	0.00	0.00	0.41	0.00	0.00	0.00	0.00	0.00	0.00	13.88	0.92	0.00	0.59	0.00	0.00	0.00
	11B	0.65	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	19.66	0.55	0.00	0.50	0.00	0.01	0.00
	12B	0.30	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.00	93.41	3.20	0.00	2.17	0.00	0.00	0.00
	13B	0.64	0.01	0.00	0.22	0.00	0.01	0.01	1.12	0.00	0.00	3.78	4.05	0.00	0.77	0.00	0.01	0.00
Transition	01B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.27	2.41	0.00	0.00	0.00	0.00	0.00
	07B	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.28	1.35	0.00	0.00	0.00	0.01	0.00
	08B	2.47	0.02	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	99.38	0.00	0.00	0.00	0.00	0.00	0.00
	19B	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.73	0.20	0.00	0.00	0.00	0.00	0.00
Statoil (5 tows/308,927 ha)																		
	Total of CPUE	1.97	0.00	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.23	19.40	5.16	0.26	0.80	0.00	0.00	1.11
	Average CPUE	0.39	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.05	3.88	1.03	0.05	0.16	0.00	0.00	0.22
Burger (4 tows/308,899 ha)																		
	Total of CPUE	0.62	0.00	0.01	0.00	0.00	0.00	0.00	0.02	0.00	0.00	7.75	2.24	0.00	0.69	0.00	0.00	1.16
	Average CPUE	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.94	0.56	0.00	0.17	0.00	0.00	0.29
Klondike (5 tows/308,936 ha)																		
	Total of CPUE	3.17	0.01	0.00	0.63	0.01	0.01	0.04	1.14	0.00	0.00	166.38	9.31	0.00	4.29	0.00	0.02	0.00
	Average CPUE	0.63	0.00	0.00	0.13	0.00	0.00	0.01	0.23	0.00	0.00	33.28	1.86	0.00	0.86	0.00	0.00	0.00
Trans. (4 tows/2,869,537 ha)																		
	Total of CPUE	2.97	0.02	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	120.67	3.96	0.00	0.00	0.00	0.01	0.00
	Average CPUE	0.74	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	30.17	0.99	0.00	0.00	0.00	0.00	0.00
Area Ttl (8 tows/3,796,299 ha)																		
	Total of CPUE	8.73	0.04	0.23	0.63	0.01	0.01	0.04	1.18	0.00	0.23	314.20	20.67	0.26	5.78	0.00	0.03	2.27
	Average CPUE	0.49	0.00	0.01	0.03	0.00	0.00	0.00	0.07	0.00	0.01	17.46	1.15	0.01	0.32	0.00	0.00	0.13
	Std Dev. Of CPUE	0.55	0.01	0.05	0.11	0.00	0.00	0.01	0.26	0.00	0.05	30.06	1.12	0.06	0.52	0.00	0.00	0.30
	Biomass Estimate (t)	1,841.94	7.59	47.98	132.73	1.69	2.76	9.15	249.27	0.61	48.55	66,265.65	4,358.41	55.44	1,218.22	0.57	6.85	479.00
	95% CI % of Estimate	52.8%	123.9%	186.6%	140.3%	142.6%	131.5%	113.3%	185.2%	196.0%	196.0%	79.6%	45.2%	188.4%	75.3%	196.0%	82.0%	109.3%
	Lower 95 CI Limit	868.95	0.00	0.00	0.00	0.00	0.00	-1.22	-212.33	0.00	0.00	13,547.09	2,388.50	0.00	300.53	0.00	0.00	-44.64
	Upper 95 CI Limit	2,814.93	17.00	137.50	318.92	4.11	6.39	19.52	710.88	1.82	143.70	118,984.20	6,328.33	159.91	2,135.91	1.67	12.47	1,002.64

Table 4. Summary of survey trawl locations (~midtow positions) at CSESP stations and environmental variables recorded for bottom trawl and pelagic trawl tows completed during 2011.

Date	Haul	Station	Latitude (midtow) (deg. min. sec.)	Longitude (midtow) (deg. min. sec.)	Depth ftm	Bottom Temp C	Bottom Salinity ppt	Surface Temp C	Tow Duration min
08/24/11	O1P	HF007	N 71 13 48.12	W 162 55 28.32	24.1	NA	NA	7.5	30.68
08/24/11	O2P	HF011	N 71 23 5.46	W 162 24 12.36	25.6	-0.5	32.7	7.1	32.00
08/25/11	O3P	HF010	N 71 23 59.82	W 162 54 39.06	23.2	-0.6	32.6	7.0	30.03
08/25/11	O4P	HF009	N 71 23 38.40	W 163 24 10.38	23.1	-0.5	32.8	6.9	33.00
08/25/11	O5P	HF013	N 71 33 29.82	W 162 52 58.74	21.9	-2.2	33.6	7.1	30.00
08/25/11	O6P	HF017	N 71 43 55.68	W 163 19 38.40	21.5	-0.2	31.2	6.4	30.00
08/25/11	O7P	HF016	N 71 45 26.58	W 163 47 52.62	20.5	-0.9	33.0	6.1	30.00
08/25/11	08P	HF018	N 71 54 46.68	W 163 49 49.20	21.9	NA	NA	6.1	30.00
08/25/11	O9P	HF015	N 71 43 28.08	W 164 22 35.52	19.1	NA	NA	6.1	30.00
08/26/11	10P	HF012	N 71 33 42.48	W 164 22 10.44	22.7	-0.5	32.6	6.6	30.00
08/26/11	11P	HF008	N 71 19 5.70	W 165 4 30.66	21.2	2.4	32.0	6.8	29.97
08/26/11	12P	HF006	N 71 3 53.46	W 165 18 1.92	21.4	2.7	31.5	6.6	30.00
08/26/11	13P	HF004	N 70 54 10.74	W 164 52 7.92	20.1	1.8	33.0	6.7	30.00
08/26/11	14P	HF001	N 70 45 4.08	W 165 17 37.62	22.3	3.4	32.0	7.6	31.02
08/27/11	15P	HF002	N 70 54 44.64	W 165 43 10.50	22.0	3.7	31.9	6.3	30.00
08/27/11	16P	HF005	N 70 59 17.34	W 166 20 50.40	23.0	3.0	31.9	7.3	31.03
08/27/11	17P	HF003	N 70 56 23.88	W 165 14 9.24	21.6	-0.8	32.9	7.3	30.03
08/28/11	18P	HF014	N 71 36 27.00	W 161 36 22.92	24.0	-1.1	33.0	7.1	30.05
08/28/11	19P	HF020	N 72 16 25.86	W 160 36 12.84	22.3	NA	NA	5.5	29.98
08/29/11	01B	HF019	N 72 17 32.17	W 162 30 54.06	19.8	0.9	24.7	5.3	16.67
08/29/11	02B	HF018	N 71 54 13.40	W 163 49 18.56	21.8	1.0	17.0	6.0	16.20
08/29/11	03B	HF017	N 71 43 53.83	W 163 19 16.99	21.5	-0.9	32.9	6.2	12.07
08/29/11	04B	HF016	N 71 44 19.74	W 163 48 37.51	20.8	-0.4	32.7	6.4	16.57
08/29/11	05B	HF015	N 71 44 15.36	W 164 18 38.72	19.4	0.3	32.7	6.5	16.27
08/29/11	06B	HF012	N 71 34 44.59	W 164 18 2.66	22.1	-2.5	29.5	6.4	17.40
08/30/11	07B	HF008	N 71 20 0.99	W 165 3 45.01	21.5	1.5	32.3	6.4	16.53
08/30/11	08B	HF005	N 71 0 15.05	W 166 28 33.72	23.2	4.0	31.8	7.4	18.23
08/30/11	09B	HF002	N 70 55 21.29	W 165 44 32.26	22.1	3.6	31.9	7.7	16.65
08/30/11	10B	HF006	N 71 4 44.14	W 165 16 43.86	21.6	2.4	32.3	7.4	16.57
08/30/11	11B	HF003	N 70 55 21.74	W 165 17 37.56	21.6	3.4	32.0	7.0	16.48
08/30/11	12B	HF001	N 70 45 52.85	W 165 17 1.64	22.1	3.7	31.9	8.1	16.78
08/30/11	13B	HF004	N 70 55 26.12	W 164 47 22.45		0.4	29.7	7.6	16.57
08/31/11	14B	HF009	N 71 23 35.88	W 163 21 51.84	22.7	-0.3	15.5	6.9	17.22
08/31/11	15B	HF013	N 71 33 19.31	W 162 51 58.31	21.9	1.6	30.9	6.4	16.42
08/31/11	16B	HF010	N 71 23 48.00	W 162 53 0.00	23.7	-3.5	32.4	7.1	8.88
08/31/11	17B	HF007	N 71 13 54.68	W 162 55 20.09	24.0	NA	NA	7.0	16.63
08/31/11	18B	HF011	N 71 22 58.95	W 162 24 5.89	25.4	-1.5	32.4	7.3	16.53
08/31/11	19B	HF014	N 71 37 42.19	W 161 36 40.77	24.0	-1.4	33.2	7.2	16.62

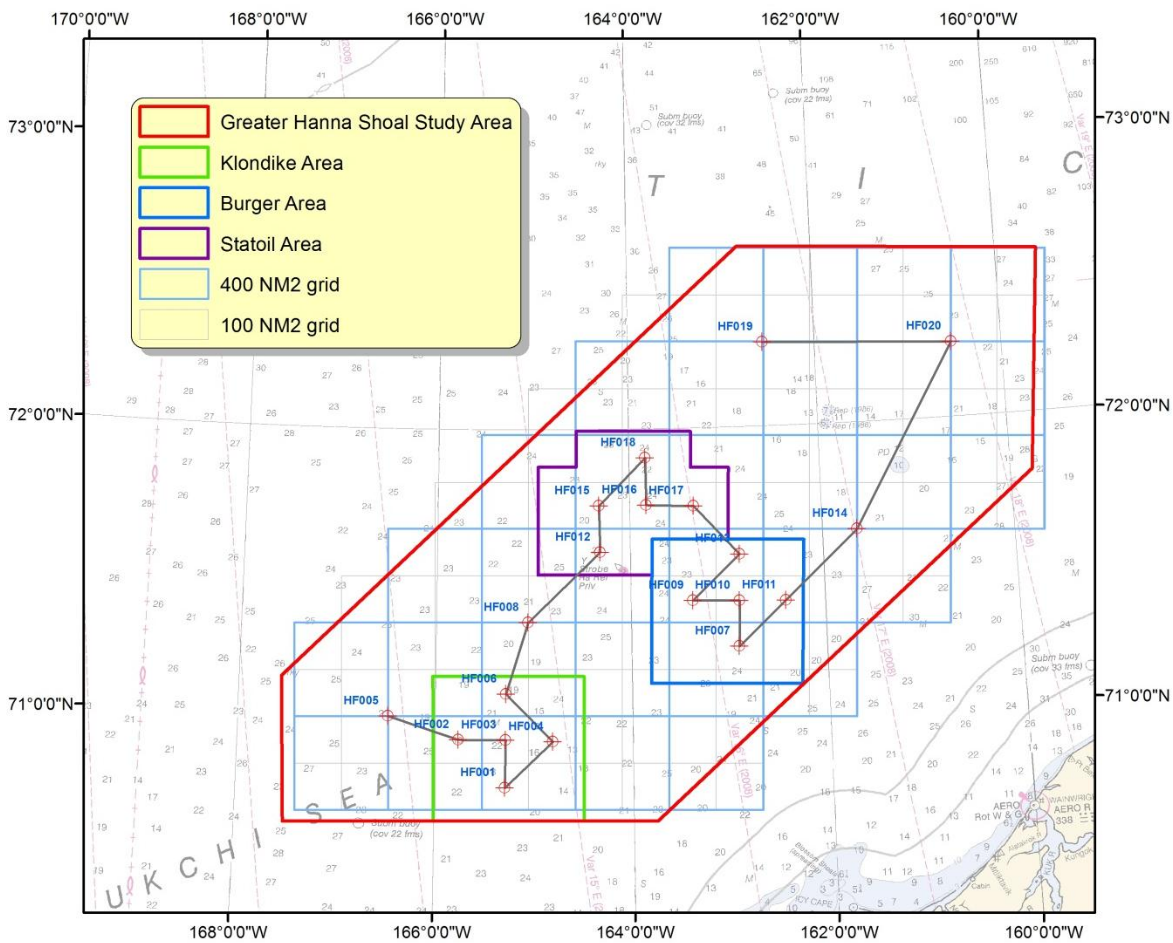
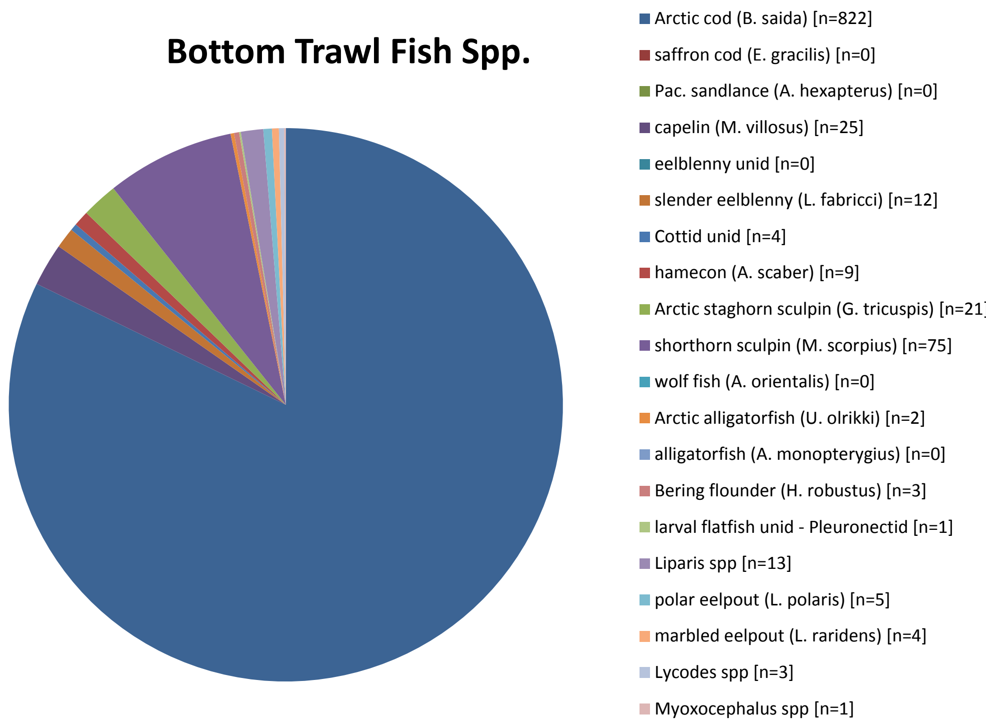


Figure 1. Location of the study area, 2011 stations and lease blocks for fishery survey coverage.

Figure 2. Photos of the R/V *Pandalus* used in 2011 CSESP trawl surveys.



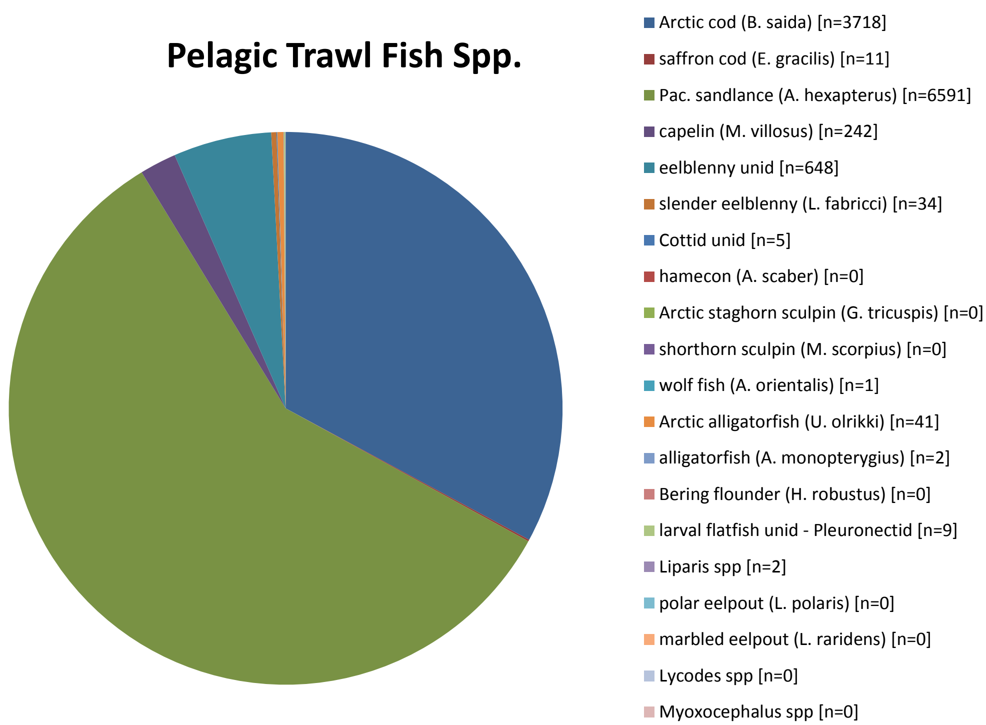
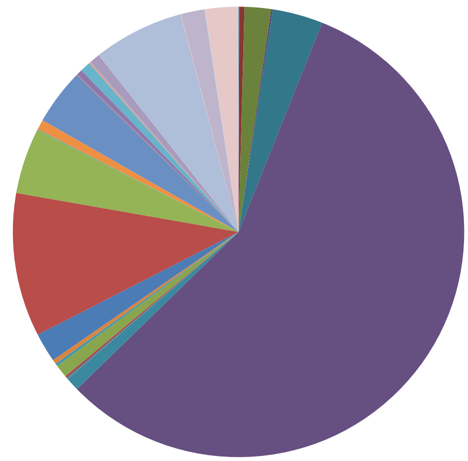


Figure 3. Fish species diversity by gear type for all tows in all study areas from NRC CSESP 2011 fish surveys. (*n* = total catch in numbers, pelagic catch adjusted by tow duration).

Invertebrate Species	BTR	PTR
Ampelisca eschrichti	7	0
anemone unidentified	35	0
Argis dentata	189	0
Argis lar	11	0
Astarte borealis	360	0
barnacle unidentified	**0**	0
Boltenia ovifera	**0**	0
brittle star unidentified	**0**	0
bryozoan unidentified	**0**	0
Chionoecetes opilio	5,643	1
chiton unidentified	98	0
clam unidentified	2	0
Clinocardium ciliatum	8	0
cookie star unidentified	14	0
Crossaster papposus	92	0
Eogonatus tinro	0	3
Eunoe nodosa	19	0
Gersemia spp	32	0
Gorgonocephalus eucnemis	209	0
hermit crab spp unidentified	1,027	0
Hyas coarctatus	470	0
jellyfish unidentified	0	**0**
Lebbeus groenlandicus	5	0
Leptastarias arctica	72	0
Leptasterias polaris	399	0
Musculus niger	4	0
nudibranch unidentified	1	0
Ocnus glacialis	42	0
Pandalus goniurus	73	3
Paralithodes platypus	1	0
Saduria entomon	1	0
scale worm unidentified	9	0
scallop unidentified (sm)	3	0
sea worm unidentified	75	0
Serripes groenlandicus	1	0
snail eggs	**0**	0
snail unidentified	644	0
sea star unidentified	4	0
sea star unidentified (4 leg/lg)	1	0
sea star unidentified (5 leg/lg red)	168	0
sea star unidentified (slime)	5	0
Themisto lebellula	0	444
Thysanoessa raschii	0	32
tunicate unidentified	230	0
tunicate unidentified (sea squirt)	0	0
urchin unidentified	6	0

* counts of zero in bold for BTR have positive catches but quantities are not reported.

Bottom Trawl Invertebrate Spp.



Pelagic Trawl Invertebrate Spp.

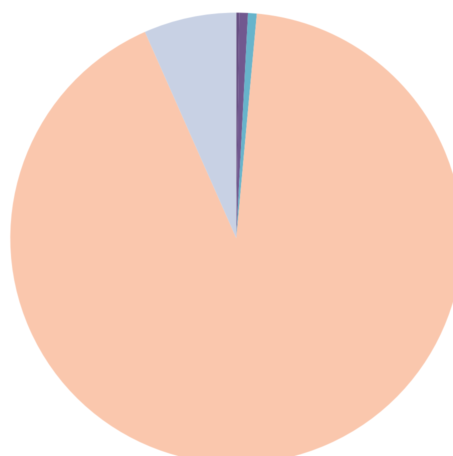


Figure 4. Invertebrate species diversity by gear type for all tows in all study areas from NRC CSESP 2011 fish surveys. (*n*=total catch in #s, pelagic trawl adjusted by tow duration).

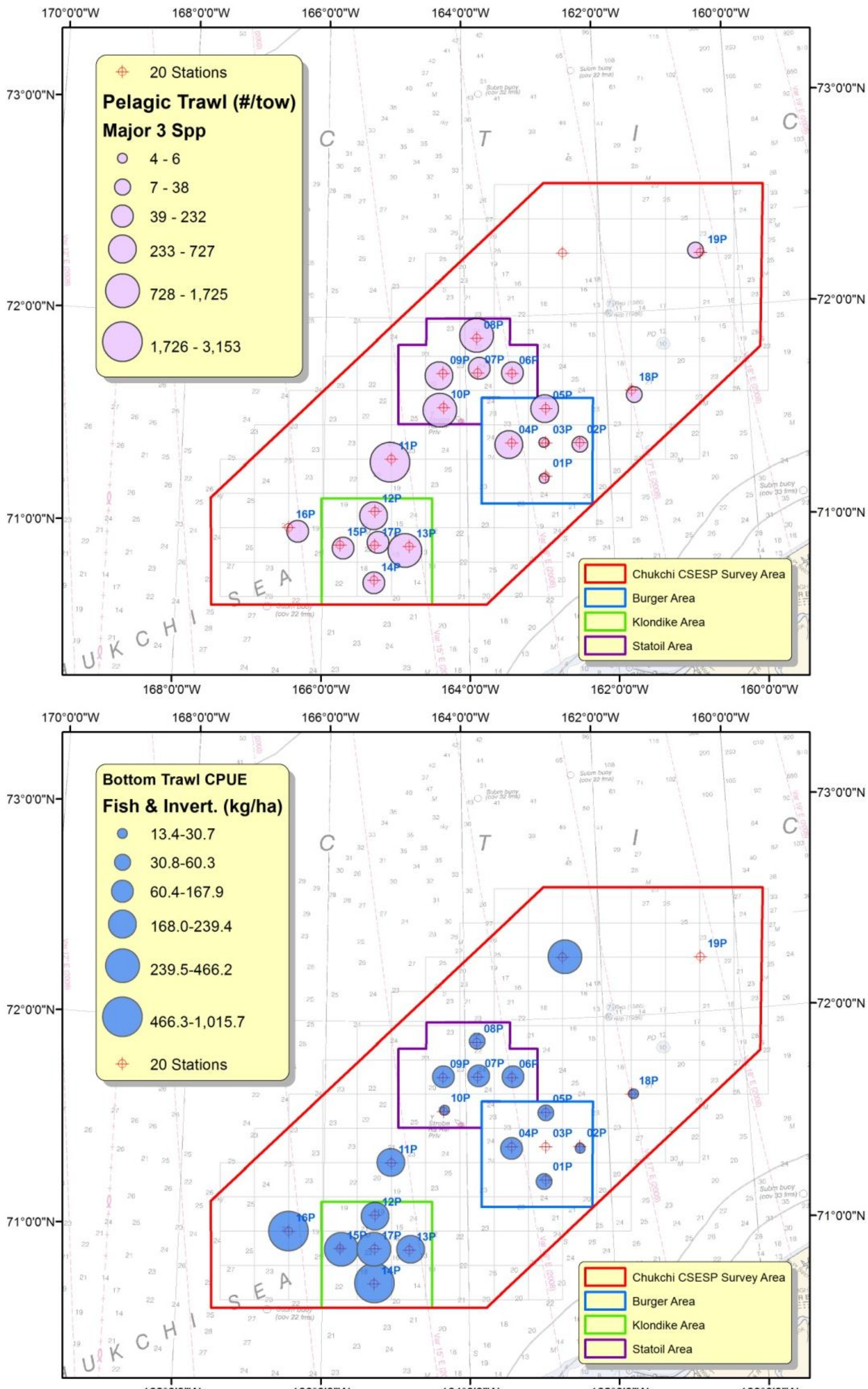


Figure 5. Distribution of catches per station across lease blocks from pelagic tows (total catch of 3 major fish species [Arctic cod, Pacific sandlance and capelin]) and bottom tows (CPUE in kg/ha of fish and invertebrates) during NRC CSESP 2011 fish surveys.

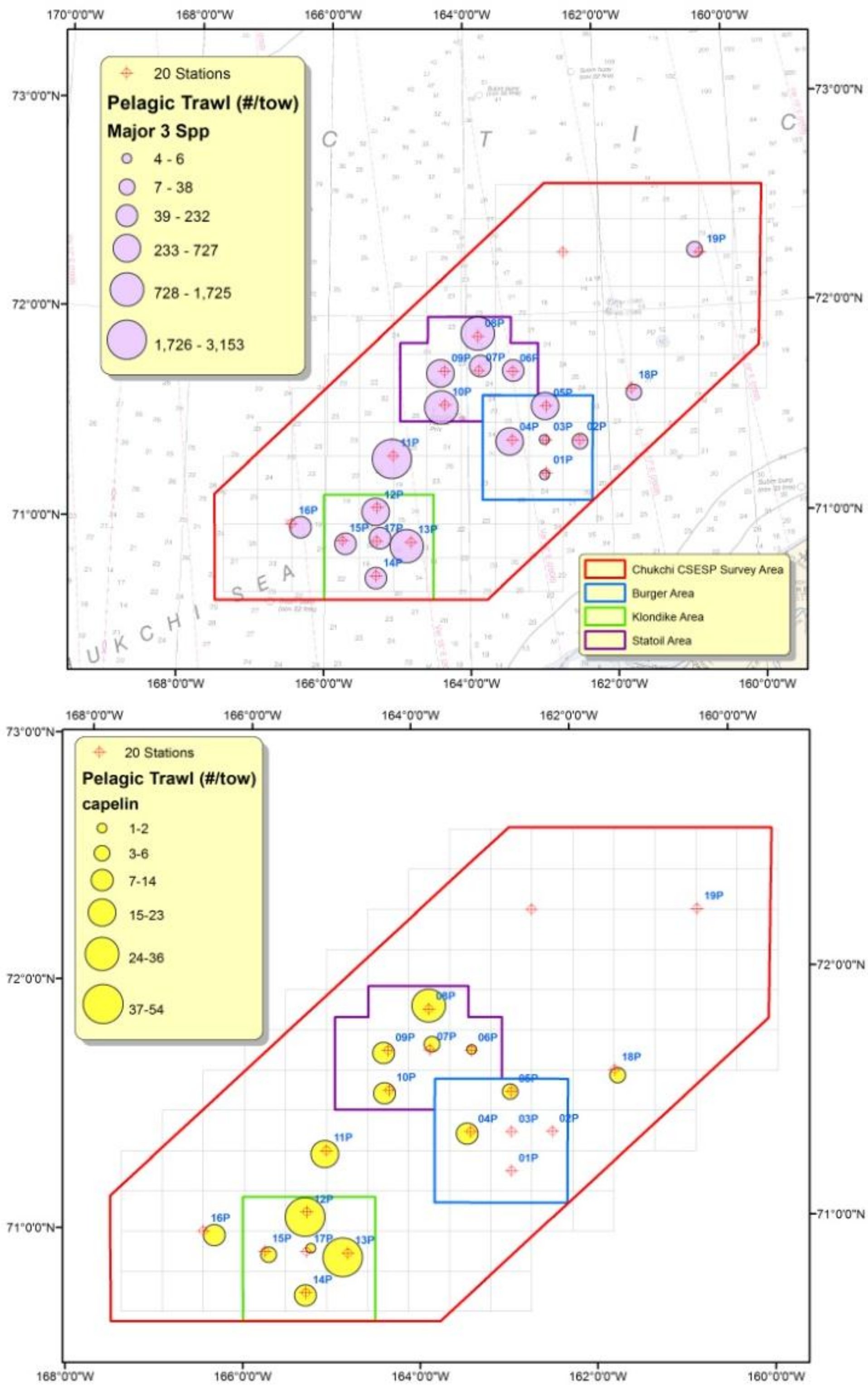


Figure 6. Total catch per tow (standardized) of three main fish species (Arctic cod, Pacific sandlance and capelin) from pelagic trawl tows completed during NRC CSESP 2011 fish surveys.

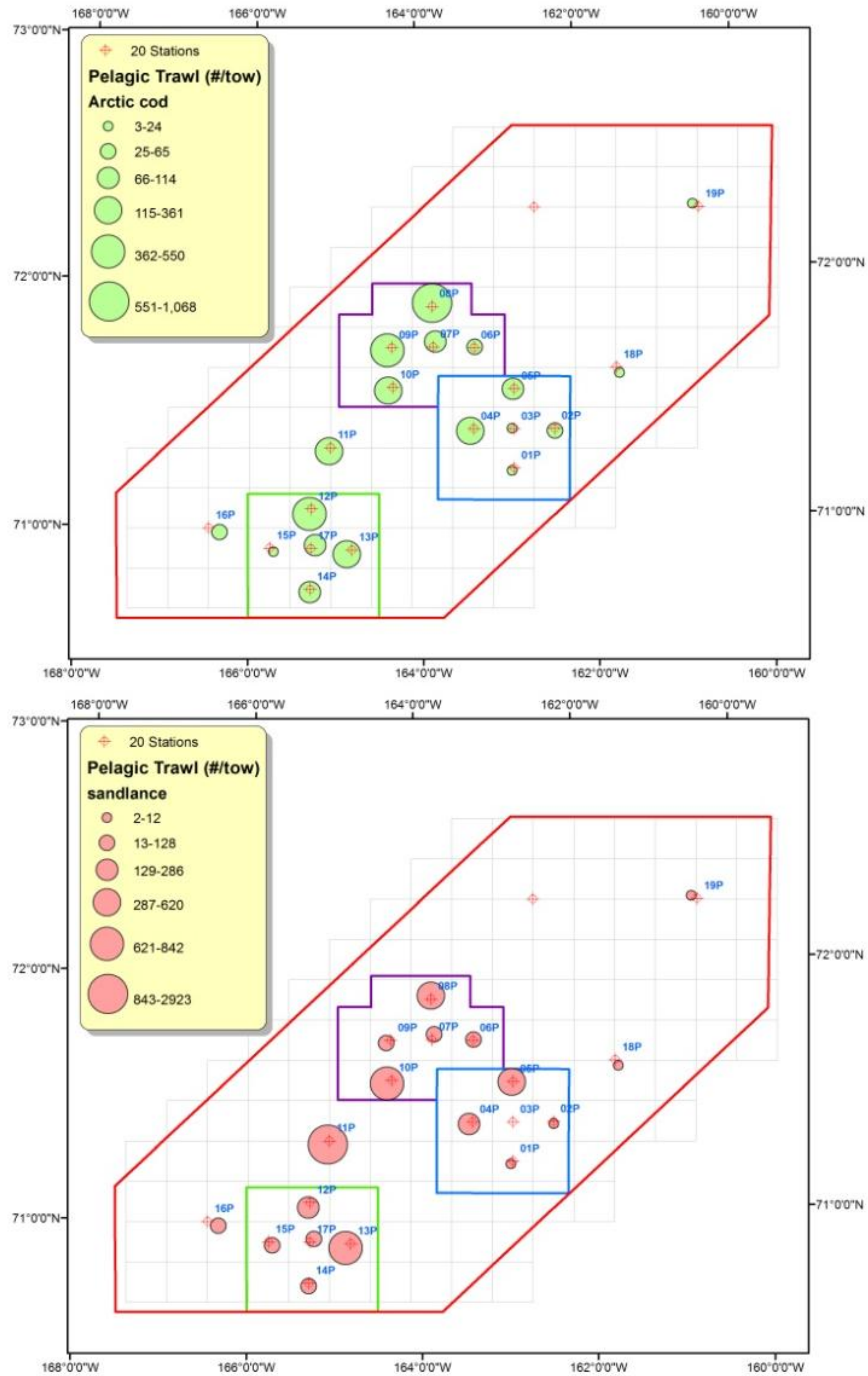


Figure 6. Continued…total catch per tow (standardized) of three main fish species (Arctic cod, Pacific sandlance and capelin) from pelagic trawl tows completed during NRC CSESP 2011 fish surveys.

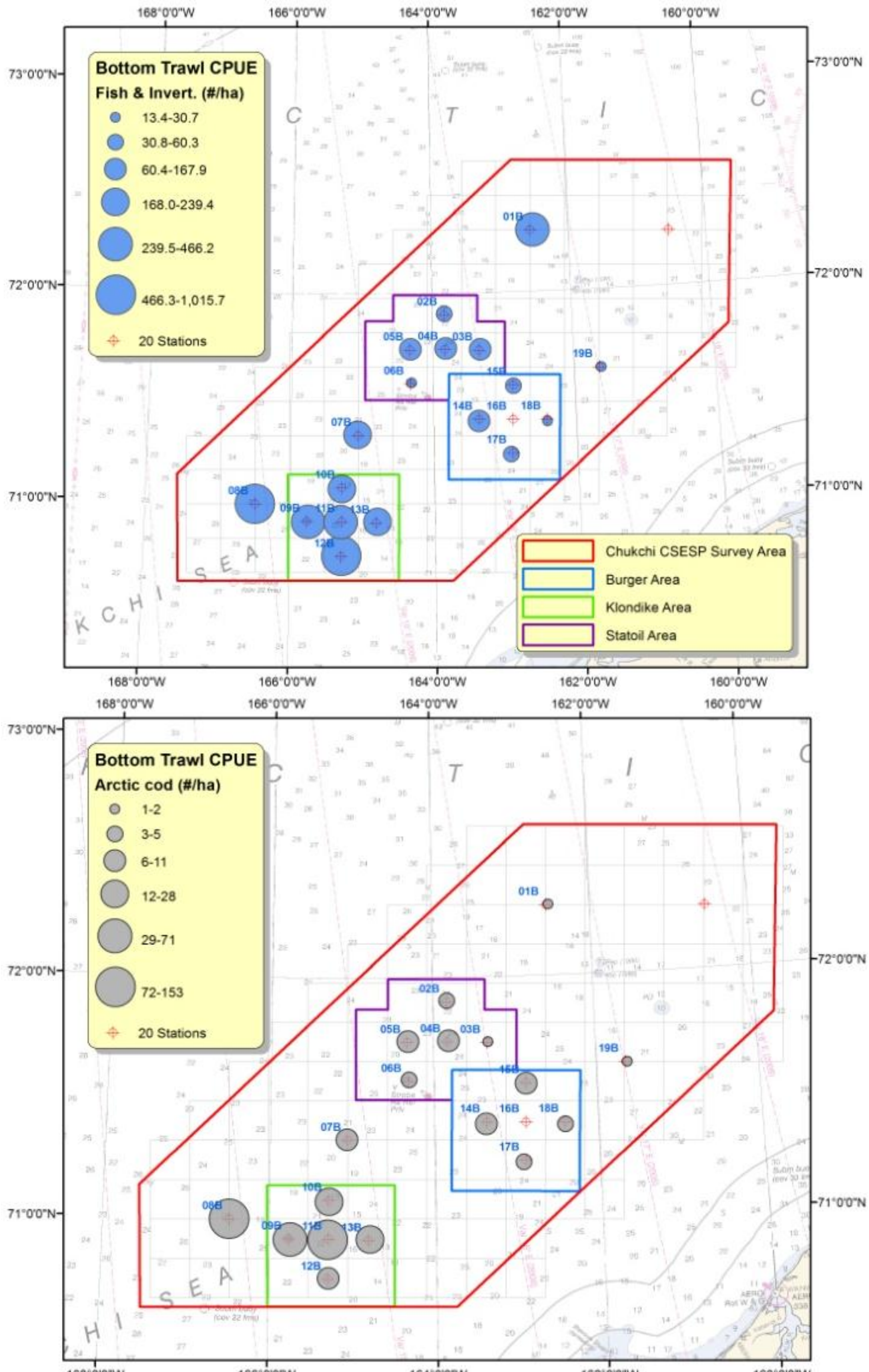


Figure 7. CPUE per tow (# animals/ha) of total fish and invertebrates and three main species (Arctic cod, snow crab and Arctic lyre crab) from bottom trawl tows completed during NRC CSESP 2011 fish surveys.

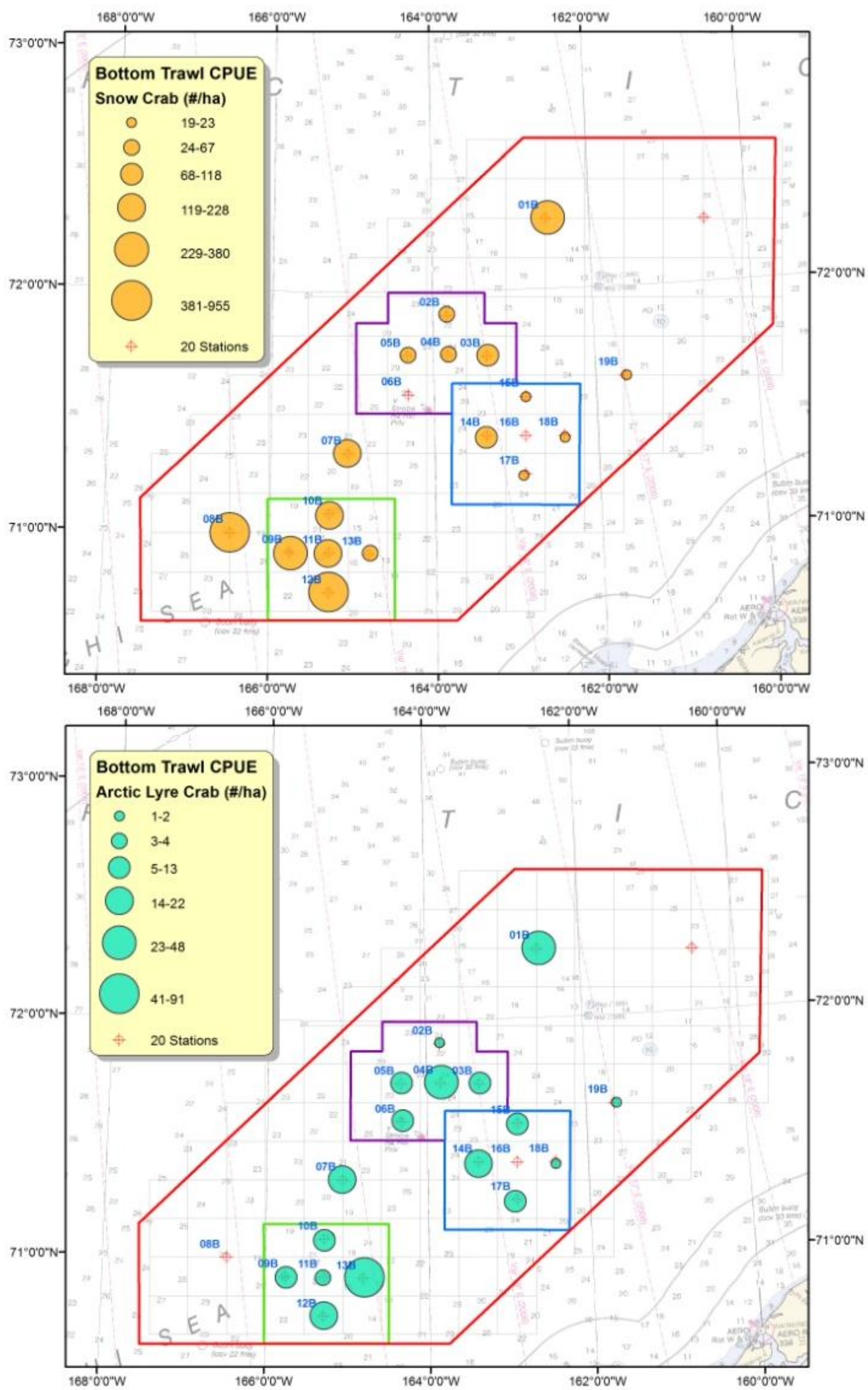


Figure 7. Continued…CPUE per tow (# animals/ha) of total fish and invertebrates and three main species (Arctic cod, snow crab and Arctic lyre crab) from bottom trawl tows completed during NRC CSESP 2011 fish surveys.

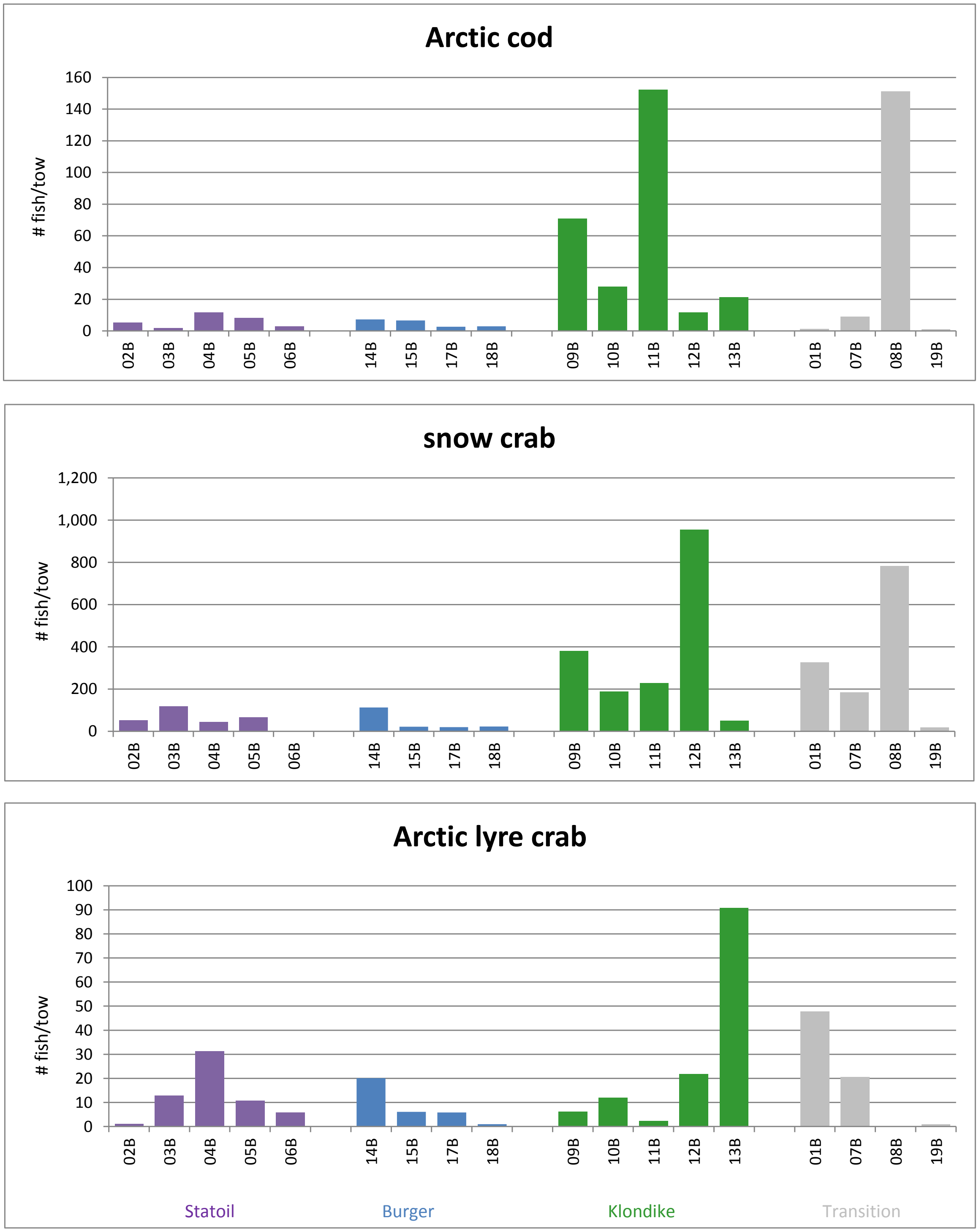


Figure 8. Summary of CPUE for Arctic cod, snow crab and Arctic lyre crab in the Eastern 400 bottom trawl during the 2011 NRC Chukchi Sea CSESP fish surveys by lease area within the study area.

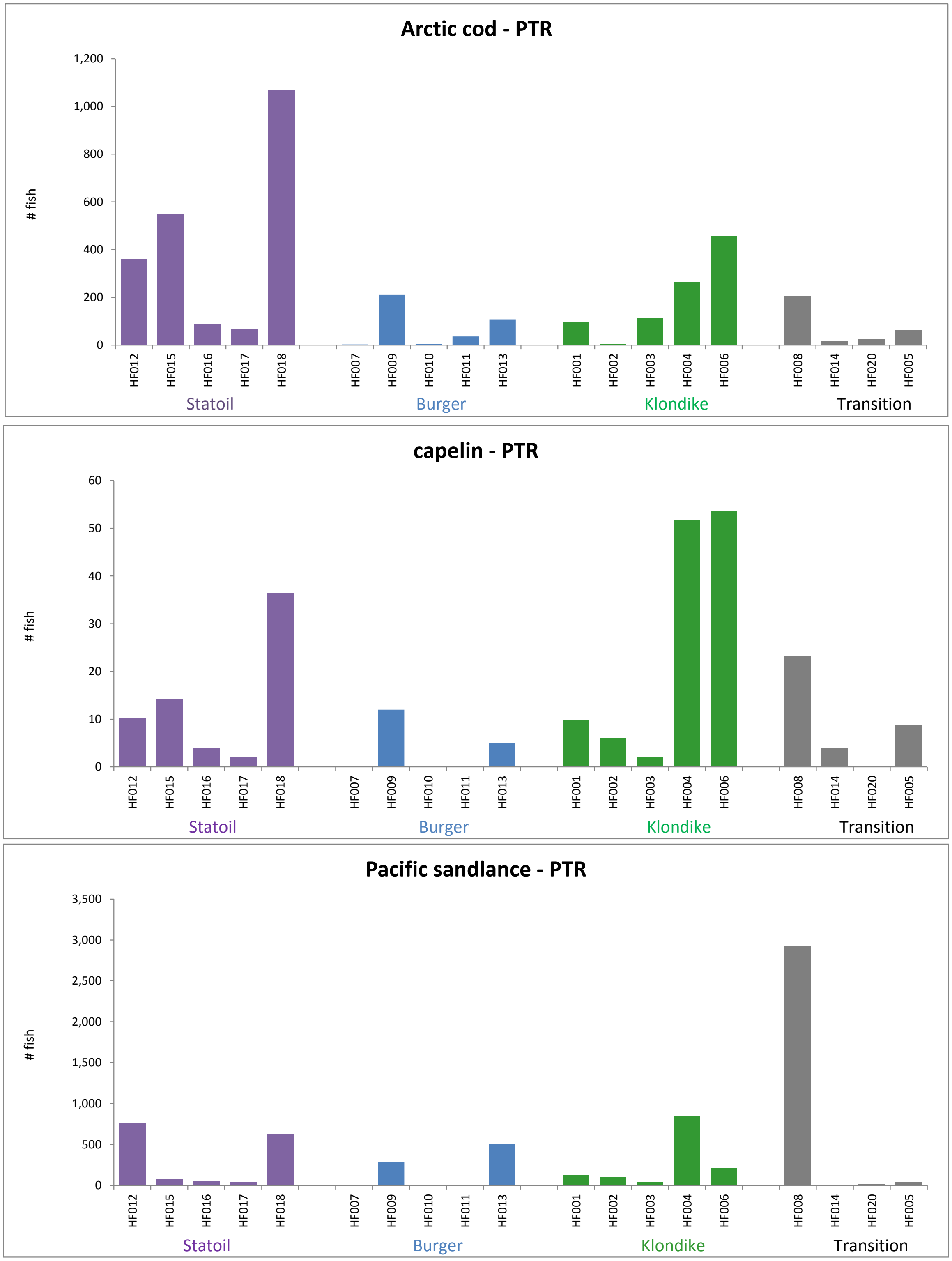


Figure 9. Summary of relative catches for three major species in the pelagic trawl during the 2011 NRC Chukchi Sea CSESP fish surveys by lease area within the study area.

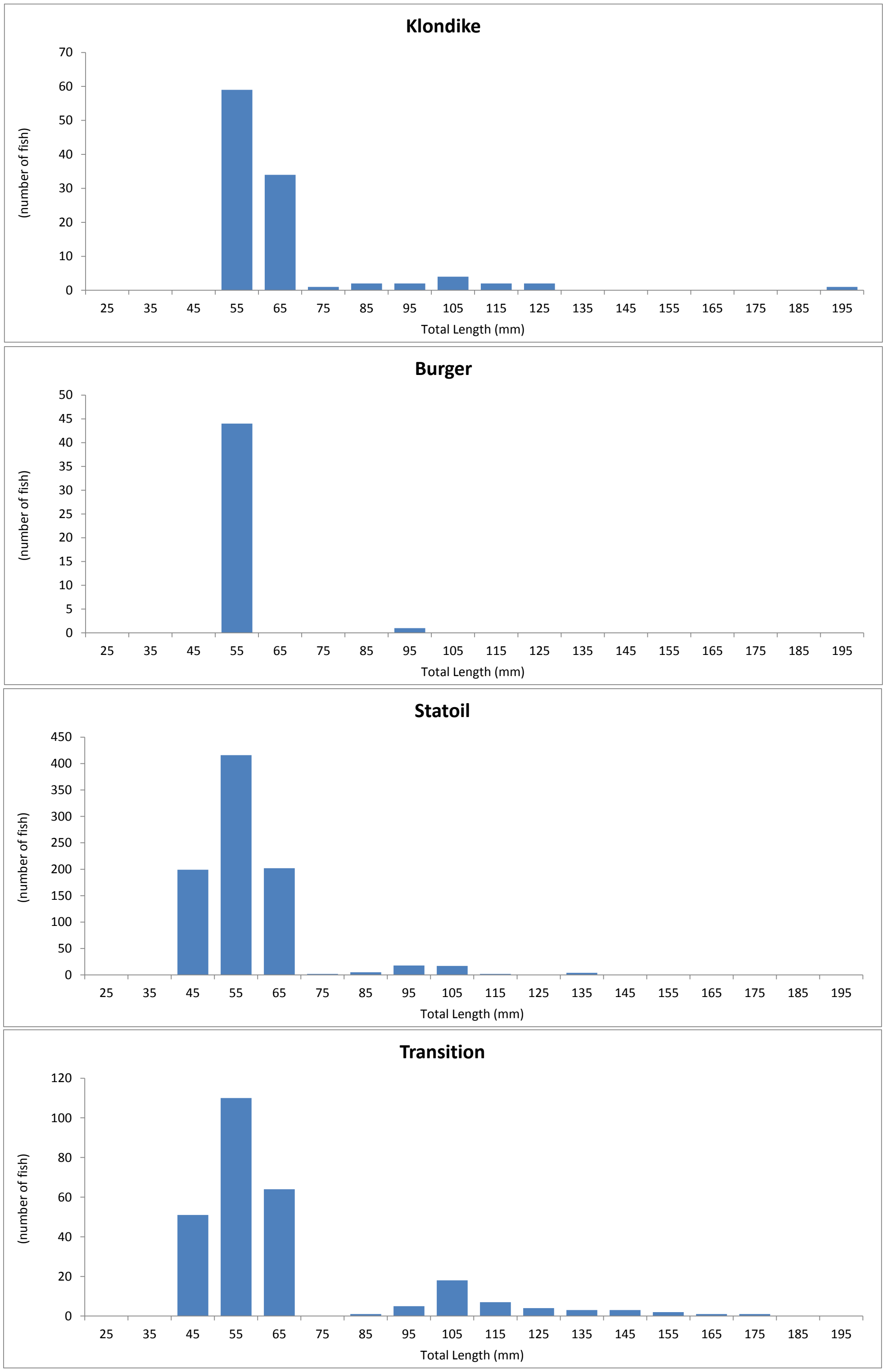


Figure 10. Length-frequency of measured Arctic cod caught during the 2011 NRC Chukchi Sea CSESP fish surveys by lease area within the GHS study area.

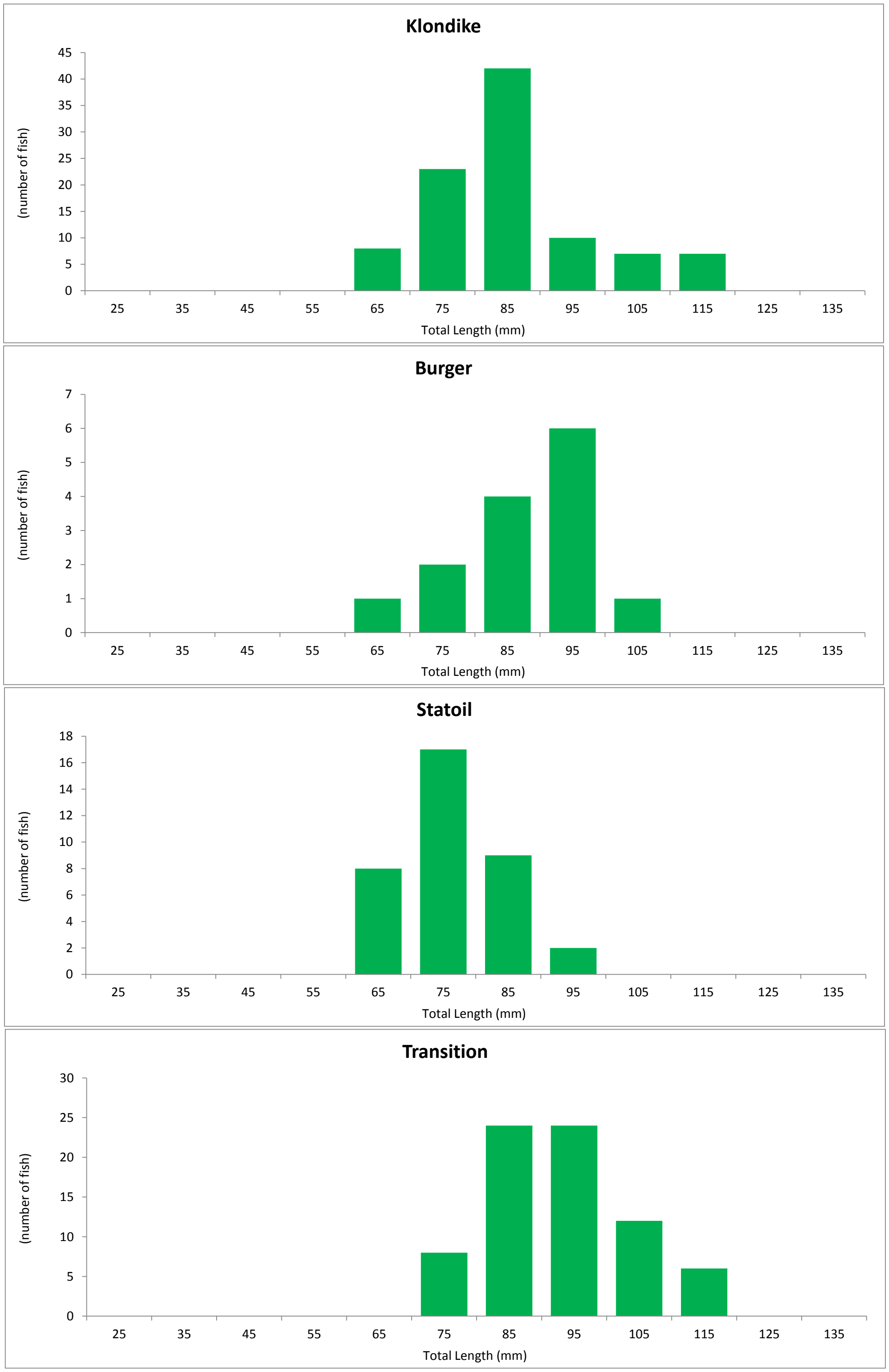


Figure 11. Length-frequency of measured capelin caught during the 2011 NRC Chukchi Sea CSESP fish surveys by lease area within the GHS study area.

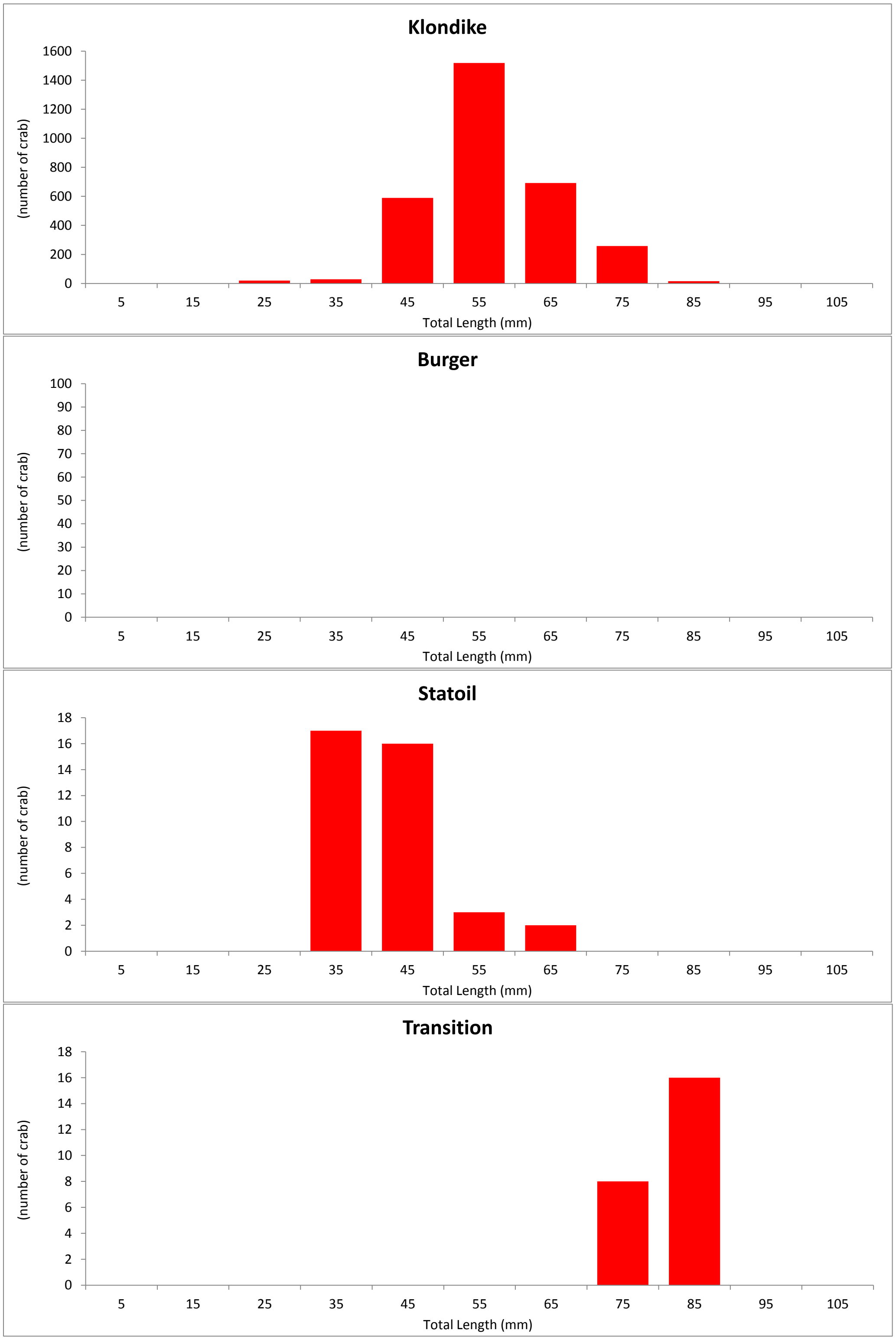


Figure 12. Length-frequency of measured snow crab caught during the 2011 NRC Chukchi Sea CSESP fish surveys by lease area within the GHS study area.

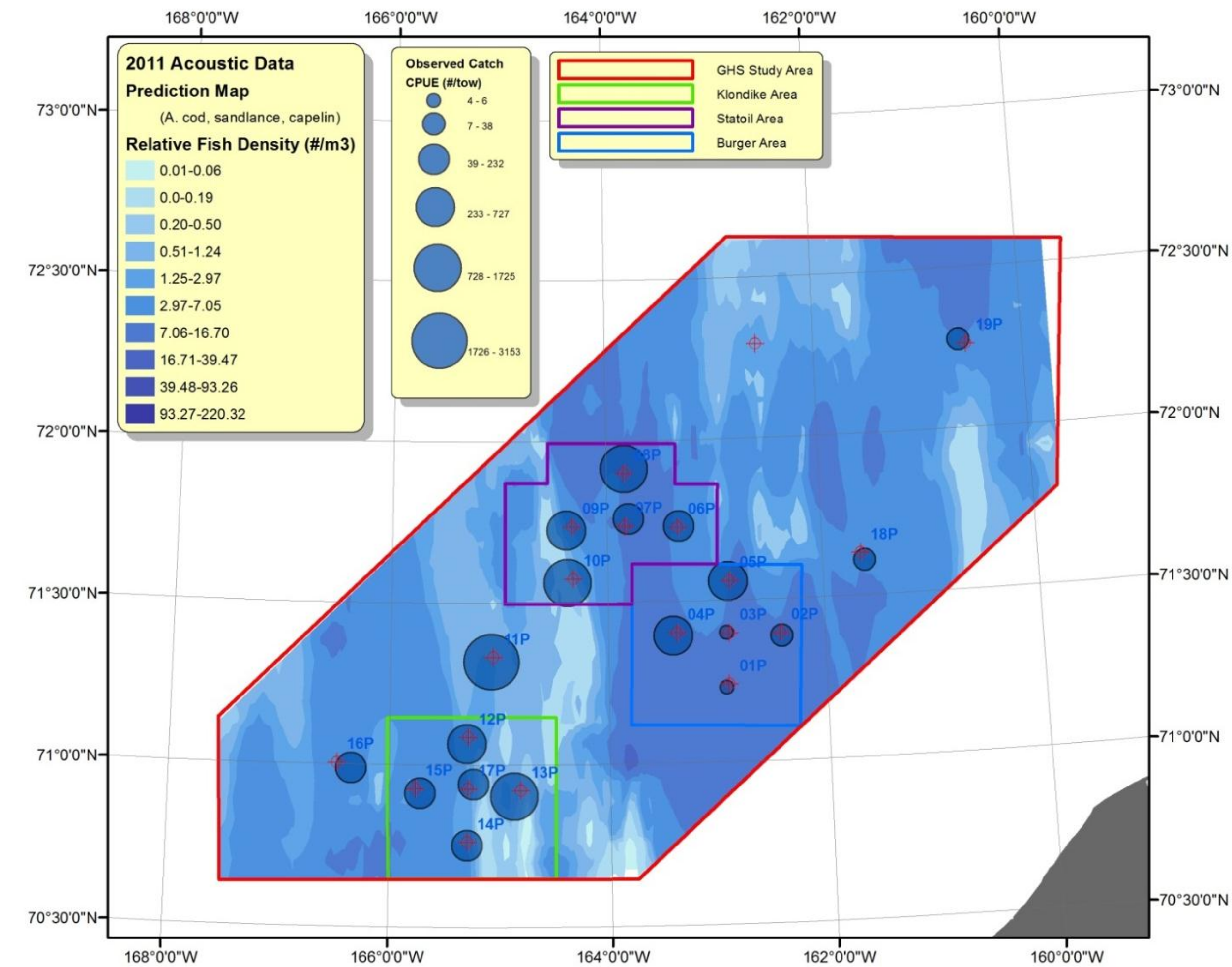


Figure 13. Acoustic data overlay (predicted relative density in fish/m^3) from R/V *Westward Wind* with pelagic fish CPUE of Arctic cod, sandlance and capelin from the 2011 pelagic trawls conducted during 2011 CSESP surveys.