Northern Bering Sea surface trawl survey, 2019

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Abstract

The northern Bering Sea (NBS) surface trawl survey is a multi-disciplinary research survey that has supported annual sampling of the inner domain (bottom depths generally less than 55 m) of the NBS (60°N–66.5°N). Average sea surface temperature (SST) (upper 10 m) during the 2019 survey (11.5°C) was the warmest on record and contributed to significant changes in the NBS ecosystem. Similar to prior years, the jellyfish species, Northern Sea Nettle (*Chrysaora melanaster*), had the largest surface trawl catch biomass with a total catch of 6,989 kg in 2019. Pacific Herring (*Clupea pallasii*) were the most abundant fish species with a catch of 142,512 fish. Juvenile Pink Salmon (*Oncorhynchus gorbuscha*) were the most abundant species of salmon with a total catch of 13,507 fish. Annual catch rates of Sockeye Salmon (*O. nerka*) in the NBS survey increased significantly with SST (ρ=0.9). Catch rates of Coho Salmon (*O. kitsutch*) (ρ=0.7), age-0 Walleye Pollock (*Gadus chalcogrammus*) (ρ=0.6), and Pacific Herring (ρ=0.6) also increased significantly with SST. Capelin (*Mallotus villosus*) was the only species that significantly decreased with SST (ρ=-0.6). The abundance and proportion of juvenile Yukon River Chinook Salmon (*O. tshawytscha*) stock groups were the lowest on record during 2019. The abundance of the Canadian-origin stock group (stock proportion of 30%) was estimated at 575,100 juveniles. The abundance of the Total Yukon River stock group (stock proportion of 65%) was estimated at 1,246,000 juveniles. Projected run-sizes for Yukon River Chinook Salmon in 2021 and 2022 are 52,300 and 46,300 for the Canadian-origin stock group and 143,800 and 129,000 for the Yukon River stock group, respectively. The abundance of juvenile Pink Salmon reached a record high abundance in 2019, resulting in an outlook of 6.5 million Pink Salmon for Yukon River and Norton Sound in 2020. Average lengths of juvenile salmon were typical of past years except for Coho Salmon, which had the lowest recorded average length in 2019. The energy density (ED) of juvenile Chinook Salmon was average in 2019, but was lower than 2018. This reduction in ED may be due to increased metabolic rates and/or negative impacts on prey quality or quantity associated with unusually warm conditions in 2019. Average stomach fullness of juvenile Chinook, Pink, and Chum Salmon has declined with increasing SST in the NBS and the stomach fullness of Chum and Chinook Salmon reached record low levels in 2019. Chinook Salmon fed primarily upon fish, however, piscivory by juvenile Chinook Salmon also has decreased with warming temperature in the NBS. A decline in the availability of high quality prey during early ocean residence may be contributing to the decrease in Chinook Salmon energy density and stomach fullness in recent years. The proportion of non-target prey consumed by Coho and Chum Salmon has increased in recent years suggesting a decrease in preferred prey. A total of 2,870 km of transects were surveyed. We recorded 3,310 birds on transect, comprised of 38 species plus a few unidentified passerines, with the Northern Fulmar (*Fulmarus glacialis*) the most abundant seabird species encountered.

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Introduction

The northern Bering Sea (NBS) surface trawl survey (NBS survey) is a multi-disciplinary survey that supports research on pelagic fish and oceanographic conditions in the Eastern Bering Sea. Surface trawl surveys in the NBS were initiated by NOAA–Alaska Fisheries Science Center (AFSC) in 2002 as part of the Bering-Aleutian Salmon International Survey (BASIS). BASIS was a basin-wide research program developed by member nations of the North Pacific Anadromous Fish Commission and designed to improve our understanding of the marine ecology of salmon in the Bering Sea. Surface trawl surveys in the NBS were continued through 2007 as part of the BASIS survey for the Eastern Bering Sea shelf. The NBS was not sampled in 2008, but has been sampled on an annual basis since 2009 to support research objectives on the ecology of salmon in the NBS and to improve our understanding of how the NBS ecosystem is changing in response to warming climate and loss of Arctic sea ice.

The NBS survey has supported a range of different survey operations and research objectives in the NBS. Survey operations have included: surface and midwater trawl sampling for pelagic nekton, midwater acoustics, seabird and marine mammal observations, bongo net sampling for zooplankton and ichthyoplankton, electronic oceanographic data (CTD data), and water collections for chlorophyll-a, phytoplankton, and nutrients. Survey objectives have supported research objectives on salmon and other pelagic fish resources in the NBS, including: juvenile salmon abundance and run-size forecasts (Murphy et al. 2017, Howard et al. 2019, Howard et al. 2020, Farley et al. 2020), size selective mortality (Murphy et al. 2013, Howard et al. 2016), energy allocation (Andrews et al. 2009, Murphy et al. 2013, Moss et al. 2017), diet (Farley et al. 2009, Andrews et al. 2016, Auburn & Sturdevant 2013, Honeyfield et al. 2016, Garcia and Sewall In Review), and species distribution (Murphy et al. 2009, Murphy et al. 2016, Andrews et al. 2016). An emphasis has been given to Chinook Salmon over the last five to ten years due to the decline in their survival (ADFG 2013) and their importance to subsistence fisheries in the Yukon River. The declining run sizes of Chinook Salmon in the Yukon River has a wide-spread impact on subsistence fisheries throughout Alaska and the Yukon Territory, and has had a significant impact on pollock fisheries in the Eastern Bering Sea through efforts to reduce Chinook Salmon bycatch (Ianelli and Stram 2014, Stram and Ianelli 2014).

The 2019 NBS survey was a cooperative research survey by AFSC, the Alaska Department of Fish and Game (ADF&G), the Alaska Pacific University (APU), and the U.S. Fish and Wildlife Service (USFWS) to improve our understanding of the marine ecosystem in the NBS. Key funding was provided by the Alaska Sustainable Salmon Fund to help maintain research on juvenile salmon in the NBS. The primary objectives of the 2019 NBS surface trawl survey were to: 1) conduct surface trawl operations in support of ecosystem science, with a focus on the marine ecology of juvenile fish species; 2) estimate stock-specific abundance of juvenile Chinook Salmon and update run-size forecast models for the Yukon River; 3) collect electronic oceanographic data and water samples for temperature, salinity, chlorophyll-a, nutrients, particulate organic carbon, and harmful algal blooms with a SBE9-11 CTD and Niskin bottles; 4) collect zooplankton and icthyoplankton samples with a 20 cm (150 µm mesh) and 60 cm (505 µm mesh) bongo array; and, 5) assess the distribution and abundance of seabirds and marine mammals on the NBS shelf.

Methods

Survey

The 2019 NBS survey began and ended in Dutch Harbor, AK with a port call in Nome, AK. The survey occurred over 25 days inclusive of mobilization, demobilization, travel, sampling, and weather days aboard the chartered fishing vessel *F/V Northwest Explorer*, August 27 - September 20, 2019. The survey crew consisted of scientists from NOAA-Alaska Fisheries Science Center, Alaska Department of Fish and Game (ADF&G), U.S. Fish and Wildlife Service (USFWS), and the Alaska Pacific University (APU) (Table 1). The survey consisted of 44 stations in the NBS between 60°N–66.5°N and east of 171°W, and three additional stations just north of the Bering Strait (Figure 1, Table 2). Rough weather conditions at the end of the survey prevented sampling at the distributed biological observatory (DBO) stations in 2019. Each day typically consisted of sampling 3 stations during daylight hours. The order of operations at each station was: (1) a Conductivity Temperature Depth (CTD) instrument system, (2) a Van Veen grab sample to collect benthic organisms and sediment samples for the presence of harmful algal blooms (HABs), (3) an oblique zooplankton net tow with bongo array and a FastCat CTD, and (4) one surface trawl tow. Seabird and marine mammal observations were recorded while travelling between stations.

Oceanographic Conditions

The primary CTD (SeaBird Instruments SBE-9-11+) was outfitted with dual temperature and conductivity (TC) sensors, a Photosynthetically Active Radiation (PAR) spherical sensor (QSP 2300, Biospherical Instruments), chlorophyll-a fluorometer, beam transmissometer (Wet Labs C-star), and two dissolved oxygen sensors (SeaBird Instruments SBE-43). The CTD measured temperature (°C), salinity (psu), and pressure (db) from the surface down to 5 m from the bottom. A SeaBird Instruments SBE-32 carousel water sampler frame with 1.5 liter Niskin bottles was used to collect water samples from the surface down to 5 m from the bottom in 10 m increments. The water samples from the Niskin bottle were filtered following water collection protocols (Appendix 1).

The temperature and salinity for each meter of the CTD cast was calculated by averaging the readings from the primary and secondary temperature and salinity sensors. Sea surface temperature (SST) and salinity were estimated by averaging the temperature and salinity measurements from the top 10 m of the water column. Bottom temperature and salinity were equal to the measurements from the deepest cast of the CTD at each station. The average annual SST was estimated for all stations within the NBS (latitudes: 60°N - 65.5deg;N) and for a restricted spatial range to account for changes in sampling locations over time (longitudes east of 171°W, and latitudes south of 64°N). Norton Sound stations were restricted to three stations along 64°N.

Mixed-layer depth (MLD) was defined as the depth where seawater density (kg/m^3) increased by 0.10 kg/m^3 relative to the density at 5 m (Danielson et al. 2011; Murphy et al. 2017). Seawater density was calculated from temperature and salinity using the oce package (Kelley and Richards 2020) in R (R Core Team 2020). The MLD was set to the maximum depth of the CTD cast when the water column was mixed. The MLD was calculated from the FastCat CTD (SeaBird Instruments SBE-49) when the primary CTD data were not available. Average MLD from adjacent stations was used when both the CTD and FastCat data were not available.

A bongo net array was deployed to sample zooplankton and ichthyoplankton throughout the water column. The bongo array consisted of two 60-cm diameter bongo nets with 505 micron mesh and two 20-cm diameter bongo nets with 153 micron mesh. A FastCat CTD was affixed to the bongo net array to measure depth in real time using a conducting wire. The bongo nets were towed obliquely from the surface down to 5 m off the bottom at a 45° angle. One net from each bongo frame was preserved in 5% buffered formalin, the second bongo net was sorted for on-board Rapid Zooplankton Assessment (Appendix 1).

Rapid Zooplankton Assessment (RZA) was used to provide information on zooplankton abundance and community structure from coarse taxonomic categories of zooplankton during the 2019 NBS survey. Taxonomic categories included small copepods (< 2 mm; example species: *Acartia* spp., *Pseudocalanus* spp., and *Oithona* spp.), large copepods (> 2 mm; example species: *Calanus* spp. and *Neocalanus* spp.), and euphausiids (< 15 mm; example species: *Thysanoessa* spp.). Small copepods were counted from the 153 µm mesh, 20 cm bongo net. Large copepods and euphausiids were counted from the 505 µm mesh, 60 cm bongo net. Bongo net samples were split with Stemple pipettes to reach a total count of at least 100 individuals per sample. This method was first used in the NBS survey in 2018.

Surface Trawl Data

A Cantrawl 400/601 rope trawl from Cantrawl Pacific Ltd. (Murphy et al. 2003) was used to conduct surface trawl operations. All surface trawl tows were 30 min in duration and trawl dimensions were monitored during each tow with a Simrad FS70 net sounder. A SeaBird Instruments SBE-39 temperature and depth sensor mounted to the center of the footrope measured footrope depth and temperature during each tow. The number of fish (or weight of jellyfish) caught in a single tow was divided by the area swept by the trawl (km^2) to estimate catch-per-unit-effort (CPUE) and was used to describe species distribution and abundance. The area swept by the trawl was calculated using the horizontal opening from the net sonar and the distance sampled from GPS positions at the start and end of the trawl set.

Surface trawl catches were sorted by species and life history stage and up to 50 individuals from each species and life history stage combination were measured for length and weight at each station. Individual specimen weights were not recorded for species with weights less than 10 g due to the limited accuracy of ship-board weights. Mixed-species subsamples were used to estimate the catch of a few small and numerous species (typically Ninespine Stickleback (*Pungitus pungitius*), age-0 Pacific Herring (*Clupea pallasii*), and Moon Jellyfish (*Aurelia* spp.)). Total catch weight and average weight of measured individuals were used to estimate the total number of species when a subsample of the catch was measured. Annual sample requests were used to define specimen collection protocols for juvenile salmon (*Oncorhynchus* spp.), immature/mature salmon, and non-salmon species (Appendix 1). Subsample sizes for juvenile salmon species were reduced in 2019 to accommodate specimen requests from the unexpectedly large numbers of juvenile Pink (*O. gorbuscha*), Chum (*O. keta*), and Sockeye (*O. keta*) Salmon. Subsample sizes for individual jellyfish widths and weights were also reduced to 10 individuals per species per station in 2019. All biological data were recorded in an electronic catch logging system developed by AFSC referred to as CLAMS. Individual specimens collected in surface trawls were assigned a specimen number (barcode number) and electronically scanned into CLAMS to ensure a consistent record of all specimens collected during the survey. Juvenile Chum and Pink Salmon caudal fins were collected for genetic analysis, frozen, and assigned a station number. Chum and Pink Salmon genetic samples were not assigned individual barcode numbers. All Chinook Salmon were scanned for missing adipose fins, coded-wire-tags (CWTs), and Passive Integrated Transponder (PIT) tags.

Correlations between CPUE of the most abundant pelagic fish species and SST were plotted using the ggcorrplot package (Kassambara 2019) in R (R Core Team 2020) to provide insight into how the NBS fish community is responding to warming climate conditions in the eastern Bering Sea. Species-specific CPUE indices were based on log-transformed average CPUE adjusted for MLD as:

$$ln(CPUE_y) = ln\left(\frac{\sum_x C_{iy}M_{iy})}{\sum_x a_{iy}}\right),$$

where C_{iy}, and a_{iy} are the catch and effort, at station i, and year y, respectively, and M_{iy} is equal to the ratio of mixed-layer depth to trawl depth when trawl depth is shallower than mixed layer depth at station *i*, and 1.0 when trawl depth is below the mixed-layer depth. The Extended Reanalysis Sea Surface Temperature (ERSSTv5) dataset (Huang et al. 2017) for the eastern Bering Sea shelf (54-66°N, and 146-176°W) from June through August was used in lieu of *in-situ* SST measured by the CTD to enable a broader spatial and temporal scale of temperature. Temperature data at this scale was thought to be more relevant to the overall distribution and abundance of fish species in the NBS; however, in situ temperatures were highly correlated with the broader-scale SST data, therefore, the overall conclusions are similar with both temperature datasets.

A multi-year distribution of juvenile Chinook Salmon (*O. tshawytscha*) CPUE was created using a simple kriging model with a gaussian semivariogram as part of the geostatistical analyst extension in ArcGIS (ESRI, 2019). Juvenile Chinook Salmon CPUE was multiplied by average effort (across all years) to scale the distribution to the catch at each station and a first order trend was removed before kriging. The prediction surface was generated with a neighborhood kriging model with a minimum of five and maximum of 20 points within each of four search quadrants. CPUE data from the southern Bering Sea and Chukchi Sea were included to help define the spatial distribution of juvenile Chinook; however, CPUE within Bristol Bay (near the Kuskokwim and Nushagak rivers) were excluded to maintain a focus on the distribution of Chinook Salmon within the NBS. The locations of CWT and adipose fin clipped juveniles from the Whitehorse Rapids Fish Hatchery (WRFH) within the Yukon River were added to the distribution map of juvenile Chinook Salmon to highlight the known locations of Yukon River Chinook Salmon.

Length-frequency distributions, length-weight relationships, and box plots of lengths were used to describe the size of juvenile salmon and primary non-salmon species captured in the surface trawl. Length-weight relationships were used as a quality control measure to ensure large errors in length or weight were not present. Juvenile salmon lengths (fork length, mm) were standardized to a common capture date using juvenile growth rates calculated from previous NBS surveys (Howard et al. 2019). The common capture date was equal to the average capture date calculated for each species. Growth rates of 1.06 mm/day for Chinook Salmon, 1.69 mm/day for Chum Salmon, and 1.76 mm/day for Pink Salmon were then used to standardize length (Howard et al. 2019). Growth rates of Coho and Sockeye Salmon in the NBS are not available; therefore, Coho Salmon were assumed to grow at the same rate as Chinook Salmon (1.06 mm/day) and the average growth rate of all juvenile salmon species was used to standardize Sockeye Salmon lengths (1.50 mm/day). Length frequency distributions of species captured in surface trawls were corrected by the proportion of the catch that was measured at each station to ensure length distributions reflected the total number of fish caught during the survey.

Juvenile Chinook Salmon Genetic Mixed Stock Analysis

Caudal fin clips were collected from all juvenile Chinook and Coho Salmon and from a subsample of Sockeye, Pink, and Chum Salmon captured during the survey. Pectoral fin clips were collected from all immature Chinook and Chum Salmon. Individual fin clips were placed on Whatman paper cards specific to Chinook, Coho, and Sockeye Salmon and barcode IDs were recorded on the Whatman cards. Caudal fin clips were collected from juvenile Chum and Pink Salmon and were placed on plastic wrap, frozen, and pooled by species for each station. Pelvic fin clips from immature Chum Salmon were individually labeled and stored in plastic bags. All genetic tissue samples were shipped to the ADF&G Gene Conservation Lab as part of the cooperative NOAA/ADFG research on salmon stock origin. Genetic mixed stock analysis has not been initiated for Sockeye, Coho, and Pink Salmon but samples are being archived to support analyses when funding and specific interest becomes available.

Genetic mixed-stock analysis was completed for juvenile Chinook and Chum Salmon and immature Chinook Salmon, but only stock mixtures of juvenile Chinook Salmon are reported here. DNA was extracted from the tissue samples using the NucleoSpin 96 Tissue Kit (Macherey-Nagel, Düren, Germany). Single nucleotide polymorphism (SNP) genotyping of the 80 SNPs common to the AYK baseline of 60 populations (Howard et al. 2019) was performed with standard TaqMan chemistry (Applied Biosystems, Waltham, USA). Quality control analyses included comparison of discrepancy rates between original genotypic data and genotypic data of 8% of individuals that were re-extracted and re-genotyped, removal of individuals missing 20% or more genotypic data, and removal of duplicate individuals. Stock composition was estimated by comparing genotypes of catch samples to reference baseline allele frequencies using the Bayesian statistical approach implemented in the software package BAYES with a flat prior (Pella and Masuda 2001). Contributions of juvenile Chinook Salmon from four reporting groups were estimated: Lower Yukon, Middle Yukon, Upper Yukon, and Other Western Alaska. Estimates from the 3 intra-Yukon River groups (Lower Yukon, Middle Yukon, and Upper Yukon) were summed to estimate the total Yukon River stock contribution.

Juvenile Chinook Salmon Abundance and Run Forecasts

The methods for estimating juvenile Chinook abundance were initially described in Murphy et al. (2017), and revised in Howard et al. (2019) and Howard et al. (2020). Juvenile Chinook Salmon catches are scaled to the MLD by dividing the catch of juvenile Chinook Salmon by the proportion of the mixed layer sampled at that station. The NBS was divided into four latitude strata: 1) Lower NBS (60–62°N), 2) Upper NBS (62–64°N), 3) Norton Sound, and 4) the Bering Strait region. The average CPUE within each stratum i, was estimated by dividing the total catch by the total effort as:

$$CPUE_i = \frac{\sum_{x=1}^{X} C_{xi}}{\sum_{x=1}^{X} a_{xi}},$$

where C_{xi} and a_{xi} are the MLD adjusted catch and area swept, respectively, for station x and stratum i, and X is the total number of stations in stratum i (Quinn and Deriso 1999). The variance of $CPUE_i$ for each stratum was defined as:

$$V(CPUE_i) = \frac{X}{X-1} \frac{\sum_x (C_x i - CPUE_i \cdot a_x i)^2}{(\sum_x a_x i)^2}.$$

The area sampled within each strata (A_i) was calculated from the number of stations in the strata and the average grid area (the average area of the 0.5° latitude by 1° longitude grid, calculated with average latitude). A fixed sample grid area (A_{NS}) was assumed for the Norton Sound stratum as the effective habitat for juvenile Chinook salmon was assumed to be limited by the high turbidity and shallow bottom depths (Murphy et al. 2017). The mean proportion of juvenile Chinook Salmon in the Bering Strait (6.7%) and Norton Sound (8.2%) during 2003, 2007, 2009–2015, and 2017 were used to adjust abundance estimates in years when these strata were not sampled (2004–2006 for Bering Strait and 2016 for Norton Sound). The sum of the individual strata areas was used to estimate the total survey area, A. The average CPUE for the survey, $CPUE_A$, and variance, $V(CPUE_A)$, were calculated as:

$$CPUE_A = \sum_i \frac{A_i}{A} CPUE_i$$

$$V(CPUE_A) = \sum_i \left(\frac{A_i}{A}\right) V(CPUE_i),$$

The total juvenile abundance estimate for the survey area ($\hat{N}$) and variance, V($\hat{N}$), were estimated as:

$$\hat{N} = CPUE_A \cdot A,$$

$$V(\hat{N}) = A^2 \cdot V(CPUE_A).$$

Juvenile Chinook Salmon abundance estimates were apportioned by stock composition to Upper Yukon (hereafter Canadian-origin) and total Yukon River groups (combined Canadian-origin, Middle Yukon, and Lower Yukon stock groups). The variance of stock-specific abundance was derived from a Taylor series approximation to the multiplicative variance of 2 random variables (X and Y) using the Delta method as:

$$V(X, Y) = \mu_Y^2 \sigma_X^2 + \mu_X^2 \sigma_Y^2 + 2\mu_X \mu_Y \rho \sigma_X \sigma_Y,$$

where μ_X and σ_X are the mean and standard deviation of juvenile abundance, μ_Y and σ_Y are the mean and standard deviation of the stock group proportion, and ρ is the correlation between juvenile abundance and stock proportion.

Canadian-origin and Total Yukon Chinook Salmon forecasts were generated using juvenile abundance estimates, brood tables, and age at maturity estimates for both Canadian-origin and Total Yukon Chinook Salmon. The number of juvenile Chinook Salmon predicted to return to the Yukon River was based on the midpoint and 80% prediction interval of a robust linear regression model (Venables and Ripley 2002) between juvenile abundance and adult returns. The majority of Yukon River Chinook Salmon spend a full year growing in freshwater after hatching and therefore juvenile abundance is assumed to be offset from spawner abundance by two years (one year is added to account for overwinter egg incubation). The marine ages of returning adults (typically two to four years) are used to scale juvenile abundance to run year. Projected run sizes were based on recent 3-year average maturity schedules derived from Canadian-origin brood tables (JTC 2020) and the total Yukon River drainage (Howard et al. 2020).

Juvenile Pink Salmon Abundance

Catch and effort, abundance indices, and forecast models for Yukon River and Norton Sound Pink Salmon were developed and reported in Farley et al (2020). Mixed layer depth corrections were applied to the annual abundance index as:

$$\theta_y = \frac{\sum_i M_{iy} C_{iy}}{\sum_i C_{iy}},$$

where C_{iy} is the catch at station i and year y, and M_{iy} is equal to the ratio of mixed-layer depth to trawl depth when trawl depth is shallower than mixed layer depth, and 1.0 when trawl depth is below the mixed-layer depth. The juvenile abundance index for Pink Salmon was estimated as:

$$N_y = \frac{\sum_i ln(CPUE_{iy})}{n_y} \cdot \theta_y,$$

where n_y is the number of trawl stations in year y.

Juvenile Salmon Diets

Stomach contents were examined either at sea or in a laboratory setting between 2004 and 2019. Stomach processing followed standard methods developed by Tikhookeanskiy Nauchno-Issledovatelskiy Institut Rybnogo Khozyaystva I Okeanografiy (Chuchukalo and Volkov, 1986; Volkov and Kuznetsova, 2007; Moss et al., 2009; Coyle et al., 2011). Typically, the contents of up to 10 stomachs from randomly sampled fish were combined together from each station, and prey composition was recorded as a stomach content index (SCI) and stomach fullness index (SFI). The SCI was calculated as individual prey taxon weight (g) multiplied by 10,000 and divided by predator body weight (g). Multiplying by a factor of 10,000 made these numbers easier to handle, as predator body weight was always much larger than prey taxon weight. The SFI was equal to the sum of all prey SCIs at a given station and gives an indication of fullness as a proportion of prey weight to predator weight. The average SFI was calculated for each year and compared with SST. In some cases, accurate prey weights could not be measured due to movement of the vessel. In these instances, prey taxon weight was estimated based upon percent volume and the assumption of equal body density of all prey items. Laboratory based weights were typically measured at 0.001 g. Prey composition was summarized as %SCI contribution (individual prey category SCI divided by the sum of SCI in a given year). Prey categories occurring in less than 10% of all stomachs within a predator species were combined into broader taxonomic groups. Prey groups were determined by the overall contribution to the diet within a predator species across all years, the proportion of the SFI within years, and in terms of percent frequency of occurrence over all years. Rare prey items that did not fall into a larger category were placed into an "Other" category. All stations where stomachs were analyzed, but no prey was present in stomachs were removed from this analysis. In years and predator instances where stomachs were analyzed at fewer than 5 stations, results were omitted from figures.

Juvenile Chinook Salmon Energetic Condition

Energetic condition (energy density, ED) of juvenile Chinook Salmon from the NBS was obtained using bomb calorimetry on dried samples of homogenized whole fish tissues for 2006 -2019 (Fergusson et al. 2010). From 2006–2015, samples were heated at 75°C in a drying oven and manually re-weighed until mass was constant. Starting in 2016, the method of sample drying and moisture determination prior to bombing was changed. Since 2016, samples were heated at 135°C to dryness using a LECO Thermogravimetric Analyzer 601. Moisture values obtained by the two methods were known to differ by less than 1% (Vollenweider et al 2011).

Comparing annual average ED among years required use of weighted least squares in Welch's ANOVA (Welch 1951, Day and Quinn 1989) due to unequal variances among years. Testing for differences in ED among years while controlling for fish size was accomplished using one-way ANCOVA and post-hoc Tukey's pairwise comparisons of adjusted means. Due to unequal variances among years, ANCOVA results were compared to results from a rank-based Kruskal-Wallis test performed on the residuals from a simple linear regression of ED against length, followed by Tukey's pairwise comparisons on the ranked residuals.

Spearman's rank correlation test was used to evaluate the effects of SST on ED and nonlinearity in the relationship was described using generalized additive models (GAMs; Wood 2006) limited to 4 knots to avoid overfitting. Multiple linear regression models of fish length and SST on annual average ED were selected based on Akaike Information Criteria (AICc) (Burnham and Anderson 2004).

Seabird and Marine Mammal Observations

The USFWS conducted seabird surveys during the NBS survey. The USFWS was supported by an Interagency Agreement with the Bureau of Ocean Energy Management (project AK-17-03: Marine Bird Distribution and Abundance in Offshore Waters). This study will combine data collected during the NBS survey with data from other USFWS seabird surveys to examine the distribution of marine birds relative to prey and oceanographic properties. It will also be used to describe seasonal and interannual changes in marine birds and their communities in the Beaufort and Chukchi Planning Areas. Marine birds and mammals were surveyed from 28 August-19 September, 2019. Survey data will be archived in the North Pacific Pelagic Seabird Database (http://alaska.usgs.gov/science/biology/nppsd).

Marine birds and mammals were surveyed from the port side of the bridge using standard USFWS protocols. Observations were conducted during daylight hours while the vessel was underway. The observer scanned the water ahead of the ship using hand-held 10x42 binoculars for identification and recorded all birds and mammals. Bird surveys used a modified strip transect methodology with four distance bins from the center line: 0-50 m, 51-100 m, 101- 200 m, 201-300 m. Rare birds, large flocks, and mammals beyond 300 m or on the starboard side ('off transect') were also recorded but will not be included in density calculations. We recorded the species, number of animals, and behavior (on water, in air, foraging). Birds on the water or actively foraging were counted continuously, whereas flying birds were recorded during quick 'Scans' of the transect window.

Geometric and laser hand-held rangefinders were used to determine the distance to bird sightings. Observations were directly entered into a GPS-interfaced laptop computer using the DLOG3 program (Ford Ecological Consultants, Inc., Portland, OR). Location data were also automatically written to the program in 20-second intervals, which allowed us to track survey effort and simultaneously record changing weather conditions, Beaufort Sea State, glare, and ice coverage (no ice was encountered during this cruise). Other environmental variables recorded at the beginning of each transect included wind speed and direction, cloud cover, sea surface temperature, and air temperature.

Results and Discussion

Oceanographic Conditions

The CTD was successfully deployed at each of the 47 stations sampled in 2019, from which station-specific surface temperature, surface salinity, mixed layer depth, bottom depth, and bottom temperature were calculated (Table 2). Surface temperatures (upper 10 m) in the NBS in 2019 ranged from 7.9°C - 13.8°C with an average of 11.5°C, which was 2.9°C above average (restricted SST range, 2003-2018) (Figure 2). Surface temperatures were higher at nearshore stations and in Norton Sound relative to offshore stations. The coldest surface temperatures were at stations northeast of St. Lawrence Island (Figure 3). Surface salinities ranged from 21.7 PSU to 31.9 PSU. The lowest salinities encountered during survey operations were in eastern Norton Sound and just outside the Yukon River delta with salinity increasing with distance from shore (Figure 4). Mixed layer depths ranged from 7 m to 29 m with an average of 19 m (Table 3, Figure 5). The MLD estimates from the SBE9-11 CTD for stations 2 and 5 were missing data from the top 11 m of the water column, therefore, the MLD estimates for those stations were derived from the FastCat (SBE49) data collected during the bongo tow.

Small copepods (<2 mm)were abundant across the sampling area, with abundances approaching 10,000 ind/m3 (Figure 6). In contrast, large copepod (>2mm) abundances were low overall, and copepods were largely absent in many stations between 62°N and 64°N. Large copepods abundances would be expected to be higher in an average year, based on the accumulation of Calanus spp. C5 stages later in the year (Stabeno and Bell, 2019). Small copepods have faster turnover times, multiple generations per year, and metabolic rates that scale less dramatically with temperature. Warm temperatures in 2018 and 2019 are likely a contributing factor to the elevated abundance of small versus large zooplankton (Kimell et al. 2018, Kimell et al. 2019). The abundance of small and large copepods declined from 2018 and may indicate an overall decline in productivity during 2019. Euphausiid numbers were also low across the NBS, with no euphausiids recorded north of 62°N. Above average temperatures in 2019 may have caused earlier entry into diapause or increased advection of local populations of Calanus spp. into the Chukchi Sea. The low euphausiid abundance was expected; bongo tows typically undersample adult euphausiids due to depth distribution.

Surface Trawl Data

Bottom depths ranged from 14 m to 63 m (Table 2) during the survey, and were typical of the shallow shelf habitat in the NBS. The average horizontal and vertical opening of the trawl was 49.8 m and 17.5 m, respectively. The average footrope depth from the SeaBird SBE39 depth sensor was 18.9 m (Table 4), which indicates average headrope depth was 1.4 m. The average distance towed during each 30 min trawl set (based on GPS coordinates of the start and end of each tow) was 3.9 km, which results in a calculated average speed of 4.2 knots. MLD expansions were required at 27 of the 47 stations and ranged from 2 to 33% (Table 4).

Similar to previous years, the species with the largest biomass in the surface trawl catches was the Northern Sea Nettle (*Chrysaora melanaster*) at 6,898 kg, and the species with the largest catch in numbers was Pacific Herring (*Clupea pallasii*) at 142,512 individuals (Tables 5-7). Juvenile Pink Salmon (*Oncorhynchus gorbuscha*) was the most abundant species of salmon at 13,507 fish. Ninespine stickleback (*Pungitius pungitius*) were the third most abundant species at 9,464 individuals. The catch of age-0 Walleye Pollock (*Gadus chalcogrammus*, n=8,798) was above average, but the catch of other forage fish species, including Arctic or Pacific Sand Lance (*Ammodytes spp.*, n = 2) (Orr et al. 2015) and Capelin (*Mallotus villosus*, n=11) were quite low. Sand Lance are able to avoid capture with trawl gear, therefore, a low catch does not necessarily reflect low abundance. Capelin are known to be less abundant in the NBS during warm years (Andrews et al. 2016).

Juvenile Chum and Pink Salmon were the most widely distributed salmon species with high CPUEs across the survey grid (Appendix 2). Juvenile Chinook Salmon CPUEs were patchy in 2019. Juvenile Chinook Salmon exhibited high CPUEs in stations in and west of Norton Sound. Unlike previous years, juvenile Chinook Salmon were absent in a number of stations between 60°N and 62°N. Juvenile Coho Salmon exhibited high CPUEs south of 62°N, in Norton Sound, and just northwest of the Yukon Delta. Juvenile Sockeye Salmon catches were concentrated at offshore stations south of St. Lawrence Island. Sockeye Salmon runs in the Yukon River and Norton Sound are relatively small so we suspect the high catches of Sockeye Salmon encountered during the 2019 survey were of Southern Bering Sea origin. Except for Sockeye Salmon, all other salmon species were caught at stations north of 66°N. Of the jellyfish species, *Aequorea* spp. and the Cross Jelly (*Staurophora mertensi*) were encountered infrequently. The Moon Jellyfish (*Aurelia* spp.) were found throughout the survey except just west of Norton Sound. The Northern Sea Nettle, the most abundant species encountered in 2019, and was caught in all but four stations during the 2019 survey. Lion's Mane Jellyfish exhibited the largest CPUEs in nearshore stations. Age-0 Walleye Pollock had high CPUEs west of 167.5°W and south of 63°N whereas age-1+ Walleye Pollock catches were sparsely distributed throughout the survey grid. Both age-0 and age-1+ Walleye Pollock were caught in tows north of the Bering Strait. Pacific Herring were concentrated in Norton Sound and in nearshore stations but were encountered in smaller numbers at stations farther from shore. Rainbow Smelt were caught at nearshore stations and in Norton Sound and were absent west of 168°W. Similar to Rainbow Smelt, Ninespine Sticklebacks were constrained to nearshore stations east of 168°W and Norton Sound. Documenting species catch and distribution during NBS surface trawl surveys will help identify northward shifts in species's migration and distribution as the Bering Sea becomes warmer.

Approximately half of the primary species captured in the NBS were significantly ($\alpha = 0.025$) correlated with SST (Figures 7 and 8). Average catch rates of Sockeye Salmon (*O. nerka*) had the highest positive correlation with SST ($\rho = 0.9$). Increased catch rates of Sockeye Salmon with temperature is due to northward dispersal of juveniles from the southeastern Bering Sea (SEBS) (primarily Bristol Bay) as there are only a few small populations of Sockeye Salmon within the Yukon River and Norton Sound (Estensen et al. 2018, Menard et al. 2020). Spawning locations of Walleye Pollock also occur in the SEBS and therefore the positive correlation between age-0 pollock and SST reflects increased northward dispersal of age-0 pollock with temperature. There are significant spawning stocks of Coho Salmon (*O. kisutch*) in the Yukon River and Norton Sound (Estensen et al. 2018, Menard et al. 2020); therefore the correlation with SST ($\rho = 0.7$) most likely reflects an increase in the abundance of Coho Salmon stocks within the NBS. Capelin was the only species with a negative correlation ($\rho = 0.6$) with SST. Capelin are known to have a preference for cooler water in the Eastern Bering Sea (EBS) (Andrews et al. 2016), therefore this may also reflect a northward shift in their distribution (into the Chukchi Sea) as temperatures increase in the EBS.

Significant positive correlations were present between catch rates of Ninespine Stickleback and Pacific Herring ($\rho = 0.8$), Arctic Lamprey (*Lethenteron camtschaticum*) ($\rho = 0.7$), and Chinook Salmon ($\rho = 0.6$) (Figure 8). Ninespine Stickleback are only captured in the shallow coastal habitats (Appendix 2) and are a key species of the nearshore estuarine fish community in the NBS. Nearly all (99.5%) of the Ninespine Stickleback captured during the surface trawl surveys on the eastern Bering Sea shelf have occurred in shallowest stations sampled in the NBS. Although age-0 Pacific Herring are likely the dominant species within the nearshore fish community, catches of age-0 Pacific Herring are not separated from the older age classes, therefore herring catches within the NBS could represent a mixture of herring from the NBS and SEBS (Andrews et al 2016). The highly piscivorous diet of juvenile Chinook Salmon (Farley et al. 2009, Auburn and Sturdevant 2013, Honeyfield et al. 2016, Miller et al. 2016, Garcia and Sewall *In Review*) and Arctic Lamprey (Shink et al. 2019) would logically support a dependency of these two species on the nearshore fish community. It is possible that the correlations between CPUE of Ninespine Stickleback and juvenile Chinook Salmon and Arctic Lamprey could stem from a dependency of Chinook Salmon and Arctic Lamprey on the nearshore estuarine fish community in the NBS in general, not necessarily a dependency or association with Ninespine Stickleback.

Size distributions

Length-frequency distributions for the primary species captured in surface trawl catches are summarized in Figures 9-11. Juvenile salmon lengths in 2019 were typical of those encountered in past NBS surveys (Figure 9). Individual lengths and weights of juvenile salmon (Appendix 3) confirm that there is limited error in the size data and that juvenile salmon have a relatively stable relationship between length and weight. Juvenile Chinook Salmon lengths ranged from 10 to 24 cm, and averaged 20 cm. Most juvenile Chinook Salmon caught in the NBS survey spend one year in freshwater (total age-2), however, smaller juvenile Chinook may be indicative of sub-yearlings, juvenile Chinook that emigrated straight to the ocean after emerging from the gravel. Due to their multi-year residence in freshwater, Coho Salmon were the largest juvenile salmon species caught in the survey with lengths between 20 and 30 cm and averaging 25 cm. Chum and Pink Salmon were the smallest species caught with lengths ranging between 12 and 25 cm. The overlap in juvenile Chum and Pink Salmon lengths suggests that their growth rates during the early marine stage may be similar. Except for a few larger individuals, juvenile Sockeye Salmon lengths ranged between 15 and 22 cm.

Although juvenile salmon lengths vary by temperature, there was not a consistent trend in the size of juvenile salmon within or between species across the time series (Figure 12). To assess how length varied by SST, 2003-2005 and 2014-2019 were considered warm years and 2006-2012 were considered cold years (Figure 2). The average lengths of juvenile Chinook Salmon from recent warm years (2016-2019) are smaller than those from earlier warm years (2003-2005, 2014-2015). The average lengths of juvenile Coho Salmon have progressively declined in the recent warm years (2014-2019). This pattern suggests that warmer than average temperatures, like those experienced in recent years, may inhibit juvenile Chinook and Coho Salmon size and growth, possibly through changes in prey quality and quantity. The average length of juvenile Coho Salmon in 2019 was the lowest since the survey began in 2003. Due to the multiple freshwater ages of Coho Salmon, the reduced size of Coho Salmon may reflect a combination of reduced growth and earlier age of marine entry.

The average length of juvenile Sockeye Salmon increased during the 2013-2015 warm years reflecting the potential for increased growth with warming temperatures up to a species-specific optimum (Beauchamp et al 2007; Laurel et al 2016). However, the average length declined dramatically between 2015 and 2016, and remained relatively stable between 2016 and 2019. Similar to both juvenile Coho and Chinook Salmon, juvenile Sockeye Salmon may have reached a threshold temperature where prey may not be sufficient to support increasing metabolism with warmer temperature (Gillooly et al. 2001).

There was no apparent effect of temperature on juvenile Chum and Pink Salmon lengths, with smaller and larger than average lengths present in both warm and cold years for each species. Both juvenile Chum and Pink Salmon distribute offshore quicker than juvenile Chinook and Coho Salmon, and as a result of their quicker distribution they can access both nearshore and offshore prey during their early marine stage. Future NBS surveys will continue to document juvenile salmon lengths to assess how their early ecology may be affected by continued warming in the Bering Sea.

The size and growth of juvenile salmon during the early marine life stage have important implications for future marine survival. Larger juvenile salmon are more likely to survive than smaller individuals because they are able avoid predators and maintain high energy reserves necessary to survive their first winter at sea (Pearcy 1992, Beamish and Mahnken 2001, Beamish et al. 2004). Prior research on juvenile Chinook Salmon correlated growth and size in the early marine stage with increased adult returns (Tomaro et al. 2012). Additionally, scale pattern analyses have shown that small juvenile Chinook, Coho, Pink, and Sockeye Salmon are subject to size-selective mortality during their first summer at sea (Beamish et al. 2004, Moss et al. 2005, Farley et al. 2007, Howard et al. 2017), providing further evidence that larger juvenile salmon have higher likelihoods of surviving than their smaller conspecifics. Juvenile salmon caught in the NBS are caught in September, after they have spent their first summer in the ocean, and their size at this critical period may inform whether they are likely to survive their first marine winter.

Length measurements were also taken from immature salmon and non-salmon species. Fork lengths were measured for immature Chum, Sockeye, and Chinook Salmon (Figure 10). Immature Sockeye (n=19) and Chinook Salmon (n=24) are less frequently encountered during the NBS survey compared to immature Chum Salmon (n=194). Immature Sockeye Salmon lengths ranged from 26 to 53 cm and averaged 36 cm. Immature Chinook Salmon (n=24) ranged from 31 to 79 cm and averaged 43 cm. Immature Chum Salmon lengths ranged from 29 to 79 cm. The bimodal distribution of fork length measurements for immature Chum Salmon suggest two age classes are encountered during survey operations. Although immature Sockeye Salmon greater than 45 cm suggest the presence of a separate, older age class, there are not enough samples to categorize age distributions. Bell diameters for Moon Jellyfish (*Aurelia* spp.), Northern Sea Nettle, and Lion's Mane Jellyfish (*Cyanea capillata*) were between 10 and 50 cm. Bell diameters were skewed towards smaller sizes between 10 and 15 cm for *Aurelia* spp. (mean of 15.3 cm), centered around 23 cm for the Northern Sea Nettle and bimodal at 18 cm and 33 cm for Lion's Mane Jellyfish (Figure 11, Table 7). Ninespine Stickleback were larger than those encountered in the NBS survey in past years, ranging between 4.0 cm and 6.5 cm (Figure 11, Howard et al. 2020). Pacific Herring, Rainbow Smelt, and Walleye Pollock length frequencies reflect the multiple age classes of each species encountered during the survey (Figure 11).

Juvenile Chinook Salmon Abundance and Run Forecasts

Juvenile Chinook Salmon are distributed within the inner domain (bottom depths less than 55 m) of the NBS and can occur throughout the latitude range of the NBS (Figure 13). CWT recoveries are particularly useful in characterizing marine distributions of Chinook Salmon (Appendix 4). All CWTs recovered from juvenile Chinook Salmon (including two CWTs in 2019) have been from the Whitehorse Rapids Fish Hatchery (WRFH). All juvenile Chinook Salmon released from the WRFH have adipose fin clips and all tagged juveniles exhibit a subyearling migration pattern. Juveniles with an adipose fin clip and not CWT were assumed to be the result of tag shedding and were assumed to be subyearling Chinook Salmon from the WRFH. WRFH Chinook Salmon had an average length of 151 mm (range: 109 to 207 mm), and an average weight of 43 g. The size of hatchery Chinook Salmon were slightly below the average size of Pink Salmon (164 mm) and Chum Salmon (177 mm), which migrate to sea during the same year that they hatch. Although hatchery Chinook Salmon have been caught throughout the latitude range of the NBS survey, they are most commonly captured in the nearshore stations adjacent to the Yukon River Delta and within Norton Sound (Appendix 4).

Although CWTs are useful in identifying the origin of individual Chinook Salmon, genetic stock identification is the primary method used to identify the origin of Chinook Salmon in the NBS. A total of 125 juvenile

Chinook Salmon were successfully genotyped for mixed-stock-analysis (MSA) during the 2019 NBS survey. Mean stock composition estimates were: 30% Upper Yukon (hereafter Canadian-origin), 22% Middle Yukon, 14% Lower Yukon, and 35% Other Wester Alaska (non-Yukon River) stocks (Table 8, Figure 14). The Canadian-origin proportion was lower than the historical average (48%), and the non-Yukon River proportion was higher than the historical average (12%); however, the composition of Lower Yukon and Middle Yukon stocks were similar to historical averages (12% and 27%, respectively). The Canadian-origin stock group had the largest reduction from the historic average (an 18% decrease from average) followed by the Middle Yukon River stock group (6% decrease from average). The proportion of the Lower Yukon River stock group was slightly higher (2%) than the historic average. The increase in non-Yukon stocks (23% increase) may reflect a combination of northward dispersal of Chinook Salmon stocks from the southern Bering Sea (e.g. Kuskokwim River Chinook Salmon) and possibly an increase in the relative contribution of Norton Sound Chinook Salmon.

The overall abundance of juvenile Chinook Salmon in the NBS during 2019 (2.0 million fish) was significantly below their average abundance during 2003-2018, (3.2 million fish). Abundance estimates of juvenile Chinook Salmon were expanded by 10% (MLD adjustment) to account for incomplete sampling of the mixed layer, which was higher than the recent 5-year average of 2%. The abundance of Canadian-origin juvenile Chinook Salmon during 2019 was the lowest observed in the NBS at 575,094 fish (sd = 164,126; CV = 29%) (Table 9, Figure 15), and was less than half of the average abundance (1.57 million) during previous years (2003-2018). Similar to the Canadian-origin stock group, the abundance of Yukon River juvenile salmon was also the lowest observed at 1,246,038 fish (sd = 326,257; CV = 26%), and was less than half of the 2003-2018 average of 2.75 million fish (Table 10, Figure 15). The juvenile Chinook Salmon caught during the 2019 NBS survey will primarily contribute to adult runs in 2021 (as age-4), 2022 (age-5), and 2023 (age-6).

Relationships between juvenile and adult Chinook Salmon abundance are used to forecast adult returns up to three years into the future (Figure 16). Both the Canadian-origin and total Yukon runs are expected to decline over the next two years due to the reduction in juvenile abundance during 2017-2019. The projected run sizes for Canadian-origin Chinook Salmon are 52,300 (31,200 – 73,400) fish in 2021, and 46,300 (24,800 – 67,900) fish in 2022. The projected run sizes for the total Yukon River run are 143,800 (95,200 – 192,400) fish in 2021, and 129,000 (79,500 – 178,500) fish in 2022. Although the ranges of possible run sizes are very wide, they indicate an expected decline in abundance of Chinook Salmon. New forecast models for the Canadian-origin stock group are being developed by the Joint Technical Committee of the Yukon River Panel which will integrate juvenile and other sibling data into a Bayesian model framework. Similar models are also expected to be developed for the total run of Chinook Salmon to the Yukon River. Estimates of future run size to the Yukon River have been of particular interest by managers, biologists, and stakeholders within the Yukon River as it helps support fisheries management decisions needed to protect the spawning stock and subsistence fisheries in the Yukon River (JTC 2020).

The number of Chinook Salmon juveniles-per-spawner in 2019 was the lowest observed since 2003 for the Canadian-origin stock group (8.4) and the Yukon River stock group (5.3) (Figure 17, Tables 9 and 10). The number of juveniles-per-spawner have been quite low for the last three years (2017-2019) and indicates a distinct downward shift in the survival of Yukon River Chinook Salmon. Although the cause of the reduced survival is unclear, it may be tied to recent losses of Arctic Sea ice and warming of the NBS and Yukon River. The number of juveniles-per-spawner does not vary predictably with spawner abundance for either the Canadian-origin or total Yukon River stocks. Similarly, there is no relationship between the number of spawners and the resulting number of juveniles for either the Canadian-origin or Yukon River stock groups. Juveniles-per-spawner and returns-per-spawner are highly correlated (ρ=0.76) for both the Canadian-origin and Yukon River stock groups (Tables 9 and 10) and therefore the survival of Yukon River Chinook Salmon during the initial freshwater and/or marine stages of salmon is the key factor in both the decline and variation in abundance over time.

Measurement error in juvenile abundance is a key limitation in the analysis and interpretation of juvenile survival. There are a number of unique features of the NBS survey that help limit the measurement error of surface trawl estimates of the distribution and abundance of juvenile salmon. We are able to restrict abundance of juvenile Chinook Salmon to large stock groups such as the Total Yukon (average proportion of 86%) and the Canadian-origin (average proportion of 47%) stock groups, which minimizes the stock identification error in abundance estimates. The shallow depths and presence of the eastern Bering Sea cold pool play a key role in limiting the vertical distribution of juvenile salmon in the NBS. MLD corrections are used to account for changes in the sampling depth of surface trawls relative to juvenile habitat. The relatively limited dispersal rate of juvenile Chinook Salmon in the NBS (compared to coastal habitats in the Gulf of Alaska) allows a single survey to sample through the distribution of juveniles and limits the influence of year to year variation in the migration of juveniles on abundance estimates. There has been limited mixing of juvenile Chinook Salmon stocks from regions outside of the Yukon River prior to 2019. This has helped clarify the spatial distribution and dispersal patterns of juvenile Chinook Salmon stocks from the NBS and has helped establish survey designs for juvenile Chinook Salmon in the NBS. However, caution is still needed when interpreting abundance estimates as measurement has not been stationary over time due to changes in sea states, vessel platforms, juvenile distributions, and survey designs over time.

Juvenile Pink Salmon Abundance

The juvenile Pink Salmon abundance index ranged from 1.0 to 5.4 with an overall average of 2.9 from 2003 to 2019 (Figure 19). The index is significantly correlated with Pink Salmon returns to Yukon and Norton Sound rivers and provides an informative tool to forecast adult returns to these regions (Figure 20). The preliminary index for 2019 was 5.3, which forecasted an adult return of 6.5 million Pink Salmon to the region in 2020. Juvenile Pink Salmon abundance has increased along with the recent warming conditions in the eastern Bering Sea. The NBS is experiencing significant warming and extremes in seasonal ice extent and thickness that may benefit the growth and survival of Pink Salmon stocks in this region. Increased Pink Salmon abundance in the NBS and overall warming climate conditions are both thought to play an important role in the expansion of Pink Salmon into the Arctic (Farley et al. 2020). The critical period (Beamish and Mahnken 2001) in the production dynamics of Pink Salmon in the NBS appears to be more strongly tied to the initial life-history stages (freshwater and initial marine) than later marine life-history stages and may reflect temperature limitations present in high latitude stocks of salmon. Stock-specific information on juvenile Pink Salmon abundance would significantly improve our understanding of their movement and production dynamics in the NBS. Farley et al. (2005) identified discontinuous distribution in the size of juvenile Pink Salmon that may stem from the presence of both North American and Russian stocks in the NBS. Russian-origin stocks of juvenile salmon have been shown to occur in the NBS in Kondzela et al. (2009) where 76% of the juvenile Chum Salmon in the Bering Strait region were identified as Russian-origin stocks during the 2007 NBS survey.

Juvenile Salmon Diets

Stomach fullness and species composition of juvenile salmon diets are summarized in Figures 21-27 and in Appendix 5. Station numbers and the number of stomachs sampled are also summarized in Appendix 5. Chum Salmon fed upon gelatinous plankton, fish, Hyperiid amphipods, and Euphausiids in most years (Figure 21). The proportion of other non-target prey increased during recent years (2015-2019) which corresponded to a period of warmer than usual conditions in the Bering Sea. Increased diversity in prey composition may indicate a shift to foraging for less preferred prey. A similar increase in other prey occurred in 2012 which occurred concurrently with a decrease in consumption of fish (Figure 21). An increase in the proportion of Hyperiid amphipods, which are rich in fatty acids (Persson and Vrede 2006), occurred during cool years (2006-2012). Feeding on prey high in fatty acids and lipids facilitates the accumulation of energy stores which are needed for overwinter survival (Heintz et al. 2013, Rogers et al. 2020).

Pink and Sockeye Salmon fed on a combination of fish and zooplankton confirming findings from previous investigations (Cook and Sturdevant 2013). Pink and Sockeye Salmon demonstrated no preference for a single species of zooplankton prey. Fish prey were most common in Pink Salmon diets during anomalously warm conditions (2003-2006), a transitional period from warm to cool (2007), and during the anomalously warm year of 2015 (Figure 22). The composition of prey in Sockeye Salmon diets varied inter-annually and no pattern or prey preference during cool or warm years was apparent (Figure 23). The bulk of prey in

Sockeye Salmon diets consisted of two prey items during most years (Figure 23), suggesting that Sockeye Salmon feed opportunistically.

Coho Salmon preyed primarily upon Sand Lance, age-0 Walleye Pollock, Capelin, and other fish (Figure 24). Capelin increased in Coho Salmon when ocean conditions were cool (2007-2011) and Capelin abundance was elevated in the NBS (Andrews et al. 2016). The proportion of decapods and other prey items not commonly consumed by Coho Salmon increased during warm years (2006-2012, 2014-2019), with the exception of 2007 and 2014, which were years when thermal conditions switched from anomalously warm to cool and cool to warm, respectively. Age-0 Walleye Pollock accounted for a larger proportion of prey in Coho Salmon diets during warm years, which corresponds with a more northerly distribution range for age-0 Walleye Pollock in the Bering Sea (Eisner et al. 2020).

Chinook Salmon fed primarily upon fish in the NBS (Figure 25) which has also been reported by previous investigations (Cook and Sturdevant 2013, Garcia and Sewall *In Review*). However, piscivory by juvenile Chinook Salmon has decreased as SSTs have increased in the NBS (Figure 26). There has been a clear decline in piscivory in Chinook Salmon relative to other species of juvenile salmon in the NBS. Fish have composed 88.9% of the diet of Chinook Salmon on average during 2004-2017, but decreased to 72.8% on average during 2018-2019. The level of piscivory in Chinook Salmon during 2005 was very atypical and was treated as an outlier in the time series (Figure 26). The 2005 survey started later than usual in 2005 and stations were sampled from North to South. Stations at the southern end of the NBS were sampled in early October rather than early September and many juveniles had already dispersed into the SBS at this point. The unusual distribution of juvenile Chinook Salmon in 2005 is believed to be contributing to an atypical pattern in their diet. Age-0 Walleye Pollock were common in Chinook Salmon diets when ocean conditions were anomalously warm but were rare when conditions were cool. Capelin was a common prey item composing 16.7-68.4% of the diet during 2004-2013, with the exception of one year (2012), when Capelin were not detected. The absence of capelin from the 2012 diet is more likely an artifact of the diet processor than an ecological reflection. No fish were identified to species from the 2012 survey, though a large percent of the diet was still fish. The presence of Capelin declined from 4.7-11.8% during 2014-2017 and disappeared entirely from the diet samples in recent years (2018-2019) (Figure 25). Concurrent with the disappearance of Capelin was an increase in the consumption of decapod larvae during 2018-2019, which may reflect a decrease in the availability of fish prey or a reduced ability to capture fish resulting from a concurrent decrease in body size. A decrease in Chinook Salmon energy density and survival in recent years may be occurring due to a decline in the availability of high quality prey during early ocean residence. Our findings highlight the importance of feeding ecology during early ocean residence.

The average stomach fullness index (SFI) of Chinook, Chum, and Pink Salmon has declined as SSTs have increased in the NBS (Figure 27). The overall average SFI was similar for Chinook (157), Pink (156), and Coho Salmon (153), but lower for Chum Salmon (126). The average SFI in 2019 for Chinook Salmon (67) and Chum Salmon (49) were the lowest on record and less than half of their overall average. Warmer temperatures increase metabolic rates which would require a higher overall amount of prey consumed or an increase in the energetic quality of prey consumed for a fish to realize the same growth rate under cooler conditions. Therefore, the combination of an increase in thermal experience and a decrease in the amount of food consumed will have a larger effect on growth than an increase in thermal experience alone.

Larger body size requires higher energy prey (Schabetsberger et al. 2003). Years in which piscivory decreased for juvenile Coho and Chinook Salmon may signal a lack of energy-rich forage. Sand Lance and Capelin are energetically rich prey (Litzow 2006). In the absence of high quality prey, lower quality prey may be substituted (Weitcamp and Sturdevant 2008), and an increase in prey diversity may indicate more generalized feeding and a greater reliance on non-preferred prey items (Weitcamp and Sturdevant 2008). If ocean conditions continue to warm and alter lower trophic levels in the Bering Sea (Hunt et al. 2011), these changes are likely to cascade up to higher trophic levels and affect salmon growth and survival. This analysis combined all juvenile salmon diets of a given species without regard to habitat (bottom depth) to provide a synoptic view across the entire NBS survey area. Previous studies have noted that certain prey may be more commonly consumed in certain habitats by juvenile salmon (Cook and Sturdevant 2013) and forage fishes (Andrews et al. 2016).

Juvenile Chinook Salmon Energetic Condition

The energetic condition of NBS juvenile Chinook Salmon varied across the 12 years of available data, partially driven by differences in fish size (Figure 28). Average ED (kJ/g dry tissue mass) differed significantly among years (Welch's ANOVA, F = 10.36, r^2 = 17.9%, $p < 0.001$), with 2016 being the highest, 2011 the lowest, and 2019 of intermediate value slightly lower than 2018. Average lengths of analyzed fish also differed among years (Welch's ANOVA, F = 22.12, r^2 = 21.9%, $p < 0.001$), with 2007 the largest, 2011 the smallest, and 2019 of intermediate size slightly larger than 2018. With all data pooled across years, linear regression analysis indicated that the energetic condition of juvenile Chinook Salmon increased with fish length (slope = 0.0230; r^2= 39.7%; $p < 0.001$; Figure 29). This positive relationship was expected, as energetic condition commonly increases with size in fishes that must store energy prior to winter (Post and Parkinson 2001), and has been previously observed in juvenile Chinook Salmon (Murphy et al. 2014). However, this indicated that approximately 60% of the variation in individual ED was due to factors other than fish size. Including year in addition to length increased the explained variation to 50.9%, with a significant effect of year after controlling for length (ANCOVA, $F_{11,562}$ = 11.56, $p < 0.001$). Mean size-adjusted energetic condition overlapped significantly among years but was lowest in 2011 and highest in 2018 (Table 11). Similar results regarding yearly comparisons were obtained using a rank-based test and comparisons of ranked residuals from the regression fit of ED versus length (Kruskal-Wallis Test, H = 103.9, $p < 0.001$; Table 12). Monitoring yearly differences in autumn energetic condition may help understand and project juvenile survival, as cohorts that are able to store more energy prior to their first winter are more likely to survive (Sogard and Olla 2000).

Differences in ED among years also may be driven by annual differences in SST. Annual mean Chinook ED generally increased with mean autumn SST across years (Spearman's rho = 0.583, p = 0.047. However, temperature may have a non-linear, dome-shaped relationship to ED, as indicated by a GAM model fit (k=4, edf = 2.26, adj. r^2= 36.4%, p = 0.108) in which ED was highest at intermediate SST and appeared to decline at the highest SST observed in 2019 ($\leq$ ~11 °C; Figure 30). Temperature effects on ED were evaluated in combination with fish size, given that average length alone accounted for 46.5% of the variation in annual average ED (slope= 0.0237; $F_{1,10}$= 8.68, p = 0.015; Figure 31) in a simple linear regression model. Temperature combined with length in a multiple regression model explained 64.0% of the variation in average ED ($slope_{SST}$ = 0.146, $slope_{LEN}$= 0.0211; $F_{2,9}$= 7.99, p = 0.010). The effect of SST on ED was marginally not significant (p = 0.066) in that model and was potentially weakened by collinearity with length due to the non-significant but positive influence of SST on length (slope = 1.72; $F_{1,10}$= 0.313; r^2= 3.04%, p = 0.588). The 17.5% improvement in fit versus length alone justified the inclusion of the SST term in the model (ΔAICc = -0.034).

The positive influence of temperature on juvenile Chinook Salmon energetic condition across most of the observed temperature range through 2018 may be expected for fish near the northern limit of their distribution, where temperatures are likely below optimal for growth and condition. Warmer temperatures are expected to have a positive effect up to a species-dependent optimal temperature, given the typical dome-shaped responses of fish growth and condition to temperature (Beauchamp et al 2007; Laurel et al 2016). Warmer temperatures in the past have supported higher survival of northern stocks of Pink, Chum, and Sockeye Salmon potentially through indirect effects on prey production (Mueter et al. 2002). However, anomalously warm temperatures seen in 2019 may have exceeded the optimum for juvenile Chinook Salmon, and thus led to a decline in ED.

The 2019 decline in ED may have been caused by a combination of increased metabolic rates (Gillooly et al. 2001) and negative impacts on prey quality or quantity associated with unusually warm conditions. Higher ED observed in warmer years through 2018 suggests that juvenile Chinook Salmon energetic condition during that period generally was not limited by food energy intake. Juvenile Chinook Salmon may have adapted to decreased availability of capelin in warm years (Andrews et al. 2016) by eating more Sand Lance and early-stage decapods. Diet differences in warmer versus colder years make it difficult to strictly distinguish temperature effects from diet effects on energetic condition. However, despite eating fewer fish and less prey overall in warmer years, NBS juvenile Chinook Salmon diets were adequate to support higher energetic condition than in cooler years through 2018. The 2019 decline in ED suggests juvenile Chinook Salmon were unable to ingest sufficient energy to support optimal energetic condition, though it is difficult to infer mechanisms or trends based on a single anomalous year. If energetic condition consistently declines in response to anomalously warm conditions, continued ocean warming could lead to decreased survival of juveniles, which in 2019 had among the lowest abundances since monitoring began in 2003. These data indicate juvenile Chinook Salmon energetic condition is sensitive to temperature-driven changes in ocean conditions that could impact future returns.

Seabird and Marine Mammal Observations

A total of 2,870 km were surveyed during the cruise with 324 km in the Chukchi Sea, 1,734 km in the NBS, and 809 km in the southern Bering Sea during transit to port in Dutch Harbor, AK. We observed a total of 3,310 birds on transect, comprising 38 species plus several unidentified passerines(Table 13).

The Northern Fulmar (*Fulmarus glacialis*) was the most abundant seabird species (28%) recorded during the survey. Highest concentrations of fulmars were observed in the southern Bering Sea south of 60°N near the shelf-break and the middle domain (Figure 32). In the northern Bering and Chukchi seas, fulmar observations were generally lower and fulmars were largely absent on transects offshore of Norton Sound. Short-tailed Shearwaters (*Ardenna tenuirostris*) and unidentified shearwaters (*Ardenna spp.*) were a predominant bird species (15%) recorded throughout the study area (Table 13). Shearwaters were widely distributed, with higher numbers in the Southern Bering Sea, along with larger concentrations of birds near Bering Strait (Figure 33). Another *Procellariidae* species, the Fork-tailed Storm-petrel, was also common in the Bering Sea, with distribution centered in the southern Bering Sea (Figure 33).

Aethia auklets (Crested, Least, and Parakeet) combined comprised 6% of the total seabird observations during the survey (Table 13). Crested Auklets were primarily observed in two areas, southeast of St. Lawrence Island and near King Island in the NBS (Figure 34). Least and Parakeet Auklets were more widely dispersed south of St. Lawrence Island, west of Nunivak Island, and in the southern Bering Sea (Figure 34). Tufted Puffins (3%) and Common Murres (3%) were other commonly detected *Alcid* species.

Phalaropus spp. consisting of Red Phalaropes (*P. fulicarius*), Red-necked Phalaropes (*P. lobatus*), and unidentified phalaropes, comprised 8% of total birds recorded during the survey. Phalaropes were mostly found in the NBS near St. Lawrence Island, the Bering Strait, and extending into the Chukchi Sea (Figure 35). Black-legged Kittiwakes (*Rissa tridactyla*) were the prevalent *Laridae* species recorded and comprised 19% of total seabird observations. Kittiwakes were widely distributed, with the highest numbers detected near the Pribilof Islands, east of St. Matthew Island, and Bering Strait (Figure 36).

We recorded marine mammals during surveys, but because we used seabird survey protocols our observations cannot be used to calculate marine mammal densities. The USFWS observer recorded 65 marine mammals of seven species, including off-transect individuals (Table 14). Northern Fur Seals (*Callorhinus ursinus*) were the most commonly encountered marine mammal, with individuals observed in the Bering Sea within 200 km of Dutch Harbor. The most common cetacean species observed was the Humpback Whale (*Megaptera novaeangliae*).

Sandhill Cranes (*Grus canadensis*) were observed in five flocks near Bering Strait on September 14 and 16, totaling 604 birds. We recorded three observations of Aleutian Terns (*Onychoprion aleuticus*) totaling four birds in early to mid-September, east of St. Paul Island, north of Nunivak Island, and northeast of St. Lawrence Island. Near Nunivak Island we also observed two female Steller's Eiders (*Polysticta stelleri*), and one Marbled Murrelet (*Brachyramphus marmoratus*) in early September.

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Tables and Figures

Table 1: Name and affiliation of scientific crew members during the northern Bering Sea surface trawl survey, 2019. AFSC—Alaska Fisheries Science Center, Auke Bay Laboratories, Juneau, AK; ADFG—Alaska Department of Fish and Game, Commercial Fisheries Division, Anchorage, AK; USFWS—US Fish and Wildlife Service, Office of Migratory Bird Management, Anchorage, AK; APU—Alaska Pacific University, Anchorage, AK.

Name (Last, First)	Title	Date Embark	Date Disembark	Affiliation
Murphy, Jim	Fish Bio/Chief Scientist	27-Aug	20-Sep	AFSC
Gray, Andrew	Sup Fish Bio	27-Aug	8-Sep	AFSC
Sewall, Fletcher	Fish Bio	27-Aug	8-Sep	AFSC
Dimond, Andrew	Fish Bio	27-Aug	8-Sep	AFSC
Jallen, Deena	Fish Bio	27-Aug	8-Sep	ADFG
Labunski, Elizabeth	Seabird Observer	27-Aug	8-Sep	USFWS
Waters, Charlie	Fish Bio	8-Sep	20-Sep	AFSC
Garcia, Sabrina	Fish Bio	8-Aug	20-Sep	ADFG
Nicols, Dave	Fish Bio	8-Sep	20-Sep	AFSC
Conlon, Ryan	Student	8-Sep	20-Sep	APU
Zeller, Tamara	Seabird Observer	8-Sep	20-Sep	USFWS

Table 2: Dates, locations, and sampling events completed at each station during the northern Bering Sea surface trawl survey, 2019.

Station	Date	Latitude	Longitude	Bottom Depth (m)	CTD Cast	Bongo Cast	Surface Trawl	Benthic Grab
1	8/30/2019	60.01	-167.98	21	Yes	Yes	Yes	No
2	8/30/2019	59.99	-168.97	36	Yes	Yes	Yes	No
3	8/31/2019	59.99	-169.97	49	Yes	Yes	Yes	No
4	8/31/2019	59.99	-170.98	63	Yes	Yes	Yes	No
5	8/31/2019	60.51	-170.96	57	Yes	Yes	Yes	No
6	9/1/2019	60.51	-169.98	43	Yes	Yes	Yes	No
7	9/1/2019	60.51	-168.97	33	Yes	Yes	Yes	No
8	9/1/2019	60.51	-167.96	25	Yes	Yes	Yes	No
9	9/2/2019	60.51	-167.04	22	Yes	Yes	Yes	No
10	9/2/2019	60.99	-167.04	17	Yes	Yes	Yes	No
11	9/2/2019	61.00	-168.02	25	Yes	Yes	Yes	Yes
12	9/3/2019	60.99	-169.05	32	Yes	Yes	Yes	No
13	9/3/2019	60.99	-170.02	42	Yes	Yes	Yes	No
14	9/3/2019	61.03	-170.98	49	Yes	Yes	Yes	No
15	9/4/2019	61.49	-170.96	46	Yes	Yes	Yes	No
16	9/4/2019	61.51	-169.98	40	Yes	Yes	Yes	No
17	9/4/2019	61.50	-169.00	30	Yes	Yes	Yes	No
18	9/5/2019	61.49	-168.01	24	Yes	Yes	Yes	No
19	9/5/2019	61.54	-167.06	17	Yes	Yes	Yes	No
20	9/5/2019	61.99	-166.98	24	Yes	Yes	Yes	Yes
21	9/6/2019	61.98	-167.98	23	Yes	Yes	Yes	No
22	9/6/2019	62.00	-169.04	32	Yes	Yes	Yes	No
23	9/6/2019	62.02	-170.07	39	Yes	Yes	Yes	Yes
24	9/7/2019	62.01	-170.95	45	Yes	Yes	Yes	Yes
25	9/7/2019	62.50	-166.96	29	Yes	Yes	Yes	No
26	9/7/2019	63.01	-165.95	16	Yes	Yes	Yes	Yes
27	9/8/2019	63.51	-165.96	19	Yes	Yes	Yes	No
28	9/9/2019	63.49	-166.94	21	Yes	Yes	Yes	Yes
29	9/9/2019	62.99	-167.03	20	Yes	Yes	Yes	No
30	9/10/2019	62.49	-167.94	24	Yes	Yes	Yes	Yes
31	9/10/2019	62.50	-169.04	27	Yes	Yes	Yes	No
32	9/10/2019	62.48	-170.03	31	Yes	Yes	Yes	Yes
33	9/11/2019	62.49	-170.98	38	Yes	Yes	Yes	No
34	9/11/2019	63.49	-167.96	28	Yes	Yes	Yes	No
35	9/11/2019	64.00	-167.97	32	Yes	Yes	Yes	No
36	9/12/2019	64.52	-166.99	22	Yes	Yes	Yes	No
37	9/12/2019	64.01	-166.96	28	Yes	Yes	Yes	Yes
38	9/13/2019	64.01	-165.96	17	Yes	Yes	Yes	No
39	9/13/2019	64.10	-162.54	16	Yes	Yes	Yes	Yes
40	9/13/2019	64.10	-163.56	19	Yes	Yes	Yes	Yes
41	9/14/2019	64.10	-164.47	17	Yes	Yes	Yes	Yes
42	9/14/2019	64.53	-168.01	31	Yes	Yes	Yes	No
43	9/14/2019	65.02	-167.55	20	Yes	Yes	Yes	Yes
44	9/15/2019	65.42	-168.04	36	Yes	Yes	Yes	Yes
45	9/15/2019	66.62	-165.80	14	Yes	Yes	Yes	Yes
46	9/15/2019	66.61	-166.99	26	Yes	Yes	Yes	Yes
47	9/16/2019	66.12	-167.45	17	Yes	Yes	Yes	Yes

Table 3: Temperature, salinity, and mixed layer depth (MLD) measurements from CTD (SBE 9-11+) and FastCat (SBE-43) casts at each station during the northern Bering Sea surface trawl survey, 2019. Surface values are averaged across top 10 meters, and bottom values are readings taken at maximum gear depth.

Station	CTD Surface Temp (°C)	CAT Surface Temp (°C)	CTD Surface Salinity (PSU)	CAT Surface Salinity (PSU)	CTD Bottom Temp (°C)	CAT Bottom Temp (°C)	CTD Bottom Salinity (PSU)	CAT Bottom Salinity (PSU)	Mixed Layer Depth (m)
1	12.42	12.41	31.15	27.63	12.42	12.41	31.12	30.78	17
2	11.84	11.84	NA	31.82	7.66	7.71	31.91	31.91	22
3	11.99	12.08	31.91	31.91	4.17	4.27	32.05	32.05	21
4	11.99	11.54	31.91	32.05	4.17	2.65	32.05	32.23	21
5	11.68	11.67	NA	31.95	2.90	2.90	32.18	32.18	26
6	11.76	NA	31.89	NA	4.88	NA	31.97	NA	22
7	10.91	10.94	31.56	31.58	10.09	10.42	31.68	31.65	22
8	12.43	12.44	NA	30.97	12.43	12.43	30.97	30.96	21
9	12.87	12.88	30.71	30.71	12.85	12.85	30.73	30.73	19
10	13.77	13.77	29.23	29.15	13.74	13.74	29.30	29.30	13
11	12.59	12.59	30.88	30.88	12.57	12.57	30.88	30.88	20
12	11.03	11.03	31.46	31.46	11.02	11.03	31.46	31.46	29
13	11.27	11.27	31.78	31.77	5.68	5.66	31.86	31.86	24
14	11.41	11.41	31.93	31.92	3.13	3.12	32.09	32.09	27
15	11.37	11.36	31.90	31.89	2.73	2.73	32.04	32.04	23
16	10.95	10.93	31.44	31.44	5.74	5.84	31.69	31.69	20
17	11.23	11.23	31.38	15.89	11.23	11.24	31.38	31.36	26
18	11.93	11.90	30.69	12.07	11.93	11.93	30.69	30.65	21
19	12.96	12.96	30.22	28.47	12.96	12.96	30.22	30.20	16
20	12.87	12.89	30.14	27.37	12.88	12.89	30.19	29.82	22
21	11.02	11.04	NA	29.07	11.02	11.07	30.81	30.82	21
22	10.89	10.95	NA	24.52	8.02	8.08	31.32	31.33	21
23	11.33	11.33	31.50	31.50	3.44	3.43	31.57	31.57	24
24	11.24	11.26	31.64	31.64	1.77	1.77	31.87	31.88	19
25	12.57	12.56	30.10	28.87	12.07	12.10	30.32	30.31	20
26	12.28	12.32	29.78	27.82	12.03	12.04	29.98	29.99	12
27	11.09	11.18	30.74	27.17	10.31	10.40	31.02	31.01	10
28	9.99	10.02	31.24	12.70	9.53	9.71	31.28	31.01	19
29	11.02	11.18	30.89	21.06	10.95	10.96	30.98	30.96	19
30	11.27	11.39	31.05	26.29	10.47	10.48	31.05	31.35	15
31	11.11	11.10	31.28	30.63	2.96	2.95	31.53	31.57	18
32	11.39	11.39	31.37	30.01	2.02	2.03	31.66	31.67	18
33	11.38	11.39	31.37	31.37	1.72	1.72	31.77	31.77	19
34	10.02	9.88	31.67	31.63	6.42	6.42	31.72	31.73	12
35	10.29	10.30	NA	31.06	2.80	2.77	32.11	32.16	20
36	10.62	10.63	30.86	30.88	10.45	10.47	30.96	30.66	19
37	8.45	8.46	31.55	31.45	8.00	8.05	31.72	31.73	27
38	10.36	10.37	31.19	30.53	10.37	10.36	31.19	31.18	16
39	12.93	12.90	21.68	15.56	12.97	12.97	22.06	19.90	14
40	12.93	12.43	21.68	19.35	12.97	12.46	22.06	24.01	14
41	12.07	12.14	29.17	28.83	11.91	11.91	29.47	29.57	8
42	7.91	7.86	31.26	28.00	5.66	5.73	31.93	31.93	17
43	11.38	11.67	NA	23.86	11.37	11.35	30.23	30.22	19
44	11.45	11.84	29.30	22.01	10.68	10.68	30.76	30.76	6
45	10.79	10.76	29.59	18.89	10.75	10.74	29.60	29.53	14
46	11.89	11.90	28.50	27.49	11.68	11.78	28.88	28.80	14
47	11.97	11.94	27.36	19.02	11.60	11.63	28.37	28.28	10

Table 4: Surface trawl net dimensions and mixed layer depth (MLD) expansions for each station during the northern Bering Sea surface trawl survey, 2019. The MLD expansion refers to the correction applied to the catch based on the proportion of the mixed layer depth that was sampled by the surface trawl gear.

Station	Horiz. Net Spread (m)	Vert. Net Spread(m)	SBE39 Footrope Depth (m)	Mixed Layer Depth Expansion
1	38.45	17.15	18.72	1.00
2	49.50	19.00	21.59	1.02
3	51.00	16.40	18.11	1.16
4	51.00	18.50	20.27	1.04
5	51.00	19.00	19.95	1.30
6	50.00	19.00	20.45	1.08
7	48.62	20.87	23.17	1.00
8	49.60	19.20	21.23	1.00
9	51.00	12.00	12.80	1.48
10	51.22	15.39	16.53	1.00
11	52.00	15.00	16.44	1.22
12	50.00	22.00	24.58	1.18
13	48.00	21.00	22.94	1.05
14	52.38	17.12	18.87	1.43
15	49.50	20.00	22.30	1.03
16	50.50	16.00	16.74	1.19
17	50.00	19.24	22.02	1.18
18	50.00	20.19	21.33	1.00
19	50.50	16.50	17.46	1.00
20	51.00	18.00	19.03	1.16
21	49.00	17.00	18.41	1.14
22	49.00	17.00	19.56	1.07
23	52.00	17.00	18.43	1.30
24	49.50	19.50	21.22	1.00
25	51.00	17.50	19.19	1.04
26	51.62	15.00	15.02	1.00
27	53.01	15.34	17.23	1.00
28	44.00	17.00	18.66	1.02
29	48.00	18.00	18.96	1.00
30	49.00	17.00	18.75	1.00
31	51.00	16.00	17.09	1.05
32	45.00	17.00	18.29	1.00
33	47.00	17.75	19.07	1.00
34	51.00	21.00	23.22	1.00
35	47.00	19.50	20.11	1.00
36	48.00	16.00	16.17	1.18
37	47.00	18.50	18.83	1.43
38	51.00	16.50	16.97	1.00
39	52.71	14.29	14.39	1.00
40	51.00	15.50	16.08	1.00
41	51.50	15.00	16.27	1.00
42	50.50	19.00	21.48	1.00
43	51.00	17.00	18.98	1.00
44	53.00	20.00	23.10	1.00
45	53.00	13.00	14.10	1.00
46	51.00	18.50	19.65	1.00
47	49.00	14.50	16.61	1.00

Table 5: Average size (length and weight), total catch, and catch-per-unit-effort (CPUE) of salmon species captured during the northern Bering Sea surface trawl survey, 2019.

Common Name	*Scientific Name*	Life History Stage	Average Length (cm)	Average Weight (g)	Average CPUE (n/km^2)	Total Number Caught
Chinook salmon	*Oncorhynchus tshawytscha*	Juvenile	19.75	96.98	13.38	125
Chum salmon	*Oncorhynchus keta*	Juvenile	16.73	48.85	417.91	3660
Coho salmon	*Oncorhynchus kisutch*	Juvenile	24.82	194.46	19.95	182
Pink salmon	*Oncorhynchus gorbuscha*	Juvenile	15.37	33.85	1530.79	13507
Sockeye salmon	*Oncorhynchus nerka*	Juvenile	18.54	64.27	294.50	2553
Chinook salmon	*Oncorhynchus tshawytscha*	Immature	42.17	1271.04	3.04	26
Chum salmon	*Oncorhynchus keta*	Immature	42.92	1186.73	20.89	194
Coho salmon	*Oncorhynchus kisutch*	Immature	65.00	3870.00	0.12	1
Sockeye salmon	*Oncorhynchus nerka*	Immature	36.05	647.89	2.23	19

Table 6: Average size (bell width and weight), total weight, and catch-per-unit-effort (CPUE) of common jellyfish species captured during the northern Bering Sea surface trawl survey, 2019.

Common Name	*Scientific Name*	Average Bell Diameter (cm)	Average Weight (g)	Average CPUE (kg/km^2)	Total Weight (kg)
Water jellyfish	*Aequorea sp.*	15.40	218.00	2.47	22.87
Moon jellyfish	*Aurelia sp.*	15.32	302.65	40.25	377.56
Northern sea nettle	*Chrysaora melanaster*	22.91	872.36	801.44	6898.00
Lions mane	*Cyanea capillata*	22.60	962.02	70.78	609.69
Fried egg jellyfish	*Phacellophora camtschatica*	NA	NA	0.18	1.68
Whitecross jellyfish	*Staurophora mertensi*	NA	NA	7.30	68.70

Table 7: Average size (length and weight), total catch, and catch-per-unit-effort (CPUE) of non-salmon species captured during the northern Bering Sea surface trawl survey, 2019.

Common Name	*Scientific Name*	Life History Stage	Average Length (cm)	Total Weight Caught (kg)	Total Num. Caught	Average CPUE (n/km²)
Alaska plaice	*Pleuronectes quadrituberculatus*	None	18.75	0.360	4	0.44
Arctic lamprey	*Lethenteron camtschaticum*	None	38.22	1.782	20	2.17
Arctic staghorn sculpin	*Gymnocanthus tricuspis*	None	28.83	0.880	3	0.29
Atka mackerel	*Pleurogrammus monopterygius*	Age 0	NA	0.028	1	0.09
Capelin	*Mallotus villosus*	None	10.85	0.082	11	1.01
Crested sculpin	*Blepsias bilobus*	None	12.18	0.840	13	1.53
Gonatus spp.	*Gonatus spp.*	None	6.42	0.064	9	0.96
Greenling	*Hexagrammos spp.*	None	11.49	0.220	7	0.70
Longhead dab	*Limanda proboscidea*	None	3.20	0.002	2	0.22
Ninespine stickleback	*Pungitius pungitius*	None	5.28	10.478	9464	1003.37
Northern rock sole	*Lepidopsetta polyxystra*	None	19.50	0.080	1	0.12
Pacific cod	*Gadus macrocephalus*	Age 0	8.13	0.016	3	0.34
Pacific herring	*Clupea pallasi*	None	14.42	1842.099	142152	14300.16
Rainbow smelt	*Osmerus mordax*	Age 0	6.56	3.551	2350	255.48
Rainbow smelt	*Osmerus mordax*	None	12.85	13.817	1040	120.94
Saffron cod	*Eleginus gracilis*	Age 0	10.48	0.128	14	1.42
Saffron cod	*Eleginus gracilis*	Age 1+	21.26	2.995	35	3.62
Salmon shark	*Lamna ditropis*	None	210.00	191.000	2	0.20
Sand lance	*Ammodytes spp.*	None	14.55	0.026	2	0.23
Smooth lumpsucker	*Aptocyclus ventricosus*	None	NA	1.610	1	0.10
Starry flounder	*Platichthys stellatus*	None	24.54	5.333	27	2.81
Sturgeon poacher	*Podothecus accipenserinus*	None	26.00	0.070	1	0.10
Threespine stickleback	*Gasterosteus aculeatus*	None	4.26	1.174	1464	149.07
Walleye pollock	*Gadus chalcogrammus*	Age 0	6.51	25.945	8798	1013.63
Walleye pollock	*Gadus chalcogrammus*	Age 1+	42.83	27.149	51	5.74
Yellowfin sole	*Limanda aspera*	None	27.37	0.787	3	0.34

Table 8: Stock composition percentages (mean, standard deviation) for reporting groups (Upper Yukon, Middle Yukon, Lower Yukon, and Other Western Alaska) of juvenile Chinook Salmon captured during the northern Bering Sea surface trawl surveys, 2003-2019. Stock composition estimates are not available for 2008 (no survey), 2012 and 2005 (low sample size), and 2013 (genetic samples contaminated during a flooding event aboard the survey vessel).

	Upper Yukon		Middle Yukon		Lower Yukon		Other Western Alaska	
Year	Mean	SD	Mean	SD	Mean	SD	Mean	SD
2003	48.29	3.50	23.44	3.06	16.55	4.34	11.72	4.13
2004	57.37	4.46	26.26	4.03	5.49	3.72	10.88	4.15
2006	48.98	5.34	26.51	4.80	14.99	5.59	9.52	5.14
2007	50.59	3.49	29.88	3.27	13.84	3.09	5.69	2.50
2009	52.43	4.77	28.06	4.42	6.26	4.25	13.25	4.63
2010	48.78	4.59	27.36	4.13	15.27	4.09	8.59	3.54
2011	46.74	2.88	22.46	2.44	17.53	3.52	13.27	3.38
2014	50.62	3.71	36.60	3.62	8.80	2.64	3.98	2.13
2015	44.17	2.93	30.02	2.79	11.87	3.35	13.94	3.37
2016	54.18	3.47	20.84	2.93	9.54	3.27	15.44	3.49
2017	42.30	3.67	19.94	3.04	9.28	4.32	28.47	4.97
2018	34.43	4.03	30.89	4.02	19.18	5.05	15.51	4.82
2019	29.99	4.50	21.17	4.19	13.88	6.04	34.96	6.63

Table 9: Juvenile abundance, standard deviation (SD) of abundance, and juveniles-per-spawner for Yukon River Canadian-origin Chinook Salmon stock group during the northern Bering Sea surface trawl surveys, 2003-2019 (juvenile years). Canadian-origin Chinook Salmon spawner abundance, adult returns, and returns-per-spawner are included.

Brood Year	Juvenile Year	Juvenile Abundance (000s)	Juvenile Abundance (SD) (000s)	Adult returns (000s)	Spawner abundance (000s)	Juveniles-per-spawner	Returns-per-spawner
2001	2003	2,691	506	120	53	51.2	2.3
2002	2004	1,449	298	55	42	34.2	1.3
2003	2005	1,659	485	98	81	20.6	1.2
2004	2006	772	161	56	48	15.9	1.2
2005	2007	1,621	493	78	68	23.8	1.2
2006	2008	–	–	59	63	–	0.9
2007	2009	984	418	45	35	28.2	1.3
2008	2010	974	254	42	34	28.7	1.2
2009	2011	1,843	756	81	65	28.2	1.2
2010	2012	719	292	55	32	22.4	1.7
2011	2013	2,924	881	107	46	63.1	2.3
2012	2014	1,789	412	87	33	54.8	2.7
2013	2015	2,113	677	70	29	73.7	2.4
2014	2016	2,126	746	68	63	33.6	1.1
2015	2017	1,049	219	–	83	12.7	–
2016	2018	888	224	–	69	12.9	–
2017	2019	575	164	–	68	8.4	–

Table 10: Juvenile abundance, standard deviation (SD) of abundance, and juveniles-per-spawner for the Total Yukon River Chinook Salmon stock group during the northern Bering Sea surface trawl surveys, 2003-2019 (juvenile years). Total Yukon River Chinook Salmon spawner abundance, adult returns, and returns-per-spawner are included.

Brood Year	Juvenile Year	Juvenile Abundance (000s)	Juvenile Abundance (SD) (000s)	Adult returns (000s)	Spawner abundance (000s)	Juveniles-per-spawner	Returns-per-spawner
2001	2003	4,920	878	322	–	–	–
2002	2004	2,249	435	154	113	19.9	1.4
2003	2005	2,952	698	263	264	11.2	1.0
2004	2006	1,426	262	108	150	9.5	0.7
2005	2007	3,020	884	189	207	14.6	0.9
2006	2008	–	–	178	187	–	0.9
2007	2009	1,629	676	175	128	12.7	1.4
2008	2010	1,824	437	94	147	12.4	0.6
2009	2011	3,422	1,391	200	153	22.3	1.3
2010	2012	1,279	467	101	114	11.2	0.9
2011	2013	5,204	1,285	276	130	40.1	2.1
2012	2014	3,393	724	238	111	30.6	2.2
2013	2015	4,115	1,294	220	129	31.8	1.7
2014	2016	3,318	1,149	208	173	19.2	1.2
2015	2017	1,773	361	–	151	11.7	–
2016	2018	2,181	493	–	163	13.4	–
2017	2019	1,246	326	–	236	5.3	–

Table 11: Grouping information from post-hoc Tukey pairwise comparisons of energy density (covariate: length) by year, ordered by mean value, for juvenile Chinook Salmon caught during the northern Bering Sea surface trawl surveys, 2006–2019. Years that share a common letter do not significantly differ (95 percent confidence).

			Group				
Year	N	Mean energy density (kJ/g)	A	B	C	D	E
2018	41	22.359	A				
2017	49	22.213	A	B			
2016	36	22.154	A	B	C		
2010	95	22.152	A	B			
2014	87	21.884		B	C	D	
2019	50	21.733			C	D	
2007	49	21.684			C	D	
2006	10	21.594	A	B	C	D	E
2015	69	21.550				D	E
2012	31	21.550				D	E
2009	17	21.548		B	C	D	E
2011	41	21.076					E

Table 12: Grouping information from post-hoc Tukey pairwise comparisons of ranked residuals from simple linear regression of energy density versus length, ordered by mean rank, for juvenile Chinook Salmon caught during the northern Bering Sea surface trawl surveys, 2006–2017. Years that share a common letter do not significantly differ (95 percent confidence).

			Group				
Year	N	Mean rank	A	B	C	D	E
2018	41	412.6	A				
2017	49	366.7	A	B			
2016	36	356.3	A	B	C		
2010	95	351.8	A	B			
2014	87	285.2		B	C	D	
2019	50	259.3			C	D	E
2007	49	254.9			C	D	E
2012	31	230.0				D	E
2006	10	213.9		B	C	D	E
2015	69	211.2				D	E
2009	17	206.1				D	E
2011	41	167.3					E

Table 13: Number of marine birds recorded on transect during the northern Bering Sea surface trawl survey, 2019.

		S. Bering		N. Bering		Chukchi		Total	
Common Name	*Scientific Name*	Num.	%	Num.	%	Num.	%	Num.	%
Red-throated Loon	*Gavia stellata*					2	0.8	2	0.1
Pacific Loon	*Gavia pacifica*	2	0.1	10	0.8	5	2	17	0.5
Yellow-billed Loon	*Gavia adamsii*			1	0.1			1	0
Unid. Loon	*Gavia spp.*			4	0.3	2	0.8	6	0.2
Red-necked Grebe	*Podiceps grisegena*			2	0.2			2	0.1
Black-footed Albatross	*Phoebastria nigripes*	7	0.4					7	0.2
Laysan Albatross	*Phoebastria immutabilis*	3	0.2					3	0.1
Northern Fulmar	*Fulmarus glacialis*	762	40.7	160	13.5	3	1.2	925	27.9
Fork-tailed Storm-Petrel	*Oceanodroma furcata*	97	5.2	3	0.3	1	0.4	101	3.1
Short-tailed Shearwater	*Ardenna tenuirostris*	281	15	182	15.3	19	7.5	482	14.6
Unid. Dark Shearwater	*Ardenna spp.*	7	0.4					7	0.2
Pelagic Cormorant	*Phalacrocorax pelagicus*	3	0.2	4	0.3			7	0.2
Harlequin Duck	*Histrionicus histrionicus*			3	0.3			3	0.1
Long-tailed Duck	*Clangula hyemalis*			1	0.1			1	<0.1
Steller's Eider	*Polysticta stelleri*			2	0.2			2	0.1
Unid. Duck	*Anatinae (gen, sp)*			1	0.1			1	0
Unid. Eider	*Somateria spp.*			3	0.3			3	0.1
Sandhill Crane	*Grus canadensis*			9	0.8	145	57.5	154	4.7
Dunlin	*Calidris alpina*			1	0.1			1	<0.1
Unid. Shorebird	*Scolopacidae spp.*			4	0.3			4	0.1
Red Phalarope	*Phalaropus fulicarius*	14	0.7	170	14.3	20	7.9	204	6.2
Red-necked Phalarope	*Phalaropus lobatus*	2	0.1	21	1.8			23	0.7
Unid. Phalarope	*Phalaropus spp.*	2	0.1	21	1.8	15	6	38	1.1
Long-tailed Jaeger	*Stercorarius longicaudus*	2	0.1					2	0.1
Parasitic Jaeger	*Stercorarius parasiticus*	5	0.3	2	0.2			7	0.2
Pomarine Jaeger	*Sterocorarius pomarinus*	4	0.2	5	0.4	3	1.2	12	0.4
Unid. Jaeger	*Stercocorarius spp.*			1	0.1			1	<0.1
Aleutian Tern	*Onychoprion aleuticus*	1	0.1	1	0.1			2	0.1
Arctic Tern	*Sterna paradisaea*	3	0.2	3	0.3			6	0.2
Unid. Tern	*Sterna spp.*	1	0.1					1	<0.1
Black-legged Kittiwake	*Rissa tridactyla*	318	17	296	24.9	20	7.9	634	19.2
Glaucous Gull	*Larus hyperboreus*	2	0.1	16	1.3	10	4	28	0.8
Glacous-winged Gull	*Larus glaucescens*	27	1.4	11	0.9			38	1.1
Herring Gull	*Larus argentatus*	8	0.4	1	0.1			9	0.3
Red-legged Kittiwake	*Rissa brevirostris*	5	0.3					5	0.2
Sabine's Gull	*Xema sabini*	6	0.3	22	1.9			28	0.8
Slaty-backed Gull	*Larus schistisagus*	2	0.1					2	0.1
Unid. Gull	*Larid spp.*	6	0.3	7	0.6	3	1.2	16	0.5
Common Murre	*Uria aalge*	56	3	40	3.4			96	2.9
Thick-billed Murre	*Uria lomvia*	18	1	13	1.1			31	0.9
Unid. Murre	*Uria spp.*	14	0.7	17	1.4	1	0.4	32	1
Ancient Murrelet	*Synthliboramphus antiquus*			5	0.4			5	0.2
Marbled Murrelet	*Brachyramphus marmoratus*			1	0.1			1	<0.1
Crested Auklet	*Aethia cristatella*	1	0.1	14	1.2			15	0.5
Least Auklet	*Aethia pusilla*	30	1.6	52	4.4			82	2.5
Parakeet Auklet	*Aethia psittacula*	49	2.6	36	3			85	2.6
Unid. Auklet	*Aethia spp.*	14	0.7	4	0.3			18	0.5
Horned Puffin	*Fratercula corniculata*	20	1.1	19	1.6	2	0.8	41	1.2
Tufted Puffin	*Fratercula cirrhata*	97	5.2	15	1.3	1	0.4	113	3.4
Unid. Alcid	*Alcid spp.*	1	0.1	3	0.3			4	0.1
Passerine spp.	*Passeriformes spp.*			1	0.1			1	<0.1
Unid. Bird.	*Aves(gen, sp)*	1	0.1					1	<0.1
Total		**1871**		**1187**		**252**		**3310**	

Table 14: Marine mammals recorded on and off transect during the northern Bering Sea surface trawl survey, 2019.

Common Name	*Scientific Name*	Southern Bering	Northern Bering	Total
Dall's Porpoise	*Phocoenoides dalli*	2	9	11
Fin Whale	*Balaenoptera physalus*		2	2
Harbor Seal	*Phoca vitulina*	1		1
Humpback Whale	*Megaptera novaeangliae*		20	20
Killer Whale	*Orcinus orca*		3	3
Northern Fur Seal	*Callorhinus ursinus*	2	24	26
Unidentified Whale	*Cetacea spp.*		2	2
Total		**5**	**60**	**65**

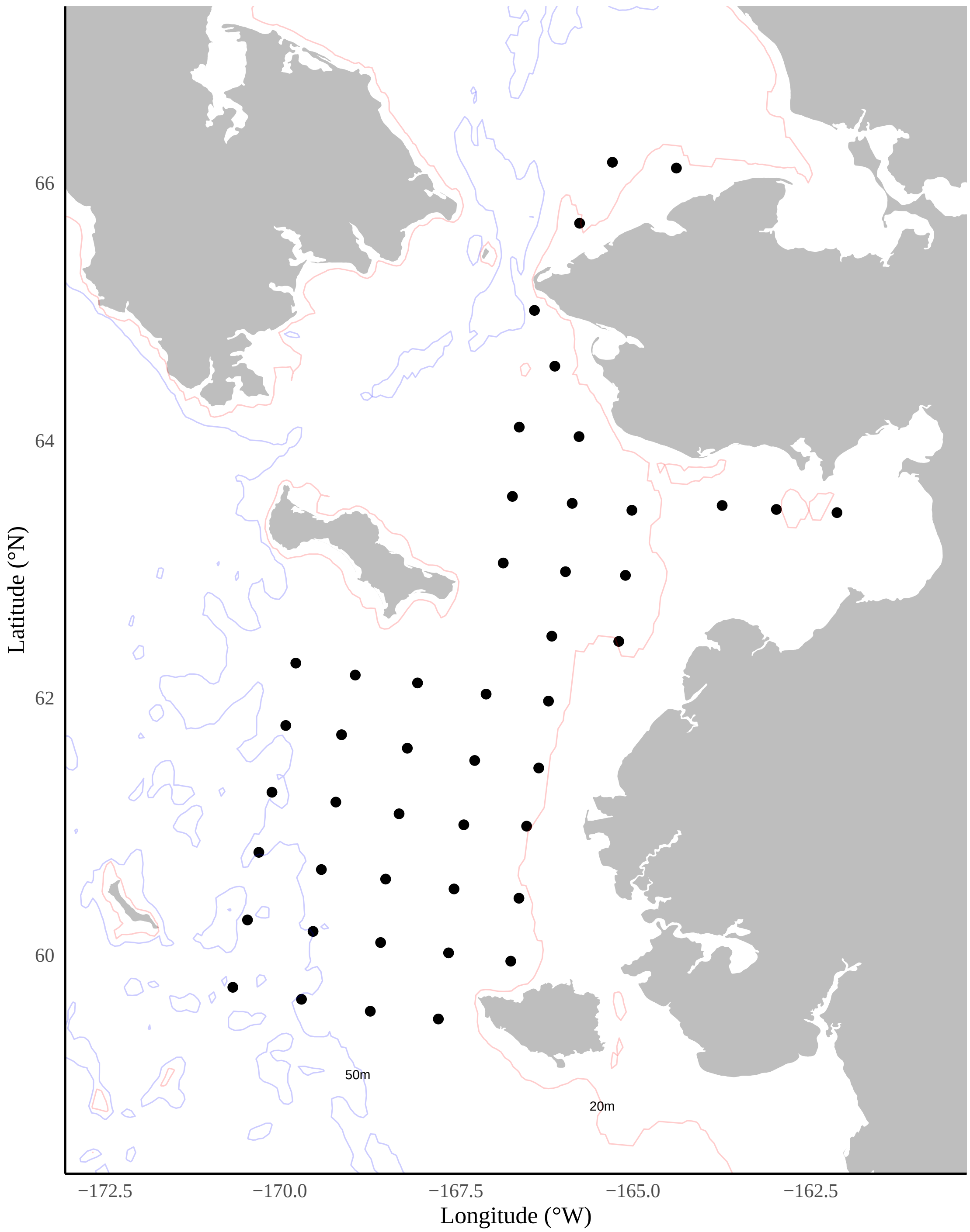

Figure 1: Map of stations sampled during the northern Bering Sea surface trawl survey, 2019.

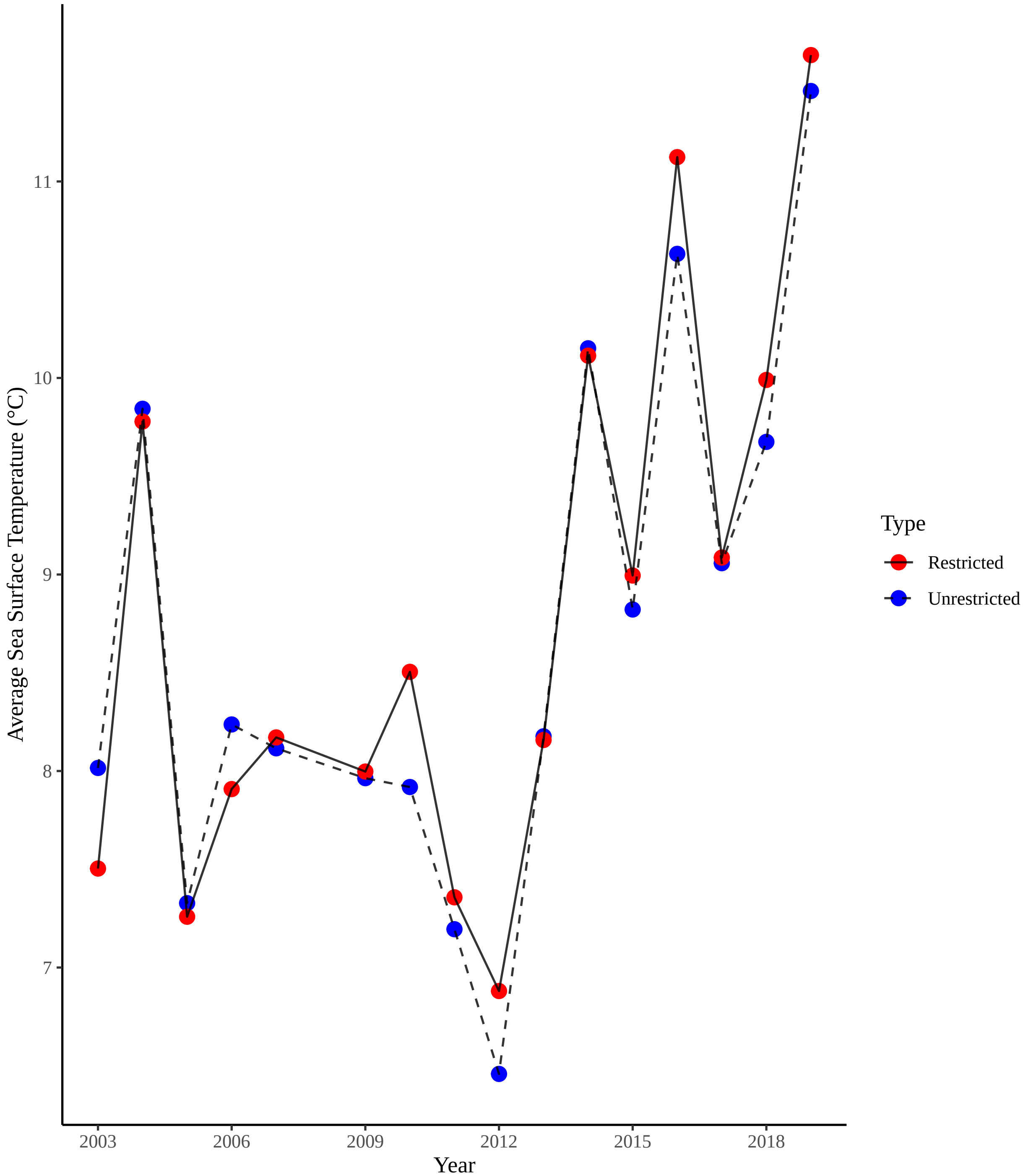

Figure 2: Average annual sea surface temperature (top 10 m of the water column) measured *in situ* during the northern Bering Sea surface trawl surveys, 2003-2019. Unrestricted temperatures includes all stations sampled in the northern Bering Sea, restricted temperatures are from stations east of 171°W and south of 64°N.

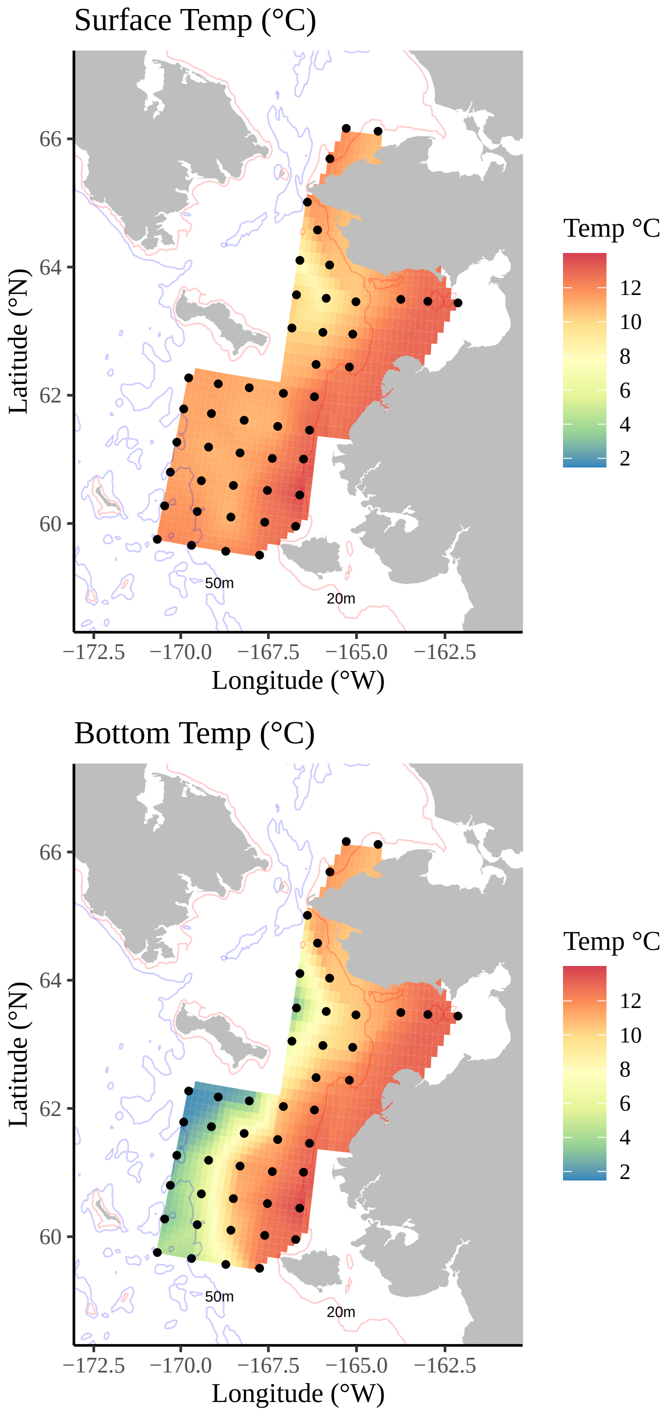

Figure 3: Predicted sea surface temperature (upper 10m) (top) and bottom (deepest depth sampled) temperature (bottom) (°0C) from CTD casts at each station sampled during the northern Bering Sea surface trawl survey, 2019.

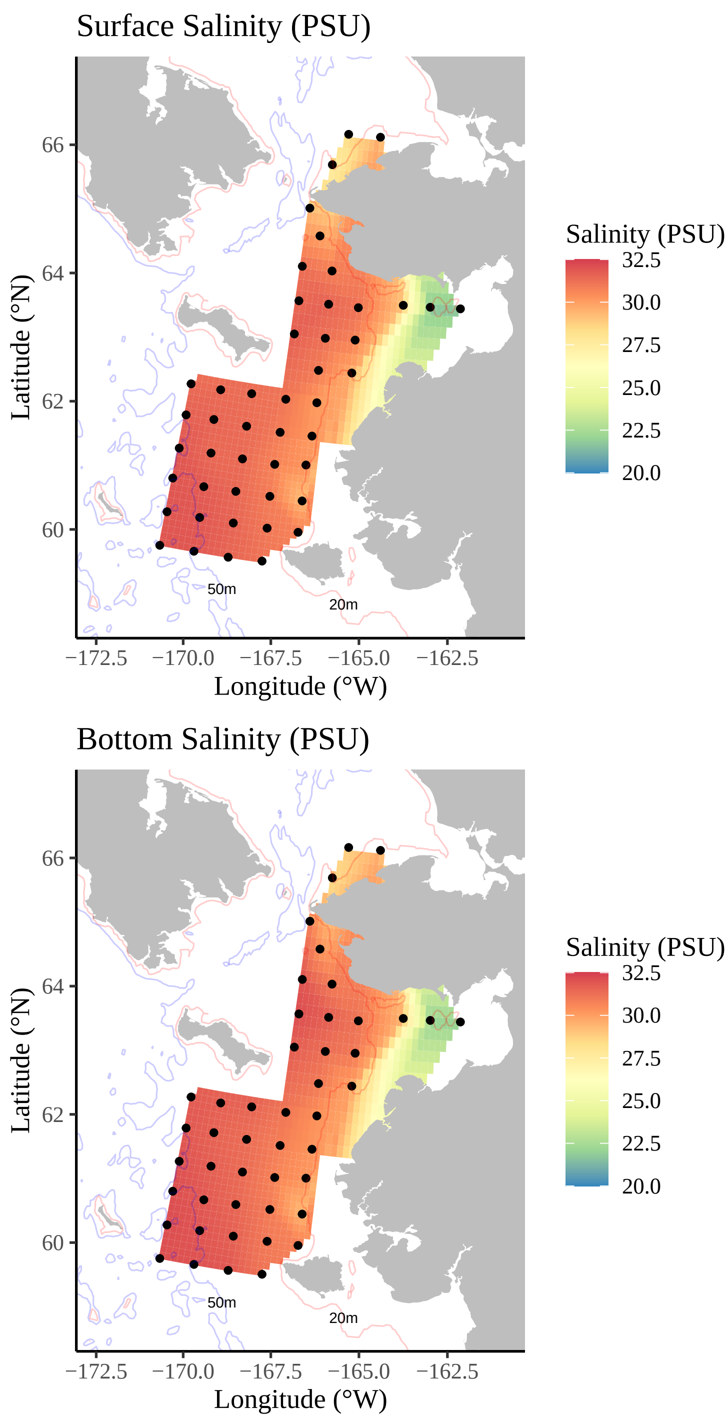

Figure 4: Surface salinity (average top 10m) and bottom salinity heatmaps created from stations sampled in the 2019 Northern Bering Sea survey.

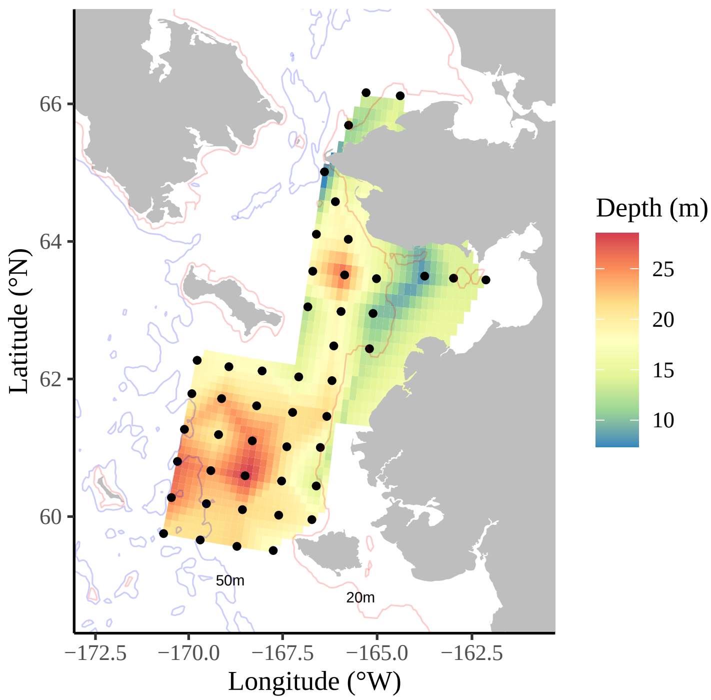

Figure 5: Predicted mixed layer depth (m) from CTD casts at each station sampled during the northern Bering Sea surface trawl survey, 2019.

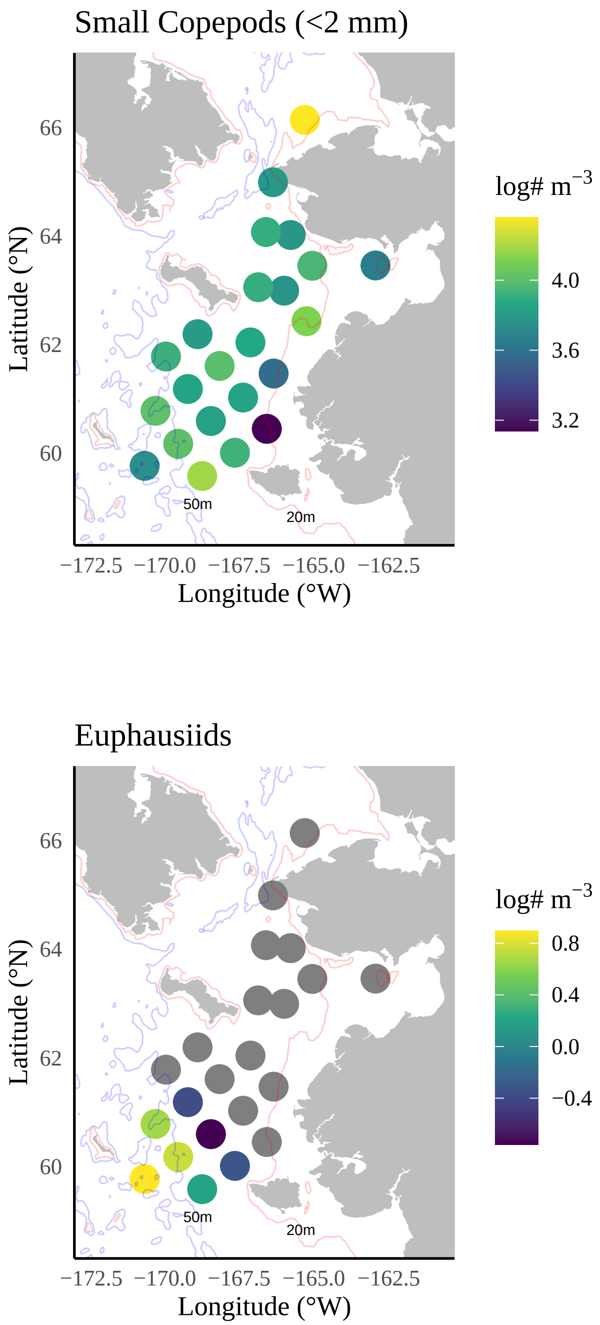

Figure 6: Distribution of small copepods, large copepods, and euphausiids sampled using Rapid Zooplankton Assessment (RZA) protocols during the northern Bering Sea surface trawl survey, 2019.

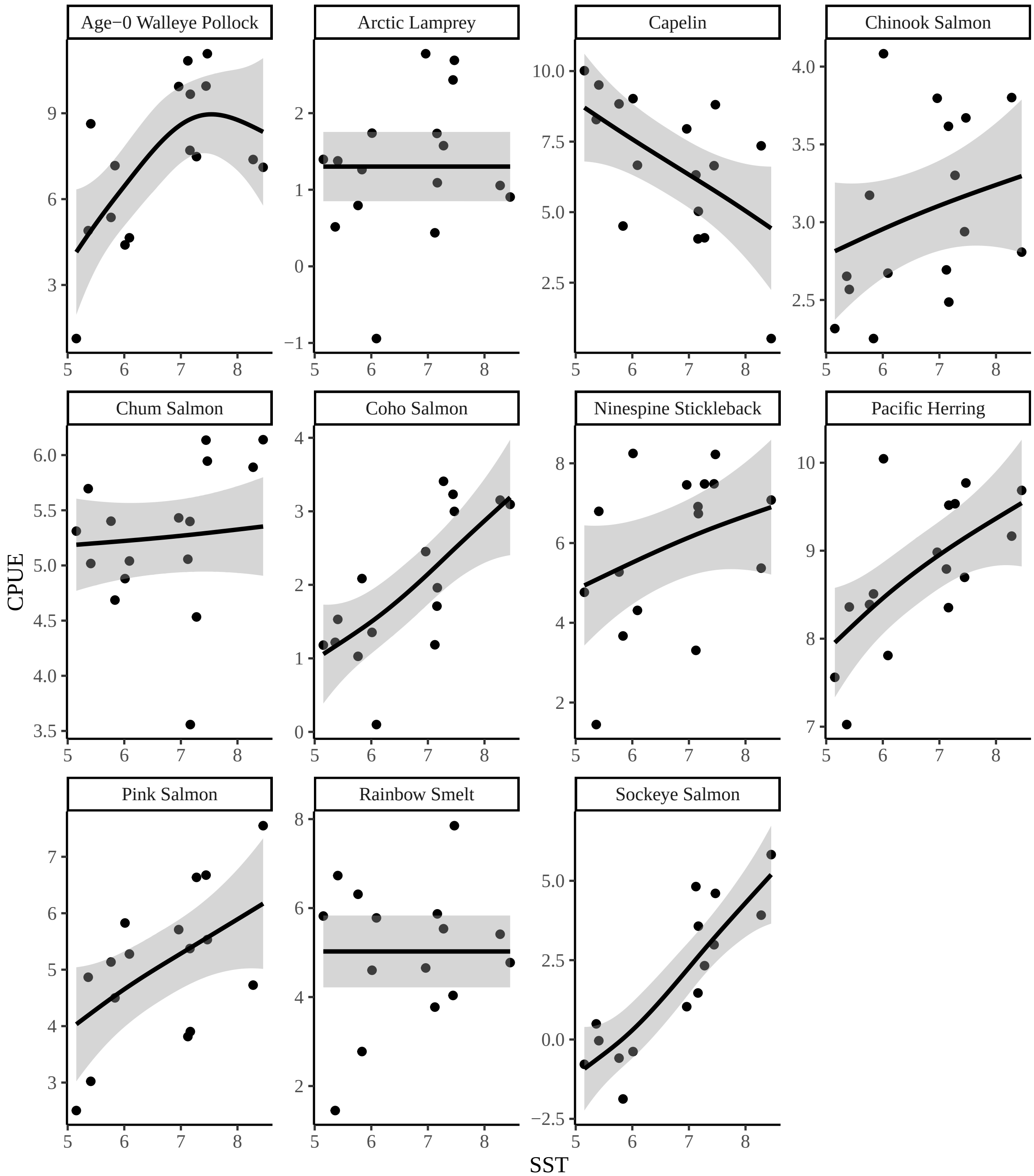

Figure 7: Relationships between average sea surface temperature (SST) of the eastern Bering Sea shelf and average catch rate (CPUE) for primary fish species captured during the northern Bering Sea surface trawl surveys, 2003-2019.

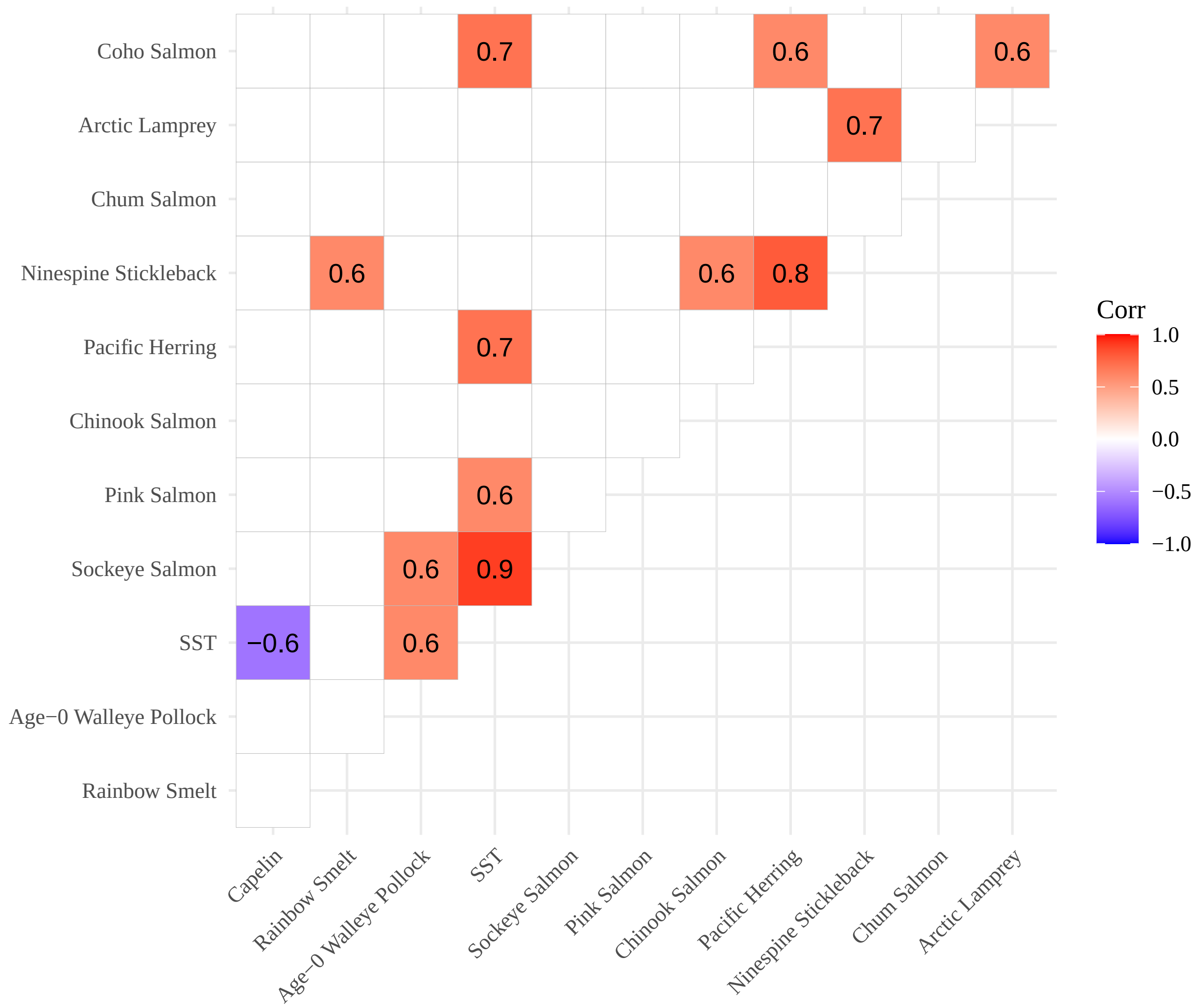

Figure 8: Significant ($alpha = 0.025$) correlations (Corr) between average catch rate (ln(CPUE)) of primary species in the northern Bering Sea surface trawl surveys and extended reanlysis sea surface temperature (ERSSTv5) of the eastern Bering Sea shelf, 2003-2019.

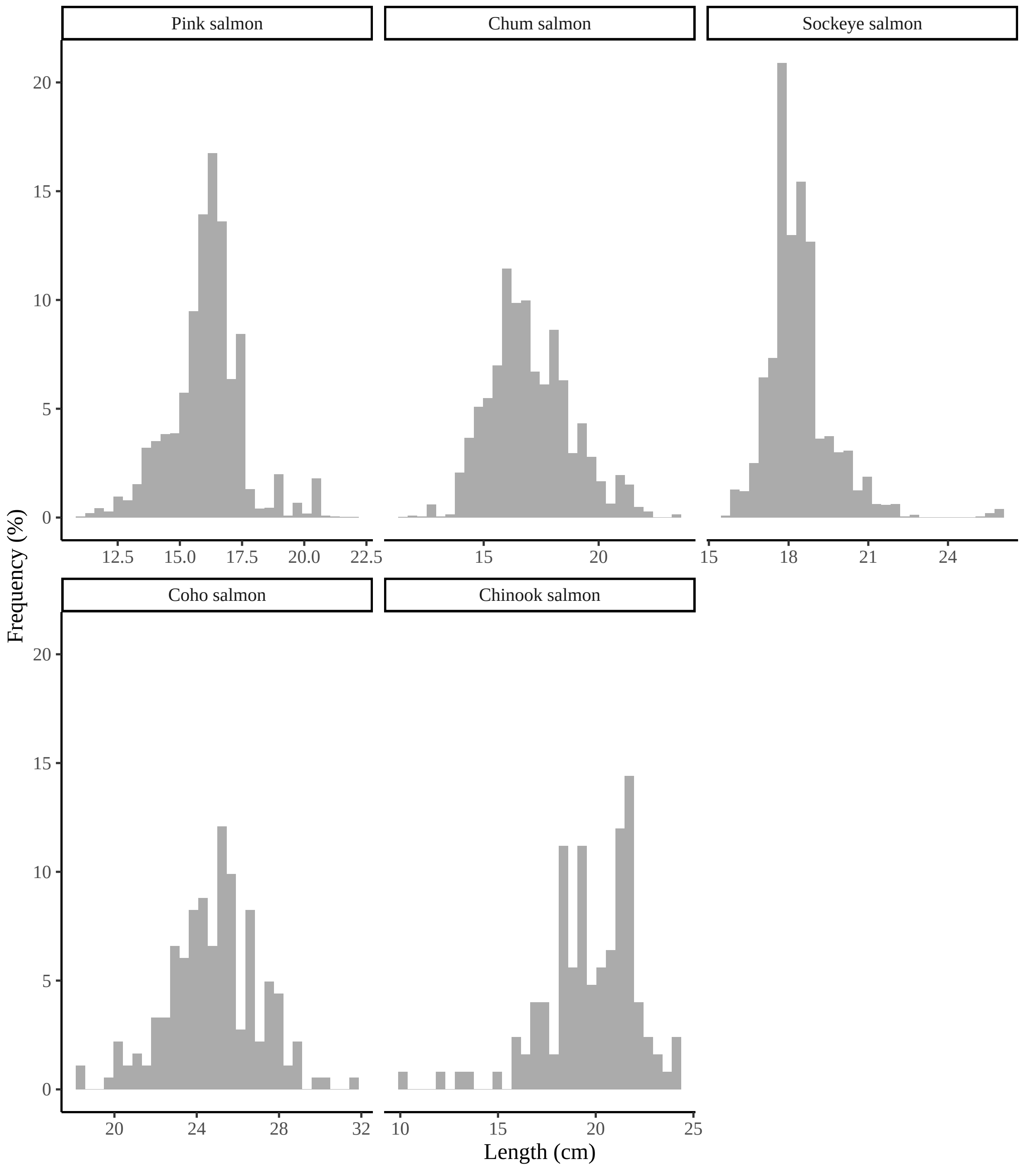

Figure 9: Length frequency distributions of juvenile salmon species captured during the northern Bering Sea surface trawl survey, 2019.

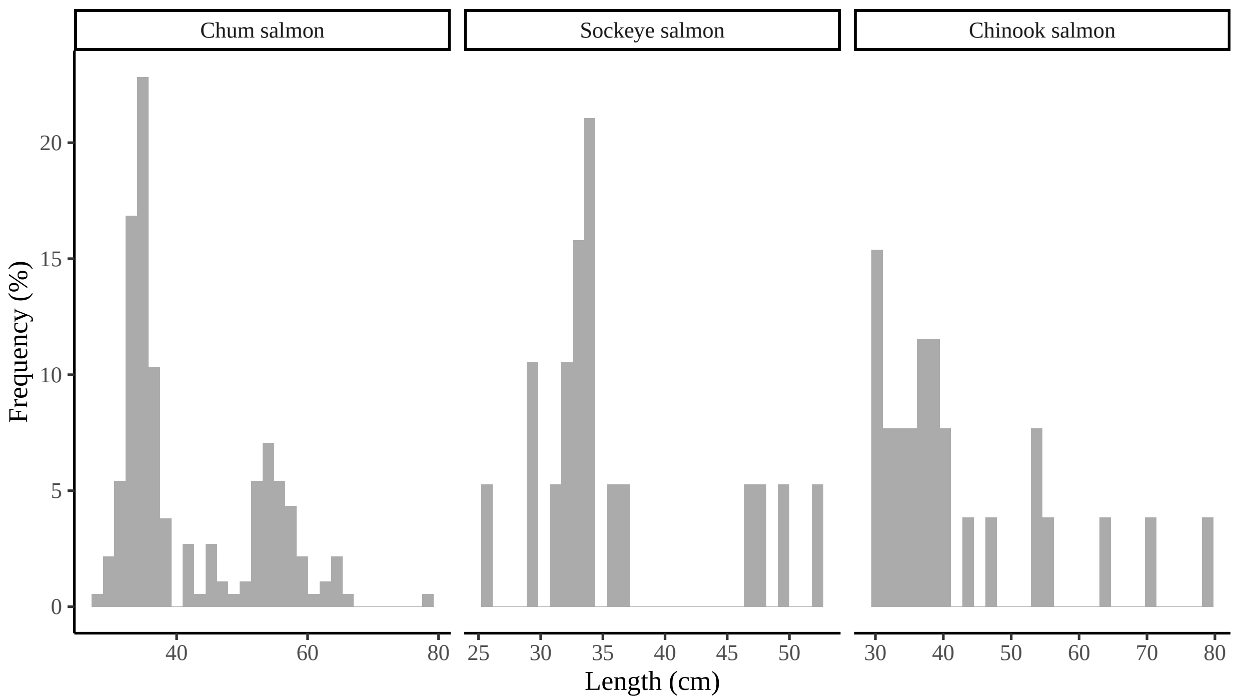

Figure 10: Length frequency distributions of immature salmon species captured during the northern Bering Sea surface trawl survey, 2019.

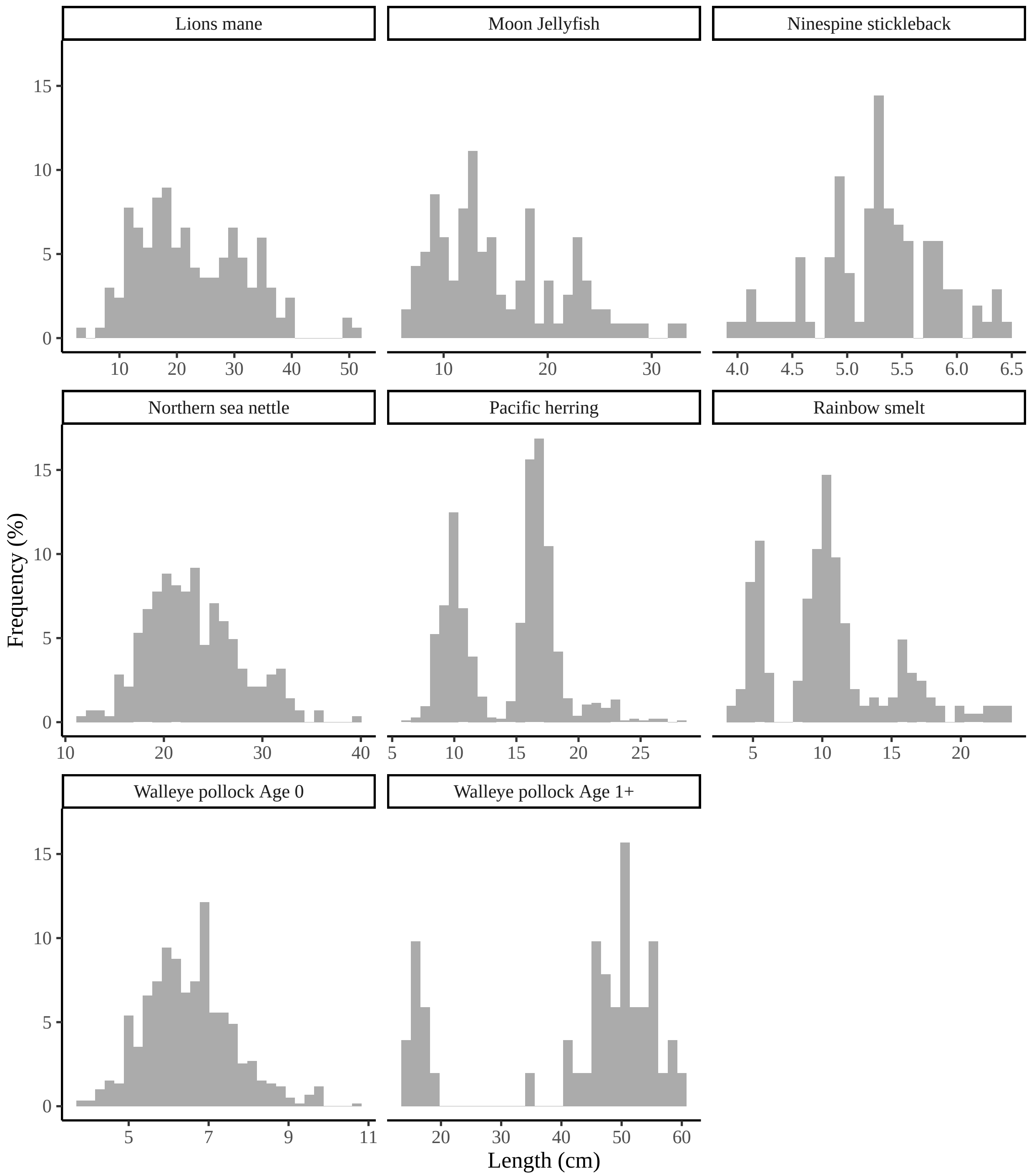

Figure 11: Length frequency distributions of other key species sampled during the northern Bering Sea surface trawl survey, 2019.

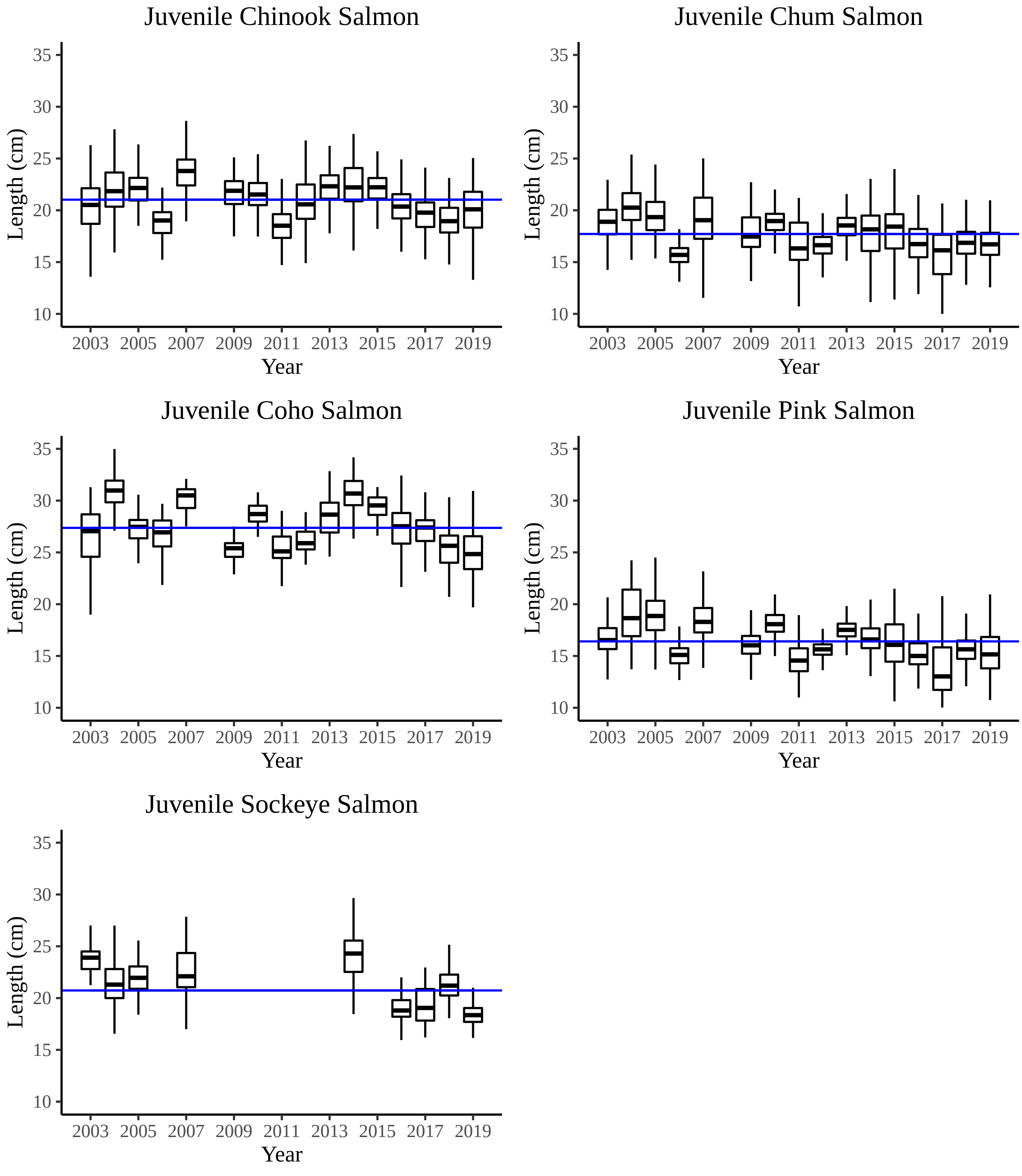

Figure 12: Length box plots of juvenile salmon species sampled during the northern Bering Sea surveys, 2003-2019. Y intercept indicates mean length across all years. Due to inconsistent sampling, Sockeye Salmon lengths were limited to years where >20 lengths were sampled.

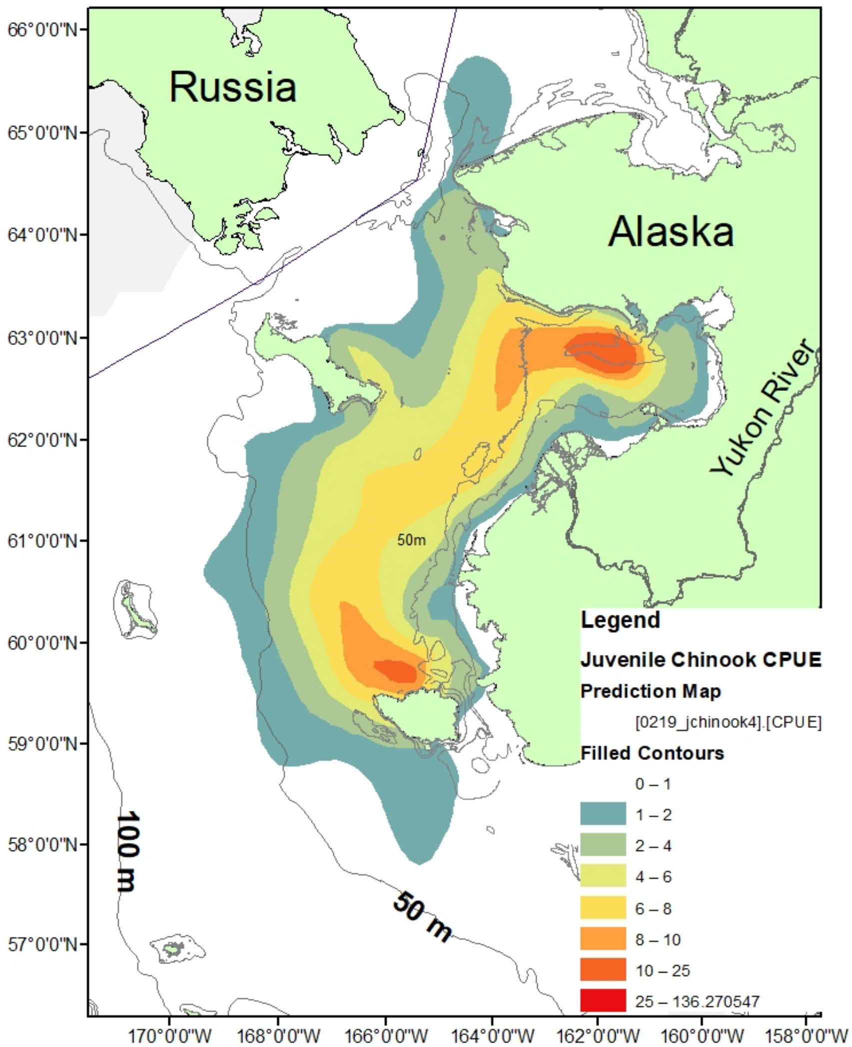

Figure 13: A kriging predicted surface of juvenile Chinook Salmon catch rates during the northern Bering Sea surface trawl surveys, 2003-2019.

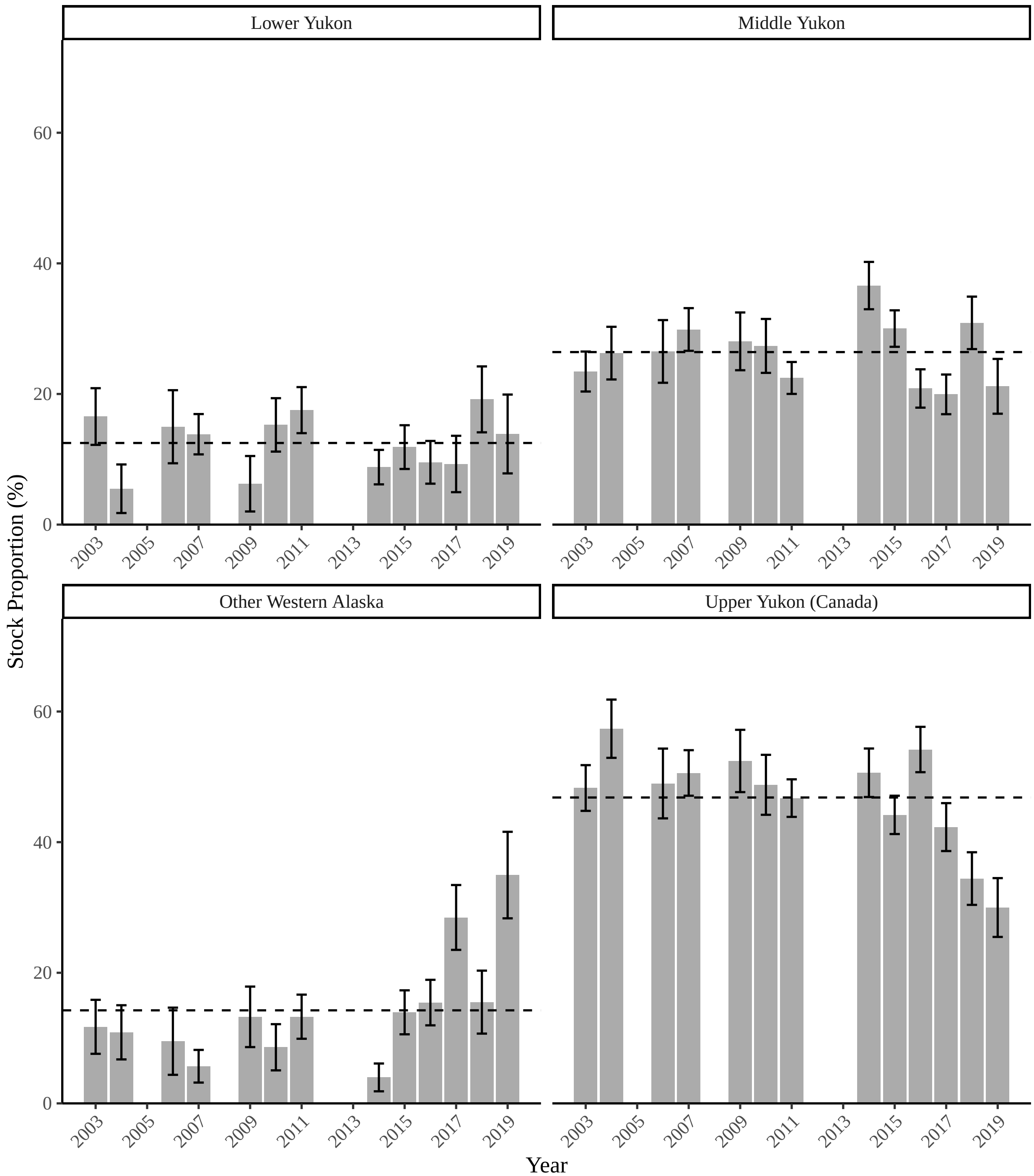

Figure 14: Genetic stock proportions of juvenile Chinook Salmon captured during the northern Bering Sea surface trawl surveys, 2003-2019. Average stock proportions (dashed line) are included for each stock group.

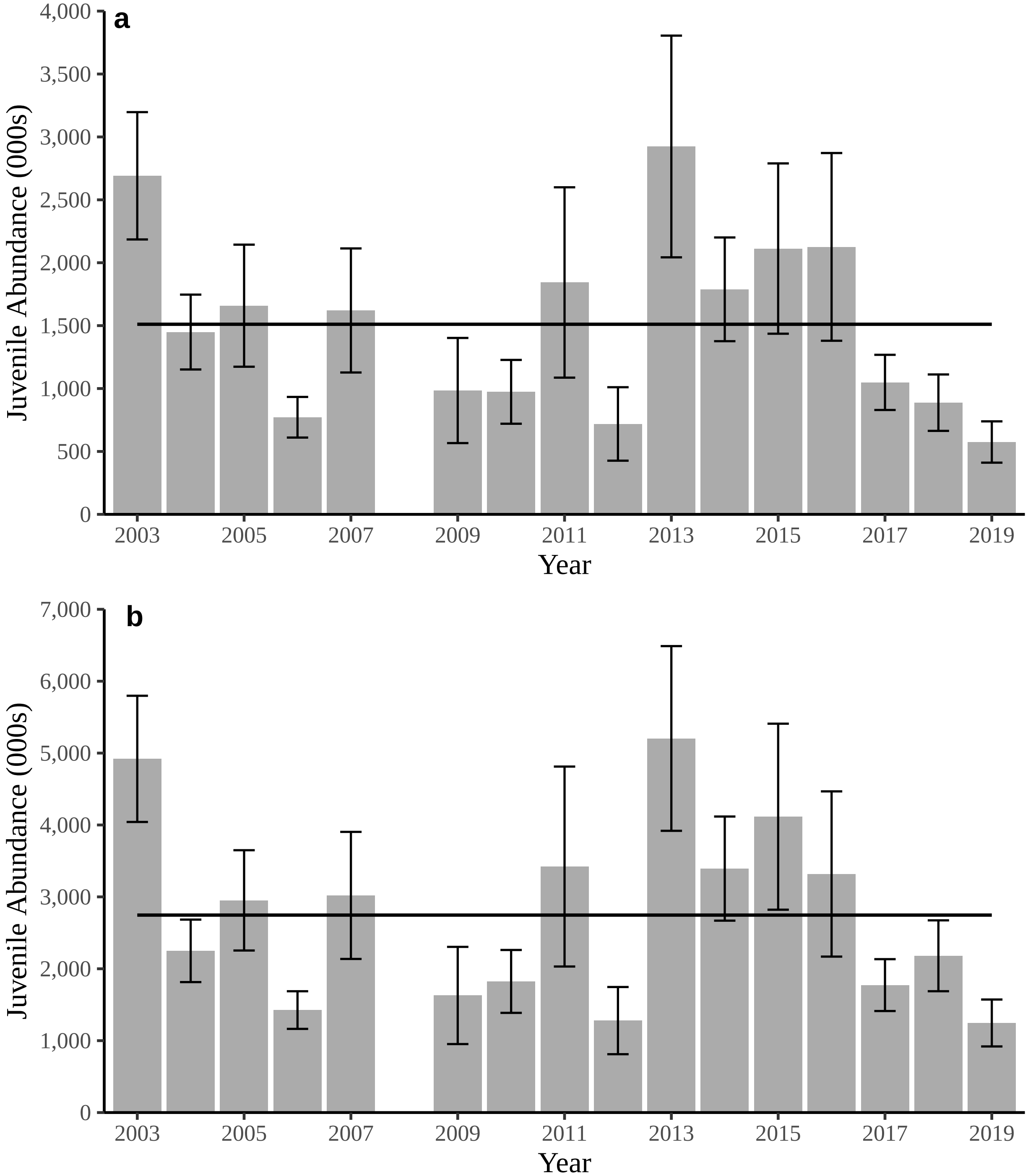

Figure 15: Stock-specific abundance estimates of Yukon River Canadian-origin (a) and Total Yukon (b) stock groups of Chinook Salmon during the northern Bering Sea surface trawl surveys, 2003-2019. Average abundance for each stock group (solid line) is included.

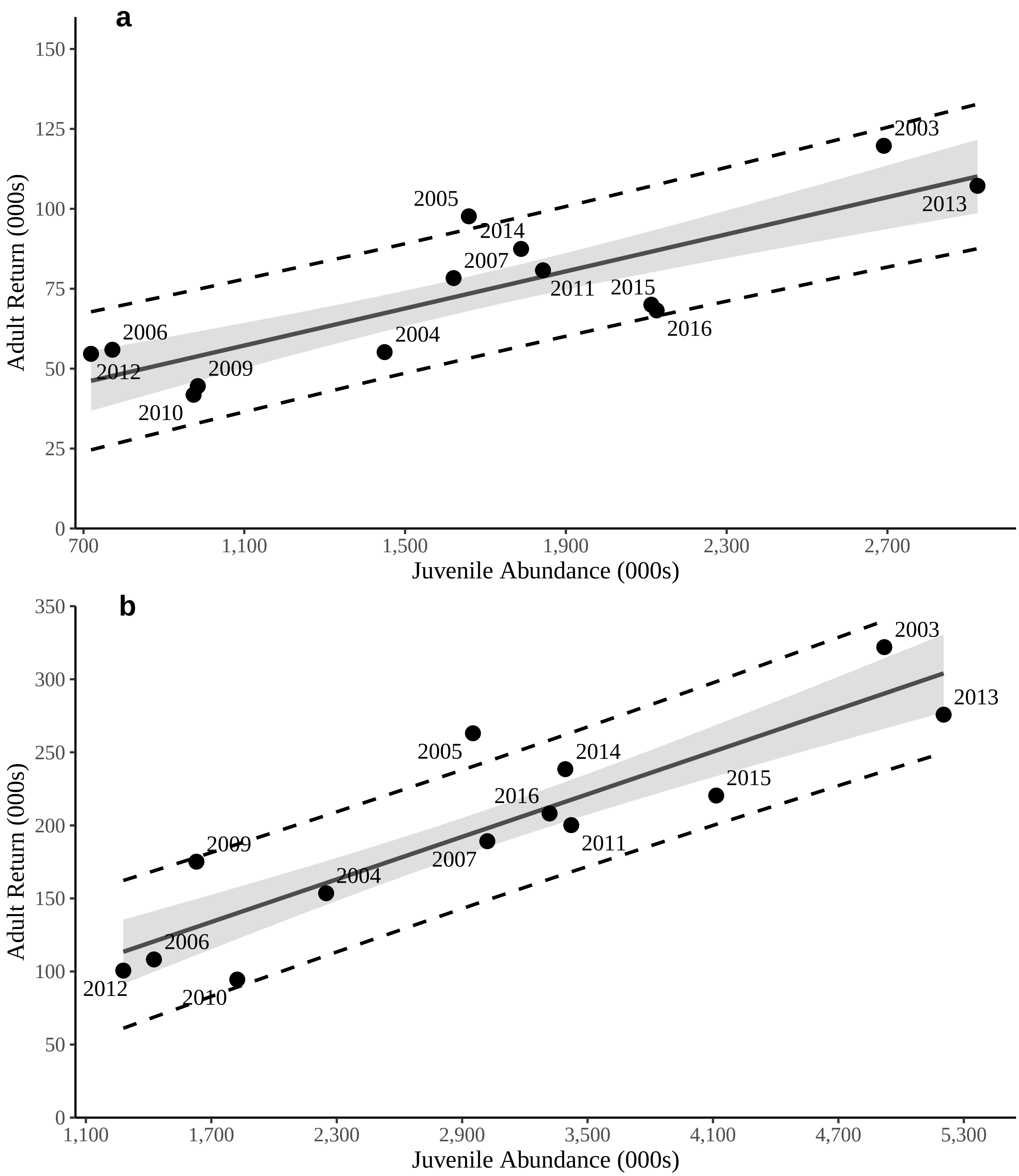

Figure 16: Relationships between juvenile abundance and resulting adult returns of Yukon River Canadian-origin (a) and Total Yukon (b) stock groups of Chinook Salmon, 2003-2016. The fitted relationship (solid line), 80% prediction interval (dashed lines), 80% confidence interval (shaded region), and survey years (labels) are included.

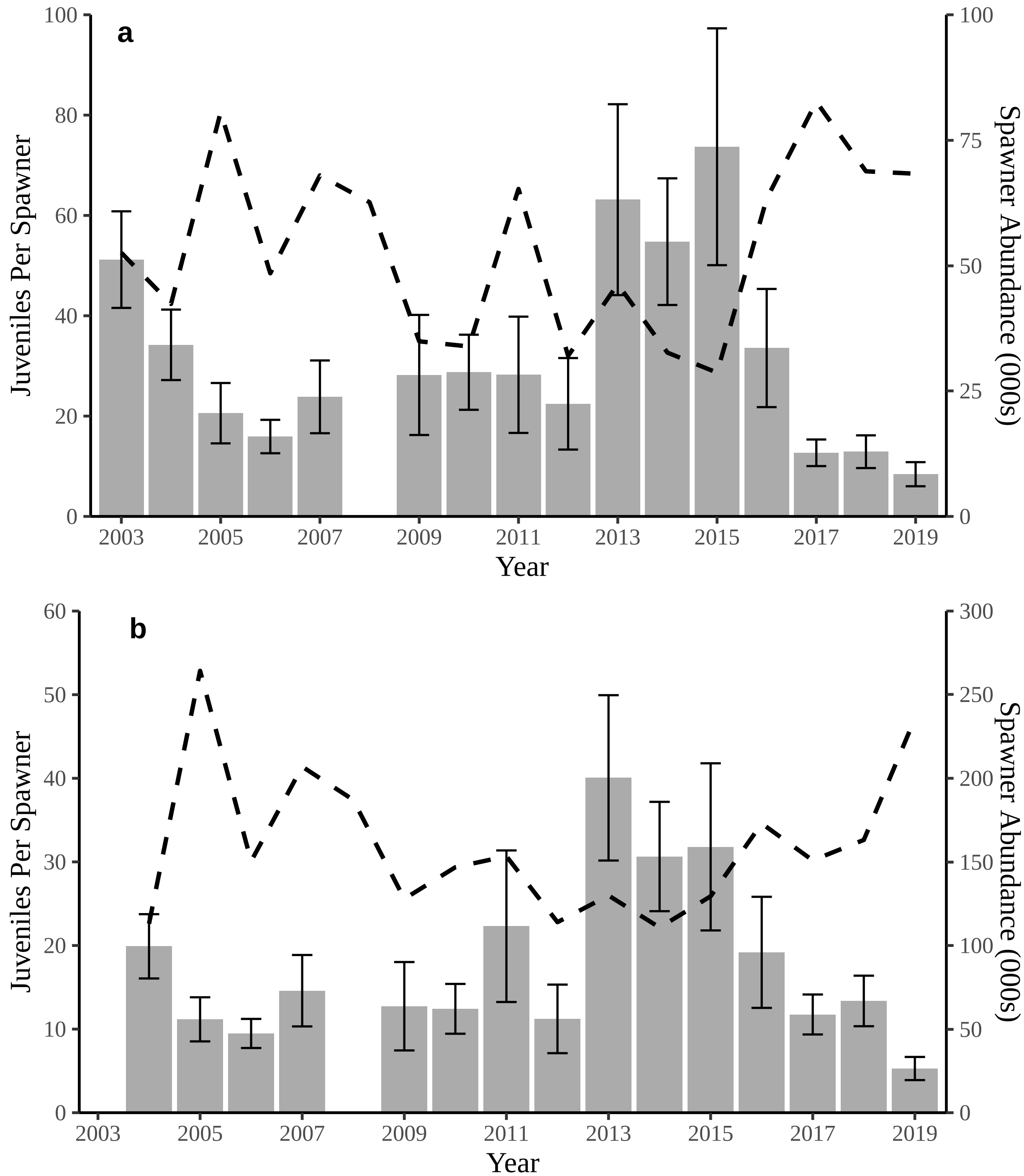

Figure 17: The number of juveniles-per-spawner (gray bars) and spawner abundance (dashed line) for the Yukon River Canadian-origin (a) and Total Yukon (b) stock groups of Chinook Salmon, 2003-2019.

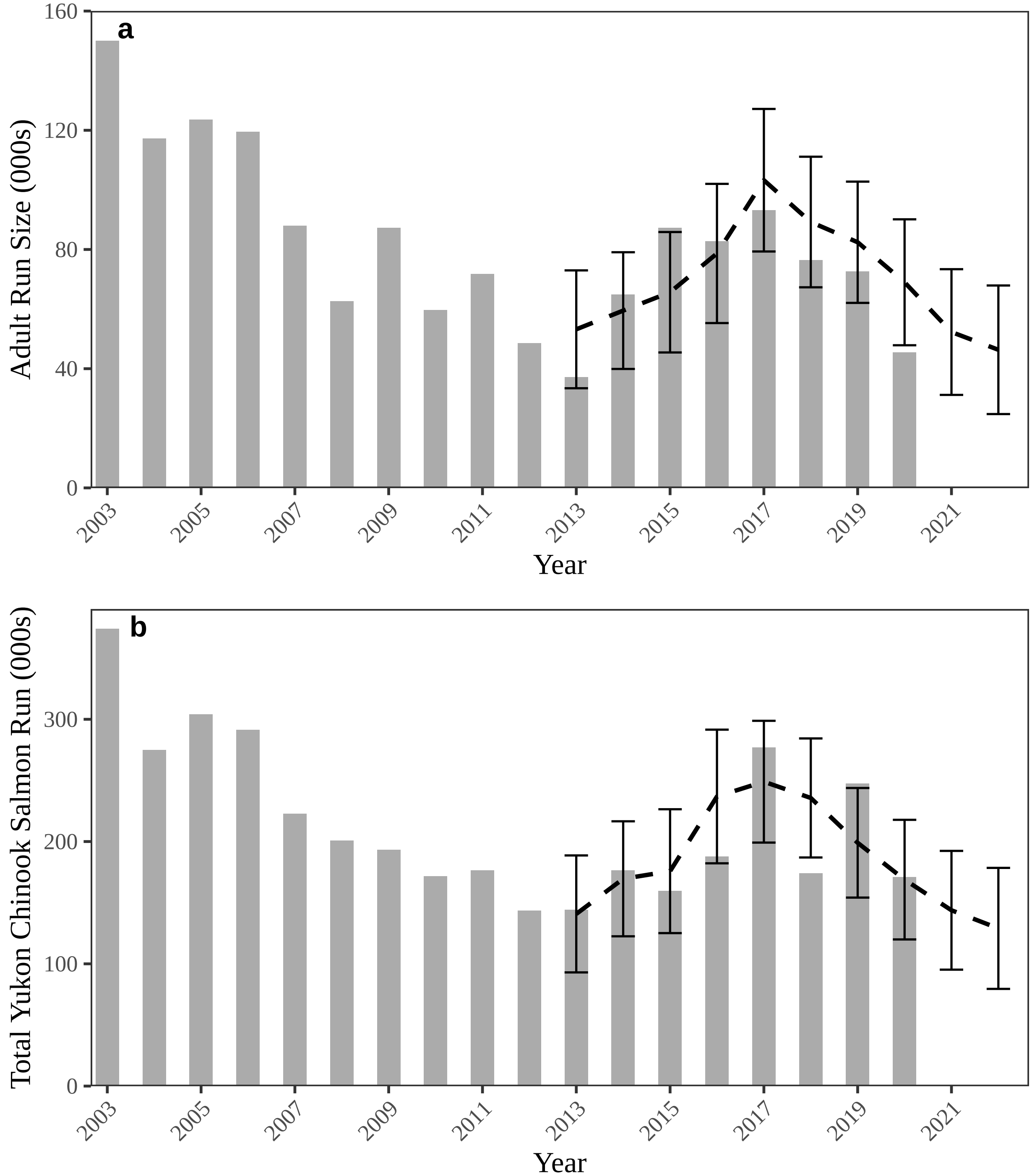

Figure 18: Observed (gray bars) and 80% predicted intervals of projected run sizes (black error bars) for the Yukon River Canadian-origin (a) and Total Yukon (b) stock groups of Chinook Salmon, 2003-2022.

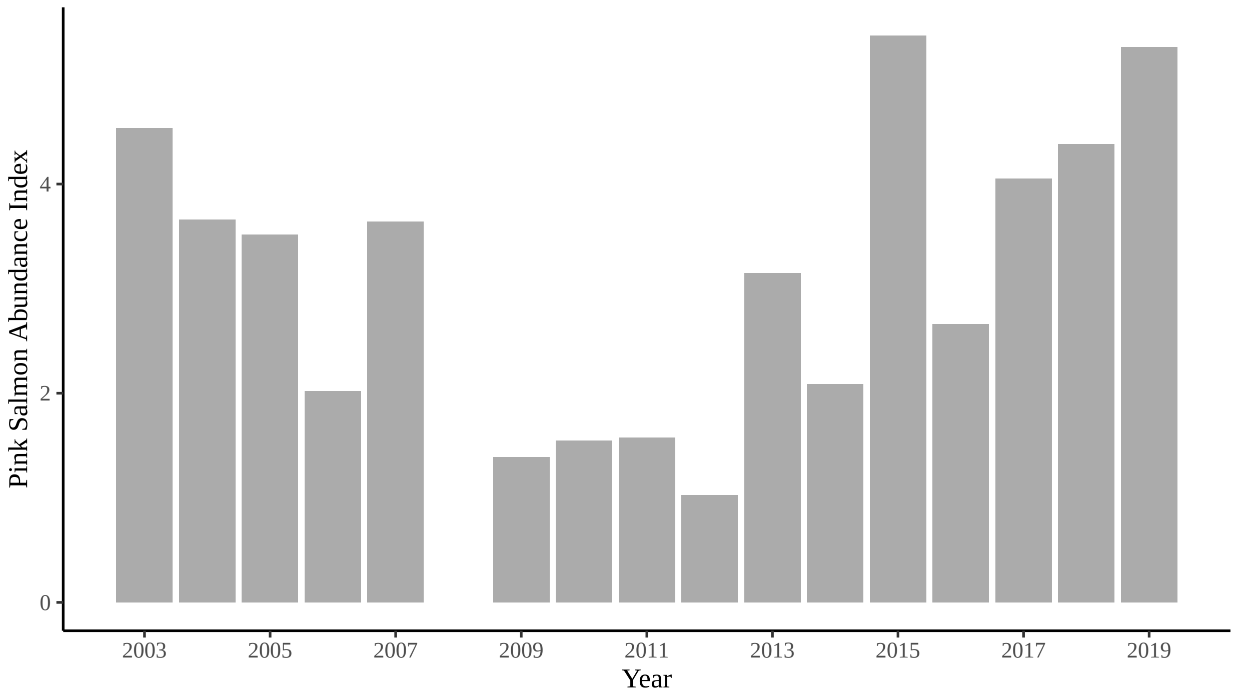

Figure 19: The juvenile Pink Salmon abundance index (Ln(CPUE)) estimated from the northern Bering Sea surface trawl surveys, 2003-2019.

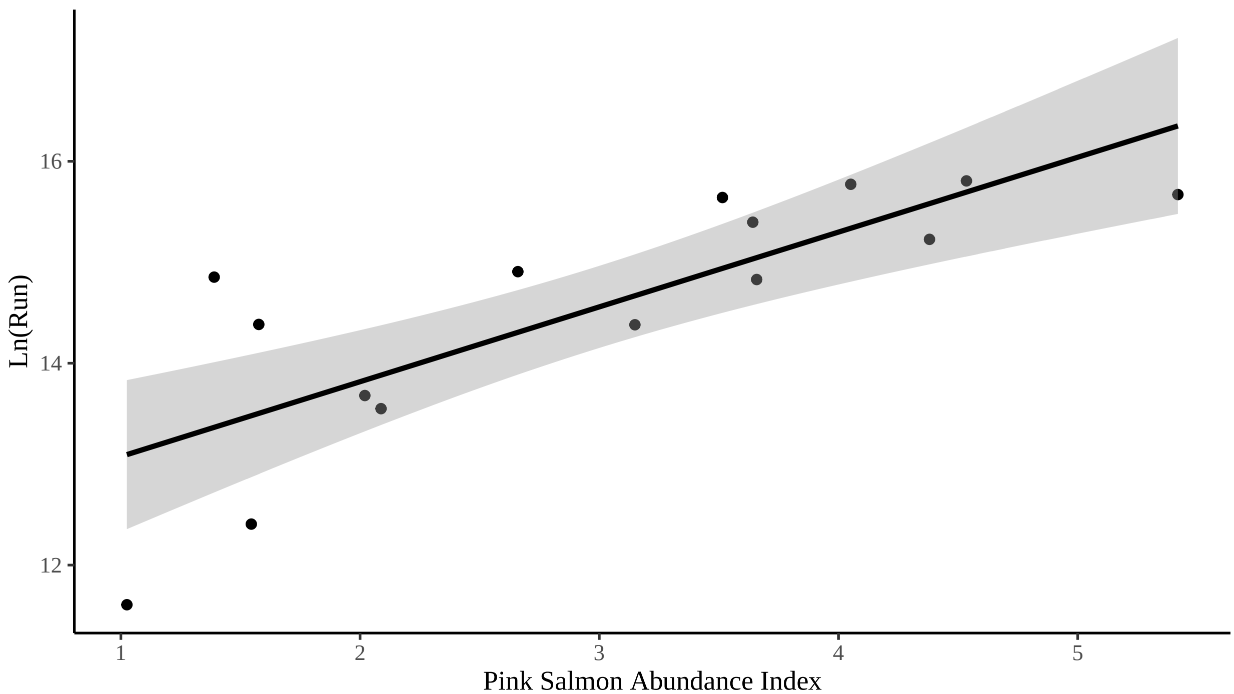

Figure 20: The relationship (black line) between the juvenile Pink Salmon abundance index from the northern Bering Sea surface trawl surveys (black dots; 2003-2018) and the natural log of the adult Pink Salmon run index (Yukon River and Norton Sound; 2004-2019).

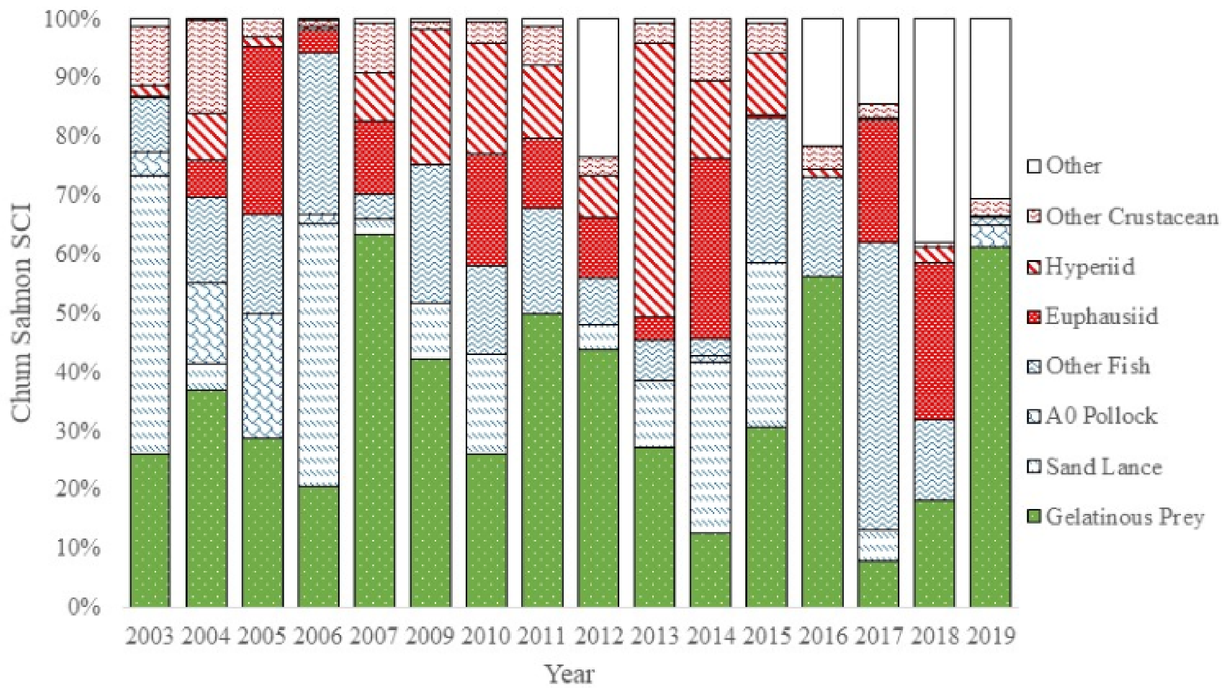

Figure 21: The percent of taxonomic prey groups by stomach content index in the stomachs of juvenile Chum Salmon sampled from the northern Bering Sea surface trawl surveys, 2003-2019. Blue categories represent fish, red are crustaceans, and green are gelatinous prey.

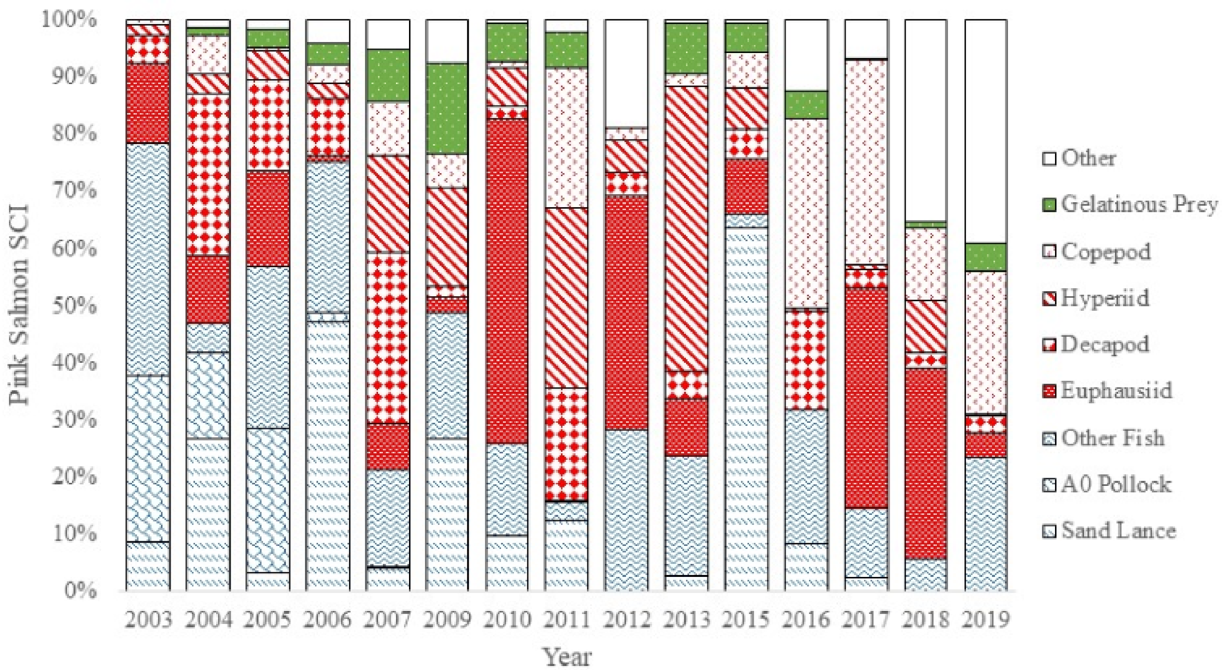

Figure 22: The percent of taxonomic prey groups by stomach content index in the stomachs of juvenile Pink Salmon sampled from the northern Bering Sea surface trawl surveys, 2003-2019. Blue categories represent fish, red are crustaceans, and green are gelatinous prey.

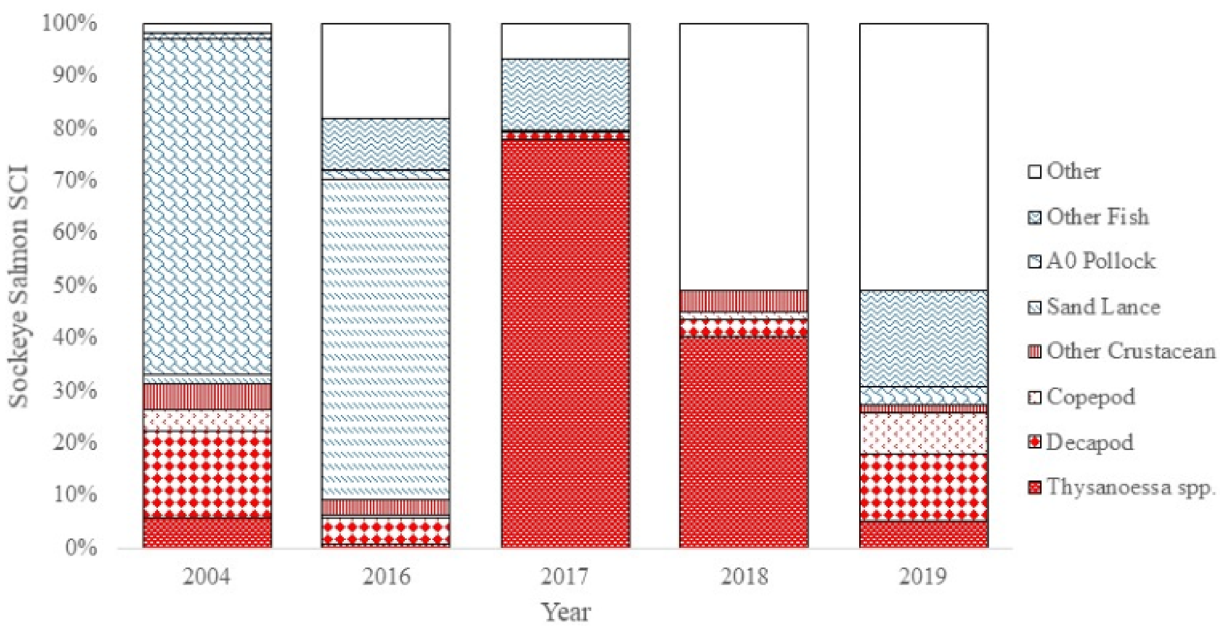

Figure 23: The percent of taxonomic prey groups by stomach content index in the stomachs of juvenile Sockeye Salmon sampled from the northern Bering Sea surface trawl surveys, 2003-2019. Blue categories represent fish, red are crustaceans.

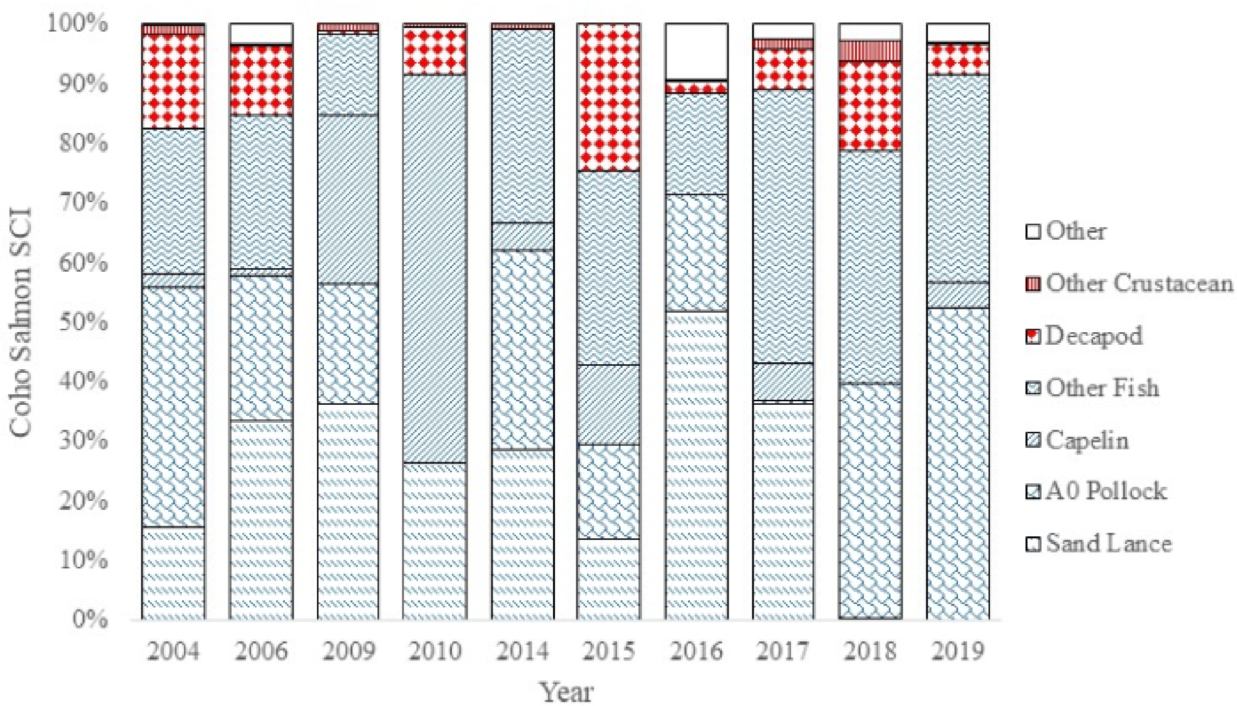

Figure 24: The percent of taxonomic prey groups by stomach content index in the stomachs of juvenile Coho Salmon sampled from the northern Bering Sea surface trawl surveys, 2004-2019. Blue categories represent fish, red are crustaceans.

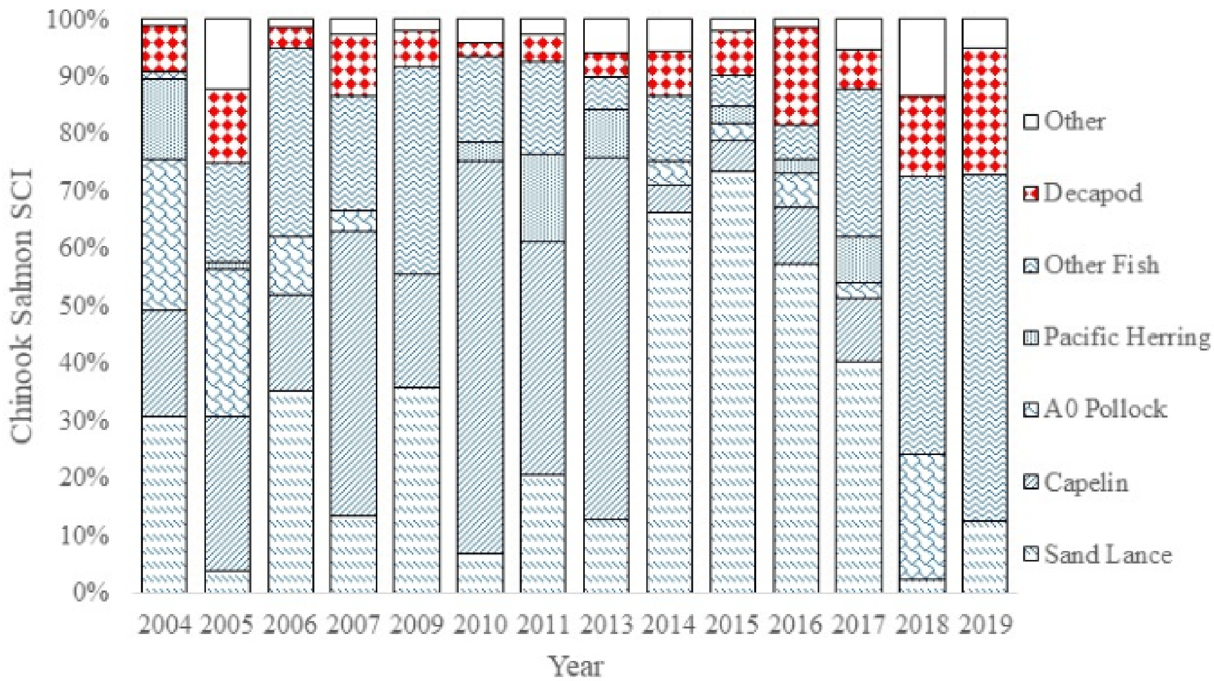

Figure 25: The percent of taxonomic prey groups by stomach content index in the stomachs of juvenile Chinook Salmon sampled from the northern Bering Sea surface trawl surveys, 2004-2019. Blue categories represent fish, red are crustaceans.

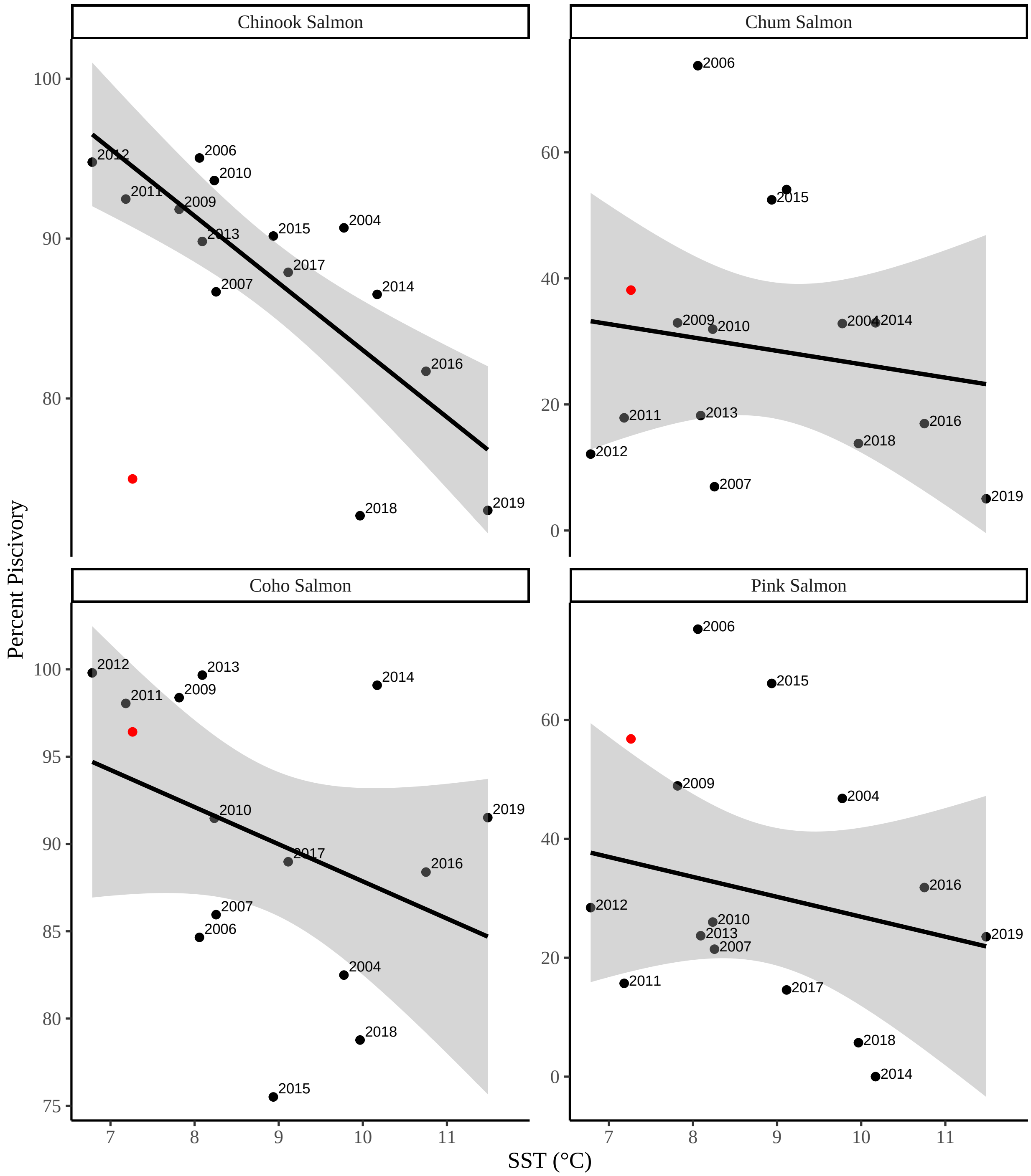

Figure 26: The relationship between the average percentage of fish in the stomachs of juvenile Chinook, Chum, Coho, and Pink Salmon sampled during the northern Bering Sea surface trawl surveys, 2004-2019, relative to sea surface temperature (SST). Survey year 2005 was an atypical survey year, is treated as an outlier in the time series, and was not included in the regression. The year 2005 is demarcated by a red dot and other years are represented by black dots.

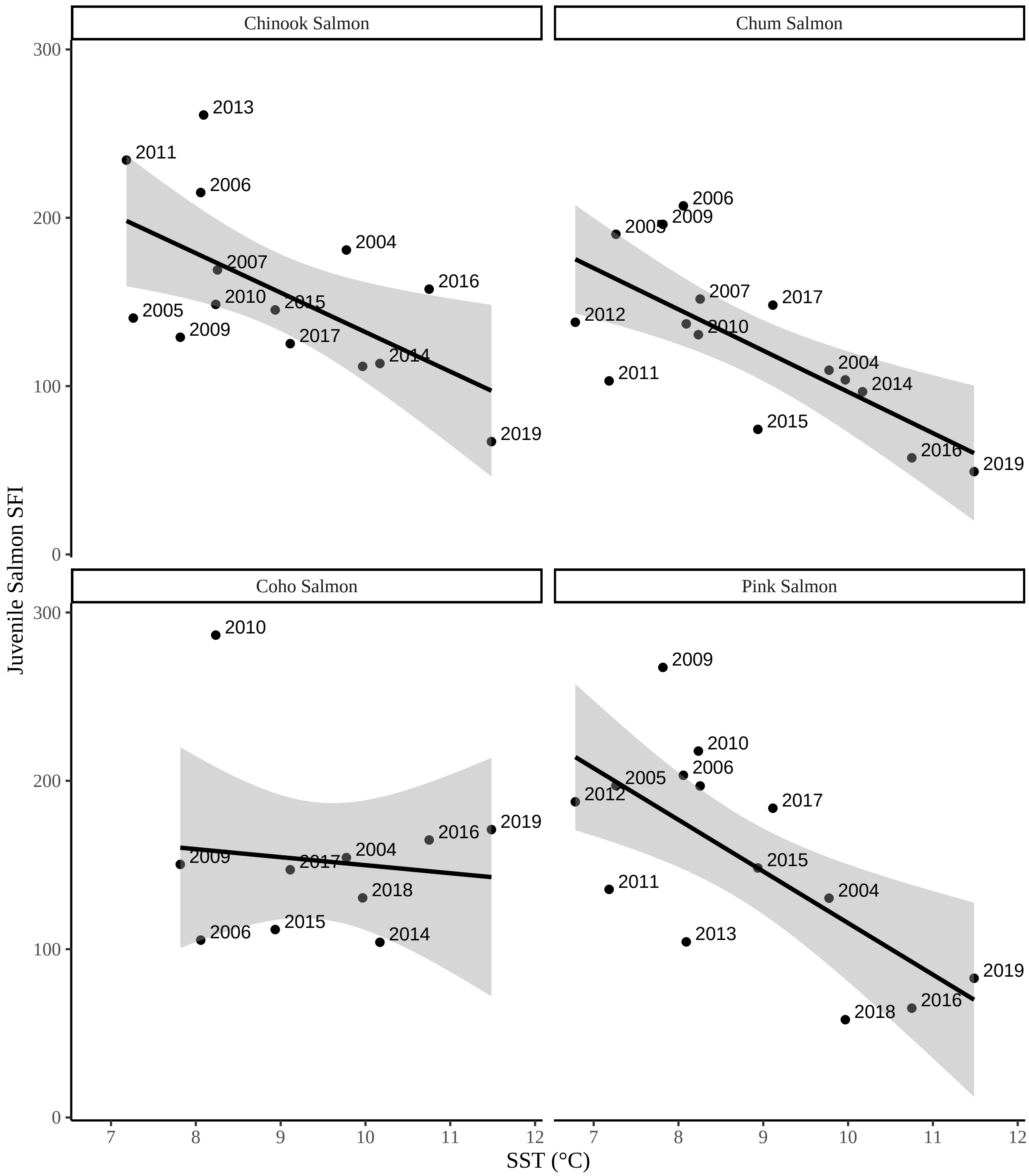

Figure 27: The relationship between the average stomach fullness index (SFI) of juvenile Chinook, Chum, Coho, and Pink Salmon and sea surface temperature (SST) sampled during the northern Bering Sea surface trawl surveys, 2004-2019.

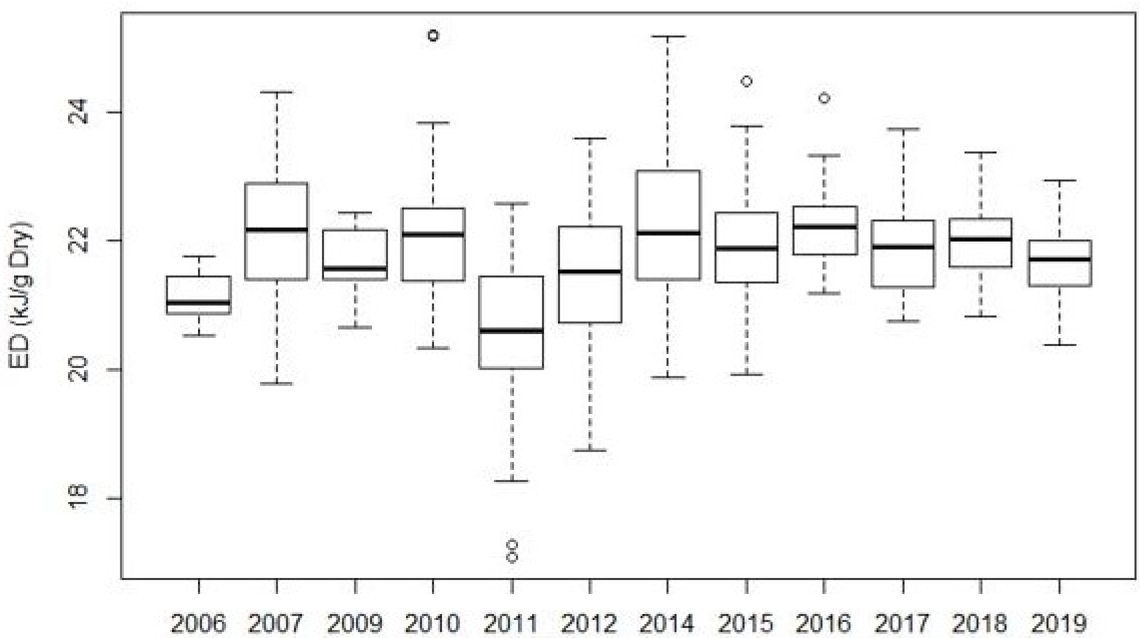

Figure 28: Boxplots of juvenile Chinook Salmon sampled for energy density (kJ/dry tissue mass, n=575) sampled during northern Bering Sea surface trawl surveys, 2006-2019. Data unavailable for 2008 and 2013. Medians, interquartile ranges (IQR), whiskers (1.5 IQR), and outliers (empty circles, >1.5 IQR) are shown.

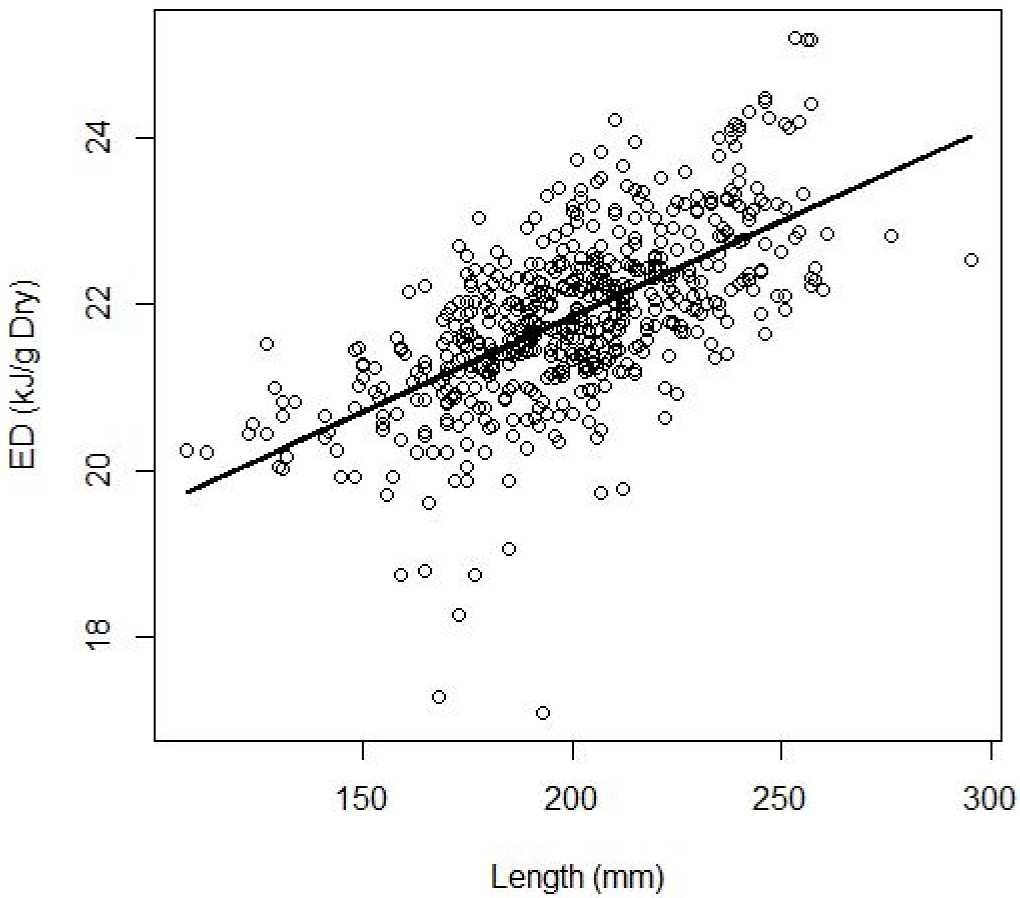

Figure 29: Energy density (kJ/g) of dry tissue mass by fork length (mm) of juvenile Chinook Salmon caught during the northern Bering Sea surface trawl surveys, 2006-2019. Simple linear regression model fit shown by line (n = 575).

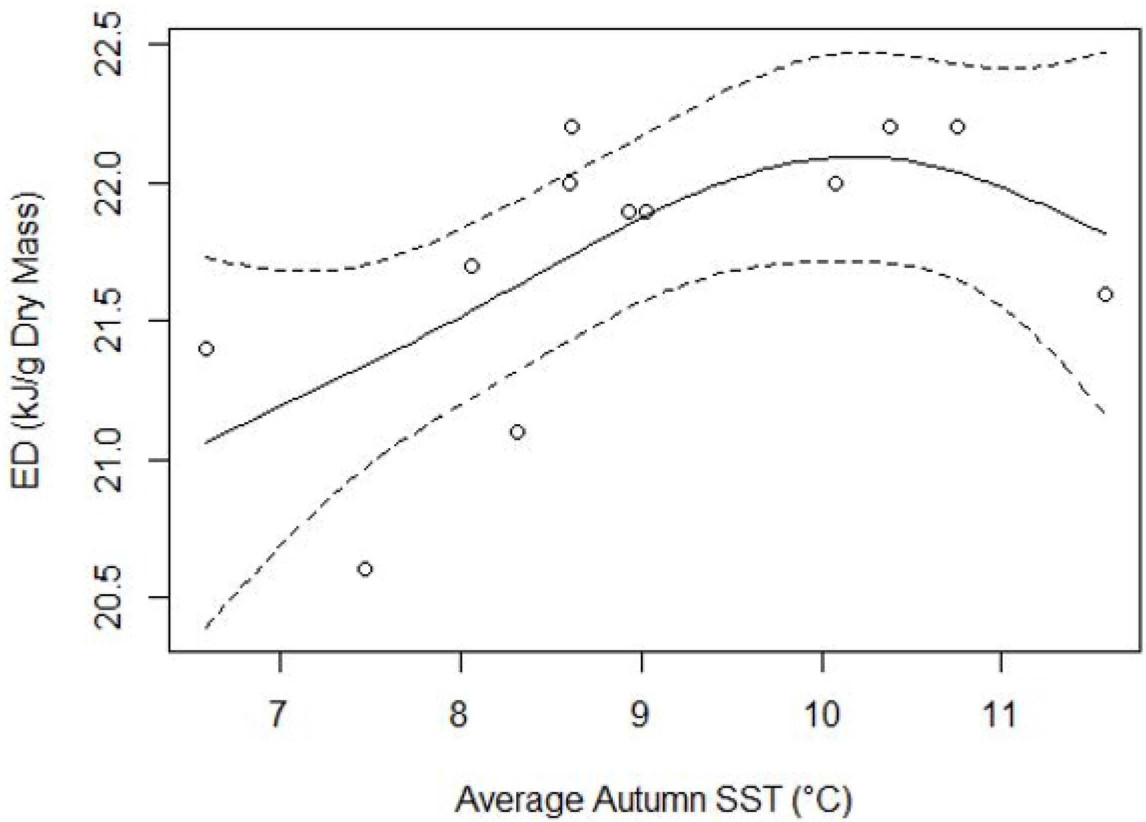

Figure 30: Annual mean energy density (kJ/g) of dry tissue mass by average autumn sea surface temperature (°C) for juvenile Chinook Salmon caught during the northern Bering Sea surface trawl surveys, 2006-2019. Generalized additive model fit shown by solid line, dashed lines represent ± 1 SE. Data unavailable for 2008 and 2013.

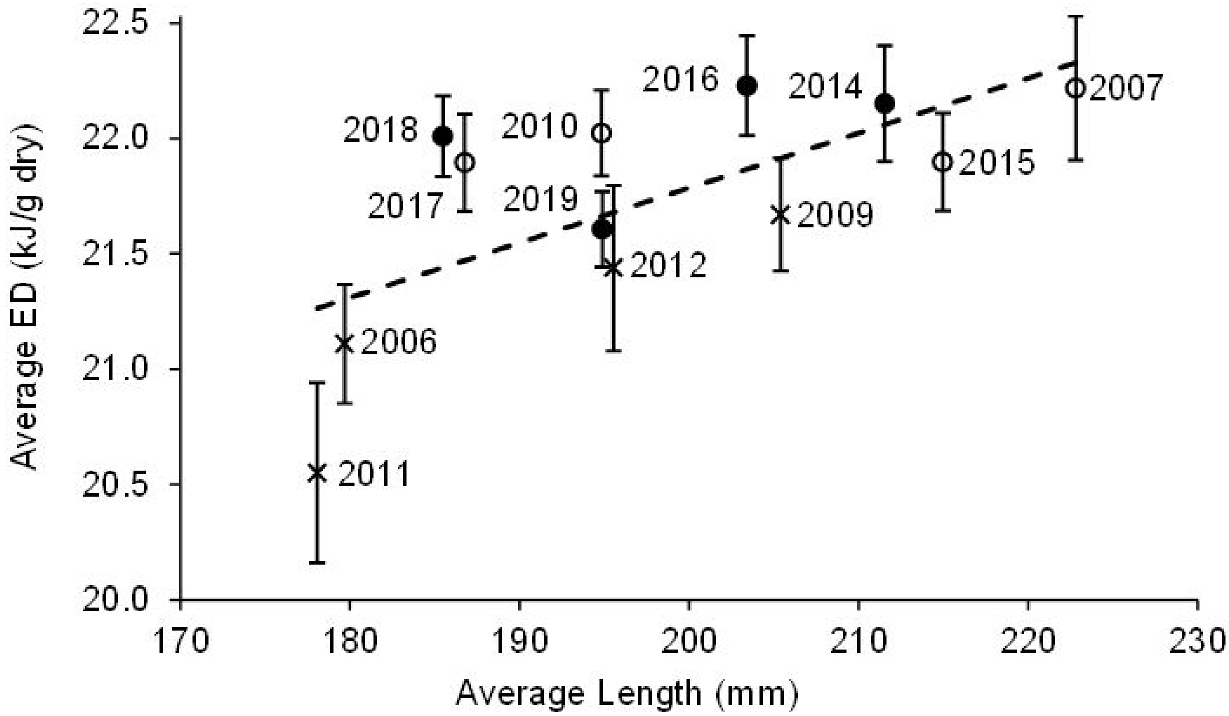

Figure 31: Annual mean energy density (kJ/g) of dry tissue mass by fork length (mm) of juvenile Chinook Salmon caught during the northern Bering Sea surface trawl surveys, 2006-2019. Simple linear regression model fit shown by dashed line (n = 12 years). Error bars represent 95% confidence intervals. Data unavailable for 2008 and 2013. Symbols indicate four warmest years (filled circles; autumn SST > 9.5°C), four coldest years (X; autumn SST < 8.5°C), and four intermediate years (empty circles).

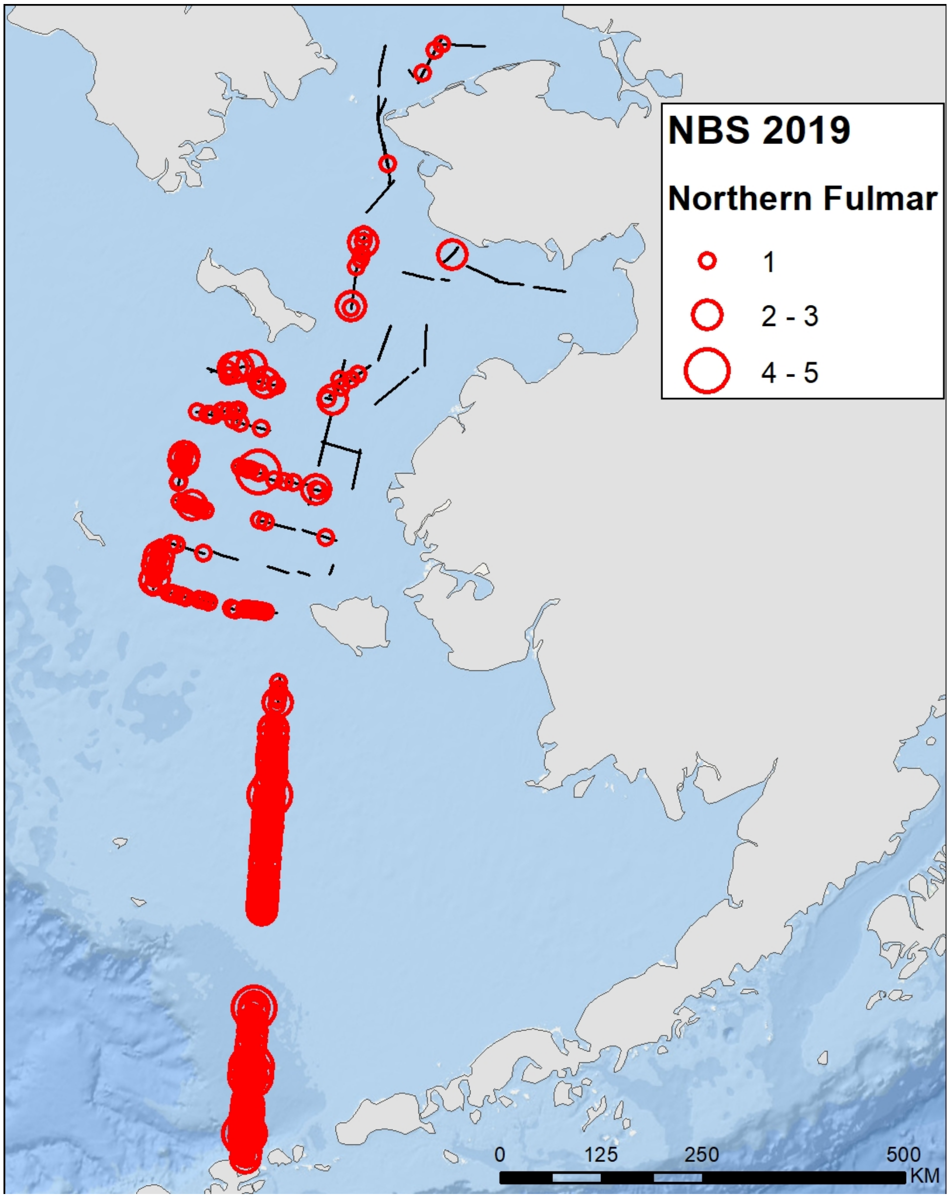

Figure 32: Distribution of Northern Fulmars observed during the northern Bering Sea surface trawl survey, 2019.

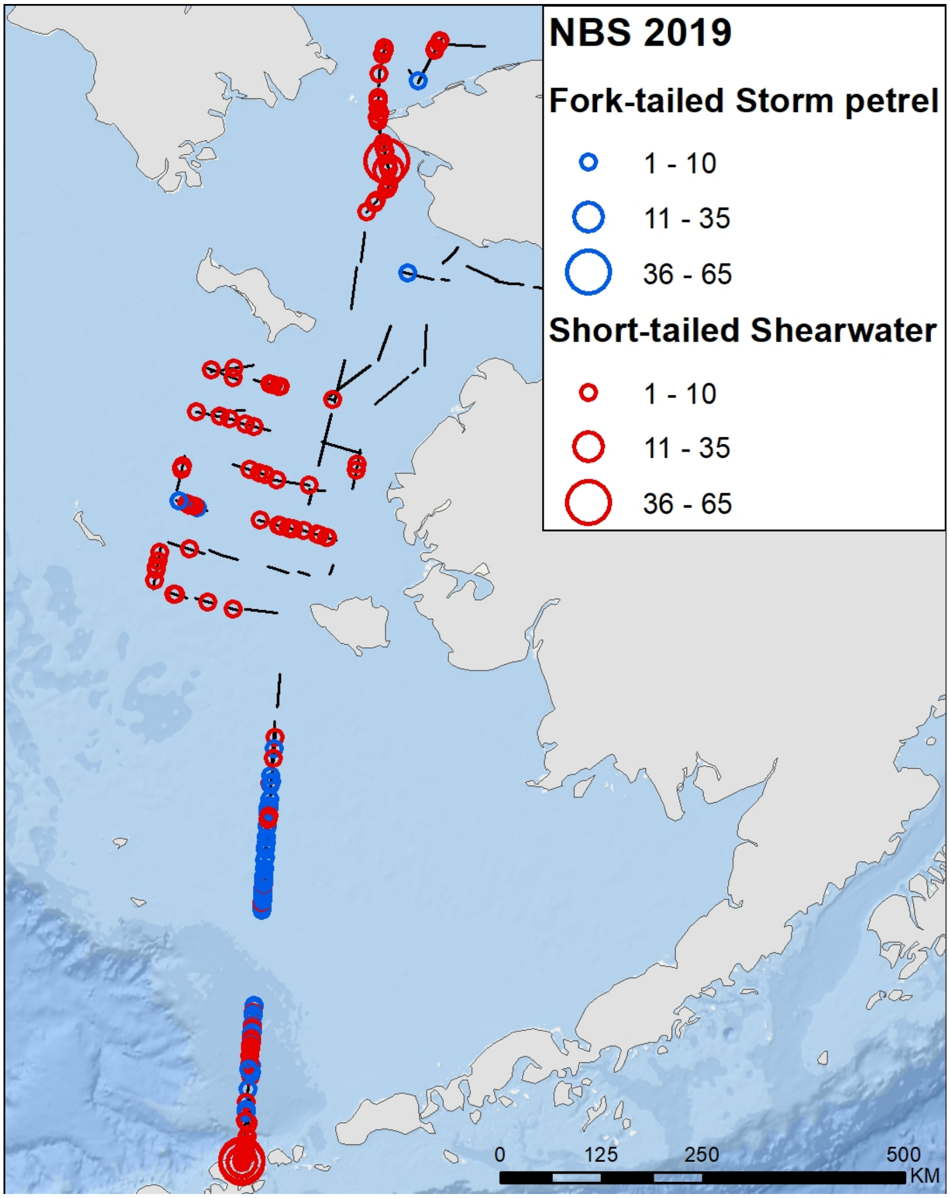

Figure 33: Distribution of shearwaters and Fork-tailed Storm-petrels during the northern Bering Sea surface trawl survey, 2019.

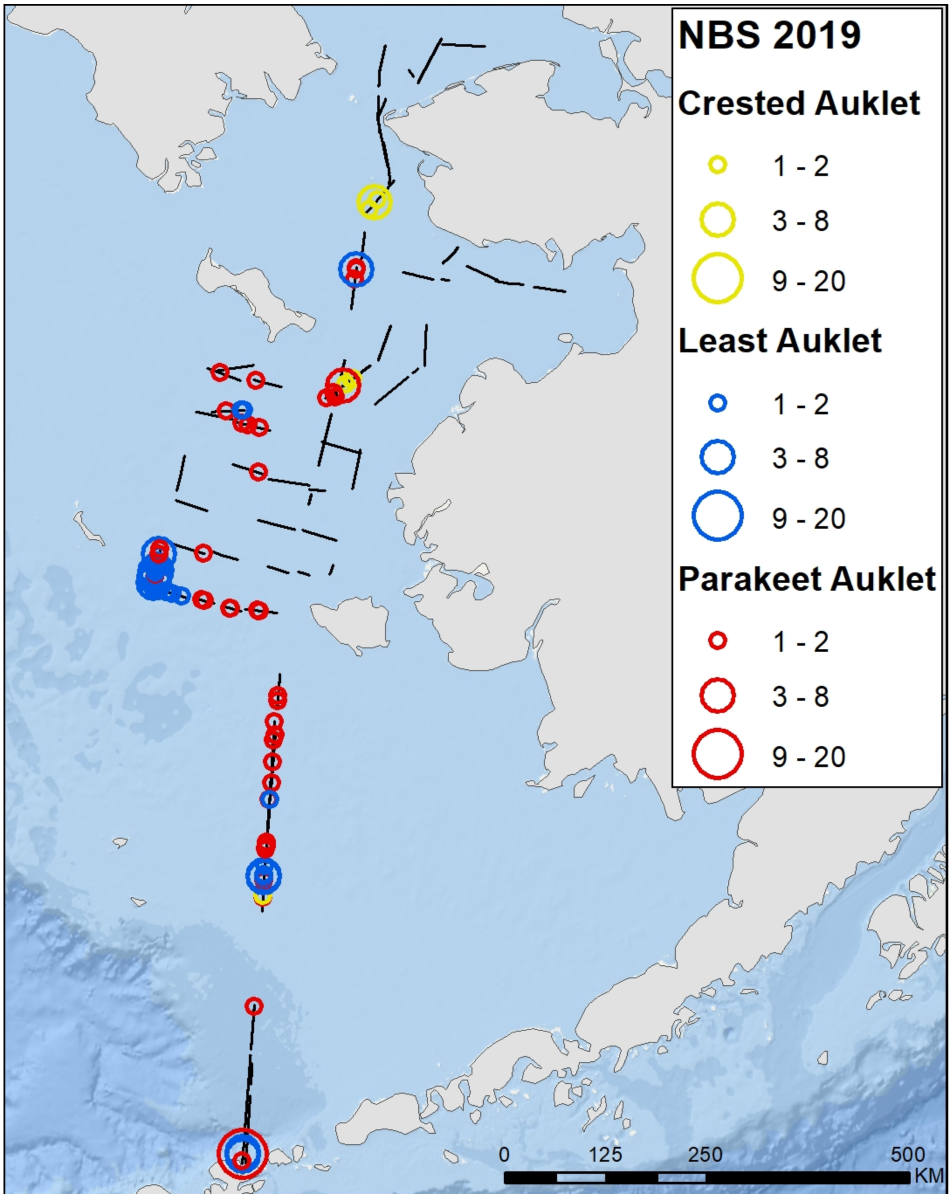

Figure 34: Distribution of auklet species during the northern Bering Sea surface trawl survey, 2019.

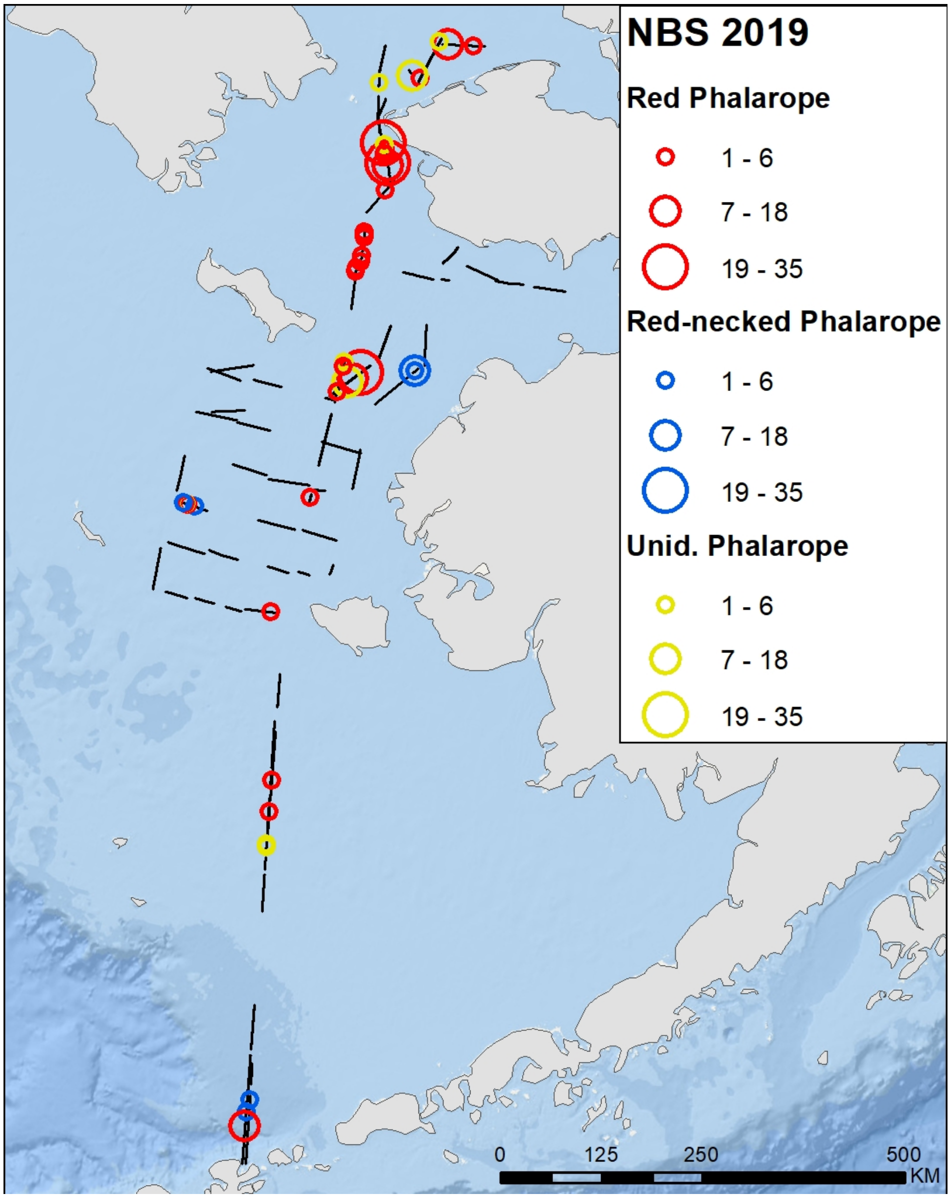

Figure 35: Distribution of phalarope species observed during the northern Bering Sea surface trawl survey, 2019.

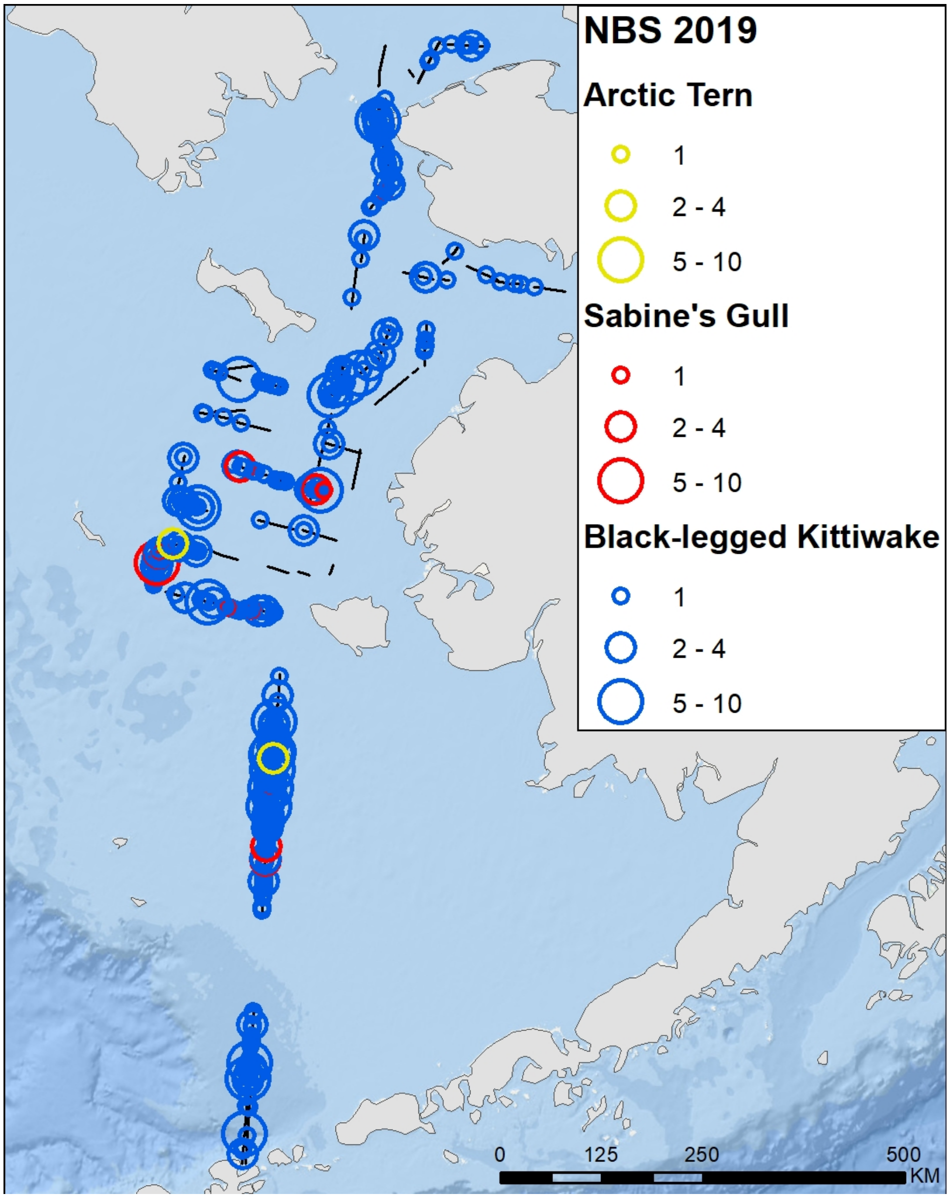

Figure 36: Distribution of Arctic Tern, Sabine's Gull, and Black-legged Kittiwakes observed during the northern Bering Sea surface trawl survey, 2019.

Appendicies

Appendix 1. Collection protocols during the northern Bering Sea surface trawl survey, 2019.

Water Collection Protocol

Depth	GFF	>10 Large Diameter	GFF and >10 Duplicates	Blanks	Nutrients	Salinity	Phyto preservation	Genomics samples (phyto)	HABs samples
	Every station	Every Station	1/day	Every other day	Every station	(1/day, alternate surface/deep)	Every station	Every Station	Every station
0	X				X	X (OR) ↓			X
10	X	X			X		X	X	
20	X				X				
30	X				X				
40	X (OR) ↓				X (OR) ↓				
50	X (OR) ↑								
60									
75									
100					X (OR) ↑	X (OR) ↑			

X (OR) ↑ (Sample either here or at shallower depth depending on criteria)

X (OR) ↓ (sample either here or at deepest depth available)

Figure A1.1: Water sample collection protocol broken down by depth and frequency.

Zooplankton Collection Protocol

MasterCod project Code (BF). Target Wire 45° Good range is 35° - 55°. Wire out 40 m/min and wire up 20 m/min. Target depth: 5-10m off bottom or 200m if water is deeper than 200m. Zooplankton Distribution and Abundance (ECO-FOCI) (20BON and 60BON). Preserve plankton from net 1 from the 20cm bongo (153 micron, 20BON) and 60cm (505 micron, 60BON) bongo jars with 50 ml of formaldehyde and sodium borate. Use 2 jars if a single jar is more than 1/2 full of plankton. Mark number of jars on label and COD forms. Freeze net 2 20BON for stable isotopes. Sort net 2 60BON for Rapid Zooplankton Assessment (RZA).

Zooplankton Lipids (Miller) (60BON-RZA samples)

Collect at least 3 large Calanus copepods and 2 adult euphausiids per event, more is better. Take photo and annotate in the lipid logbook. Use a kimwipe to wick the samples dry. Place each group of zooplankton in separate glass vials. Store in coldest available freezer

Zooplankton stable isotopes (Miller) (20BON & 60BON-RZA samples)

Collect adult euphausiids from 60BON-RZA samples and collect bulk zooplankton from net 2 20BON samples from 5-10 stations. Collect from the first 5 stations observing euphausiids, then spread the other 5 collections to other stations. Store in coldest available freezer

Salmon Collection Protocol

Juveniles (0-320 mm) Take lengths and weights of 50 of each species and life-history stage at each station. Note any fin clips, scarring, parasites, or skeletal deformities. Photograph unusual features with notation in CLAMS. Collect specimens from pink salmon (Oncorhynchus gorbuscha), chum salmon (O. keta), sockeye salmon (O nerka), coho salmon (O. kisutch), and Chinook salmon (O. tshawytscha). Scan Chinook salmon for adipose fin clips and CWT. Use pre-assigned barcode numbers for Chinook salmon (1-600), Coho salmon (601-900), and Sockeye salmon (901-1200).

Salmon Genetics

Juvenile Chinook, coho, and sockeye salmon, and immature Chinook salmon (Garcia/Dann/Habicht/Liller): Remove a caudal fin clips from juveniles and pectoral fin clips from immature salmon and staple onto separate Whatman paper sheets for each species and station. Place Whatman sheets in a desiccant container to dry. Record barcode number range for the specimens collected on each Whatman sheet.

Juvenile chum salmon (Kondzela) and juvenile pink salmon (Garcia/Dann/Habicht/Liller)

Collect and freeze caudal fin clips from measured juveniles not saved whole for energetics, wrap fin clips in plastic wrap, bag by station, and freeze at -40. Collect additional fin clips if time permits.

Immature chum salmon (Kondzela)

Remove pectoral fin clips from immature chum, wrap in plastic wrap, bag by station, and freeze at -40.

Salmon Diets ((Cieciel)

Collect up to 10 stomachs by species and life-history stage at each station. Place stomachs in a soil bag, label with station number and species. Preserve in 5-gallon bucket of 10% formalin. Flag Stomach in CLAMS.

Juvenile Salmon Otoliths (Murphy)

Save whole or heads of Chinook, Sockeye, and Coho salmon. Wrap heads in plastic wrap with barcode tag, freeze at -20, and flag Head collection in CLAMS. Juvenile Salmon Energetics (Sewall) Wrap 2-5 average sized whole fish in plastic wrap with barcodes and freeze at each station. Flag whole fish in CLAMS. Stomachs will be removed from frozen whole fish and provided to Cieciel, otoliths will be removed from frozen whole fish and provided to Murphy.

Non-Salmon Collection Protocol

Collect length or lengths and weights of up to 50 individuals per pre-assigned life-history stages at each station. Collect specimens from Saffron Cod (Eleginus gracilis), Pacific Cod (Gadus macrocephalus), Walleye Pollock (Theragra chalcogramma), Pacific Herring (Clupea pallasii), Arctic Cod (Boreogadus saida), Capelin (Mallotus villosus), Arctic Sand lance (Ammodytes hexapterus), Rainbow smelt (Osmerus mordax), and Arctic Lamprey (Lethenteron camtschaticum), and Salmon Shark (Lamna ditropis). Do not collect individual weights for fish (e.g. age-0) that are too small to accurately measure individual weights. Average weight for these fish will be based on the subsample weight. Freeze all unidentified and rare species with station or barcode data for species verification.

Diets (Cieciel)

Save 10 whole age-0 fish in formalin (soil bag), flag diet in CLAMS for: Saffron Cod, Pacific Cod, Walleye Pollock, and Pacific Herring. Save 10 whole age 1+ fish or stomachs in formalin in a single soil bag, flag diet in CLAMS for: Pacific Cod, Walleye Pollock, Arctic Cod, Capelin, Arctic Sand Lance, and Rainbow Smelt.

Energetics (Sewall)

Collect 3-5 age-0 fish and freeze with barcode, flag nutrition in CLAMS for: Saffron Cod, Pacific Cod, Walleye Pollock, and Pacific Herring. Collect 3-5 age-1+ fish and freeze with barcode, flag nutrition in CLAMS for: Arctic Cod. Capelin, and Arctic Sand Lance.

HABs (Lefebvre)

Collect and freeze whole 4 fish at each station for the following species: Saffron Cod, Pacific Cod, Walleye Pollock, Pacific Herring, and Capelin.

Arctic Lamprey (Sutton)

Freeze all specimens individually with barcode tags.

Salmon Shark (Garcia)

Record length, sex, and collect muscle biopsy plug and fin clp for genetic analysis. Tag salmon shark with dorsal fin mounted geolocation data tag and pop-up geolocation tags anchored to muscle tissue following protocols for each type of tag. Murphy/Sewall coordinates tagging on leg 1, Garcia coordinates tagging during on Leg 2.

Appendix 2. Surface trawl catch rates (CPUE) of key species in the northern Bering Sea surface trawl survey, 2019.

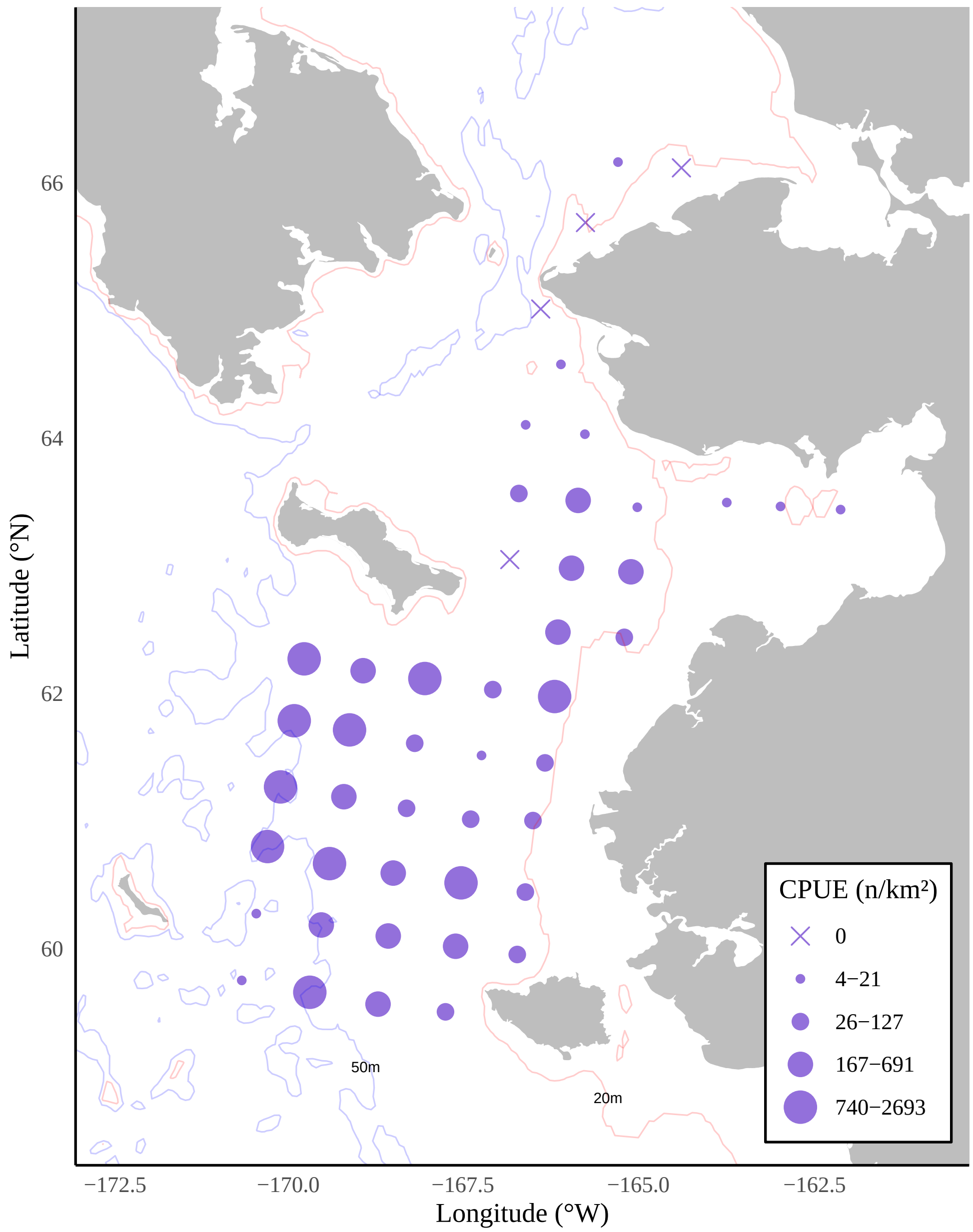

Figure A2.1: Surface trawl catch rates of juvenile Chum salmon (CPUE, n/km²) during the northern Bering Sea surface trawl survey, 2019.

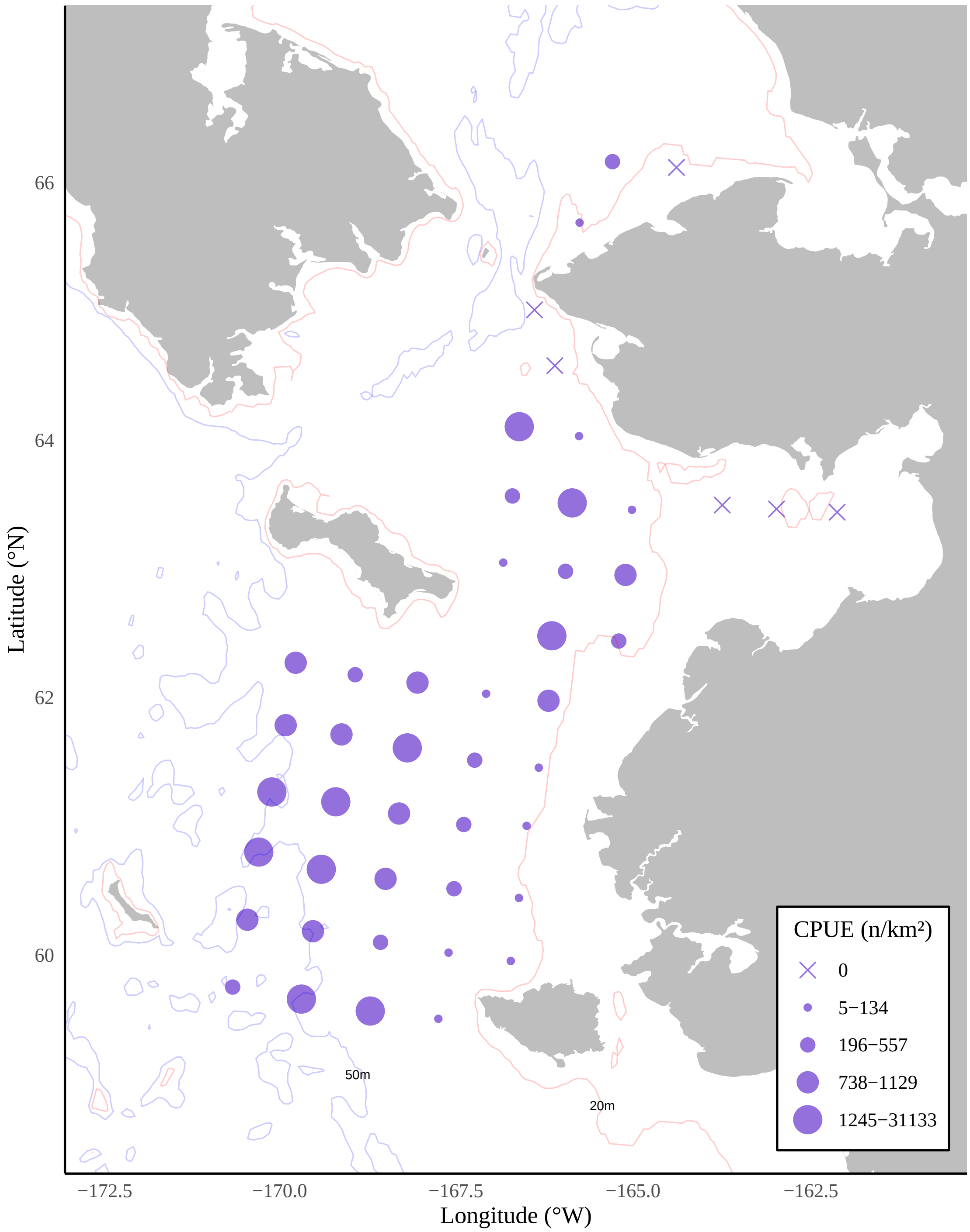

Figure A2.2: Surface trawl catch rates of juvenile Pink salmon (CPUE, n/km²) during the northern Bering Sea surface trawl survey, 2019.

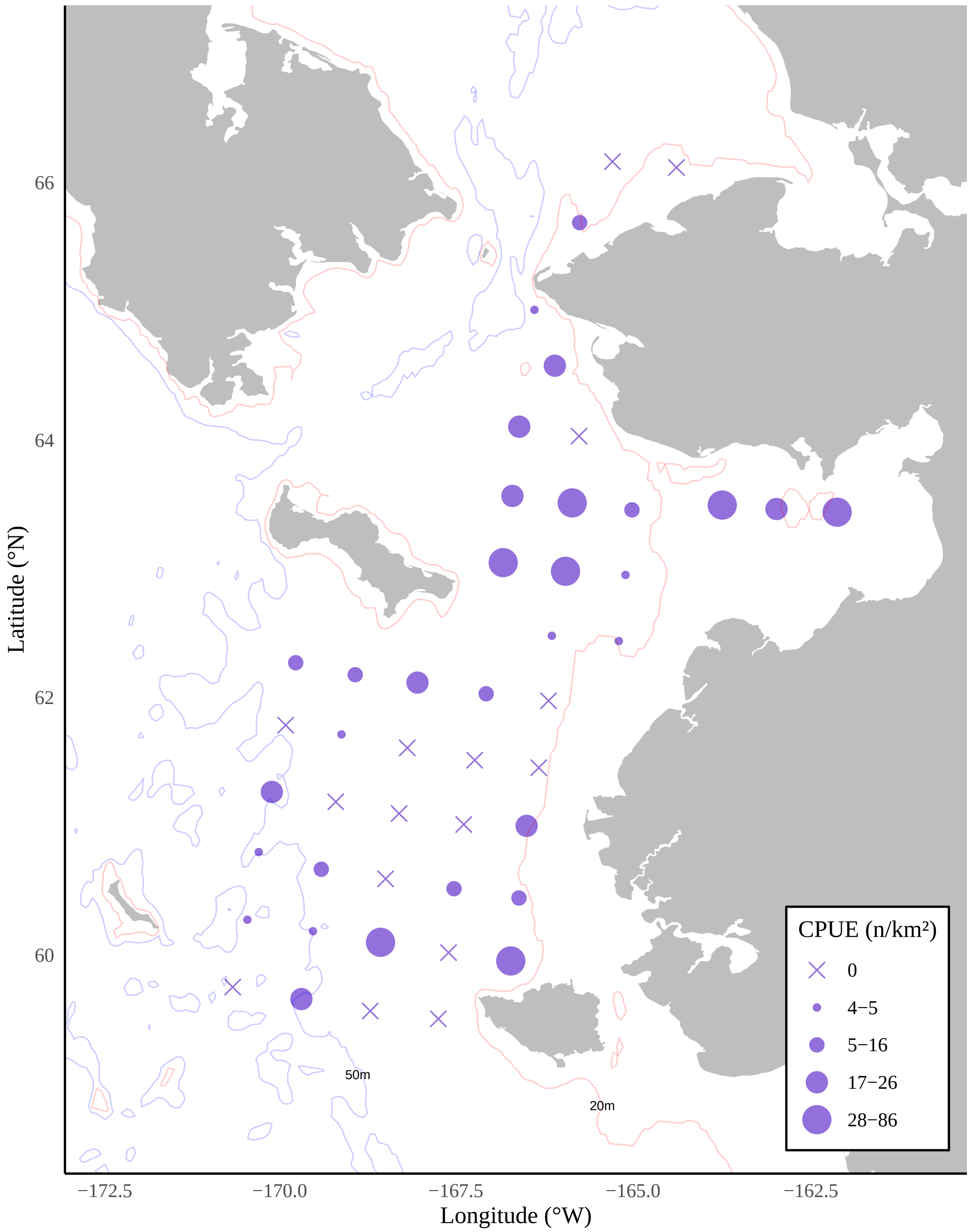

Figure A2.3: Surface trawl catch rates of juvenile Chinook salmon (CPUE, n/km²) during the northern Bering Sea surface trawl survey, 2019.

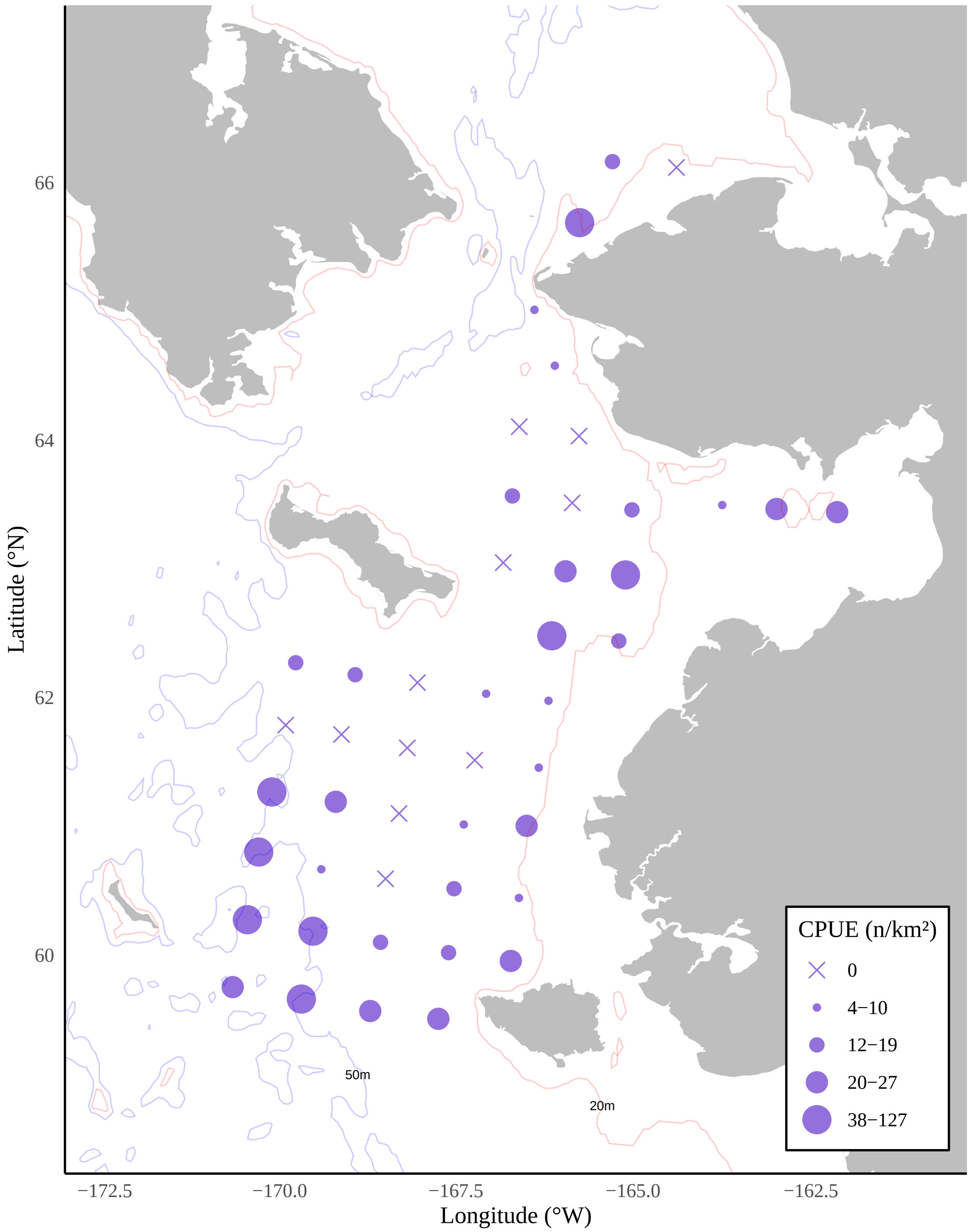

Figure A2.4: Surface trawl catch rates of juvenile Coho salmon (CPUE, n/km²) during the northern Bering Sea surface trawl survey, 2019.

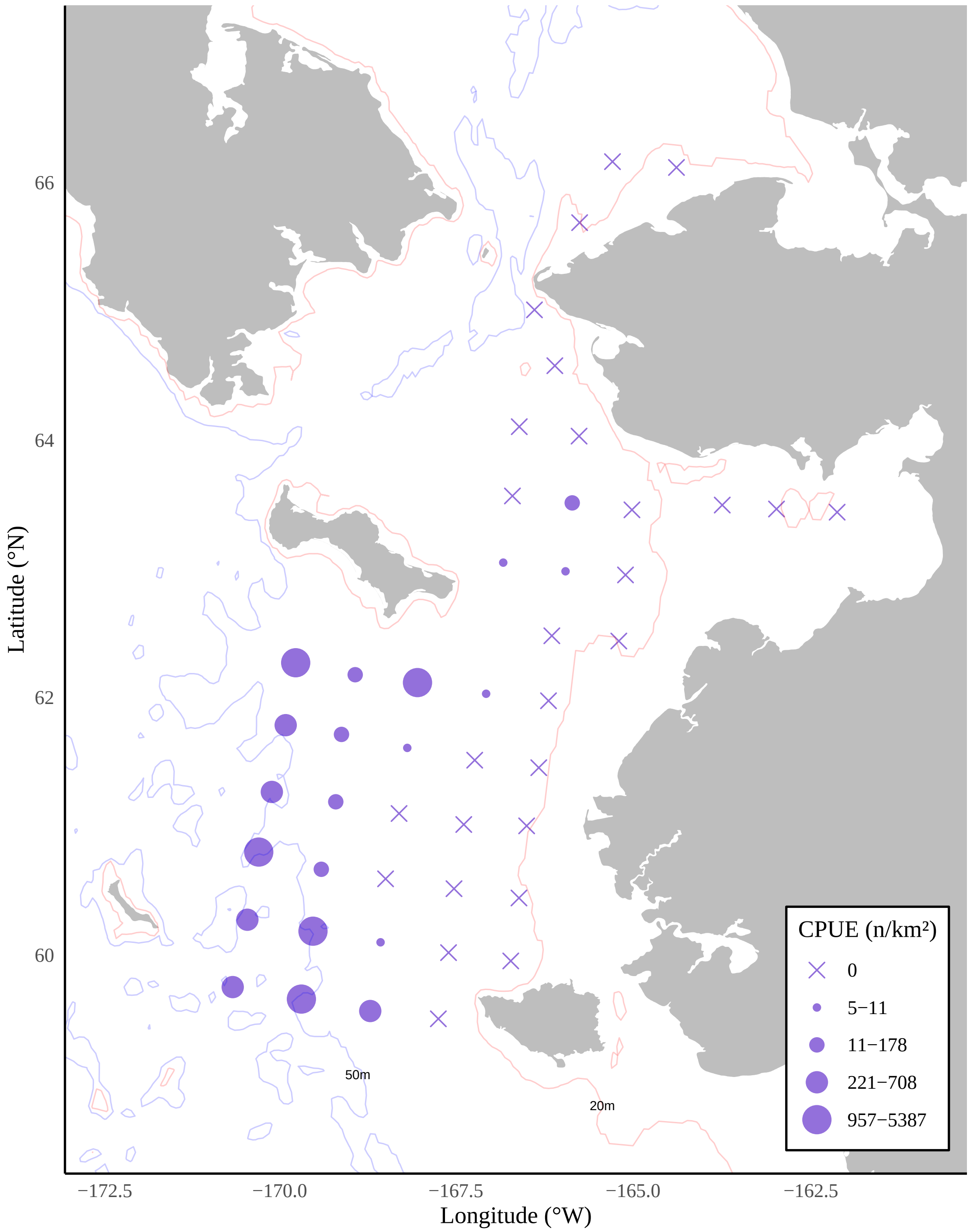

Figure A2.5: Surface trawl catch rates of juvenile Sockeye salmon (CPUE, n/km²) during the northern Bering Sea surface trawl survey, 2019.

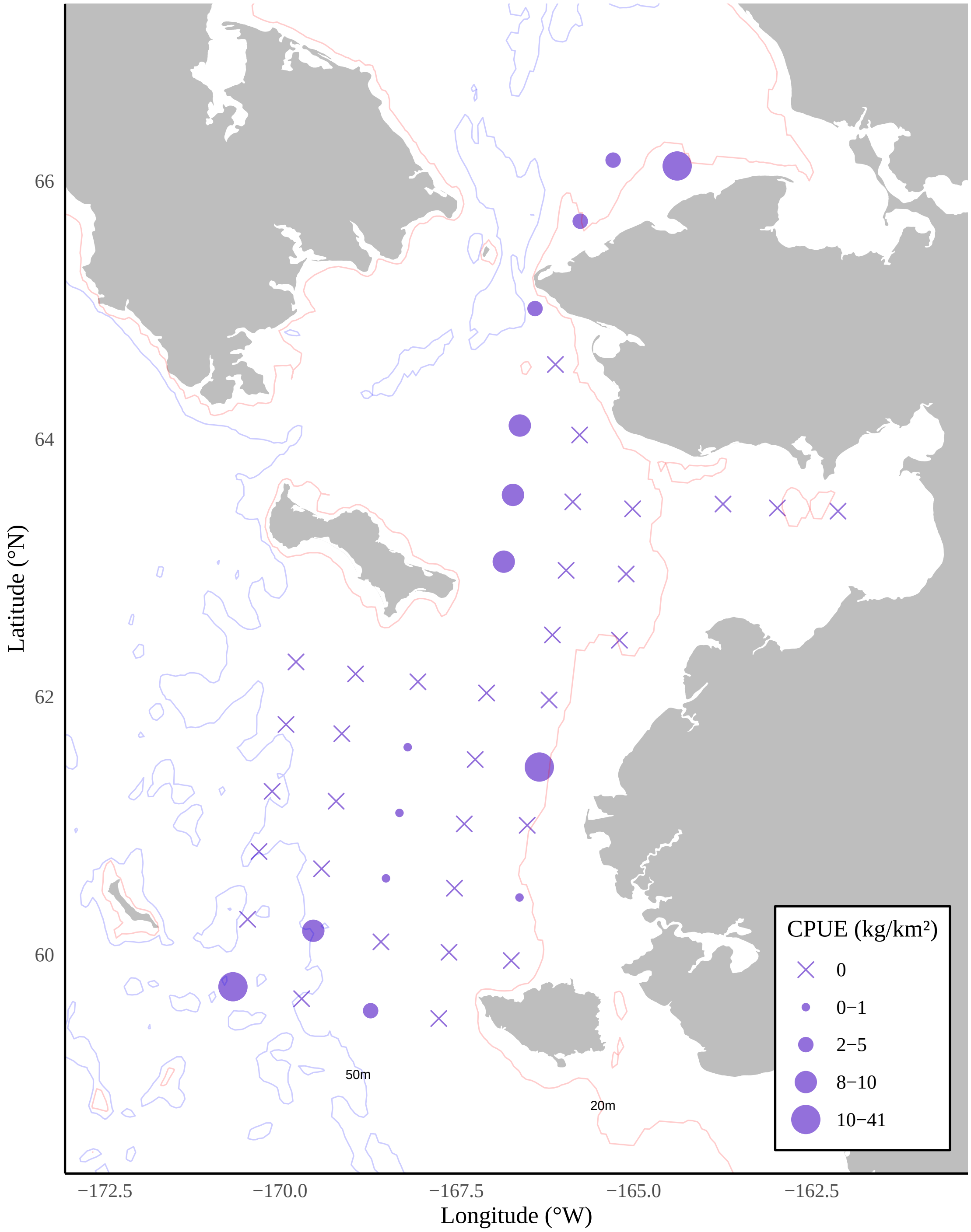

Figure A2.6: Surface trawl catch rates of Water jellyfish (CPUE, kg/km²) during the northern Bering Sea surface trawl survey, 2019.

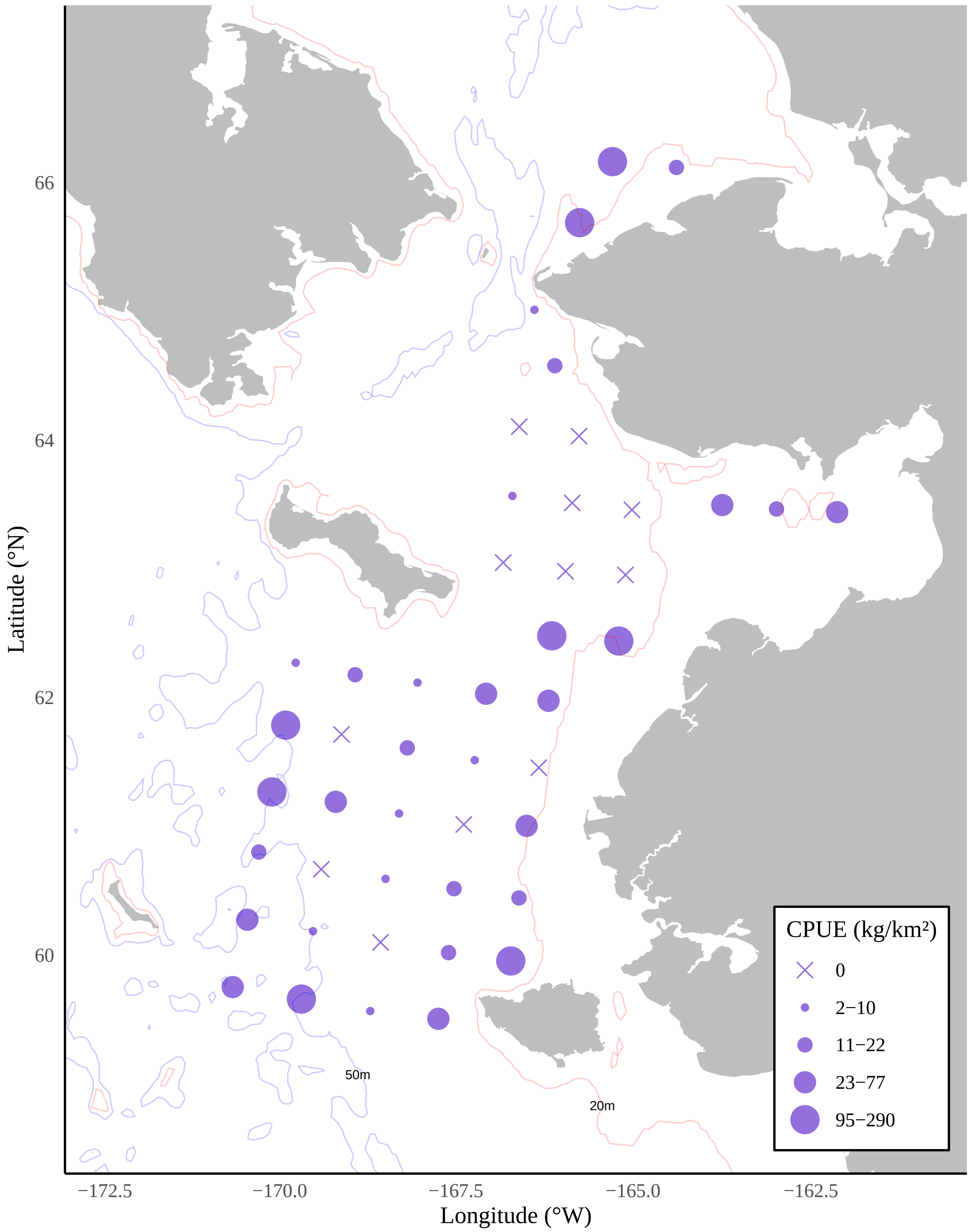

Figure A2.7: Surface trawl catch rates of Moon jellyfish (CPUE, kg/km²) during the northern Bering Sea surface trawl survey, 2019.

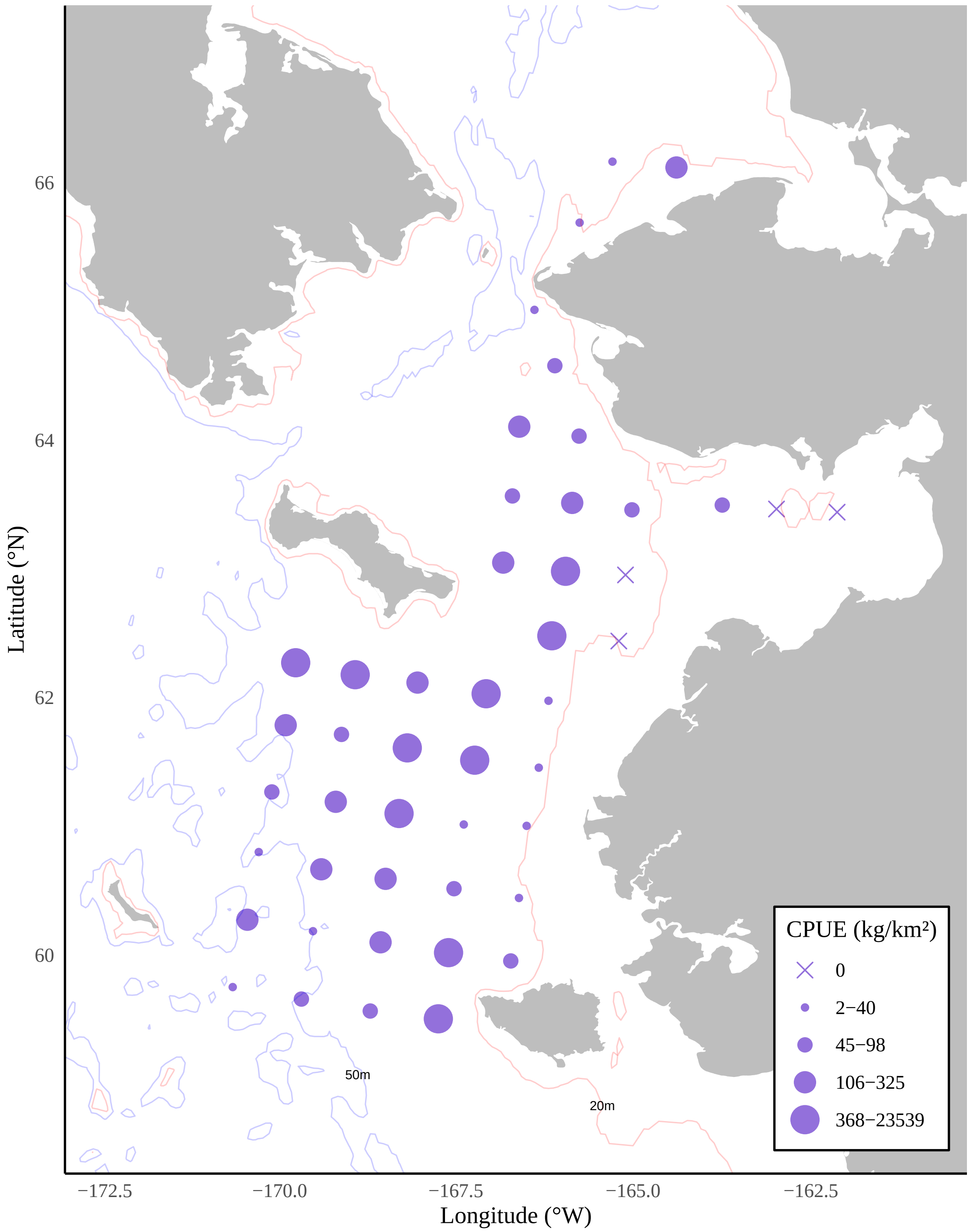

Figure A2.8: Surface trawl catch rates of Northern Sea Nettle jellyfish (CPUE, kg/km^2) during the northern Bering Sea surface trawl survey, 2019.

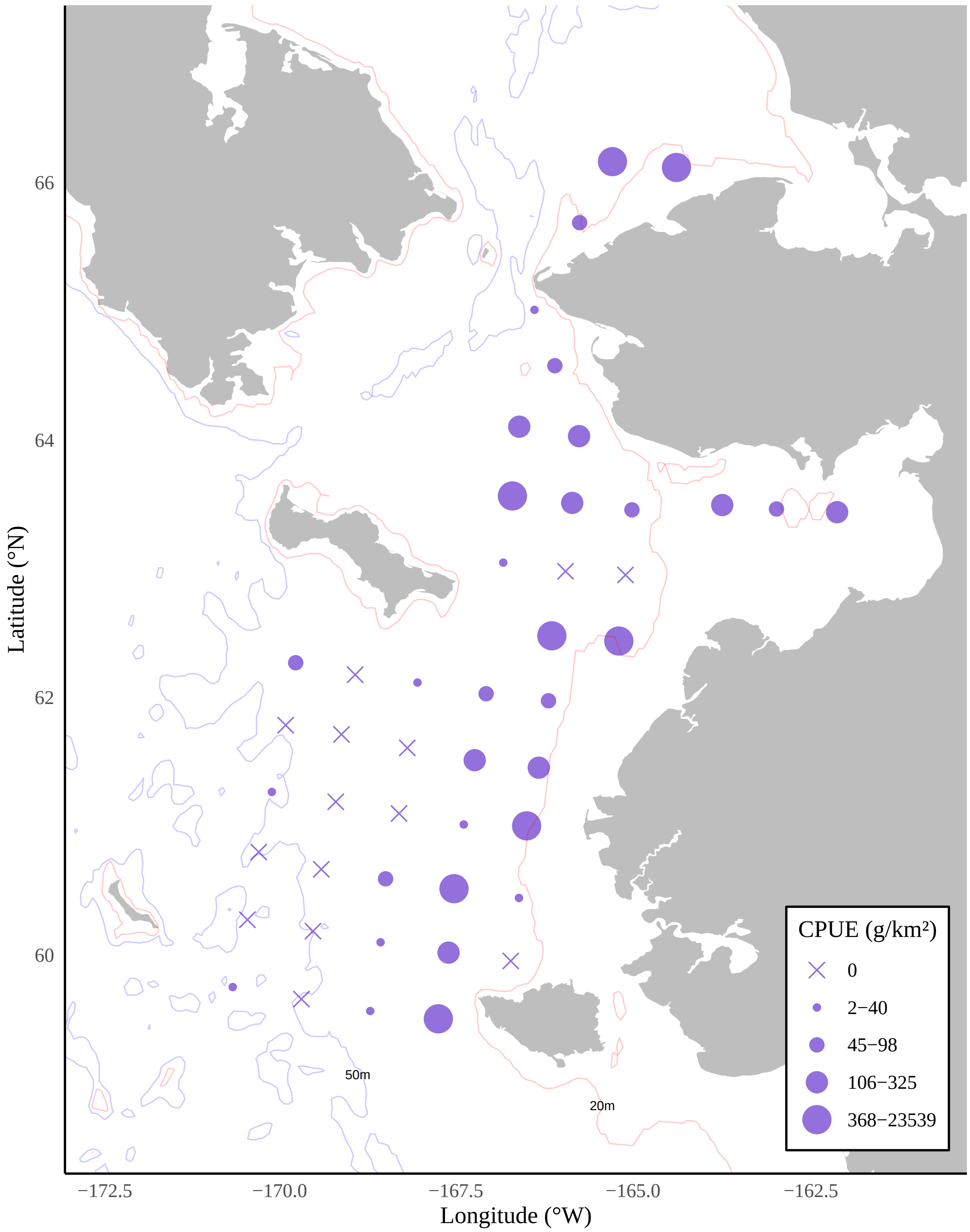

Figure A2.9: Surface trawl catch rates of Lion's Mane jellyfish(CPUE, kg/km²) during the northern Bering Sea surface trawl survey, 2019.

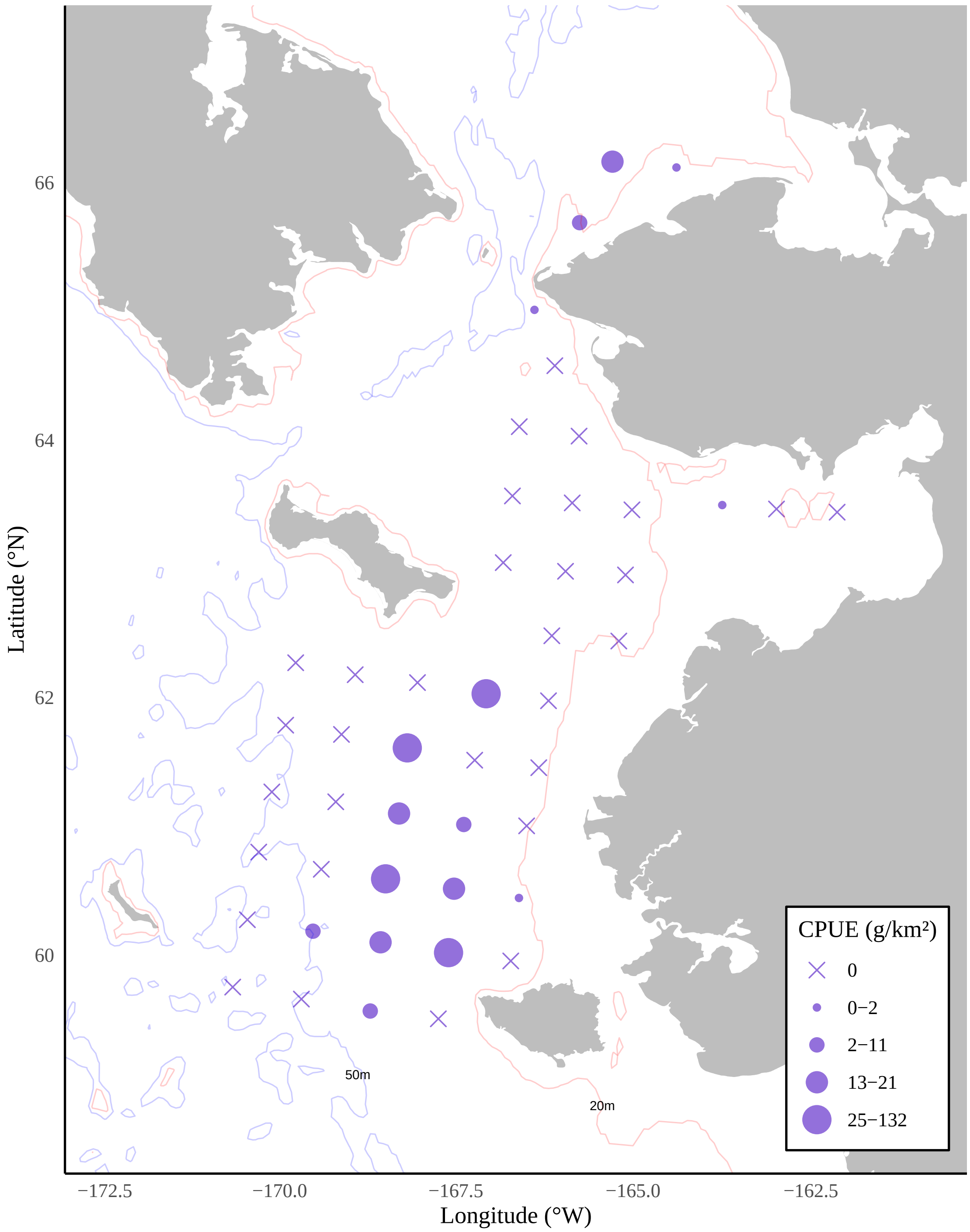

Figure A2.10: Surface trawl catch rates of Whitecross jellyfish (CPUE, kg/km²) during the northern Bering Sea surface trawl survey, 2019.

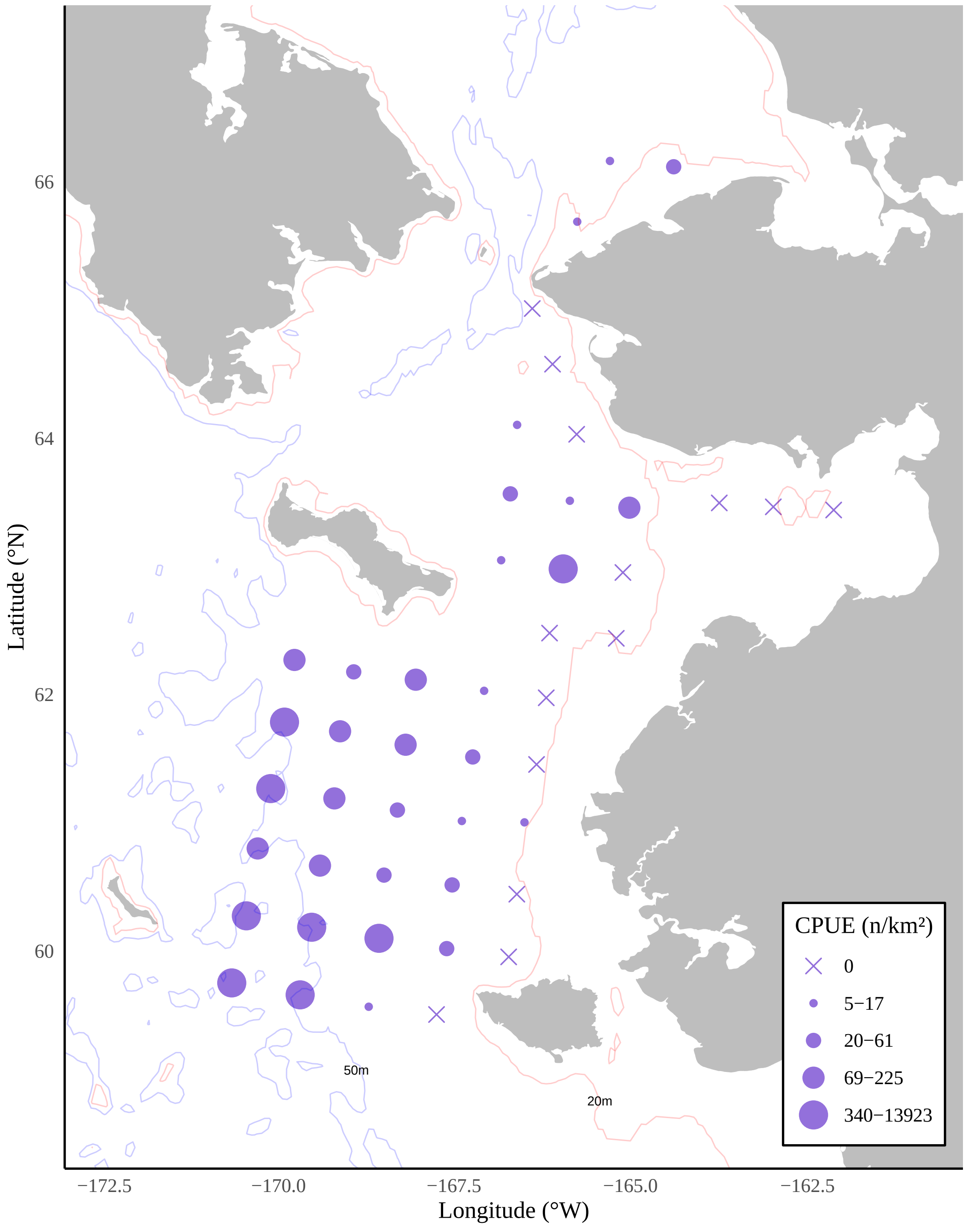

Figure A2.11: Surface trawl catch rates of age-0 Walleye Pollock (CPUE, n/km²) during the northern Bering Sea surface trawl survey, 2019.

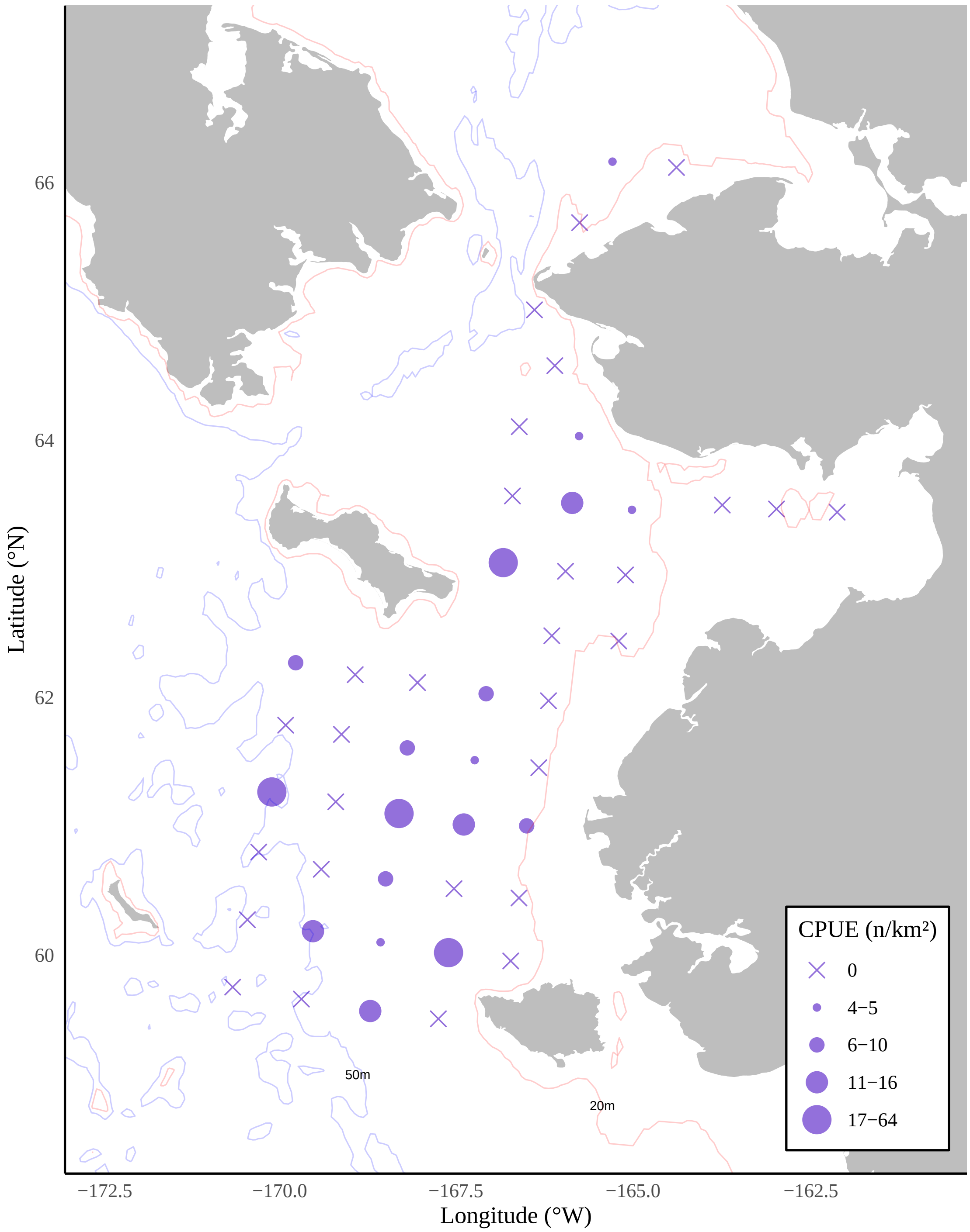

Figure A2.12: Surface trawl catch rates of age-1+ Walleye Pollock (CPUE, n/km²) during the northern Bering Sea surface trawl survey, 2019.

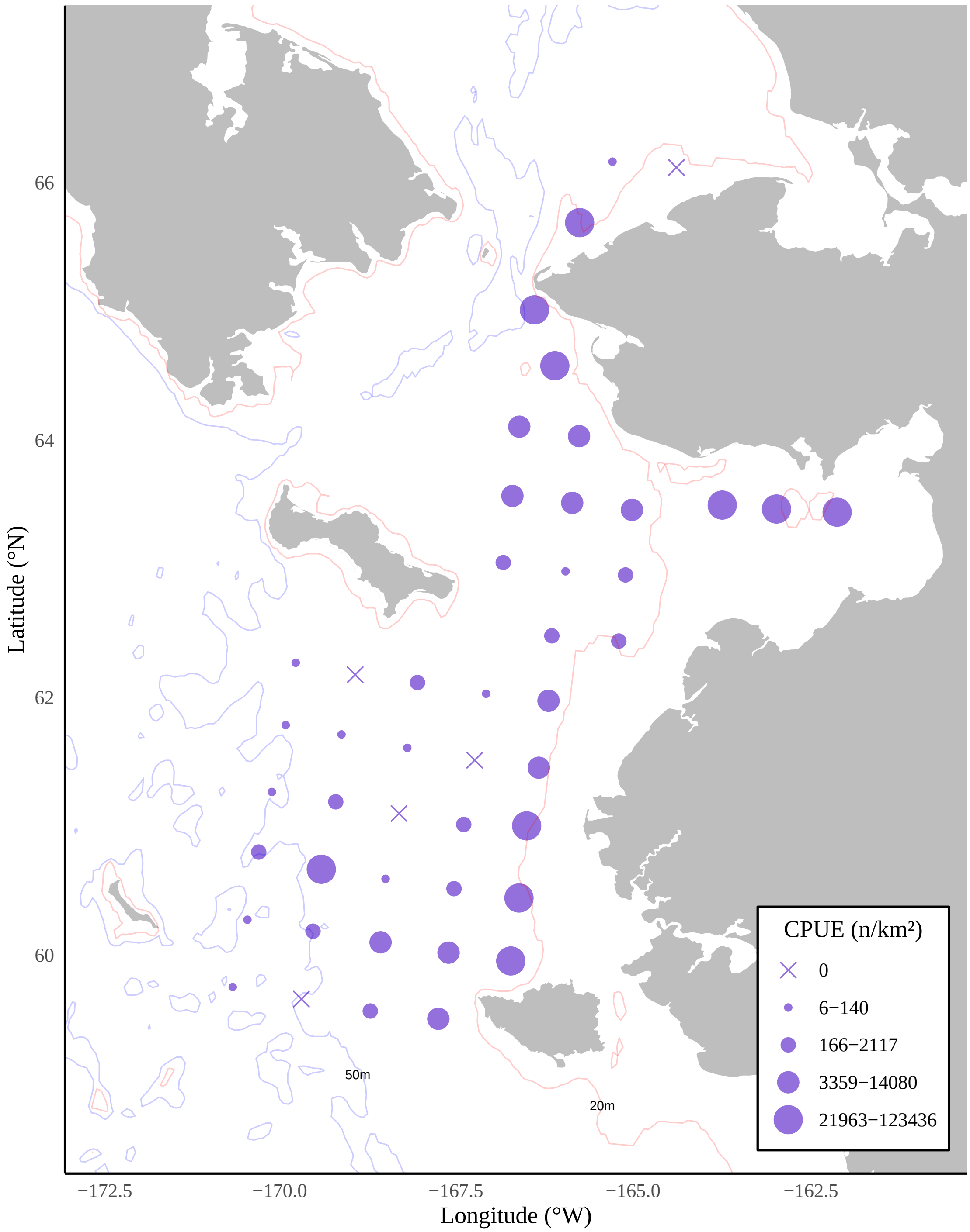

Figure A2.13: Surface trawl catch rates of Pacific Herring (CPUE, n/km²) during the northern Bering Sea surface trawl survey, 2019.

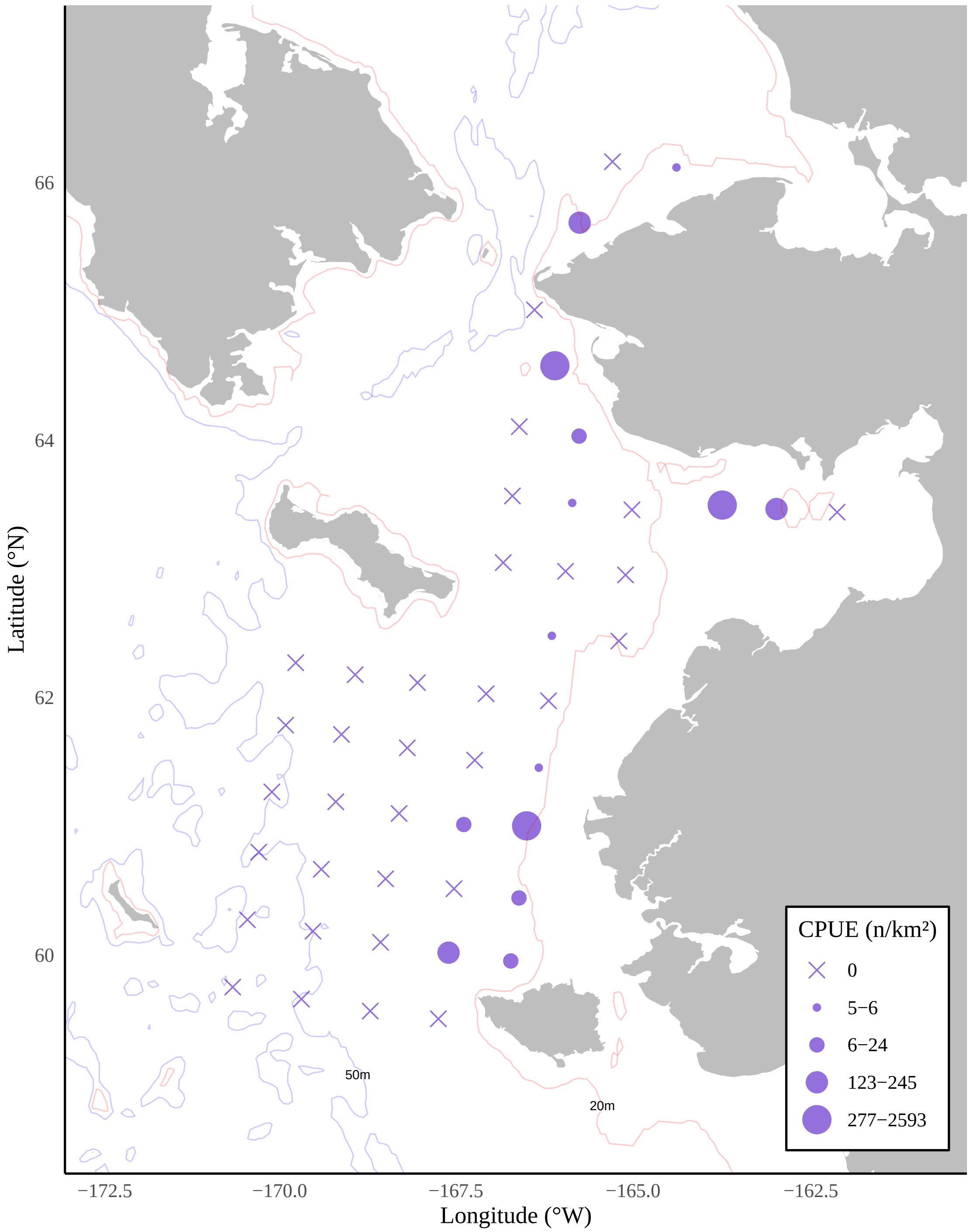

Figure A2.14: Surface trawl catch rates of Rainbow Smelt (CPUE, n/km²) during the northern Bering Sea surface trawl survey, 2019.

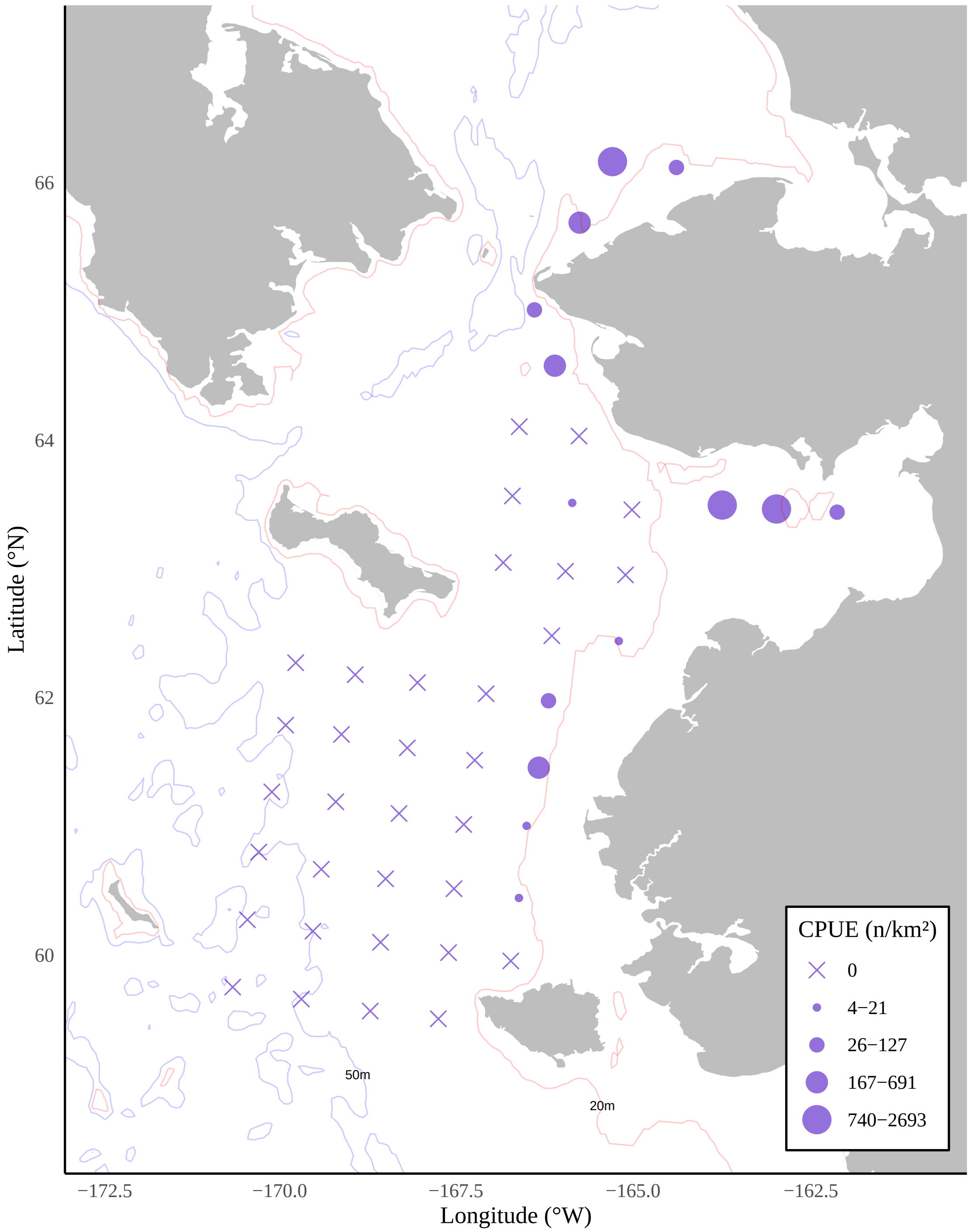

Figure A2.15: Surface trawl catch rates of Ninespine Stickleback (CPUE, n/km²) during the northern Bering Sea surface trawl survey, 2019.

Appendix 3. Length weight relationships of key species caught during the northern Bering Sea surface trawl survey, 2019.

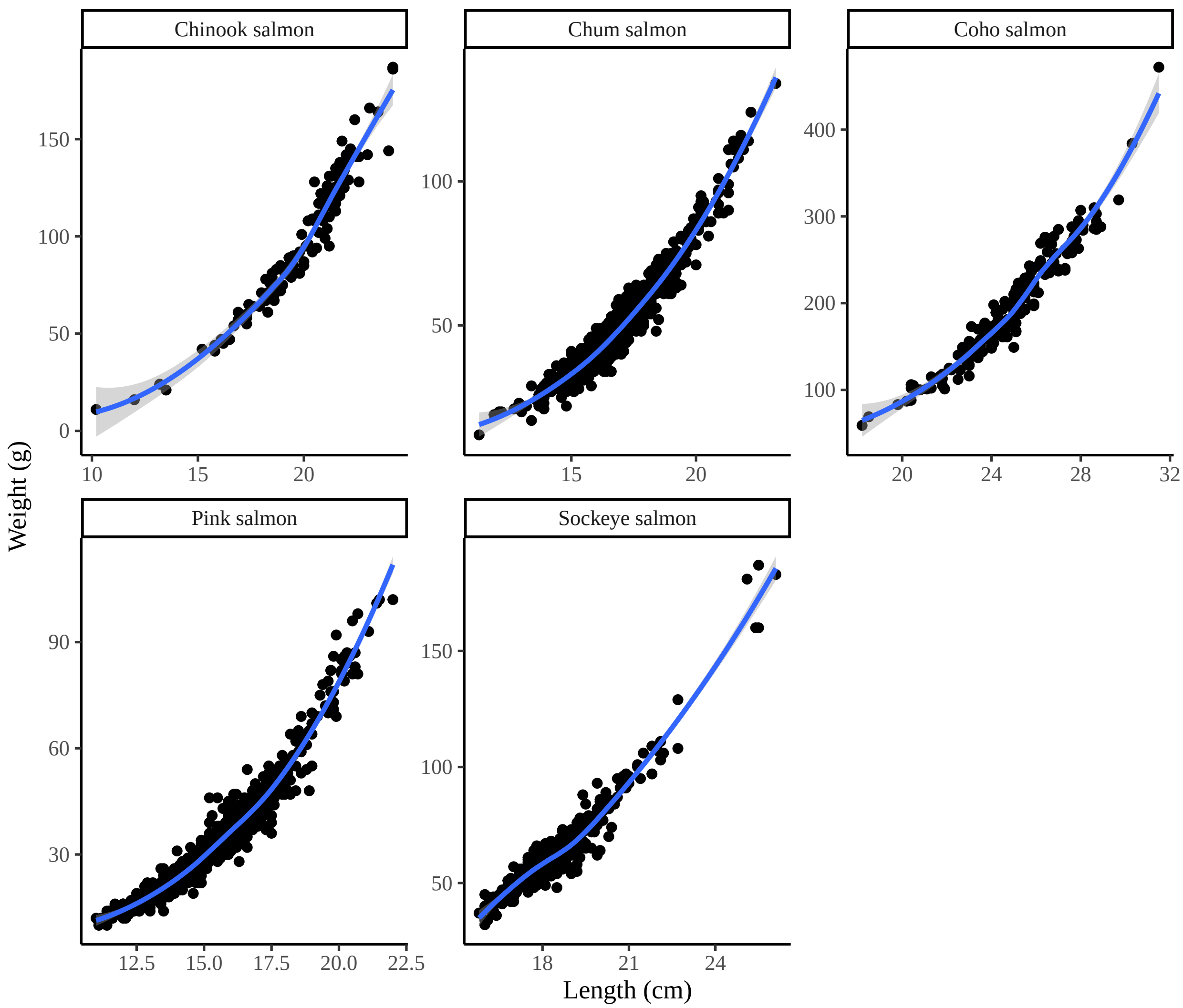

Figure A3.1: Length weight relationships of juvenile salmon species sampled during the northern Bering Sea surface trawl survey, 2019. Lines and shaded regions are from a local regression model (loess) fit and standard error.

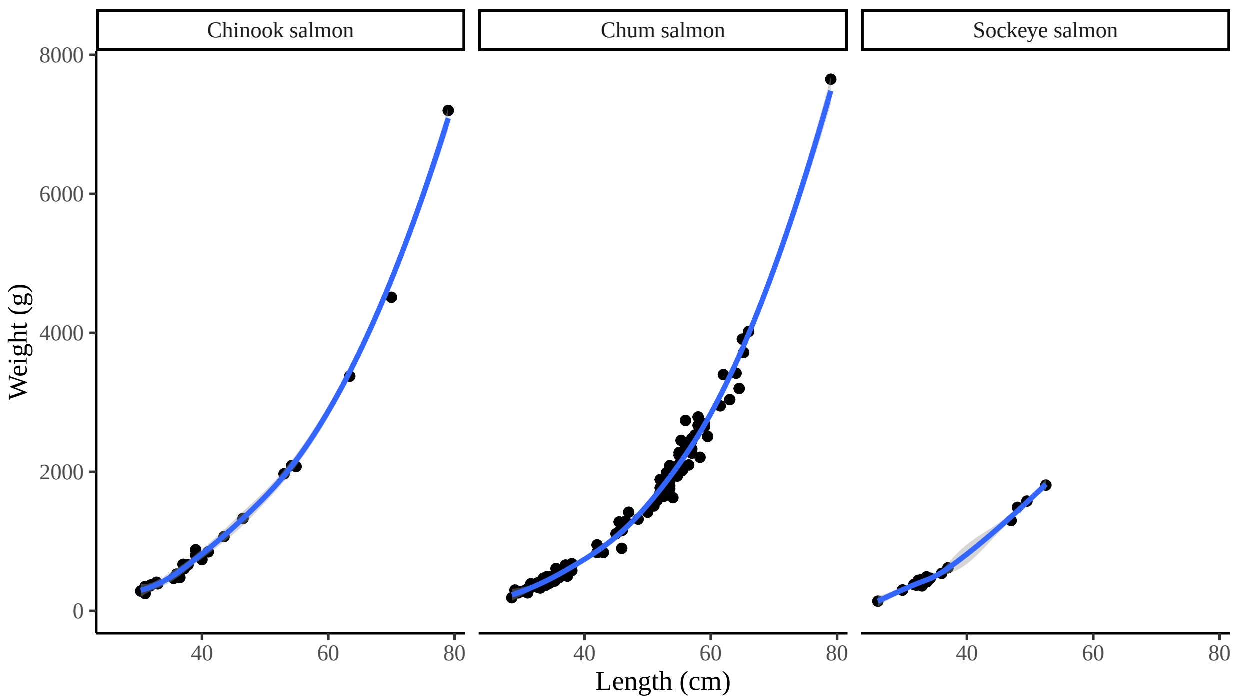

Figure A3.2: Length weight relationships of immature salmon species sampled during the northern Bering Sea surface trawl survey, 2019. Lines and shaded regions are from a local regression model (loess) fit and standard error.

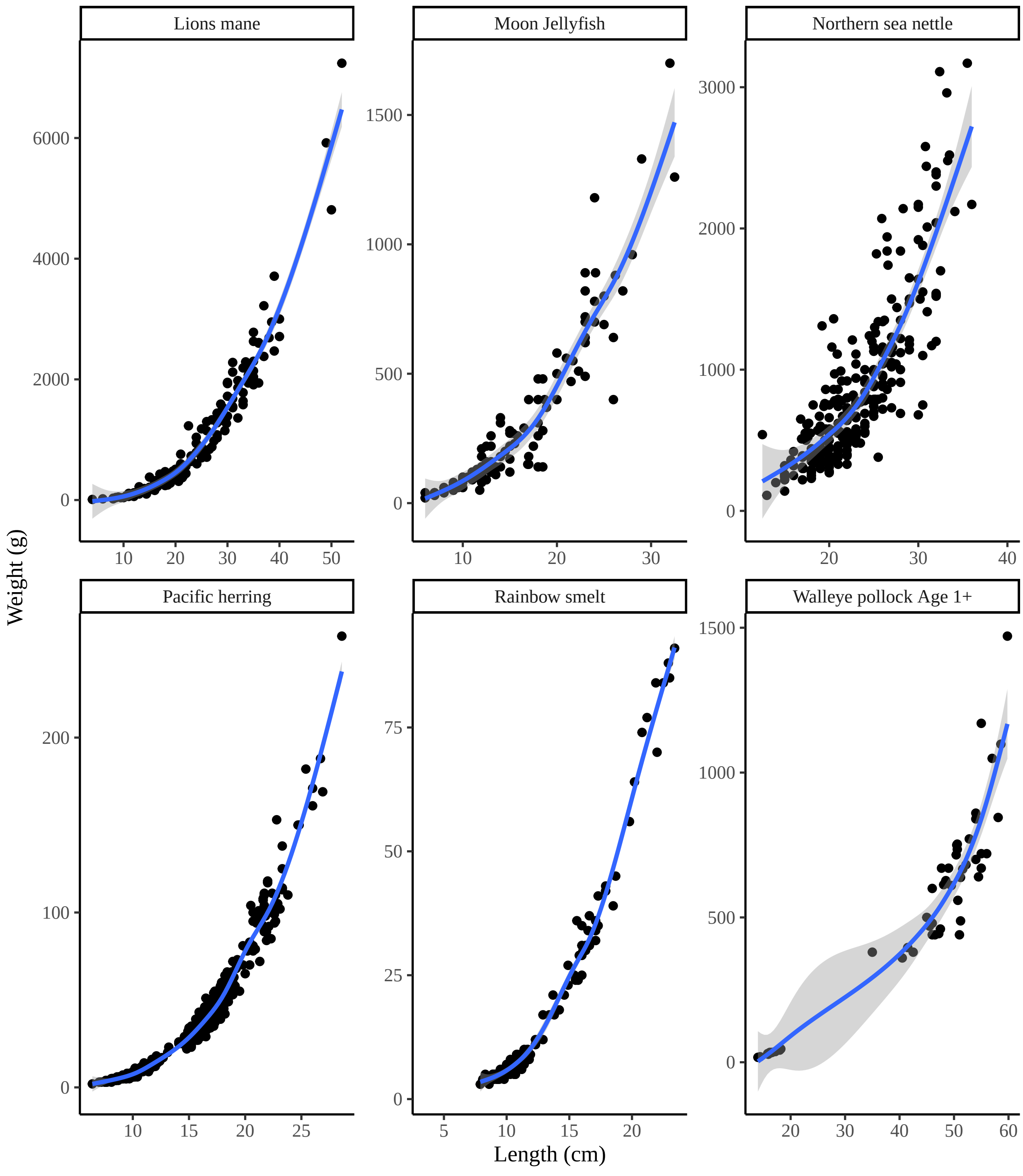

Figure A3.3: Length weight relationships of other key non-salmon species sampled during the northern Bering Sea surface trawl survey, 2019. Lines and shaded regions are from a local regression model (loess) fit and standard error.

Appendix 4. Coded-wire-tag (CWT) recovery information from Chinook Salmon from the Whitehorse Rapids Fish Hatchery captured during the northern Bering Sea surface trawl surveys, 2003-2019.

CWT Num or Ad Clip	Brood Year	Release Date	Recovery Date	Latitude	Longitude	Length (mm)	Weight (g)
185106	2001	6/10/2002	10/4/2002	64.10	164.52	193	79
185102	2001	6/2/2002	10/4/2002	64.10	164.52	155	46
185061	2001	6/10/2002	10/4/2002	63.00	165.97	161	49
18	2006	–	9/13/2007	65.20	168.10	125	18
18	2006	–	9/13/2007	65.20	168.10	176	58
18	2006	–	9/13/2007	65.20	168.10	179	58
18	2009	–	9/25/2010	64.07	162.72	164	50
181374	2011	6/6/2012	9/22/2012	61.48	167.00	138	28
181779	2011	6/6/2012	9/24/2012	64.10	163.55	160	45
181779	2011	6/6/2012	9/24/2012	60.98	168.00	138	25
182874	2013	6/6/2014	9/5/2014	63.85	165.97	126	18
183184	2013	6/1/2014	9/6/2014	63.02	166.05	120	15
183185	2013	6/6/2014	9/14/2014	62.50	167.08	192	75
183187	2013	6/6/2014	9/14/2014	62.50	167.08	177	60
183186	2014	6/8/2015	9/8/2015	62.98	165.97	109	13
183186	2014	6/8/2015	9/14/2015	64.00	166.02	120	18
183186	2014	6/8/2015	9/14/2015	64.00	166.02	124	21
184064	2014	6/3/2015	9/9/2015	63.02	167.07	112	13
184065	2014	6/3/2015	9/14/2015	64.00	166.02	129	24
184593	2016	6/7/2017	9/3/2017	62.00	168.00	110	12
185573	2018	6/12/2019	9/13/2019	64.12	162.52	152	42
185587	2018	6/12/2019	9/13/2019	64.12	162.52	132	24
ad-clip	NA		10/5/2002	63.00	167.48	134	23
ad-clip	NA		9/25/2010	63.82	162.78	190	87
ad-clip	NA		9/12/2012	64.40	166.07	185	75
ad-clip	NA		9/24/2013	60.52	167.05	207	108
ad-clip	NA		9/16/2013	63.77	164.57	183	70
ad-clip	NA		9/19/2013	62.52	167.03	202	94
ad-clip	NA		9/13/2015	64.02	167.00	113	15
ad-clip	NA		9/10/2018	63.50	166.00	127	22

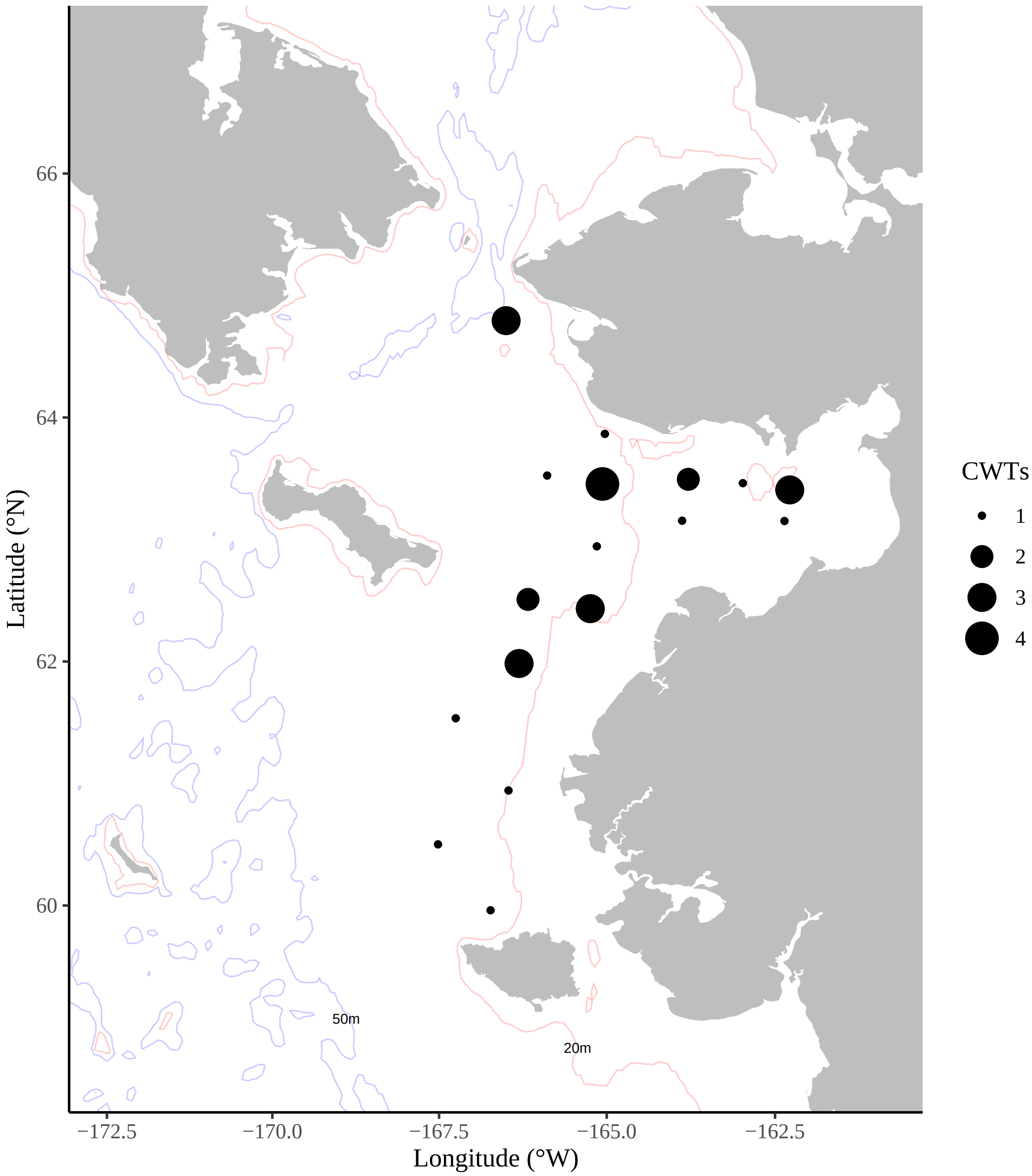

Figure A4.1: Location of all CWT recoveries during northern Bering Sea surface trawl surveys, 2003-2019.

Appendix 5. Salmon diet data collected from northern Bering Sea surface trawl surveys, 2004-2019.

Table A5.1: Juvenile Chinook, Coho, Chum, Pink, and Sockeye salmon sample size by number of stations (N), total number of stomachs (n), and the mean fullness index (SFI) sampled during the northern Bering Sea surface trawl surveys, 2004-2019.

	Chinook			Coho			Chum		
Year	Stations N	Stomachs n	Mean SFI	Stations N	Stomachs n	Mean SFI	Stations N	Stomachs n	Mean SFI
2004	37	138	180.85	27	96	154.39	42	261	109.43
2005	16	75	140.42	2	3	280.45	31	142	190.21
2006	28	87	215.00	21	78	105.36	32	213	207.07
2007	18	98	169.02	4	5	183.60	44	294	151.71
2009	11	50	129.02	5	13	150.35	18	138	196.09
2010	16	69	148.55	6	30	286.58	29	229	130.55
2011	15	111	234.26	4	13	151.29	20	177	103.09
2012	6	42	96.55	1	10	170.69	13	126	137.95
2013	20	174	261.07	3	16	292.98	17	148	136.99
2014	29	204	113.43	11	65	104.08	34	332	96.65
2015	27	180	145.26	7	43	111.65	27	215	74.29
2016	22	91	157.60	5	17	164.86	17	165	57.38
2017	28	148	125.21	19	117	147.19	18	167	148.12
2018	18	76	111.71	14	70	130.46	17	157	103.71
2019	11	46	67.01	14	76	171.04	28	242	49.19

	Pink			Sockeye		
Year	Stations N	Stomachs n	Mean SFI	Stations N	Stomachs n	Mean SFI
2004	48	323	130.29	23	173	95.35
2005	39	171	197.13	1	1	31.30
2006	24	131	203.30	2	2	172.20
2007	47	325	196.95	4	34	157.50
2009	14	121	267.38	1	10	100.90
2010	15	116	217.68	1	6	89.40
2011	14	114	135.51	1	2	105.26
2012	5	43	187.53	0	0	NA
2013	21	188	104.33	0	0	NA
2014	0	0	NA	0	0	NA
2015	24	222	148.23	3	12	54.86
2016	12	97	64.95	11	78	106.75
2017	20	194	183.73	7	42	41.45
2018	26	234	58.10	6	20	45.97
2019	23	230	82.70	13	126	42.84

Table A5.2: Juvenile Chinook Salmon diet expressed as percent stomach content index (SCI) during the northern Bering Sea surface trawl surveys, 2004-2019.

Year	Sand Lance	Capelin	A0 Pollock	Pacific Herring	Other Fish	Decapod	Other
2004	30.75	18.52	26.29	14.01	1.10	8.21	1.11
2005	3.97	26.63	25.84	1.27	17.25	12.99	12.05
2006	35.24	16.69	10.22	0.00	32.90	3.58	1.37
2007	13.33	49.59	3.62	0.00	20.13	10.81	2.52
2009	35.76	19.79	0.00	0.00	36.28	6.14	2.03
2010	6.89	68.39	0.00	3.24	15.11	2.35	4.02
2011	20.52	40.65	0.00	15.38	15.93	5.03	2.50
2012	0.00	0.00	0.00	0.00	94.78	4.22	1.00
2013	12.93	63.05	0.00	8.33	5.51	4.31	5.86
2014	66.46	4.68	4.10	0.00	11.27	7.97	5.52
2015	73.43	5.44	3.07	3.04	5.19	7.93	1.91
2016	57.29	9.90	6.06	2.31	6.14	17.01	1.29
2017	40.37	11.00	2.67	7.95	25.90	6.81	5.30
2018	2.47	0.00	21.72	0.00	48.47	14.08	13.25
2019	12.41	0.00	0.00	0.00	60.59	21.98	5.02

Table A5.3: Juvenile Coho Salmon diet expressed as percent stomach content index (SCI) during the northern Bering Sea surface trawl surveys, 2004-2019.

Year	Sand Lance	A0 Pollock	Capelin	Other Fish	Decapod	Other Crus-tacean	Other
2004	15.69	40.07	2.43	24.30	15.71	1.50	0.30
2005	0.00	0.00	0.00	96.42	0.23	0.00	3.35
2006	33.36	24.35	1.35	25.59	11.56	0.36	3.44
2007	22.19	0.00	23.88	39.88	14.04	0.00	0.00
2009	36.18	20.10	28.35	13.75	0.42	1.21	0.00
2010	26.41	0.00	65.06	0.00	8.07	0.45	0.00
2011	43.47	0.23	44.41	9.94	1.95	0.00	0.00
2012	0.00	0.00	0.00	99.80	0.00	0.20	0.00
2013	88.35	0.00	0.00	11.32	0.17	0.00	0.16
2014	28.65	33.47	4.38	32.59	0.14	0.73	0.05
2015	13.56	15.92	13.28	32.75	24.39	0.11	0.00
2016	51.99	19.48	0.00	16.92	2.06	0.27	9.27
2017	36.36	0.59	6.22	45.81	6.91	1.65	2.46
2018	0.18	39.62	0.00	38.97	15.03	3.24	2.97
2019	0.00	52.53	4.22	34.76	5.23	0.29	2.97

Table A5.4: Juvenile Chum Salmon diet expressed as percent stomach content index (SCI) during the northern Bering Sea surface trawl surveys, 2004-2019.

Year	Gelatinous Prey	Sand Lance	A0 Pollock	Other Fish	Euphausiid	Hyperiid	Other Crus-tacean	Other
2004	36.91	4.64	13.72	14.47	6.38	7.84	15.97	0.08
2005	28.74	0.00	21.10	17.04	28.51	1.56	3.05	0.00
2006	20.49	44.64	1.76	27.34	3.88	0.67	1.00	0.22
2007	63.29	2.72	0.00	4.23	12.31	8.26	8.40	0.79
2009	42.23	9.44	0.00	23.50	0.00	22.97	1.54	0.33
2010	26.07	16.87	0.00	15.07	19.08	18.86	3.46	0.59
2011	49.91	0.00	0.00	17.87	11.97	12.37	6.56	1.33
2012	43.81	4.32	0.00	7.80	10.29	7.27	3.20	23.31
2013	27.13	11.29	0.00	6.95	4.03	46.42	3.38	0.80
2014	12.71	29.10	0.84	3.01	30.55	13.42	10.38	0.00
2015	30.65	27.90	0.00	24.56	0.55	10.61	5.09	0.64
2016	56.10	0.00	0.00	16.96	0.00	1.37	4.02	21.55
2017	7.86	5.20	0.00	48.89	20.88	0.41	2.27	14.48
2018	18.07	0.00	0.00	13.80	26.66	2.64	0.85	37.97
2019	61.19	0.00	3.71	1.33	0.06	0.32	2.74	30.66

Table A5.5: Juvenile Pink Salmon diet expressed as percent stomach content index (SCI) during the northern Bering Sea surface trawl surveys, 2004-2019.

Year	Sand Lance	A0 Pollock	Other Fish	Euphausiid	Decapod	Hyperiid	Copepod	Gelatinous Prey	Other
2004	26.75	14.98	5.07	11.83	28.36	3.59	6.55	1.40	1.47
2005	3.15	25.46	28.19	16.65	15.86	5.35	0.40	3.36	1.58
2006	47.26	1.48	26.53	0.89	10.16	2.59	3.28	3.59	4.21
2007	3.96	0.37	17.11	7.86	29.96	17.04	9.50	8.97	5.24
2009	26.64	0.00	22.27	2.47	1.92	17.32	6.03	15.72	7.64
2010	9.70	0.00	16.30	56.78	1.96	6.72	1.16	6.75	0.62
2011	12.55	0.00	3.14	0.12	19.73	31.55	24.38	6.39	2.14
2012	0.00	0.00	28.43	40.91	3.95	5.72	1.96	0.00	19.01
2013	2.69	0.00	21.01	9.88	5.09	49.57	2.16	9.04	0.56
2015	63.49	0.00	2.65	9.44	5.21	7.24	6.21	5.02	0.73
2016	8.47	0.00	23.34	0.00	17.20	0.61	33.11	4.92	12.34
2017	2.35	0.00	12.24	38.56	3.31	0.59	35.78	0.00	7.18
2018	0.00	0.00	5.70	33.44	2.52	9.24	12.72	0.92	35.46
2019	0.00	0.00	23.53	4.35	2.85	0.33	25.11	4.68	39.14

Table A5.6: Juvenile Sockeye Salmon diet expressed as percent stomach content index (SCI) during the northern Bering Sea surface trawl surveys, 2004-2019.

Year	Thysanoessa spp.	Decapod	Copepod	Other Crustacean	Sand Lance	A0 Pollock	Other Fish	Other
2004	5.80	16.36	4.07	5.03	1.85	63.81	1.32	1.76
2005	0.00	0.00	0.00	0.96	0.00	0.00	69.01	30.03
2006	33.04	47.50	0.00	4.73	0.00	0.00	0.00	14.72
2007	4.82	0.65	26.96	12.07	0.00	0.00	0.49	55.01
2009	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00
2010	95.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00
2011	0.00	30.00	0.00	0.00	0.00	0.00	70.00	0.00
2015	0.20	73.57	5.91	9.45	0.00	9.44	1.44	0.00
2016	0.87	4.83	0.58	2.96	61.00	1.70	9.77	18.30
2017	77.67	1.68	0.00	0.27	0.00	0.00	13.64	6.74
2018	40.31	3.22	1.55	3.88	0.00	0.00	0.00	51.05
2019	5.20	12.67	7.86	1.49	0.00	3.34	18.56	50.87