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Northern Bering Sea Ecosystem and Surface Trawl Cruise Report, 2021

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November 2023

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National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Alaska Fisheries Science Center

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Northern Bering Sea Ecosystem and Surface Trawl Cruise Report, 2021

J. Murphy[1], J. Dimond[1], D. Cooper[2], S. Garcia[3], E. Lee[3], J. Clark[3], A. Pinchuk[4], M. Reedy[5], T. Miller[1], K. Howard[3], J. Ferguson[3], W. Strasburger[1], E. Labunski[5], and E. Farley Jr.[1]

[1]Auke Bay Laboratories
Alaska Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
17109 Point Lena Loop Road
Juneau, AK 99801

[2]Resource Assessment and Conservation
Engineering Division
Alaska Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
7500 Sand Point Way NE
Seattle, WA 98115

[3]Alaska Department of Fish and Game
Division of Commercial Fisheries
333 Raspberry Road
Anchorage, AK 99518

[4]University of Alaska, Fairbanks
17101 Point Lena Loop Road
Juneau, AK 99801

[5]United States Fish and Wildlife Service
1011 E Tudor Road # 200
Anchorage, AK 99503

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ABSTRACT

The Northern Bering Sea Ecosystem and Surface Trawl survey (NBS survey) is a multi-disciplinary research survey that supports annual sampling of fish, crab, and oceanographic indices of the inner domain (bottom depths generally less than 55 m) of the northern Bering Sea (NBS) (60°N–66.5°N).The average sea surface temperature (SST, 9.3°C, upper 10 m) during the 2021 survey declined from the peak temperatures observed in 2019 and was just slightly above the long-term average (9.1°C). Similar to prior years, the jellyfish species, northern sea nettle (*Chrysaora melanaster*), had the largest surface trawl catch biomass with a total catch of 2,590 kg in 2021. Walleye pollock (*Gadus chalcogrammus*) were the most abundant species of fish with a total catch of 81,677 age-0 fish, and 4,202 age-1+ fish. Pink salmon (*Oncorhynchus gorbuscha*) were the most abundant species of juvenile salmon with a total catch of 3,320 fish. Stomach fullness of juvenile Chinook salmon (*O. tshawytscha*) was the second lowest observed since 2004, but the fullness of other juvenile salmon species were close to average in 2021. The energetic condition of all species of juvenile salmon were above average in 2021, and the condition of juvenile chum salmon (*O. keta*) was the highest since 2009. No juvenile Chinook salmon were infected with *Ichthyophonus* but 50% of the immature Chinook salmon were infected and 25% had high prevalence of the parasite. The abundance of juvenile Chinook salmon was below average for both the Canadian-origin (957,000, SD = 317,0000) and the total Yukon River stock groups (1.6 million, SD = 645,000). The juvenile fall chum salmon abundance index (97 fish/km^2) was the highest observed since 2003. A total of 40 avian species consisting of 5,080 birds on transect and another 1,008 birds off transect were observed. Shearwaters (*Ardenna* spp.) were the most abundant seabirds during the survey and accounted for 61% of all birds encountered. A total of 8 marine mammals species consisting of 22 individuals on transect and 12 off transect were observed. Northern fur seal (*Callorhinus ursinus*) were the most abundant marine mammal during the survey.

CONTENTS

INTRODUCTION

The Northern Bering Sea Ecosystem and Surface Trawl survey (NBS survey) is a multi-disciplinary research survey that supports annual sampling of fish, crab, and oceanographic indices of the inner domain (bottom depths generally less than 55 m) of the northern Bering Sea (NBS) (60°N–66.5°N). This survey was initiated by NOAA's 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 designed to improve our understanding of the marine ecology of salmon in the Bering Sea. BASIS surveys were conducted through 2007. The NBS was not sampled during 2008 or 2020, but this survey has continued to support research in the NBS to improve our understanding of salmon and how the NBS ecosystem is changing in response to warming climate and loss of Arctic sea ice.

The NBS survey supports a wide range of scientific operations, including: surface and beam trawl sampling, bongo net and benthic grab sampling, seabird and marine mammal observations, conductivity-temperature-depth (CTD) data collections, and water collections for chlorophyll-a, phytoplankton, eDNA, and nutrients. The survey has supported research on salmon and other 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, Murphy et al. 2021), 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, Garcia and Sewall 2021), diet (Farley et al. 2009, Andrews et al. 2016, Auburn and Sturdevant 2013, Honeyfield et al. 2016, Garcia and Sewall 2021, Murphy et al. 2021), and species distribution (Murphy et al. 2009, Murphy et al. 2016, Andrews et al. 2016, Murphy et al. 2021).

The decline in Chinook salmon (*Oncorhynchus tshawytscha*) and chum salmon (*O. keta*) run sizes to the Yukon River has had a widespread impact on fisheries in Alaska and the Yukon Territory. Although there has been a persistent need for an improved understanding of why run sizes of Chinook salmon have declined over the last 10 years (e.g. Howard and von Biela 2023, Feddern et al. 2023), the recent collapse of chum salmon in the Yukon River (JTC 2023) has highlighted the need for an improved understanding of their marine ecology and impacts of warming climate on their survival (Farley et al. in press). Furthermore, an improved understanding of fish diseases originating from marine-borne pathogens, such as *Ichthyophonus* (the protozoan Mesomycetozoean and causative agent responsible for the disease Ichthyophoniasis), is needed as they are a contributing factor to Chinook salmon mortality during their spawning migration (Ferguson et al. 2022).

The 2021 NBS survey was conducted as a cooperative research survey by AFSC, the Alaska Department of Fish and Game (ADF&G), the University of Alaska, Fairbanks (UAF), and the U.S. Fish and Wildlife Service (USFWS) to improve our understanding of the NBS marine ecosystem. Key funding support was provided by the Alaska Sustainable Salmon Fund to maintain juvenile abundance estimates for salmon stocks that are harvested for subsistence in Alaska. The primary objectives of the 2021 NBS survey were to 1) estimate stock-specific Chinook salmon abundance and provide adult run size forecasts for Canadian-origin and total

Yukon River Chinook salmon stock groups; 2) define relationships between juvenile and adult abundance for pink salmon (*O. gorbuscha*) and chum salmon in the NBS; 3) evaluate how warming in the NBS is altering the diet, growth, and condition of juvenile salmon; 4) evaluate the prevalence and quantify the intensity of *Ichthyophonus* in juvenile and immature Chinook salmon heart tissues; 5) examine the diet and condition of pelagic and benthic fish species in the NBS; 6) collect electronic oceanographic data and water samples for temperature, salinity, chlorophyll-a, fatty acids, and nutrients; 7) collect zooplankton and ichthyoplankton; 8) characterize essential habitat for juvenile *Chionoecetes* spp. in the NBS; 9) sample benthic infauna and sediments; 10) collect samples of environmental DNA; 11) tag salmon shark with archival and satellite tags; and 12) record visual observations of seabirds and marine mammals.

METHODS

The 2021 NBS survey started and ended in Dutch Harbor, AK, with a port call in Nome, AK. The survey occurred over 25 days inclusive of mobilization, demobilization, transit, sampling, and weather days aboard the chartered fishing vessel FV *Northwest Explorer*, 27 August to 20 September 2021. The survey crew included scientists from Alaska Fisheries Science Center, Alaska Department of Fish and Game, U.S. Fish and Wildlife Service, and the University of Alaska, Fairbanks (Table 1). The survey consisted of 46 standard stations in the NBS between 60°N and 66.5°N and east of 171°W, and seven adaptive beam trawl stations in Norton Sound and Bering Strait to sample juvenile crab (*Chionoecetes* spp.) (Fig. 1, Table 2). Stations were assigned to spatial strata (Fig. 2) and the spatial strata that have consistently sampled over time (Strata 1-6, 8) were used to construct ecosystem indices from the survey. Each day typically consisted of sampling three stations during daylight hours. The order of operations at each station was 1) a CTD instrument system with a rosette water sampler, 2) a Van Veen grab, 3) an oblique zooplankton net tow with bongo array, 4) a 5-minute 3-m plumb staff beam trawl, and 5) a 30-minute surface trawl tow. Seabird and marine mammal observations were recorded during the transit between stations.

Oceanographic Conditions

The primary CTD (SeaBird Instruments SBE-9-11+) was outfitted with dual temperature and conductivity sensors, a Photosynthetically Active Radiation 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 A). 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 set to the measurements from the deepest depth of each CTD cast. 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) and was set to the maximum depth of the CTD cast when the water column was mixed.

CTD SST data were compared with satellite estimates of SST from the Optimal Interpolation Sea Surface Temperature (OISSTv2.1) dataset (Huang et al. 2021, accessed by NOAA's CoastWatch West Coast Regional Node ERDDAP site). Average annual CTD and OISST temperature estimates were compared at the individual station (Fig. 3a) and regional spatial and temporal scales (Fig. 3b). Satellite and CTD temperature estimates were consistent at the station level (Fig. 3a), but the 2003 and 2005 survey years were inconsistent with satellite data at the regional spatial and temporal scale (July – September, NBS region) (Fig. 3b). This is believed to reflect the differences in the survey design and timing during these years. The 2003 survey design was transect-based, which was inconsistent with subsequent survey years (grid-based). The 2005 survey was conducted later than other survey years and is likely why the average SST from the CTD was cooler than expected. The predicted average SST from OISST data (Fig. 3b) was used in place of observed SST from the CTD during 2003, 2005, and during years where CTD data were not collected (2008 and 2020) to construct the NBS SST Index.

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 µm mesh and two 20-cm diameter bongo nets with 153 µm mesh. A CTD (SeaBird Instruments SBE-49) was affixed above 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 approximately 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 (RZA) (Appendix A). RZA was used to provide information on zooplankton abundance and community structure from coarse taxonomic categories of zooplankton to provide an assessment of forage conditions during the 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.

Benthic Ecology

Benthic Grab

A Day Grab (KC Denmark, Silkeborg, Denmark) was deployed at 13 stations. The day grab is a modified van Veen grab inside a frame with added weights to improve stability and increase the probability of a successful grab. The grab samples 1,000 cm^2 surface area. Undisturbed surface sediment was sampled for harmful algal bloom (HAB) cysts, grain size analysis, organic content, lipid amount, and lipid type. Clams were removed from the remainder of the sediment and saved for HABs assessment.

Beam Trawl

A beam trawl was deployed at 40 stations. Initially, it was planned to deploy the beam trawl at every third station, however, beginning with station 15, a beam trawl was attempted at every station. The beam trawl is a small-mesh trawl with a body mesh of 7 mm and a codend mesh of 4 mm originally designed by Gunderson and Ellis (1986) and modified by Abookire and Rose (2005). The mouth opening is 2.1 m. The trawl was deployed from a net reel at a target tow speed of 1 knot for an estimated 5 minutes on the bottom at each station. A tilt sensor (Hobo pendant G, Onset Corp., Bourne, MA, USA) was attached to a waterproof housing on the net that was rigged in a manner to dangle from the footrope and change orientation when the footrope contacted the bottom. Tilt sensor data were used to determine the time when the net began and ended fishing on the seafloor, and time-stamped GPS data were used to determine the locations of the beginning and end of each tow. The benthic area swept by the trawl was calculated as the distance fished by the trawl multiplied by a trawl mouth opening of 2.1 m.

The beam trawl catch was sorted to various taxonomic groups. Fish, crab, and shrimp were sorted to the lowest taxonomic resolution possible by the survey team. Other invertebrates were sorted to larger taxonomic groups in order to complete trawl processing prior to processing the surface trawl catch. All fish and *Chionoecetes* spp. crab species were sorted and sampled, other taxa were subsampled as necessary. CPUE of taxa at each station were calculated as the number of animals divided by the trawl area swept.

Fish (length) and *Chionoecetes* spp. crab (carapace width) body sizes were measured to the nearest 1 mm. Age-0 gadid fish were measured to standard length, and other fish were measured to fork length. *Chionoecetes* spp. crab ≤ 15 mm, yellowfin sole (*Limanda aspera*), Pacific cod (*Gadus macrocephalus*), and saffron cod (*Eleginus gracilis*) were frozen for special project collections.

Surface Trawl

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 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 age-0 life-history stages or species with weights less than approximately 5 g due to the limited accuracy of ship-board weights. Total catch weight and the subsample weight of measured individuals were used to estimate the total catch in numbers when the catch was subsampled. Mixed-species subsamples were used to estimate the catch at a few stations with small and numerous species (typically ninespine stickleback (*Pungitius pungitius*), age-0 Pacific herring (*Clupea pallasii*), and moon jellyfish (*Aurelia* spp.) using standard subsampling protocols. Annual sample requests were used to construct specimen collection protocols for all species (Appendix A).

All biological data were recorded in an electronic catch logging system, known as the Catch Logger for Acoustic and Midwater Surveys (CLAMS) developed by the Alaska Fisheries Science Center. Individual specimens were assigned a specimen number (barcode number) and barcode tags were electronically scanned into CLAMS with barcode scanners. Juvenile chum and pink salmon caudal fins were collected for genetic analysis, frozen, and assigned a station number. All Chinook salmon were scanned for missing adipose fins and fish with missing adipose fins were scanned for coded-wire-tags (CWTs).

Length-frequency distributions, length-weight relationships, and box plots of lengths were used to describe the size of the most abundant 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 in the size data collected during the survey. Juvenile salmon lengths (fork length, mm) were standardized to the average date of capture of each species (Sep. 11th) with apparent growth rates estimated for each species. Juvenile salmon growth rates were estimated by the slope of linear regression models between day-of-year and fork length for each species, 2003-2021. Growth rate estimates used to standardize length were: Chinook salmon 1.06 mm/day (SE = 0.05), chum salmon 1.45 mm/day (SE = 0.02), coho salmon 1.53 mm/day (SE = 0.09), pink salmon 1.64 mm/day (SE = 0.02), and sockeye salmon 1.45 mm/day (SE = 0.05). Length frequency distributions of species captured in surface trawls during 2021 were adjusted by the proportion of the catch measured at each station to scale length distributions to total catch.

Juvenile Salmon Trophic Ecology

Diet

Stomach contents were examined either at sea or in a laboratory setting (all 2021 samples processed in the lab) between 2003 and 2021. Stomach processing followed methods used aboard Russian research vessels as Russian scientists (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 previous years, accurate prey weights could not be measured due to onboard processing and 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, mathematically equivalent to % prey weight). 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 overall years. Rare prey items that did not fall into a larger category were placed into an "Other" category. *Thysanoessa* was used as a prey category for sockeye salmon diets because 95% or higher of all the euphausiids within these stomachs were identified to the genus of *Thysanoessa*, while euphausiids was used as a broader prey category for pink and chum diets. All stations where stomachs were analyzed, but no prey was present in stomachs or contents were not identified, were removed from this analysis. Years with diet data from less than five stations were not included in the diet summaries/figures.

Energetic Condition

Two salmon of average size were sampled at each station for energy density (ED) and the average whole-body ED (kJ/g dry weight) within the core spatial strata (1-5 and 7) was used as an index of annual condition. ED was estimated with bomb calorimetry of homogenized whole fish tissues collected from 2009 to 2021 (Fergusson et al. 2010). Estimates of ED were available prior to 2009 for chum salmon, but were not consistently available for other species of salmon. Sampling issues (e.g., Chinook salmon in 2006), prevented the use of some of these data. Data prior to 2009 lacked detailed laboratory records of how these estimates were generated and were completed by a different laboratory at the Alaska Fisheries Science Center. It was decided not to combine these early estimates of ED with the primary dataset starting in 2009 in this analysis due to potential sources of inconsistencies that could be present between these two datasets. Fish specimens were dried at 75°C (2009-2015) and manually weighed until a mass was constant from 2009 to 2015, and dried at 135°C with a LECO Thermogravimetric Analyzer 601 from 2016 to 2021. Moisture values obtained by the two methods were known to differ by less than 1% (Vollenweider et al. 2011). Polynomial regression models were fit to the relationship between average ED and SST to describe how temperature influences the ED or condition of juvenile salmon in the NBS.

Ichthyophonus Investigations

Hearts were opportunistically collected from juvenile and immature Chinook salmon throughout the range of stations after minimum sample sizes for other investigations had been met. Using sterile utensils for handling, portions of each heart were cut to size and fixed in individual vials of 95% ethanol. Vials were transported back to the ADF&G Pathology Laboratory in Anchorage for analysis.

Approximately 1 g of ethanol-fixed heart was desiccated and pulverized with a stomacher into a homogenized powder. Approximately 16mg of this homogenized tissue was sub-sampled, digested overnight in protease K, followed by bead-beating, and total DNA was extracted using the Digestion Workflow for the MagMAX CORE Nucleic Acid Purification Kit on a KingFisher Flex purification system. A synthetically produced gene fragment, gBlock (Integrated DNA Technologies), was used for the standard curve. The Limit of Quantification (LOQ) for was 5 gene copies per reaction, corresponding to a C_T value of approximately 32.3. Only samples with quantifiable gene copies (i.e., ≥ the LOQ) were considered positive. Copies per reaction was converted to copies per gram of wet tissue after accounting for the dry mass used in the extraction and the moisture content lost during desiccation. A validated qPCR was performed to quantify the amount of *Ichthyophonus* present as previously described by (White et al. 2013) that targets the 18S rDNA gene.

Juvenile Salmon Origin

Caudal fin clips were collected from all juvenile Chinook and coho salmon and from a subsample of juvenile sockeye, pink, and chum salmon measured at each station. Pectoral fin clips were collected from immature Chinook and chum salmon. Chinook and coho salmon fin clips were placed on Whatman paper cards and fish barcode IDs (fish IDs assigned on the survey) were recorded on each card. Caudal fin clips from juvenile chum, pink, and sockeye salmon, and pectoral fin clips from immature chum salmon were placed on plastic wrap and frozen by species and by station. All genetic tissue samples were shipped to the ADF&G Gene Conservation Lab as part of the cooperative NOAA-ADF&G research on salmon stock origins.

Chinook Salmon

DNA was extracted from juvenile Chinook salmon fin clips 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 (Canadian-origin), and Other Western Alaska. Estimates from the three intra-Yukon River groups (Lower Yukon, Middle Yukon, and Upper Yukon) were summed to estimate the total Yukon River stock contribution.

Chum Salmon

DNA was extracted from juvenile chum salmon fin clips using the NucleoSpin 96 Tissue Kit (Macherey-Nagel, Düren, Germany). For juvenile chum salmon collected during the 2003-2007 surveys, samples were genotyped at 11 microsatellite genetic markers included in a coastwide chum salmon baseline of 381 populations (Beacham et al. 2009). For juvenile chum salmon collected during the 2009-2021 surveys, samples were genotyped at 96 SNPs common to the Western Alaska Salmon Stock Identification Program (WASSIP) baseline of 310 populations was performed on the juvenile chum salmon samples (DeCovich et al. 2012). Stock compositions were estimated by comparing juvenile genotypes with reference baseline allele frequencies using mixed-stock-analysis (MSA) with the R package rubias (Moran and Anderson 2019), a Bayesian approach to the conditional genetic stock identification model. Quality control analyses were the same as those performed for juvenile Chinook salmon and described above. Estimates are reported for five reporting groups: Asia, Kotzebue Sound, Coastal Western Alaska, Yukon fall run (henceforth fall chum, which includes both U.S. and Canadian stocks of chum salmon), and Other, which is comprised of populations originating from the northern part of the Alaska Peninsula, Gulf of Alaska, British Columbia and U.S. Pacific Northwest river systems. Contributions of juvenile chum salmon from the fall chum salmon reporting group were used to estimate a stock-specific juvenile chum salmon abundance index.

Juvenile Salmon Abundance

Chinook Salmon

Methods for estimating juvenile Chinook abundance were initially described in Murphy et al. (2017) and minor revisions to this approach are described in Howard et al. (2019), Howard et al. (2020), and Murphy et al. (2021). 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 to 62°N), 2) Upper NBS (62° to 64°N), 3) Norton Sound, and 4) the Bering Strait region. The average CPUE within each stratum *n*, was estimated by dividing the total catch by the total effort as

$$CPUE_n = \frac{\sum_{i=1}^{I} C_{ni}}{\sum_{i=1}^{I} a_{ni}},$$

where C_{ni} and a_{ni} are the MLD adjusted catch and area swept, respectively, for station *i* and stratum *n*, and *I* is the total number of stations in stratum *i* (Quinn and Deriso 1999). The variance of *CPUE* by strata was defined as

$$V(CPUE_n) = \frac{I}{I-1} \frac{\sum_i^I (C_{ni} - CPUE_n \cdot a_{ni})^2}{\left(\sum_i^I a_{ni}\right)^2}.$$

The area sampled within each strata (A_n) 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 to 2015, and 2017 were used to adjust abundance estimates in years when these strata were not sampled (2004 to 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 simply the weighted average based on the strata area as

$$CPUE_A = \sum_n \frac{A_n}{A} CPUE_n,$$

$$V(CPUE_A) = \sum_n \frac{A_n}{A} V(CPUE_n).$$

Juvenile abundance ($\widehat{N}$) and variance V($\widehat{N}$) estimates for the survey were calculated as

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

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

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 two random variables (*X* and *Y*) using the Delta method as

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

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 River 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 the linear regression model between juvenile abundance and adult returns. The majority of Yukon River Chinook salmon spend a full year growing in fresh water 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 2 to 4 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 and the total Yukon River drainage (JTC 2023).

No survey was conducted in 2020 due to health and safety restrictions associated with the COVID-19 pandemic and this prevents juvenile-based run forecasts using measured abundance for 2023 and 2024. Model-based estimates of juvenile abundance in 2020 were generated with Kalman smoothing of a structural time series model (Moritz and Bartz-Beielstein 2017) of juveniles-per-spawner and scaled to juvenile abundance based on spawner abundance. Time series models were applied to juveniles-per-spawner rather than juvenile abundance as the temporal autocorrelation of juveniles-per-spawner (0.48) was higher than juvenile abundance (-0.12) during the 10 years of continuous juvenile abundance estimates, (2009 to 2019).

Chum Salmon

CPUE abundance indices for juvenile chum salmon were calculated for each survey year by summing the juvenile chum salmon catch for all stations sampled within the NBS and dividing by the total area swept:

$$CPUE_y = \left(\frac{\sum_{i=1}^{I} c_{yi}}{\sum_{i=1}^{I} a_{yi}}\right)$$

Where C_{ix} is the catch at station *i* summed across all stations sampled (*I*) in year (*y*), divided by total effort, *a*, equal to the total area swept (distance trawled multiplied by the horizontal opening of the trawl) across all stations sampled (*I*) in year *y*. The variance for the annual juvenile chum salmon CPUEs were calculated as (Quinn and Deriso 1999):

$$V(CPUE_y) = \frac{I}{I-1}\frac{\sum_i^I \left(c_{yi} - CPUE_y \cdot a_{yi}\right)^2}{\left(\sum_i^I a_{yi}\right)^2}.$$

Year-specific juvenile fall chum salmon CPUEs were calculated by multiplying the annual juvenile chum salmon CPUE by the mean genetic stock composition for fall chum salmon. For years missing genetic stock compositions (i.e., 2009 and 2013), the average fall chum salmon stock composition for adjacent years was used. The variance of stock-specific abundance indices were derived from a Taylor series approximation to the multiplicative variance of 2 random variables (*X* and *Y*) using the Delta method as described above for juvenile Chinook salmon.

Fall chum salmon adult returns corresponding to spawner years 2002–2016 were linearly regressed against juvenile fall chum salmon CPUE abundance estimates from 2003–2017 to describe marine survival and assess the suitability of using juvenile fall chum salmon CPUE as a predictor for future adult returns.

Pink Salmon

Due to the limited ability to genetically distinguish stock structure in pink salmon, genetic stock identification analyses have not been completed on juvenile pink salmon. The spatial distribution (Farley et al. 2005) and size structure (Moss et al. 2009) of juveniles support the interpretation that most of the juvenile pink salmon originate from the northern Bering Sea; however, juveniles from other production regions (e.g., Kotzebue Sound and Russia) are likely present in the northern Bering Sea (Farley et al. 2005). 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). The juvenile abundance index for pink salmon, N_y, was estimated as:

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

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

where C_{iy} is the catch at station *i* and year *y*, *l*, is the number of stations in 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.

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

Salmon Shark Tagging

Salmon shark (*Lamna ditropis*) captured during surface trawl operations were tagged with both a satellite transmitting (SPOT-257; Wildlife Computers, Redmond, California, USA) and an archival tag (miniPAT, Wildlife Computers, Redmond, California, USA). Sharks were tagged using established methodologies for reducing stress and attaching tags (Weng et al. 2005, Biais et al. 2017). Briefly, upon removing the shark from the codend of the net, a wet towel was placed over the shark's eyes to reduce stress during the tagging process. The archival tag was inserted using two attachment points in the shark's musculature. The satellite transmitting tag was affixed to the dorsal fin using hardware provided by the tag manufacturer. Tag specifications and programming details can be found in Garcia et al. (2021). In addition to tagging, sex was determined by the presence or absence of claspers (present in males) and total length (TL, tip of snout to tip of the tail along the horizontal axis of the body) was measured (m). A fin clip was taken from the rear tip of the dorsal fin and archived for future genetic analysis.

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 to 19 September 2021. 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 10 × 42 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

CTD data were collected at 53 stations in 2021 (Table 3). Surface temperatures (upper 10 m) ranged from 7.3°C to 10.9°C for the planned stations during the survey (n = 46) with an average of 9.3°C (strata 1-6 and 8), which was just slightly above the average SST index for the NBS (9.1°C) (Fig. 4, Table 4). Surface and bottom temperatures were highest in the shallow nearshore stations and in Norton Sound. Surface temperatures were coldest at stations northeast of St. Lawrence Island (Fig. 5). Bottom temperatures were much colder due to the presence of the eastern Bering Sea cold pool and were coldest just south of St. Lawrence Island (Fig. 5). Surface salinities ranged from 24.4 PSU to 32.2 PSU. The lowest salinities were in Norton Sound and just outside the Yukon River Delta with salinity increasing with distance from shore (Fig. 6). Mixed layer depths ranged from 6 m to 36 m with an average of 13 m (strata 1-6 and 8) (Table 3, Fig. 7).

Abundances of large copepods in the northern Bering Sea were generally below average across the sampling grid, with the exception of a few stations in the northern portion of the survey (Fig. 8). Average abundance of large copepods estimated by RZA in 2021 were higher than in 2018 and 2019, but low compared to the colder years of 2011-2013 (Fig. 9). The abundance of small copepods was higher in the northern part of the sample area (Fig. 8). The numbers of small copepods was fairly consistent with values measured over the last 7 years (Fig. 9). In contrast, euphausiid numbers were slightly higher in the southern portion of the northern Bering Sea (Fig. 8) with numbers slightly higher compared to recent prior estimates (Fig. 9).

Benthic Ecology

Benthic Grab

Benthic sediment samples were collected at 13 stations. HABs cyst counts have been completed and will be incorporated into the HABs study. Sediment lipid analyses have been completed and will be incorporated into the snow crab (*Chionoecetes opilio*) condition study.

Beam Trawl

The beam trawl was successfully deployed at 40 stations. The distances fished at each station ranged from 150 to 489 m with a mean of 290 m. Tow speed ranged from 0.5 to 1.7 kts with a mean of 1.3 kts. Station depths for successful beam trawls ranged from 17 to 57 m.

Some important subsistence and commercial species caught in the beam trawl included Pacific cod, saffron cod, yellowfin sole, and snow crab. Pacific cod ranged in size from 4.4 to 6.6 cm standard length (SL), and were caught at two stations in the southern part of the survey area and at three stations offshore of Norton Sound (Appendix Fig. B16). These small Pacific cod are likely age-0 fish. All Pacific cod were caught at depths greater than 20 m. Saffron cod ranged in size from 4.2 cm SL to 26 cm fork length (FL), and included age-0 and age-1+ fish. Saffron cod were preserved for aging. Saffron cod were exclusively caught in the northern half of the survey area (Appendix Fig. B17), and most stations with saffron cod present were at depths less than 20 m inside Norton Sound. Yellowfin sole ranged in size from 3.7 to 37.6 cm, and were caught in the nearshore half of the survey area.

Chionoecetes spp. crab were separated into two size categories (<= 15 mm, and >15 mm carapace width). The smaller size category remained as *Chionoecetes* spp. at sea due to difficulty in distinguishing species in this size range. Genetic analysis after the survey confirmed that all of the small crab were also snow crab. All crab in the larger size category were identified as snow crab at sea. The <= 15 mm carapace width snow crab were caught in two areas; south of St. Lawrence Island, and in nearshore areas south of Bering Strait (Appendix Fig. B19). The larger snow crab (>15-45 mm carapace width) were present in the same two general areas, but were distributed slightly offshore of the small crab in each area (Appendix Fig. B20). The smallest snow crab inhabited bottom temperatures ranging from 0.7 to 7°C. This is an important result because snow crab < 40 mm carapace width have only been reported in temperatures <2 °C (Dionne et al. 2002), and the effects of these higher temperatures on crab condition are unknown. Two hundred snow crab <= 15 mm were frozen and shipped to the AFSC Fish and Behavioral Ecology program laboratory in Newport, Oregon for lipid analyses and results will be reported in a separate report.

Surface Trawl

Bottom depths at stations sampled during the survey ranged from 17 m to 70 m (Table 2). Bottom depths recorded during the survey were increased by 2 m to account for the transducer depth of the vessel. Footrope setback chains were shortened to collapse the vertical opening of the trawl when sampling locations with bottom depths less than approximately 22 m. The average horizontal and vertical opening of the trawl was 49.4 m and 19.8 m, respectively. The average footrope depth from the SeaBird SBE39 depth sensor was 21.4 m (Table 5), indicating that the average depth of the center of the headrope (where the net sonar is located) was 1.8 m. The average distance towed during each 30 minute trawl set (based on GPS coordinates of the start and end of each tow) was 3.8 km, which results in a calculated average speed of 4.2 kts. Overall MLD expansion was 0.09 and ranged from 0.0 to 0.91 (Table 5).

Pink salmon were the most abundant species of juvenile salmon at 3,230 fish, followed by chum salmon at 2,525 fish (Table 6). Northern sea nettle (*Chrysaora melanaster*) had the largest catch biomass at 2,590 kg, and age-0 walleye pollock (*Gadus chalcogrammus*) had the largest catch in numbers at 81,677 followed by age-0 Pacific herring at 33,612 (Tables 7 and 8). The catch of Arctic or Pacific sand lance (*Ammodytes* spp., n = 463) was atypical as nearly all individuals were the age-0 stage. Age-0 sand lance are rarely captured in the surface trawl due to the mesh size of the cod-end liner and they can only be retained when jellyfish prevent them from going through the cod-end liner (12 mm mesh). Their abundance was likely much higher than indicated by their catch in the surface trawl. The catch of capelin (*Mallotus villosus*, n = 459) was higher than 2019 and likely reflects the return to average temperatures in the NBS (Andrews et al. 2016).

The spatial distribution of fish captured in surface trawls varied significantly by species (Appendix B). Surface trawl catch rates of juvenile salmon were all highest in the nearshore stations of the survey. Typically, both pink and chum salmon are more broadly distributed throughout the survey area than other species of juvenile salmon. This likely reflects a combination of reduced abundance of these species and a limited dispersal from the nearshore habitats during 2021. Age-0 walleye pollock had high CPUEs west of 167.5°W and south of 63°N and were the most abundant fish species captured during the survey. The catch of age-0 Pacific cod was also high and they were present in the same region as age-0 walleye pollock.

The size distributions for the primary species captured in surface trawl catches are summarized in Figures 10 to 13. Individual lengths and weights of juvenile salmon (Appendix C) identify relatively stable relationships between length and weight. The average size of Chinook, pink, and chum salmon in 2021 were all relatively consistent with their overall average size (Fig. 13). There was not a consistent trend in the date-adjusted length of juvenile salmon within or between species across the time series (Fig. 13), which emphasizes the importance of species-specific factors in the size and growth of juvenile salmon. Chinook salmon typically spend one year in fresh water before migrating to sea, whereas pink and chum salmon migrate to sea directly during the same year of hatching. This is reflected in their overall date-adjusted length (Chinook salmon 20.8 cm, pink salmon 16.2 cm, and chum salmon 17.4 cm). Coho salmon typically spend one or two years in fresh water before migrating to sea and therefore have the largest overall average size (27.6 cm) (Table 9). The average date-adjusted length of coho salmon in 2021 (25.4 cm) was below average and has been below average since 2018. This likely reflects a shift in the freshwater age structure of coho salmon; however, it will not be possible to distinguish between a change in age structure or growth of juvenile coho salmon until juvenile coho salmon otoliths have been aged.

The average length of juvenile salmon was not correlated with temperatures measured during the survey (Table 10), and emphasizes the importance of factors other than temperature such as age structure, timing of marine entry, and diet in their size distribution over time. The size of juvenile salmon could still be related to temperature, but at different space and time scales measured during the survey. Overall catch of immature salmon was low in 2021 (n = 54), largely due to the low catch of immature chum salmon (n = 9), which are typically the most abundant species of immature salmon captured during the survey. Immature Chinook salmon (n = 36) catches were primarily ocean age-1 (Fig. 11) and this is reflected in the relatively low overall average fork length of 46 cm (Fig. 11). The average length of walleye pollock (5.3 cm) was lower than the average length of age-0 Pacific herring (7.3 cm) and age-0 Pacific cod (8.9 cm) (Table 8, Fig 12). The average length of non-age-0 Pacific herring (18.4 cm) was smaller than walleye pollock (24.6 cm) primarily due to the younger ages (primarily age-1 and age-2) of Pacific herring captured during the survey (Fig. 12).

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 to avoid predators and maintain high energy reserves necessary to survive their first winter at sea (Beamish and Mahnken 2001). 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, and Beamish and Mahnken 2001, Moss et al. 2005, Howard et al. 2016), 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.

Juvenile Salmon Trophic Ecology

Diet

Stomach fullness and prey composition of juvenile salmon diets analyzed between 2004-2021 survey years are summarized in Figs. 14 to 18. Station numbers, the number of stomachs sampled, mean SFI and juvenile salmon diets are also summarized in Appendix D.

Chinook salmon fed primarily upon fish in the NBS (Fig. 14) which has also been reported by previous investigations (Cook and Sturdevant 2013, Garcia and Sewall 2021). Fish composed 88.9% of the diet of Chinook salmon on average during 2004-2017, but decreased to 72.8% on average during 2018-2019, then increased to 95.3% in 2021. 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), where fish prey were not taxonomically identified to species and thus the presence of capelin could not be detected. From this year, a large percent of the diet was still fish however. From 2014-2021, the presence of capelin declined to 0-11.0%, and were absent from the diet in 2019 and 2021 (Fig. 14). Concurrent with the decrease and disappearance of capelin from the diet 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. In 2021, diets reverted to higher piscivory, with sand lance (32.4%), Pacific herring (26.9%) and unidentified fish (21.7%) contributing to the total diet. Our findings highlight key features in the feeding ecology of juvenile Chinook salmon in the NBS and identify areas of potential concern.

Chum salmon fed upon gelatinous plankton, fish, hyperiid amphipods, and euphausiids in most years (Fig. 15). The proportion of hyperiid amphipods, which are rich in fatty acids (Persson and Vrede 2006), increased during cool years (2006-2012) (Appendix D). 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 salmon fed on a combination of fish and zooplankton, confirming findings from previous investigations (Cook and Sturdevant 2013). Pink 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 (Fig. 16).

Coho salmon preyed primarily upon sand lance, age-0 walleye pollock, capelin, and other fish (Fig. 17). Capelin increased in coho salmon diet 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, consistent with increased catches and of age-0 walleye pollock in the NBS and northward with warm temperatures (Murphy et al. 2021).

The average stomach fullness index (SFI) for all juvenile salmon has declined as SSTs have increased in the NBS, except for coho salmon (Fig. 18). The average annual (years between 2004-2021) SFI was similar for Chinook (152), and pink salmon (155), higher for coho salmon (170), and lower for chum salmon (126). The average SFI in 2021 for Chinook (97), coho (125), and pink salmon (138), were below average; but average SFI for chum salmon (124) was close to average and much higher than 2019 (48). 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 (Weitkamp and Sturdevant 2008), and an increase in prey diversity may indicate more generalized feeding and a greater reliance on non-preferred prey items (Weitkamp 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).

Energetic Condition

The overall average energy density for each species of juvenile salmon were similar and ranged from 21.69 kJ/g for pink salmon to 22.01 kJ/g for coho salmon (Table 11). Juvenile salmon species showed a similar parabolic relationship of mean annual energy density with annual sea surface temperature (°C) of the Northern Bering Sea ($R^2 > 0.56$, Fig. 19). This response is consistent with trends observed in metabolic growth (Beauchamp 2009) and feeding (Handeland et al. 2008) responses to temperature in salmon. Lower temperatures impose lower metabolic demands, leading to lower feeding and growth rates (Brett 1971), whereas at higher temperatures beyond an optimum, metabolic and growth demands and reduced prey quality can reduce energy available for growth and survival (Daly and Brodeur 2015). Reduced growth rates may increase the susceptibility of salmon to factors of size-dependent mortality of predation (Pyper and Peterman 1999, Saito et al. 2011) and overwintering survival (Beamish et al. 2004).

Ichthyophonus Investigations

Juvenile and immature Chinook salmon heart samples were opportunistically collected during the 2021 NBS survey to assess when Chinook salmon may become infected during their marine phase. In 2021, 30 juvenile Chinook salmon and 34 immature Chinook salmon had heart samples taken for laboratory analysis. Of the collected samples, 16 out of 64 tested samples (25.0%) had *Ichthyophonus*-positive hearts (Table 12).

None of the juvenile Chinook salmon sampled from the NBS had *Ichthyophonus*-positive hearts. However, nearly half of the immature Chinook salmon samples were infected with a median intensity of infection regarded as fairly high at 2.0×10^7 gene copies/g, and as much as 25% of the infected samples having as many as $\geq 10^8$ gene copies/g. In comparison, Yukon River samples collected from Pilot Station Sonar had a median intensity of 7.0×10^7 gene copies/g and almost 45% of infected fish had values of $\geq 10^8$ gene copies/g (ADF&G Fish Pathology Lab Report Acc. No. 21-0039). Gene copy number is an abstract metric for infection that may include both viable and unviable parasites. Therefore, histology should be performed in the future to estimate parasite counts, assess associated pathology and other infections, and evaluate correlations between test methodologies.

Laboratory analysis results should become available more quickly going forward now that the methodologies for assessing *Ichthyophonus* infection have been established. Such work would be better supported by including histology samples to quantify parasite numbers in histological sections which would also provide valuable information about inflammation, disease state, and the occurrence of other infectious or non-infectious diseases. A summary of raw data collection can be found in Appendix E.

Interestingly, of the juveniles that were sampled from the Norton Sound stations, none were infected, where many of the juvenile salmon encountered are considered to have recently entered the marine environment residing near shore before they disperse into the Bering Sea. This may indicate that at least during the very early marine residency these fish have not yet become infected. Larger and older Chinook salmon from offshore sites would be expected to have a higher infection given that infections accumulate overtime from feeding on infected prey fish species.

In summary, none of the sampled juvenile Chinook salmon were infected with *Ichthyophonus* but nearly half the immature Chinook were infected and 25% of these infected immatures had high infections based on qPCR analysis. The lack of infection in juvenile Chinook salmon suggests that infection does not occur until later in their marine life. Larger, older fish are expected to be more infected as infections accumulate over time from feeding on infected prey fish species; however, the prey species contributing to the infections are poorly understood. There is some evidence that fish may obtain many new infections just prior to their upriver migration on the Yukon River (Dr. Richard Kocan, Univ. Wash, pers. comm.). Indeed, this was observed in a subset of fish tested at Pilot Station in 2021 where some fish had many small parasites representing new infections as the parasite grows with time within the fish host.

Juvenile Salmon Origin

A total of 155 juvenile Chinook salmon were successfully genotyped for mixed-stock-analysis (MSA) during 2021. Mean stock composition estimates were: 47% Upper Yukon (the Canadian-origin stock group), 14% Middle Yukon, 18% Lower Yukon, and 22% Other Western Alaska (non-Yukon River) stocks (Table 13, Fig. 20). The proportion of Canadian-origin Chinook salmon was very similar to its historical average of 46%. The proportion of Middle Yukon River Chinook salmon was nearly half of its historic average of 26% and the proportion of Lower Yukon River Chinook salmon was slightly above their historic average of 13%. The proportion of non-Yukon River Chinook salmon was above their historic average of 14% (Fig. 21).

A total of 384 juvenile chum salmon were successfully genotyped for MSA during 2021. Mean stock composition estimates were: 34% Yukon fall run, 56% Coastal Western Alaska (including Yukon summer run), 10% Kotzebue Sound, 0% Asia, and 0% Other Alaska stocks. The proportion of Yukon fall run chum salmon was above the historical average of 23%.

Although no coded wire tags (CWTs) were recovered in 2021, the multi-year distribution of CWTs identifies the distribution of hatchery Chinook salmon from the Whitehorse Rapids Fish Hatchery (WRFH) (the only hatchery in the Yukon River, but are released at many locations throughout the Yukon Territory). All WRFH Chinook salmon are tagged and the NBS survey has only recovered CWTs from this stock of Chinook salmon. These tag recoveries have confirmed that all WRFH Chinook salmon exhibit a subyearling migration behavior where they migrate to sea without spending a full year in freshwater. They are typically captured within the nearshore stations adjacent to the Yukon River Delta and Norton Sound (Appendix F).

Juvenile Salmon Abundance

Chinook Salmon

The overall abundance of juvenile Chinook salmon in the NBS during 2021 (2.0 million fish) was below average (3.1 million fish) (Table 14). On average, abundance estimates of juvenile Chinook salmon were expanded by 8% (MLD adjustment) to account for incomplete sampling of the mixed layer. The abundance of Canadian-origin juvenile Chinook salmon (957,000) was below average (1.47 million) in 2021 (Table 14, Fig. 22). The abundance of Yukon River juvenile salmon (1.6 million) was also below average (2.66 million) in 2021 (Table 14, Fig. 22). Juvenile Chinook salmon caught during the 2021 survey will contribute to adult runs in 2023 (as age-4), 2024 (age-5), and 2025 (age-6). The number of juveniles-per-spawner for the Canadian-origin stock group in 2021 (22.8) increased from their record low level in 2019 (8.4), but it was still below average (32) (Table 14).

Juvenile abundance is significantly ($\rho < 0.001$) correlated to the number of adult Chinook salmon returning to the Yukon River up to 3 years into the future (Fig. 23). Both the Canadian-origin and total Yukon runs are expected to remain below average for the next several years due to low juvenile abundance in 2019 and 2021. Although juvenile abundance has been a reliable indicator of expected run, the run size for the Canadian-origin stock group in 2022 (13,144, JTC 2023) was below the range expected based on juvenile abundance (25,000 – 56,000, Fig. 17) and the pre-season abundance estimates by the Joint Technical Committee (JTC) of the Yukon River Panel (41,000 – 62,000, JTC 2023). The total Yukon River run in 2022 (51,000) was also below the juvenile-based outlook (86,000 - 177,000) in 2022 and points to an atypically low marine survival or undocumented in-river mortality of the Chinook salmon returning to the Yukon River in 2022.

The run-size of Canadian-origin stock group is measured at different locations in the Yukon River and these estimates will differ due to estimation uncertainty and when mortality occurs during their upstream migration. The run-size of Canadian-origin Chinook salmon is currently estimated by the JTC from estimates of their passage at the border between the US and Canada (Eagle sonar) plus the harvest within the US portion of the drainage. The number of Yukon River Chinook salmon that pass river mile 120 is estimated at Pilot Station sonar (near the mouth of the Yukon River) and is used for in-season fisheries management. The number of Canadian-origin Chinook salmon in 2022 estimated using Pilot Station sonar and genetic data was 21,600, which was lower than the juvenile forecast range of 25,000 – 56,000 and larger than the estimate of 13,144 based on Eagle sonar plus harvest. As no directed salmon harvests were permitted in the Yukon River in 2022, the differences in run-size estimates likely reflects the presence of en-route mortality, as the estimation uncertainty does not account for the magnitude of the differences observed between the two sonars (JTC 2023). This may be due to the particularly high level of *Ichthyophonus* infections in Chinook salmon during 2022 (JTC 2023).

Run-size forecasts are of particular interest to managers, biologists, and stakeholders within the Yukon River as it supports fisheries management decisions that protect the spawning stock and subsistence, commercial, personal use, and sport fisheries. The 80% prediction interval for the juvenile-based run projections for the Canadian-origin stock group in 2023 (22,000 - 56,000, Fig. 24) is similar to the official outlook provided by the JTC (26,000 – 43,000, JTC 2023), and the point estimate (39,000) is below the escapement goal for this stock group (JTC 2023). Although the forecast in 2024 (44,000) is higher than 2023, the forecast range (27,000 - 61,000) includes run sizes that are below the escapement goal. The outlook in 2023 and 2024 should be considered cautiously due to the poor performance of the 2022 outlook and their dependence on modeled juvenile abundance and not measured juvenile abundance. The current state of the run in 2023 (ADF&G 2023) indicates a run size similar to 2022 and is again likely to come in below or near the low end of the predicted range. The JTC is considering options to implement dynamic juvenile forecast models to account for time-varying marine survival of the Canadian-origin stock group.

Measurement error is a key limitation in the analysis and interpretation of juvenile distribution and abundance. 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 have restricted abundance estimates of juvenile Chinook salmon to large stock groups such as the total Yukon River stock group (average proportion of 85%) and the Canadian-origin stock group (average proportion of 47%), 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.

Chum Salmon

Annual juvenile chum salmon abundance indices (CPUE; number of juvenile chum salmon/km^2) in the NBS have been highly variable between 2003 and 2021, ranging from a low of 37 fish/km^2 in 2005 and a high of 476 fish/km^2 in 2019 (Fig. 25). Standard errors of juvenile chum salmon abundance indices are extremely large in some years (e.g., 2009 and 2013). The 2021 juvenile fall chum salmon abundance index was 97 fish/km^2 which was well above the time series average (43 fish/km^2) and was the highest abundance index in the time series (Fig. 25). However, as seen in other years in the time series, the uncertainty associated with the 2021 abundance index is extremely large and likely due to the large number of stations with zero juvenile chum salmon caught coupled with a few stations with relatively large catches (Appendix Fig. B1).

Brood year return data for fall chum salmon are available from 2002 - 2017. However, the age-6 component for brood year 2017 is estimated based on the age-6 returns from previous years. The relationship between juvenile fall chum salmon to adult returns does not exhibit a strong linear trend like we see in Chinook salmon (Fig. 26). Juvenile fall chum salmon abundance indices generally resulted in increased adult returns between juvenile years 2003 and 2015, suggesting a consistency in later marine survival during these years and indicating factors determining adult abundance may also be occurring sometime before their first winter in the ocean. Juvenile years 2016 - 2018 all resulted in adult returns that were lower than expected based on years with similar juvenile abundance indices. From 2016 forward, later marine drivers of mortality (post-juvenile stage) became more important to determining adult return abundance.

Concurrent with this switch to later drivers of marine mortality in 2016 were the onset of marine heatwaves in the Bering Sea and Gulf of Alaska. The eastern Bering Sea has been in a warm phase since 2014, and experienced marine heatwave conditions between 2016 and 2019 (Siddon 2021). The Gulf of Alaska experienced marine heatwave conditions between 2014 and 2016 and again in 2019 (Ferriss and Zador 2021). Higher ocean temperatures increase metabolic demands, which require salmon to consume more food to meet their energetic needs. Additionally changing temperature regimes are associated with changes in the abundance, quality, and distribution of salmon prey (Siddon 2021). For juvenile chum salmon, the amount of food in their stomachs decreases with increasing sea surface temperature (Fig. 18). Additionally, the amount of energy stored by juvenile chum salmon also decreases with increasing sea surface temperature (Fig. 19). Juvenile chum salmon from the Yukon entering the Bering Sea after 2016 have been faced with marine heatwave conditions in the Bering Sea and the Gulf of Alaska, and evidence suggests they may not have stored enough energy during their first summer at sea to survive in later marine life. Though temperatures in both the Bering Sea and Gulf of Alaska rebounded to average levels in 2020 and 2021 (Siddon 2021, Ferriss and Zador 2021), lag effects of marine heatwave conditions may persist even after temperatures have returned to normal. Factors associated with these marine heatwaves may be driving the dramatic decline in Yukon River chum salmon abundance seen in recent years. The large juvenile fall chum salmon abundance index (Fig. 25), a return to average sea surface temperatures (Fig. 4), and high energy density values (Fig. 19) for juvenile chum salmon in 2021 might suggest an improvement in adult returns in the near future. However, caution is warranted in drawing conclusions between the juvenile abundance index and adult returns given the large uncertainty in the 2021 juvenile fall chum salmon abundance index.

Further refinements to the model structure may improve the juvenile to adult relationship for fall chum salmon. Genetic analyses on juvenile chum salmon caught in the eastern Bering Sea have shown that fall chum salmon are found in the greatest proportion south of 60° N (Kondzela et al. 2016). Given the high proportion of fall chum salmon in the southern Bering Sea, future iterations of the juvenile fall chum salmon model will include catch and effort data from both the northern and southern Bering Sea. Including data from both survey platforms will ensure that the juvenile fall chum salmon population is adequately sampled. Additionally, while linear models have been effective for predicting Chinook and pink salmon returns, alternate model structures may be necessary to deal with the zero-inflated juvenile chum salmon catch data or incorporation of environmental covariates, such as sea surface temperature, to address the effects of temperature on juvenile chum salmon condition and ultimately marine survival.

Juvenile chum salmon abundance models will be inherently more complicated than those for Chinook salmon given the relatively high dispersal rate for juvenile chum salmon and uncertainties in their vertical distribution in the water column. Inter-annual changes in dispersal rate can bias CPUE indices and genetic stock proportions of fall chum salmon such that annual abundance indices may not be indicative of the true juvenile fall chum salmon abundance. Years like 2021 where most of the juvenile chum salmon were caught at nearshore stations may suggest a mismatch between survey timing and juvenile chum salmon dispersal rates. MLD adjustments to chum salmon CPUE indices did not improve the relationship between juvenile and adult abundance and, therefore, were not applied to the juvenile models. Juvenile chum salmon could be more surface oriented than Chinook salmon so MLD corrections may not be needed for chum salmon. Juvenile chum salmon models will continue to be refined over time in the hopes of producing a forecasting tool that can be used by managers and stakeholders to anticipate future fall chum salmon returns.

Pink Salmon

A relative index of abundance of juvenile (first year at sea) pink salmon was constructed from late-summer (typically September) surface trawl and oceanographic surveys in the northern Bering Sea (NBS). The index is based on trawl catch-per-unit-effort data (log) and mixed layer depth, and has ranged from 0.9 to 5.4 with an overall average of 3.0 from 2003 to 2021 (no surveys in 2008 and 2020) (Fig. 20). The juvenile index is significantly correlated with an index of pink salmon returns to Yukon and Norton Sound rivers and provides an informative tool to forecast adult returns to these regions (Fig. 21). The juvenile index for 2021 was 0.9, which provided an expected adult return index of approximately 500,000 pink salmon in 2022. The actual adult return index in 2022 was significantly higher at approximately 1.5 million pink salmon. Refinements and updates to the juvenile pink salmon model may be required to ensure it remains an informative tool for this region.

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 (fresh water 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. Support for this interpretation was provided by the observation that 76% of the juvenile chum salmon in the Bering Strait region were from Russia during the 2007 NBS survey (Kondzela et al. 2009).

Salmon Shark Tagging

A male salmon shark measuring 2.2 m (TL) was successfully tagged with both a satellite transmitting and archival tag on September 6, 2021 at station 21. This individual was the third male salmon shark tagged during NBS surface trawl operations (Garcia et al. 2021). Unfortunately, the satellite transmitting tag failed 3 months after deployment and no further surface locations were reported after December 2, 2021. The archival tag popped off 9 months after it was deployed to protect the tag from extreme pressures over 1,600 m. Preliminary analysis of the depth and temperature data show that the salmon shark was actively moving throughout the water column throughout its time at liberty, primarily between the surface and 500 m. It is unknown what would have caused the shark to undertake such a deep dive. Archival tag data from salmon sharks tagged in other parts of Alaska show that sharks are able to undertake deep dives but spend most of their time at or near the surface, especially in summer months (Carlisle et al. 2011). Salmon shark tagging efforts will continue on future NBS surveys.

Seabird and Marine Mammal Observations

The data presented here includes observations within the survey area in the northern Bering Sea, including Norton Sound, as well as data collected during our transit to and from Dutch Harbor, AK. Line transect assessments of seabird abundance was monitored for a total of 3,063 km over 131 hours and a total of 40 avian species consisting of 5,080 birds on transect (Table 15) and another 1,008 birds off transect during the NBS survey in 2021. Distribution maps of the commonly seen species are available in Appendix G.

Seabirds

Shearwaters were the most abundant taxa encountered and included unidentified shearwaters, sooty shearwaters (*A.griseus*), and short-tailed shearwaters (*A. tenuirostris*), with nearly all identified being the latter species. Shearwaters were 60.6% of total birds encountered with 1 bird/linear km (Table 15). Shearwaters were widespread, with highest numbers encountered south of St. Lawrence Island and east of St. George Island (Fig. G1). Northern fulmars (*Fulmaris glacialis),* another member of the *Procellariidae* family, were 4.4% of total birds (Table 15). Northern fulmars were widespread, including in the Chirikov Basin, but they were most abundant in the southern Bering Sea (Fig. G2).

Eight species of the Laridae family were observed, including red-legged kittiwakes (*Rissa brevirostris*), black-legged kittiwakes (*R. tridactyla*), Sabines gull's (*Xema sabini*), herring gulls (*Larus argentatus*), glaucous gulls (L. *hyperboreus*), glaucous-winged gull (*L. glaucescens*), Caspian terns (*Hydroprogna caspia*), and Arctic terns (*Sterna paradisaea*) (Table 15). Total larids recorded resulted in 0.16 birds/linear km), with kittiwakes the most frequently encountered. Black-legged kittiwakes were widespread but were most abundant in the southern Bering Sea (Fig. G3).

Alcidae species recorded included thick-billed murres (*Uria lomvia*), common murres (*U. aalge*), ancient murrelets (*Synthliboramphus antiquus*), marbled murrelet (*Brachyramphus marmoratus*), parakeet auklets (*Aethia psittacula*), crested auklets (*A. cristatella*), least auklets (*A. pusilla*), Cassin's auklets (*Ptychoramphus aleuticus*), pigeon guillemots (*Cepphus columba*), horned puffins (*Fratercula corniculate*), and tufted puffins (*F. cirrhata*), which together comprised 17.6% of all birds (Table 15). Linear densities for this group ranged from < 0.001 (marbled murrelet) to 0.06 birds/km (common murres) (Table 15). Of the *Aethia* genus (5.9% of all birds), parakeet auklets accounted for 46.8% of the auklets and were the most widespread; most auklets were in the northern Bering Sea (Fig. G4).

Thick-billed murres (*Uria lomvia*) and common murres (*U. aalge*) comprised 30.5% of all alcids and 5.4% of total birds observed. Common murres were the most abundant (Table 15), and both species were more frequently observed south of St. Lawrence Island (Fig. G5). Horned and tufted puffins (genus *Fratercula*) comprised 3.6% of total birds, with tufted puffin being the most abundant overall. The majority of the *Fratercula* spp. were tufted puffins (88%) (Table 15). A large number of ancient murrelets (n = 53) were observed (Table 15), primarily between Nunivak and St. Lawrence islands.

All three Endangered Species Act (ESA)-listed marine birds were recorded during this survey: short-tailed albatross (*Phoebastria albatrus*), Steller's eider (*Polysticta stelleri*), and spectacled eider (*Somateria fischeri*) (Fig. G6). On the early morning of 12 September, one female and one first winter Steller's eiders landed on the ship's trawl deck. They were returned to the wild unharmed. Three deceased birds were found in the water. We were able to collect one, a short-tailed shearwater, which was submitted to the USGS National Wildlife Health Center in Madison, WI, for necropsy.

Marine Mammals

We observed 34 marine mammals both on and off transect, only 6 of which were observed within the study area; these were two northern fur seals (*Callorhinus ursinus*), two unidentified pinnipeds, one unidentified whale, and one minke whale (*Balaenoptera acutorostrata*). Northern fur seals were the most frequently observed marine mammal during the entire cruise (Table 16).

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TABLES AND FIGURES

Table 1. -- Name and affiliation of scientific crew members during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2021. 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; UAF—University of Alaska, Fairbanks, Juneau, AK.

Name (Last, First)	Title	Date Embark	Date Disembark	Affiliation
Murphy, Jim	Chief Scientist	8/27/2021	9/20/2021	AFSC
Dimond, Andrew	Fish Biologist	8/27/2021	9/20/2021	AFSC
Cooper, Dan	Fish Biologist	8/27/2021	9/20/2021	AFSC
Clark, Josh	Fish Biologist	8/27/2021	9/20/2021	ADF&G
Reedy, Marty	Seabird Observer	8/27/2021	9/20/2021	USFWS
Pinchuk, Alexei	Research Professor	8/27/2021	9/20/2021	UAF

Table 2. -- Dates, locations, and sampling events completed at each station during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2021. The conductivity-temperature-depth instrument (CTD) measures oceanographic characteristics.

Station	Date	Latitude	Longitude	Strata	Bottom Depth (m)	CTD Depth (m)	Bongo Depth (m)	Benthic Grab	Beam Trawl	Surface Trawl
1	8/30/2021	60.00	-168.04	1	23	20	No	Yes	No	Yes
2	8/30/2021	60.00	-169.03	2	43	30	35	Yes	No	Yes
3	8/31/2021	60.00	-170.00	2	57	50	49	Yes	Yes	Yes
4	8/31/2021	60.00	-171.01	2	70	67	60	Yes	No	Yes
5	8/31/2021	60.51	-170.96	2	64	58	55	Yes	No	Yes
6	9/1/2021	60.50	-170.00	2	52	46	44	Yes	Yes	Yes
7	9/1/2021	60.50	-169.00	2	40	36	31	Yes	No	Yes
8	9/1/2021	60.50	-168.01	1	31	27	24	Yes	No	Yes
9	9/2/2021	60.50	-166.99	1	29	25	23	Yes	Yes	Yes
10	9/2/2021	61.01	-167.00	1	24	21	18	Yes	No	Yes
11	9/2/2021	61.00	-168.00	1	31	26	23	Yes	No	Yes
12	9/3/2021	61.01	-169.01	2	39	35	33	Yes	Yes	Yes
13	9/3/2021	61.00	-169.99	2	48	45	42	Yes	No	Yes
14	9/3/2021	61.00	-171.01	2	57	51	51	No	No	Yes
15	9/4/2021	61.50	-170.99	2	52	47	No	No	Yes	Yes
16	9/4/2021	61.50	-170.00	2	47	43	41	No	Yes	Yes
17	9/4/2021	61.50	-169.00	2	38	35	31	No	No	Yes
18	9/5/2021	61.50	-168.00	1	30	27	26	No	Yes	Yes
19	9/5/2021	61.50	-167.00	1	23	20	18	No	Yes	Yes
20	9/5/2021	62.00	-167.05	3	31	28	24	No	No	Yes
21	9/6/2021	62.00	-168.02	3	29	25	23	No	Yes	Yes
22	9/6/2021	62.00	-169.00	4	39	36	33	No	Yes	Yes
23	9/6/2021	61.99	-170.02	4	46	41	39	No	Yes	Yes
24	9/7/2021	61.99	-171.01	4	51	48	45	No	Yes	Yes
25	9/7/2021	62.51	-170.99	4	46	41	40	No	Yes	Yes
26	9/7/2021	62.49	-169.98	4	38	32	34	No	Yes	Yes
27	9/8/2021	62.50	-169.00	4	33	29	28	No	Yes	Yes
28	9/8/2021	62.50	-168.00	3	31	26	24	No	Yes	Yes
29	9/8/2021	62.50	-166.99	3	35	31	28	No	Yes	Yes
30	9/9/2021	63.00	-167.00	5	32	23	20	No	Yes	Yes
31	9/9/2021	63.00	-166.00	5	23	20	17	No	Yes	Yes
32	9/9/2021	63.50	-166.00	5	26	21	21	No	Yes	Yes
33	9/10/2021	63.50	-167.00	5	29	26	25	No	Yes	Yes
34	9/10/2021	63.49	-168.00	5	34	30	28	No	Yes	Yes
35	9/10/2021	64.00	-169.00	9	36	31	30	No	Yes	Yes
36	9/11/2021	64.50	-169.00	9	43	39	37	No	Yes	Yes
37	9/11/2021	65.40	-168.01	10	40	36	35	No	Yes	Yes
38	9/11/2021	65.00	-167.50	10	28	23	22	No	Yes	Yes
39	9/12/2021	64.50	-167.00	8	29	26	24	No	Yes	Yes
40	9/12/2021	64.50	-168.00	8	37	31	32	No	Yes	Yes
41	9/13/2021	64.00	-168.00	8	38	35	33	No	Yes	Yes
42	9/13/2021	64.00	-167.00	8	34	30	27	No	Yes	Yes
43	9/13/2021	64.00	-166.00	8	23	20	17	No	Yes	Yes
44	9/14/2021	64.10	-164.50	6	21	18	16	No	Yes	Yes
45	9/14/2021	64.10	-163.49	6	25	21	21	No	Yes	Yes
46	9/14/2021	64.10	-162.53	6	22	20	17	No	Yes	Yes
47	9/15/2021	63.80	-163.50	7	17	14	No	No	Yes	No
48	9/15/2021	63.80	-164.50	7	18	15	No	No	Yes	No
49	9/15/2021	64.75	-167.25	8	30	27	No	No	Yes	No
50	9/15/2021	64.50	-167.50	8	32	29	No	No	Yes	No
51	9/15/2021	64.37	-167.33	8	32	29	No	No	Yes	No
52	9/15/2021	64.30	-167.01	8	32	29	No	No	Yes	No
53	9/15/2021	64.37	-166.65	8	30	27	No	No	Yes	No

Table 3. -- Temperature (°C), salinity (PSU), and mixed layer depth (MLD, m) measurements from conductivity-temperature-depth (CTD) casts during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2021. Average values for core stations (strata 1-6 and 8) and all stations (strata 1-10) are included.

Station	Strata	CTD Surface Temp.	CTD Surface Salinity	CTD Bottom Temp.	CTD Bottom Salinity	Mixed Layer Depth
1	1	9.54	31.63	9.54	31.63	20
2	2	9.58	31.88	9.33	31.93	30
3	2	10.22	32.09	4.68	32.12	25
4	2	9.99	32.28	3.88	32.37	26
5	2	9.88	32.13	3.64	32.33	26
6	2	9.65	31.99	5.53	32.06	26
7	2	9.29	31.73	9.20	31.74	36
8	1	10.35	31.06	10.30	31.10	27
9	1	10.56	30.68	10.45	30.68	25
10	1	10.86	29.87	10.64	30.16	11
11	1	9.84	30.77	9.83	30.82	26
12	2	9.28	31.31	8.87	31.40	19
13	2	9.63	32.00	5.74	32.01	25
14	2	9.73	32.10	3.87	32.18	27
15	2	8.98	31.97	3.08	32.02	26
16	2	9.07	31.68	5.32	31.83	19
17	2	8.97	31.38	8.57	31.50	17
18	1	9.82	30.70	9.04	31.08	19
19	1	10.82	28.50	10.29	30.11	8
20	3	10.46	29.20	9.34	30.75	7
21	3	9.14	31.03	9.07	31.03	25
22	4	9.11	31.14	4.14	31.49	15
23	4	9.17	31.33	3.71	31.62	8
24	4	9.22	31.38	1.61	31.69	12
25	4	8.64	31.13	-0.23	31.67	19
26	4	8.47	31.06	0.33	31.59	19
27	4	8.50	31.05	2.36	31.42	19
28	3	8.11	31.05	2.45	31.35	17
29	3	9.22	30.90	8.72	31.01	30
30	5	9.52	30.44	8.28	30.85	15
31	5	9.99	30.18	9.95	30.19	20
32	5	8.75	30.79	8.56	30.80	21
33	5	8.37	30.80	5.99	31.15	17
34	5	7.61	31.29	1.83	31.73	15
35	9	7.95	30.89	6.35	31.26	16
36	9	7.55	31.00	0.46	32.06	13
37	10	9.08	27.78	7.55	30.70	6
38	10	8.70	29.48	8.40	30.19	6
39	8	8.90	29.88	7.65	30.97	9
40	8	7.45	31.05	3.11	31.65	21
41	8	7.69	31.17	1.44	31.87	18
42	8	7.32	31.16	3.18	31.49	17
43	8	8.47	30.79	8.29	30.83	20
44	6	10.45	28.55	9.73	29.23	14
45	6	10.58	26.06	8.86	29.34	7
46	6	10.66	24.38	8.41	28.13	10
Avg. Strata 1-6, 8		9.33	30.75	6.39	31.21	18.36
Avg. Strata 1-10		9.24	30.67	6.33	31.20	19.57

Table 4. -- Average sea surface temperature (SST) from conductivity-temperature-depth (CTD) casts (upper 10m) during the Northern Bering Sea Ecosystem and Surface Trawl survey (NB CTD), average satellite derived estimates of sea surface temperature (SST) during July-September (JAS) for the northern Bering Sea (NBS OISST), predicted CTD SST from NBS OISST, and the SST index for the Northern Bering Sea Ecosystem and Surface Trawl survey (NBS SST Index), 2003-2021. Missing values identified as '--'.

Year	NBS CTD SST (°C)	NBS OISST (JAS) (°C)	Predicted SST (°C)	NBS SST Index (°C)
2003	8.1	9.6	9.7	9.7
2004	10.1	10.0	10.1	10.1
2005	7.3	9.4	9.5	9.5
2006	8.3	8.5	8.4	8.3
2007	8.3	9.0	9.0	8.3
2008	--	7.9	7.8	7.8
2009	8.2	7.9	7.7	8.2
2010	8.5	8.3	8.2	8.5
2011	7.5	7.4	7.2	7.5
2012	6.8	7.3	7.1	6.8
2013	8.3	8.5	8.4	8.3
2014	10.3	10.5	10.6	10.3
2015	8.9	9.1	9.1	8.9
2016	10.9	10.8	11.0	10.9
2017	9.1	9.2	9.2	9.1
2018	10.3	9.8	9.9	10.3
2019	11.5	10.7	10.9	11.5
2020	--	9.6	9.6	9.6
2021	9.3	9.0	9.0	9.3
Average	8.9	9.1	9.1	9.1

Table 5. -- Average surface trawl distance trawled, net dimensions (horizontal and vertical spread), effort, footrope depth, calculated and average (italics) headrope depth, and mixed layer depth expansions used to scale surface trawl catches to the mixed layer during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2021. Missing values identified as '--'.

Station	Distance (km)	Horiz. Net Spread (m)	Vert. Net Spread (m)	Effort (km^2)	SBE39 Footrope Depth (m)	Headrope Depth (m)	Footrope Depth (m)	Mixed Layer Depth Expansion
1	4.44	50.46	18.83	0.22	21.18	2.35	21.18	1.00
2	4.04	50.50	14.50	0.20	15.67	1.17	15.67	1.91
3	3.45	50.88	21.36	0.18	24.74	3.38	24.74	1.01
4	3.39	50.18	19.29	0.17	21.83	2.54	21.83	1.19
5	3.51	45.68	22.36	0.16	24.12	1.76	24.12	1.08
6	3.97	48.78	21.87	0.19	25.21	3.34	25.21	1.03
7	3.81	49.71	16.76	0.19	19.34	2.58	19.34	1.86
8	3.54	51.75	17.05	0.18	18.31	1.26	18.31	1.47
9	4.10	52.15	20.56	0.21	--	*1.76*	22.32	1.12
10	3.87	50.73	18.32	0.20	--	*1.76*	20.08	1.00
11	4.17	49.00	17.90	0.20	18.27	0.37	18.27	1.42
12	3.45	50.05	18.90	0.17	20.46	1.56	20.46	1.00
13	3.70	49.70	21.40	0.18	22.95	1.55	22.95	1.09
14	3.97	49.45	20.55	0.20	22.36	1.81	22.36	1.21
15	3.75	48.75	22.65	0.18	--	1.76	24.41	1.07
16	3.76	49.12	20.67	0.18	23.07	2.40	23.07	1.00
17	3.49	49.63	20.38	0.17	20.72	0.34	20.72	1.00
18	3.83	51.76	19.62	0.20	19.92	0.30	19.92	1.00
19	3.63	48.35	19.20	0.18	21.56	2.36	21.56	1.00
20	3.94	52.00	18.86	0.20	19.92	1.06	19.92	1.00
21	3.88	50.02	20.39	0.19	21.53	1.14	21.53	1.16
22	3.57	48.92	21.47	0.17	23.56	2.09	23.56	1.00
23	3.68	50.02	22.94	0.18	26.44	3.50	26.44	1.00
24	4.08	50.81	20.86	0.21	22.59	1.73	22.59	1.00
25	4.11	45.10	20.68	0.19	--	*1.76*	22.44	1.00
26	4.58	45.89	20.80	0.21	22.19	1.39	22.19	1.00
27	3.10	46.14	21.05	0.14	23.26	2.21	23.26	1.00
28	3.75	42.40	17.70	0.16	18.44	0.74	18.44	1.00
29	3.87	50.55	18.25	0.20	20.11	1.86	20.11	1.49
30	3.89	51.39	16.91	0.20	17.55	0.64	17.55	1.00
31	4.09	52.13	16.46	0.21	17.64	1.18	17.64	1.13
32	3.99	51.80	18.65	0.21	20.68	2.03	20.68	1.02
33	3.57	52.28	19.93	0.19	21.38	1.45	21.38	1.00
34	4.08	49.30	20.95	0.20	22.93	1.98	22.93	1.00
35	3.87	42.72	18.31	0.17	20.06	1.75	20.06	1.00
36	3.90	43.85	18.65	0.17	20.55	1.90	20.55	1.00
37	2.53	49.22	23.58	0.12	23.97	0.39	23.97	1.00
38	2.98	49.47	21.04	0.15	23.61	2.57	23.61	1.00
39	4.30	50.57	21.50	0.22	24.17	2.67	24.17	1.00
40	3.25	50.40	22.10	0.16	--	*1.76*	23.86	1.00
41	3.91	47.91	21.87	0.19	--	*1.76*	23.63	1.00
42	3.45	47.75	23.20	0.16	24.62	1.42	24.62	1.00
43	3.50	52.55	17.83	0.18	18.95	1.12	18.95	1.06
44	4.06	51.51	17.58	0.21	19.36	1.78	19.36	1.00
45	3.25	50.69	21.41	0.16	24.29	2.88	24.29	1.00
46	3.94	51.78	15.42	0.20	17.32	1.90	17.32	1.00
Average	3.76	49.43	19.79	0.19	21.37	1.76	21.56	1.09

Table 6. -- Average size (length and weight), total catch, and catch-per-unit-effort (CPUE) of salmon species captured during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2021.

Life History Stage	Common Name	Scientific Name	Average Length (cm)	Average Weight (kg)	Average CPUE (n/km²)	Total Number Caught
Juvenile	Pink salmon	*Oncorhynchus gorbuscha*	15.97	0.041	366	3,230
	Chum salmon	*O. keta*	16.83	0.052	276	2,525
	Sockeye salmon	*O. nerka*	21.20	0.112	1	6
	Coho salmon	*O. kisutch*	24.66	0.190	33	302
	Chinook salmon	*O. tshawytscha*	20.44	0.109	17	158
Immature	Chum salmon	*O. keta*	64.11	3.826	1	9
	Sockeye salmon	*O. nerka*	36.96	0.664	1	9
	Chinook salmon	*O.tshawytscha*	45.52	1.524	4	36
Mature	Coho salmon	*O. kisutch*	58.70	2.670	1	5

Table 7. -- Average catch-per-unit-effort (CPUE) and total catch of jellyfish species captured during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2021.

Common Name	Scientific Name	Average CPUE (kg/km^2)	Total Weight (kg)
Northern sea nettle	*Chrysaora melanaster*	332.0	2,589.8
Lion's mane jellyfish	*Cyanea capillata*	11.9	95.7
Moon jellyfish	*Aurelia labiata*	0.5	3.4
Water jellyfish	*Aequorea* spp.	0.1	1.0
Whitecross jellyfish	*Staurophora mertensi*	0.1	0.7
Fried egg jellyfish	*Phacellophora camtschatica*	0.1	0.3

Table 8. -- Average size (length and weight), total catch, and catch-per-unit-effort (CPUE) of non-salmon species captured during surface trawl operations in the Northern Bering Sea Ecosystem and Surface Trawl survey, 2021. Missing values identified as ‘--'.

Life History Stage	Common Name	Scientific Name	Average Length (cm)	Average CPUE (n/km²)	Total Num. Caught	Total Weight Caught (kg)
None	Salmon shark	*Lamna ditropis*	--	0.1	1	--
	Rainbow smelt	*Osmerus mordax*	12.2	43	406	4.7
	Arctic lamprey	*Lethenteron camtschaticum*	33.8	6	50	3.1
	Starry flounder	*Platichthys stellatus*	23.4	2	17	3.0
	Capelin	*Mallotus villosus*	9.9	26	459	2.7
	Yellowfin sole	*Limanda aspera*	34.5	0.3	3	1.3
	Ninespine stickleback	*Pungitius pungitius*	5.2	109	1,028	1.0
	Plain sculpin	*Myoxocephalus jaok*	36.3	0.2	2	1.0
	Crested sculpin	*Blepsias bilobus*	11.4	1	6	0.4
	Sand lance	*Ammodytes* spp.	5.8	58	463	0.3
	Bering wolfish	*Anarhichas orientalis*	19.8	0.3	3	0.2
	Veteran poacher	*Podothecus veternus*	15.4	0.1	1	0.02
	Greenland turbot	*Reinhardtius hippoglossoides*	6.1	0.2	2	0.002
Age 1+	Walleye pollock	*Gadus chalcogrammus*	24.6	174	4,202	174
	Pacific herring	*Clupea pallasii*	18.4	149	1,285	79
	Saffron cod	*Eleginus gracilis*	24.5	0.6	4	0.5
Age 0	Walleye pollock	*Gadus chalcogrammus*	5.3	9,348	81,677	109
	Pacific herring	*Clupea pallasii*	7.2	3,866	33,612	95
	Pacific cod	*Gadus macrocephalus*	8.9	32.9	267	2
	Saffron cod	*Eleginus gracilis*	10.9	0.48	4	0.05
	Sablefish	*Anoplopoma fimbria*	10.4	0.14	1	0.008

Table 9. -- Date-adjusted average fork lengths (cm) of juvenile salmon sampled during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2003-2021. A sample size greater than 20 was applied to estimates of average length, which resulted in several years where the average size of sockeye salmon was not estimated ('--').

Year	Chinook	Chum	Coho	Pink	Sockeye
2003	19.9	16.9	26.6	15.4	20.3
2004	21.7	19.1	29.9	17.9	20.2
2005	21.6	17.7	29.0	16.1	20.7
2006	19.2	15.6	26.9	15.4	--
2007	22.9	17.7	29.4	16.8	22.1
2009	22.1	18.2	25.7	16.7	20.7
2010	20.3	17.5	28.2	16.3	--
2011	19.2	17.2	26.6	15.8	--
2012	19.8	15.4	24.6	14.4	--
2013	21.5	17.1	27.3	16.4	--
2014	22.0	17.4	30.3	16.8	22.9
2015	22.0	18.4	30.0	16.9	--
2016	21.5	18.4	28.8	17.0	20.6
2017	20.3	17.2	28.4	15.1	20.0
2018	19.3	17.0	26.0	16.0	20.7
2019	20.4	17.8	25.9	16.4	19.8
2021	20.5	17.6	25.4	16.6	--
Average	20.8	17.4	27.6	16.2	20.8

Table 10. -- Correlation between date-adjusted average fork lengths of juvenile salmon, the surface temperature index for the Northern Bering Sea Ecosystem and Surface Trawl survey (NBS SST Index), and satellite derived estimates of sea surface temperature in the northern Bering Sea (NBS OISST) during July-September, 2003-2021.

	Chinook	Chum	Coho	Pink	Sockeye
Chinook	1.00				
Chum	0.76	1.00			
Coho	0.69	0.63	1.00		
Pink	0.82	0.94	0.65	1.00	
Sockeye	0.61	0.57	0.56	0.56	1.00
NBS SST Index	-0.02	0.08	0.08	0.04	0.14
NBS OISST (Jul)	0.11	0.12	0.21	0.12	0.14
NBS OISST (Aug)	0.18	0.14	0.36	0.12	0.27
NBS OISST (Sep)	0.01	0.10	0.19	0.09	0.29

Table 11. -- Average energy density (kJ/g dry wt.), standard deviation (SD), and sample sizes (n) of juvenile salmon sampled during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2009-2021. Missing values identified as '--'.

	Chinook salmon			Chum salmon			Pink salmon			Coho salmon		
Year	n	Avg.	SD	n	Avg.	SD	n	Avg.	SD	n	Avg.	SD
2009	18	21.70	0.57	34	21.88	1.03	--	--	--	18	21.30	1.23
2010	47	22.07	1.03	71	22.01	0.96	45	21.46	0.94	16	22.21	0.95
2011	40	20.59	1.29	53	21.79	1.30	48	21.30	1.07	17	21.26	0.78
2012	31	21.44	1.03	34	21.56	1.12	19	21.28	0.65	--	--	--
2014	58	21.86	1.18	78	21.53	1.01	--	--	--	48	23.47	0.96
2015	40	21.90	0.99	62	22.00	1.06	48	22.76	1.27	--	--	--
2016	36	22.17	0.71	41	21.44	0.71	34	21.30	1.28	--	--	--
2017	49	21.90	0.76	42	21.92	0.84	37	21.86	0.98	--	--	--
2018	41	22.01	0.58	86	22.00	1.15	80	21.93	1.12	--	--	--
2019	49	21.52	0.56	82	20.99	0.69	76	20.59	0.83	63	21.46	0.69
2021	20	22.09	0.52	31	22.64	0.86	29	22.70	0.76	31	22.36	0.71
Average		21.75	0.84		21.80	0.98		21.69	0.99		22.01	0.89

Table 12. -- Summary of *Ichthyophonus* prevalence and intensity broken down by fish developmental stage, fork length, and weight during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2021. Only prevalence could be statistically tested because too few of infected fish occurred in most of the groupings.

Groupings	n	Prevalence (%)	p-value	Mean Intensity (copies/g)
Immature	34	47.1	*<0.0001**	$5.6x10^7$
Juvenile	30	0		--
Overall	64	25		$5.6x10^7$
Length (cm)				
≤20	16	0		0
30	14	0		0
40	18	33.3		$1.1x10^8$
50	4	75		$1.4x10^7$
60	6	50	0.45	$4.2x10^7$
70	3	100		$2.6x10^7$
80	3	33.3		$5.1x10^6$
Weight (kg)				
≤1	48	12.5		$1.1x10^8$
2	5	60		$1.4x10^7$
3	5	60	*0.007**	$4.2x10^7$
4	3	100		$2.6x10^7$
5	3	33.3		$5.3x10^6$

Table 13. -- Stock composition percentages (mean, standard deviation) for reporting groups (Upper Yukon (Canadian-origin stock group), Middle Yukon, Lower Yukon, and Other Western Alaska) of juvenile Chinook salmon captured during the Northern Bering Sea Ecosystem and Surface Trawl surveys, 2003-2021. Stock composition estimates are not available for 2008 and 2020 (no survey), 2012 and 2005 (low sample size), and 2013 (genetic samples contaminated during a flooding event aboard the survey vessel). Missing values identified as '--'.

	Upper Yukon		Middle Yukon		Lower Yukon		Other Western Alaska	
Year	Mean	SD	Mean	SD	Mean	SD	Mean	SD
2003	48.29	3.5	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
2005	--	--	--	--	--	--	--	--
2006	48.98	5.34	26.51	4.8	14.99	5.59	9.52	5.14
2007	50.59	3.49	29.88	3.27	13.84	3.09	5.69	2.5
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
2012	--	--	--	--	--	--	--	--
2013	--	--	--	--	--	--	--	--
2014	50.62	3.71	36.6	3.62	8.8	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	42.3	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	4.5	21.17	4.19	13.88	6.04	34.96	6.63
2020	--	--	--	--	--	--	--	--
2021	46.69	4.01	13.52	2.87	17.29	5.69	21.95	5.77
Average	46.83	3.95	25.50	3.54	12.84	4.21	14.80	4.19

Table 14. -- Juvenile Chinook salmon abundance in the northern Bering Sea (NBS) and adult returns to the Yukon River for the Canadian-origin and total Yukon River stock groups, 2003-2021. Estimates of spawner abundance and juveniles-per-spawner are also included for the Canadian-origin stock group. Juvenile surveys were not conducted during 2008 and 2020 and the survey design in 2005 resulted in unreliable abundance estimates for juvenile Chinook salmon. Missing values identified as '--'.

	NBS Chinook		Canadian-Origin Stock Group					Total Yukon Stock		
Juvenile Year	Juvenile Abund. (000s)	Juvenile Abund. SD (000s)	Juvenile Abund. (000s)	Juvenile Abund. SD (000s)	Adult Returns (000s)	Spawner Abund. (000s)	Juv.-Per-Spawner	Juvenile Abund. (000s)	Juvenile Abund. SD (000s)	Adult Returns (000s)
2003	5,571	907	2,691	506	120	53	51.2	4,920	891	322
2004	2,619	450	1,449	300	55	42	34.2	2,333	442	154
2005	--	--	--	--	98	81	--	--	--	263
2006	1,634	257	772	163	56	48	15.9	1,479	268	108
2007	3,433	965	1,621	520	78	68	23.8	3,238	937	189
2008	--	--	--	--	59	63	--	--	--	178
2009	1,879	753	984	418	45	35	28.2	1,629	681	175
2010	1,996	457	974	254	42	34	28.7	1,824	442	95
2011	3,947	1,564	1,843	756	81	65	28.2	3,422	1,399	201
2012	1,431	466	719	292	55	32	22.4	1,279	475	101
2013	5,822	1,153	2,924	881	107	46	63.1	5,204	1,314	276
2014	3,535	734	1,789	412	87	33	54.8	3,393	729	239
2015	4,780	1,452	2,113	677	70	29	73.7	4,115	1,304	222
2016	3,511	1,191	2,126	675	68	63	33.6	2,970	1,048	211
2017	2,480	439	1,049	219	42	83	12.7	1,773	368	170
2018	2,581	535	888	224	25	69	12.9	2,181	500	107
2019	1,917	424	575	164	--	68	8.4	1,246	333	--
2020	--	--	--	--	--	54	--	--	--	--
2021	2,050	777	957	384	--	42	22.8	1,597	648	--
Avg.	3,074	603	1,467	428	68	53	32	2,663	736	188

Table 15. -- Number (n) and percent of total (%) of marine birds recorded on transect during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2021.

Common Name	Scientific Name	n	%
Unidentified waterfowl	*Anatidae* spp.	2	0.04
Unidentified eider	*Polysticta/Somateria* spp.	3	0.06
King eider	*Somateria spectabilis*	1	0.02
Spectacled eider	*Somateria fischeri*	2	0.04
Steller's eider	*Polysticta stelleri*	2	0.04
Unidentified loon	*Gavia* spp.	4	0.08
Pacific loon	*Gavia pacifica*	11	0.22
Black-footed albatross	*Phoebastria nigripes*	3	0.06
Short-tailed albatross	*Phoebastria albatrus*	2	0.04
Laysan albatross	*Phoebastria immutabilis*	6	0.12
Unidentified shearwater/fulmar	*Procellariidae family*	2	0.04
Northern fulmar	*Fulmaris glacialis*	221	4.35
Unidentified dark shearwater	*Ardenna* spp.	766	15.08
Sooty shearwater	*Ardenna griseus*	1	0.02
Short-tailed shearwater	*Ardenna tenuirostris*	2314	45.55
Fork-tailed storm-petrel	*Oceanodroma furcata*	132	2.6
Unidentified cormorant	*Phalacrocorax* spp.	4	0.08
Pelagic cormorant	*Phalacrocorax pelagicus*	1	0.02
Unidentified shorebird	*Scolopacidae family*	6	0.12
Black turnstone	*Arenaria melanocephala*	2	0.04
Unidentified phalarope	*Phalaropus spp.*	162	3.19
Red phalarope	*Phalaropus fulicarius*	3	0.06
Unidentified gull	*Laridae family*	3	0.06
Sabine's gull	*Xema sabini*	27	0.53
Unidentified kittiwake	*Rissa* spp.	2	0.04
Black-legged kittiwake	*Rissa tridactyla*	360	7.09
Red-legged kittiwake	*Rissa brevirostris*	2	0.04
Herring gull	*Larus argentatus*	2	0.04
Glaucous gull	*Larus hyperboreus*	15	0.3
Glacous-winged gull	*Larus glaucescens*	63	1.24
Arctic tern	*Sterna paradisaea*	19	0.37
Caspian tern	*Hydroprogne caspia*	2	0.04
Unidentified jaeger	*Stercorarius* spp.	6	0.12
Long-tailed jaeger	*Stercorarius longicaudus*	1	0.02
Parasitic jaeger	*Stercorarius parasiticus*	4	0.08
Pomarine jaeger	*Stercorarius pomarinus*	19	0.37
Unidentified alcid	*Alcidae family*	66	1.3
Unidentified murre	*Uria* spp.	46	0.91
Common murre	*Uria aalge*	195	3.84
Thick-billed murre	*Uria omvia*	32	0.63
Pigeon guillemot	*Cepphus columba*	9	0.18
Ancient murrelet	*Synthliboramphus antiquus*	53	1.04
Marbled murrelet	*Brachyramphus marmoratus*	1	0.02
Unidentified auklet	*Ptychoramphus/Aethia* spp.	39	0.77
Cassin's auklet	*Ptychoramphus aleuticus*	8	0.16
Parakeet auklet	*Aethia psittacula*	141	2.78
Crested auklet	*Aethia cristatella*	19	0.37
Least auklet	*Aethia pusilla*	102	2.01
Unidentified puffin	*Fratercula* spp.	2	0.04
Tufted puffin	*Fratercula cirrhata*	162	3.19
Horned puffin	*Fratercula corniculata*	20	0.39
Unidentified bird	*Aves* spp.	8	0.16
Passerine	Passeriformes (Order)	2	0.04
Total		5080	

Table 16. -- Marine mammals recorded on and off transect during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2021.

Common Name	Scientific Name	On Transect	Off Transect	Total
Sea otter	*Enhydra lutris*	4	–	4
Unidentified pinniped	*Pinnipedia suborder*	2	–	2
Northern fur seal	*Callorhinus ursinus*	8	6	14
Steller sea lion	*Eumetopias jubatus*	5	–	5
Dall's porpoise	*Phocoenoides dalli*	2	–	2
Unidentified whale	Cetacea (Order)	0	4	4
Minke whale	*Balaenoptera acutorostrata*	1	1	2
Humpback whale	*Megaptera novaeangliae*	–	1	1
Total		22	12	34

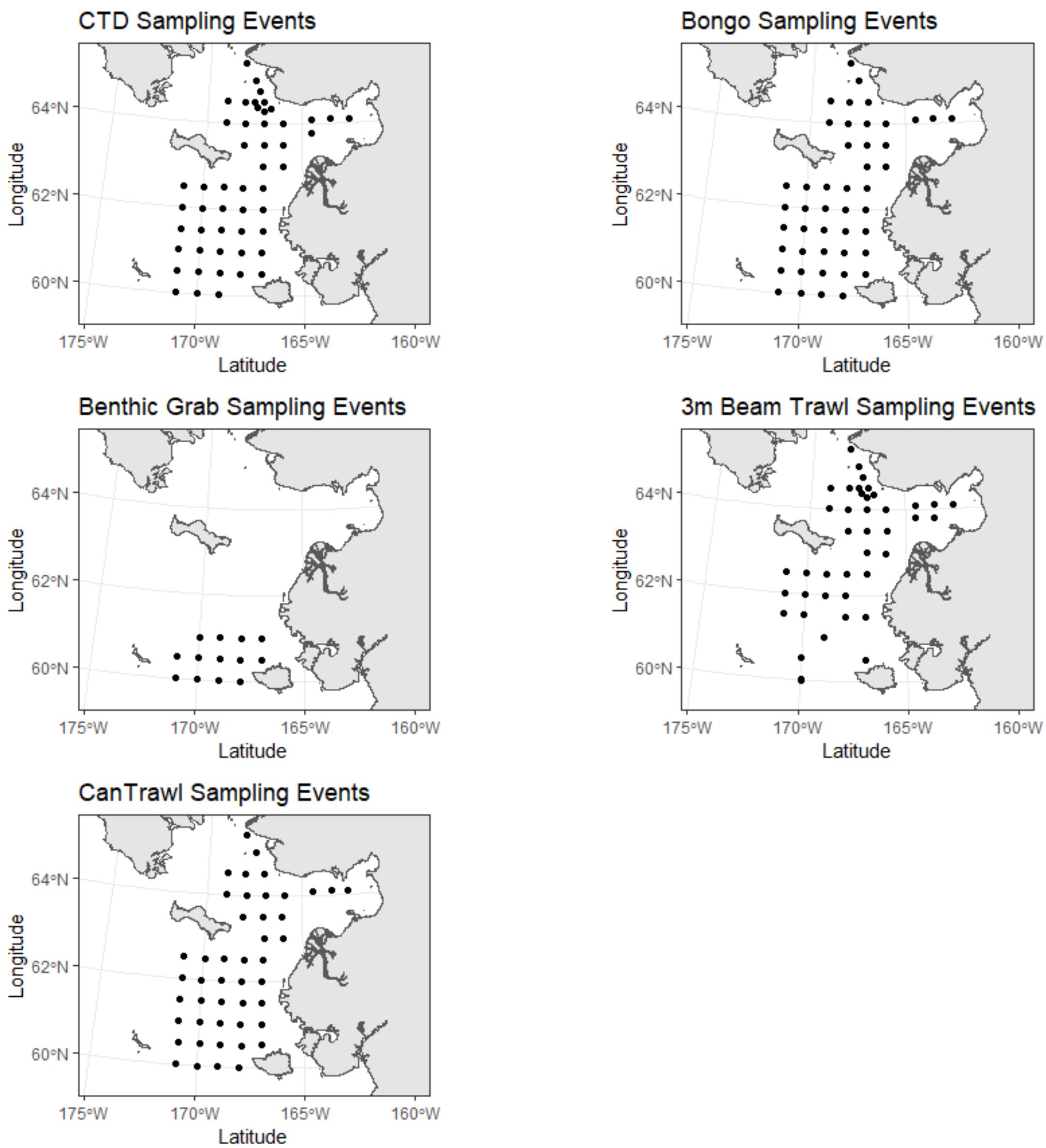


Figure 1. -- Map of stations sampled, by sampling gear, during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2021.

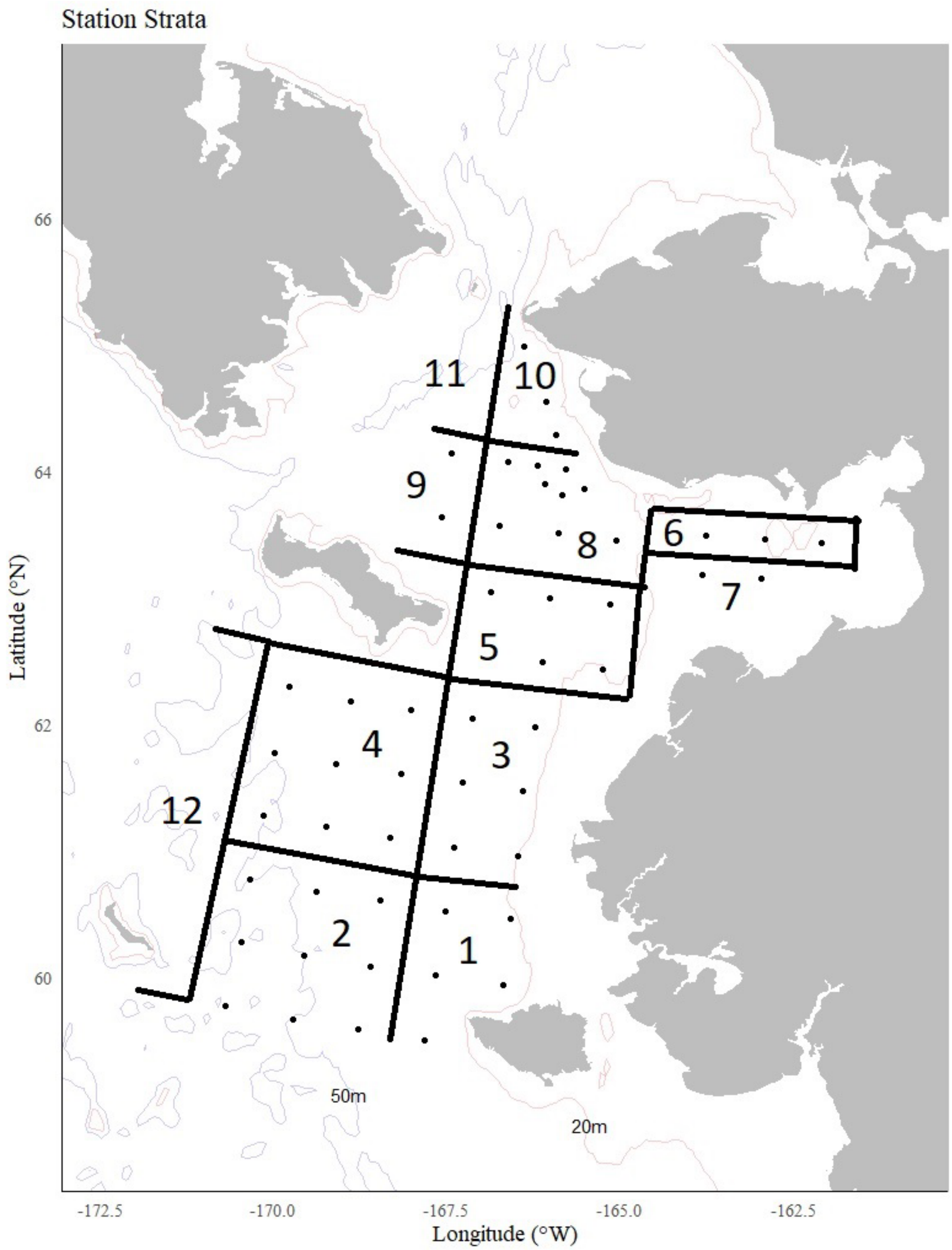


Figure 2. -- Map of spatial strata and surface trawl stations sampled during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2021.

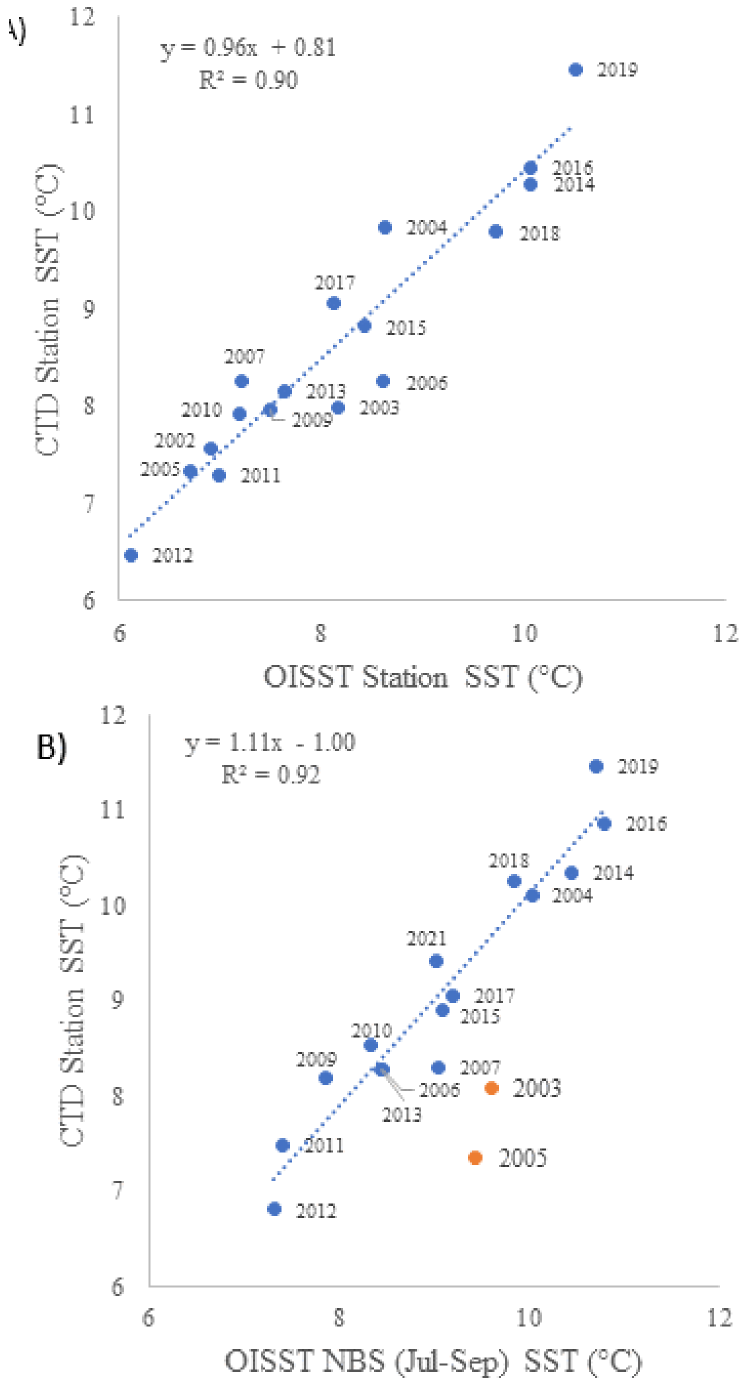


Figure 3. -- Linear regression models of (A) average sea surface temperature (SST) from CTD data (upper 10m) and satellite estimates of SST (OISST) at each station and (B) average SST from CTD data (upper 10m) and satellite estimates of SST for the northern Bering Sea region during July-September, 2003-2021. Average CTD SST estimates during 2003 and 2005 are identified as outliers in the regional model.

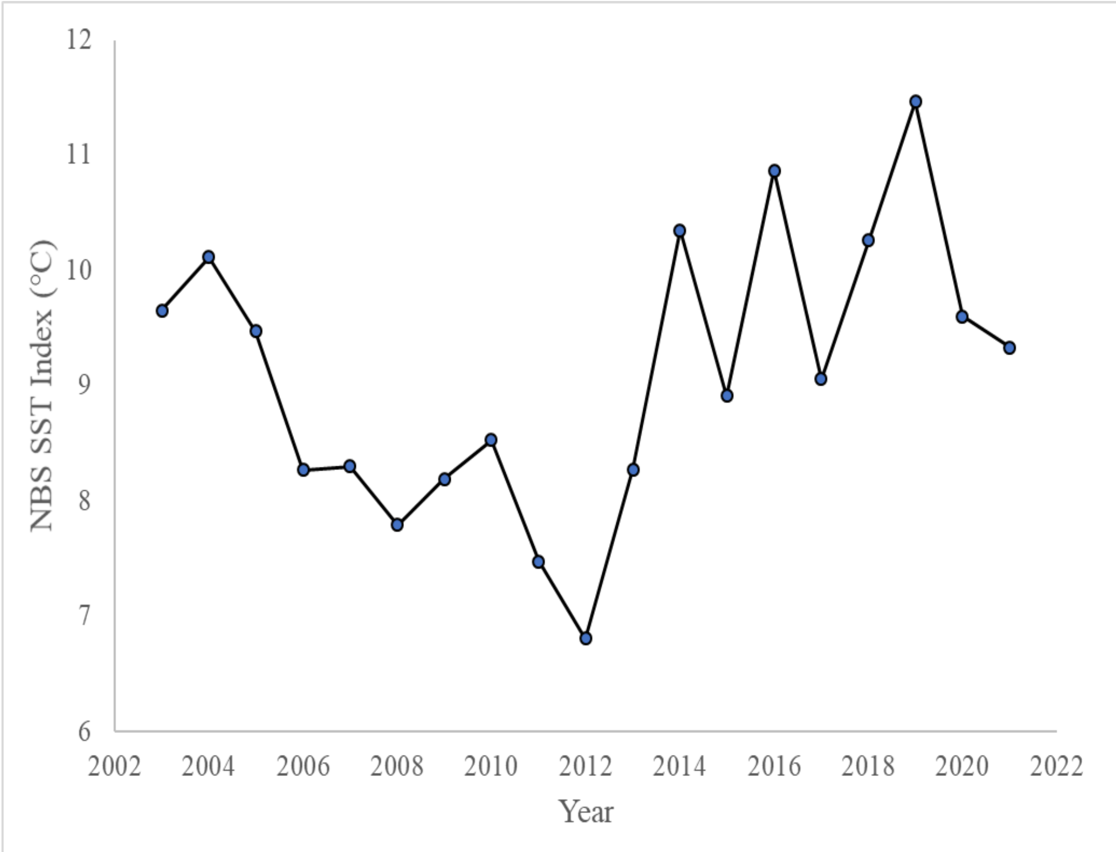


Figure 4. -- Sea surface temperature (SST) index based on CTD and satellite derived OISST data for the Northern Bering Sea Ecosystem and Surface Trawl survey, 2003-2021.

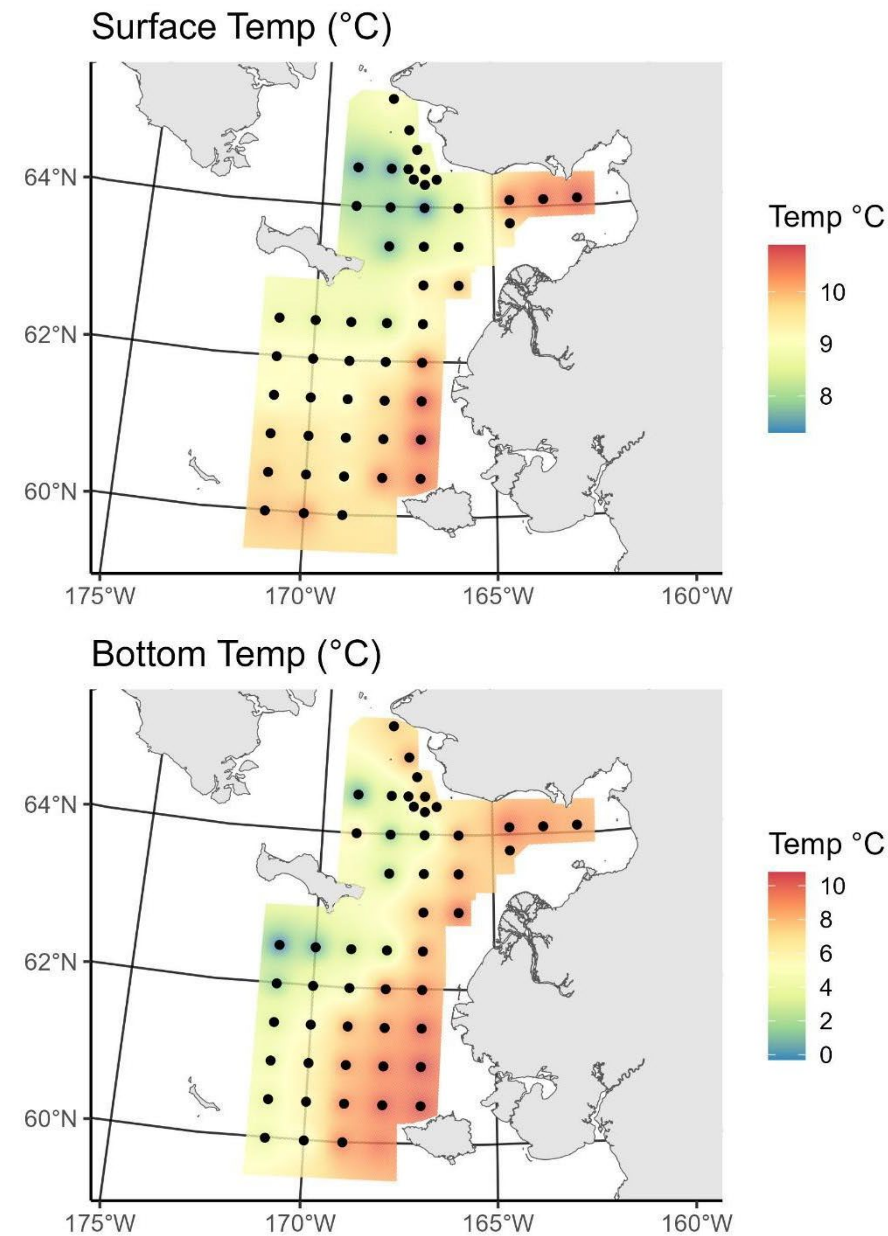


Figure 5. -- Interpolated map of surface (upper 10m) and bottom (deepest depth sampled) temperature (°C) from CTD data collected during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2021.

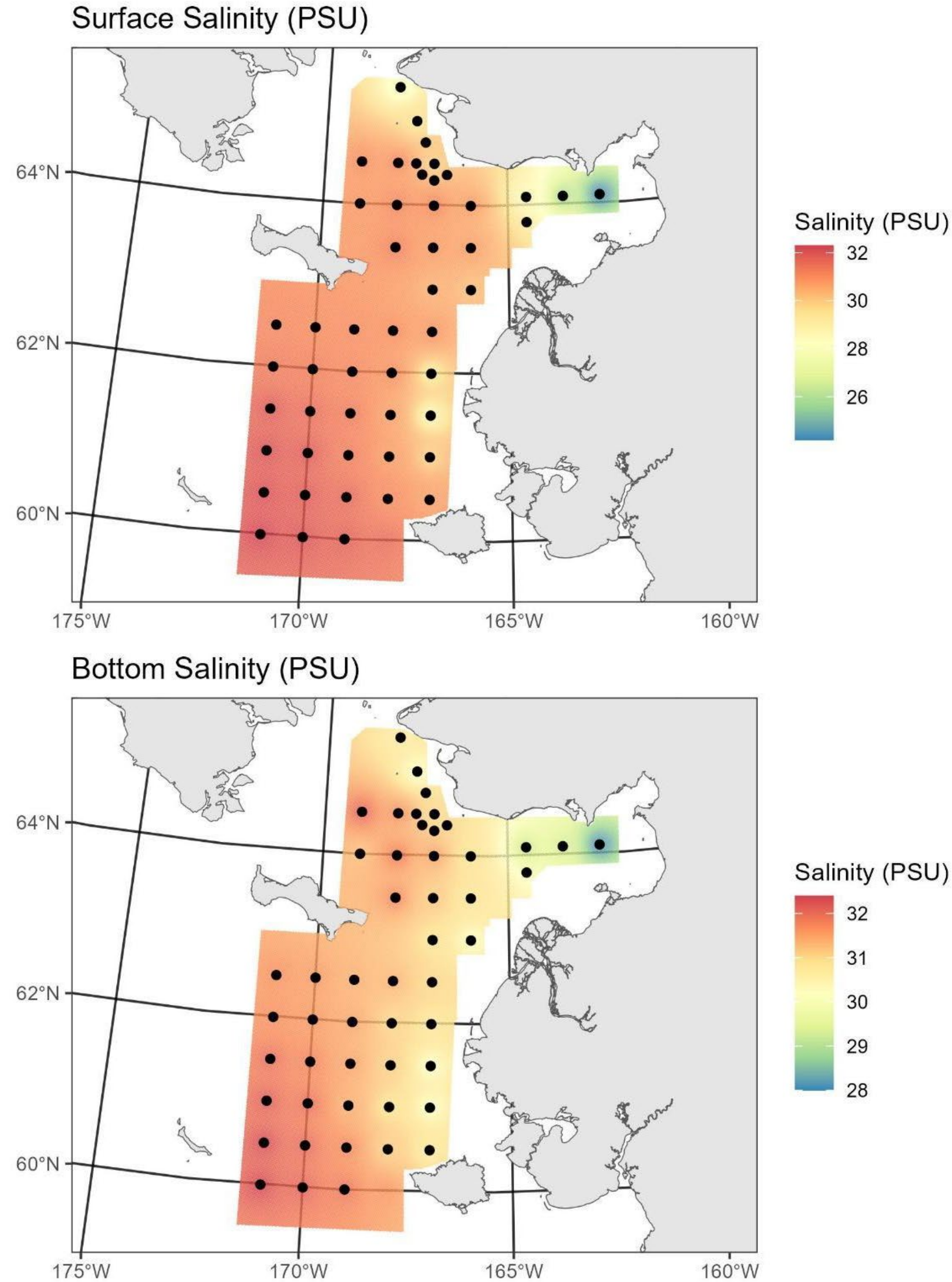


Figure 6. -- Interpolated map of surface (upper 10m) and bottom (deepest depth sampled) salinity (PSU) from CTD data collected during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2021.

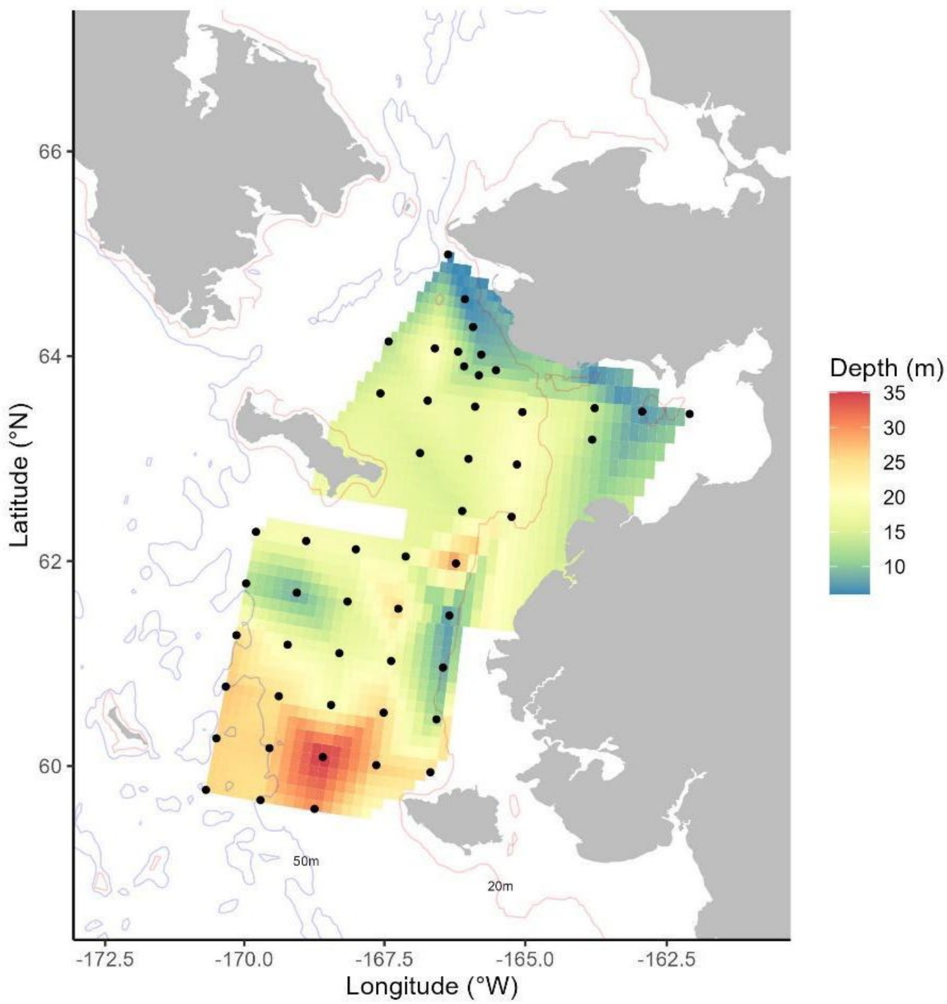


Figure 7. -- Interpolated map of mixed layer depth (m) from CTD data collected during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2021.

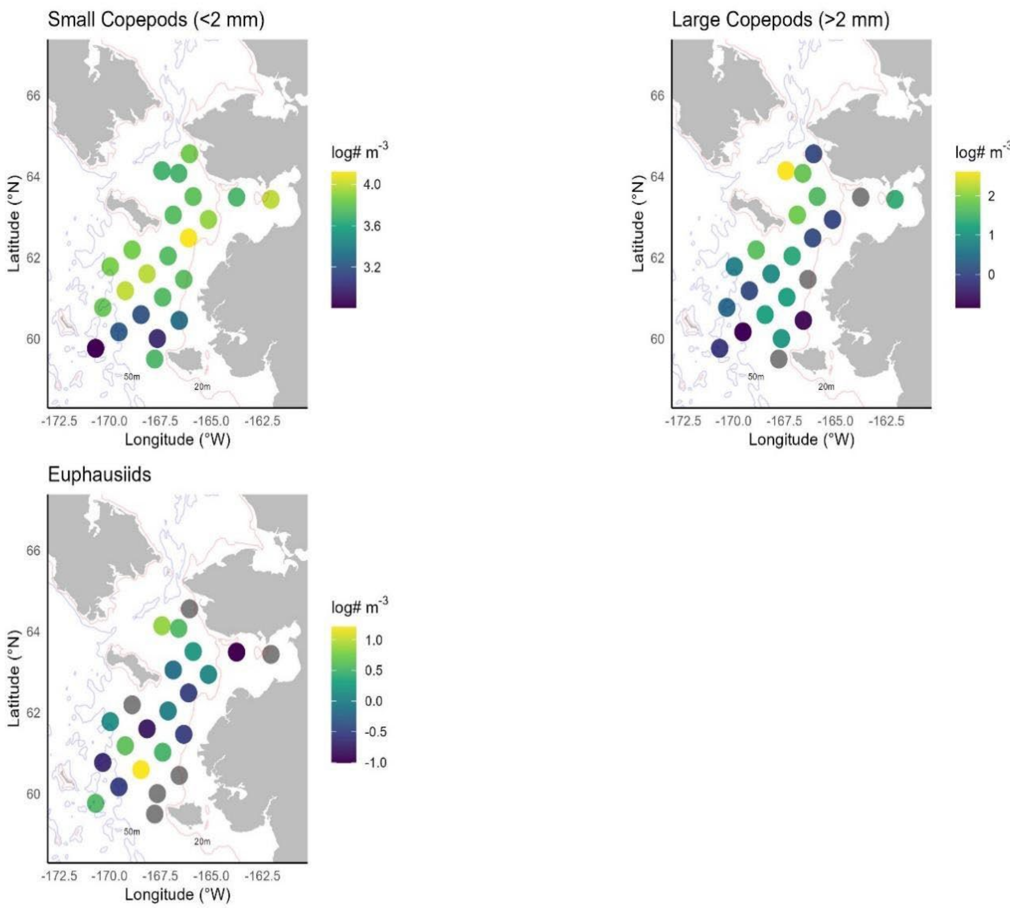


Figure 8. -- Distribution of small copepods, large copepods, and euphausiids determined by rapid zooplankton assessment methods during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2021.

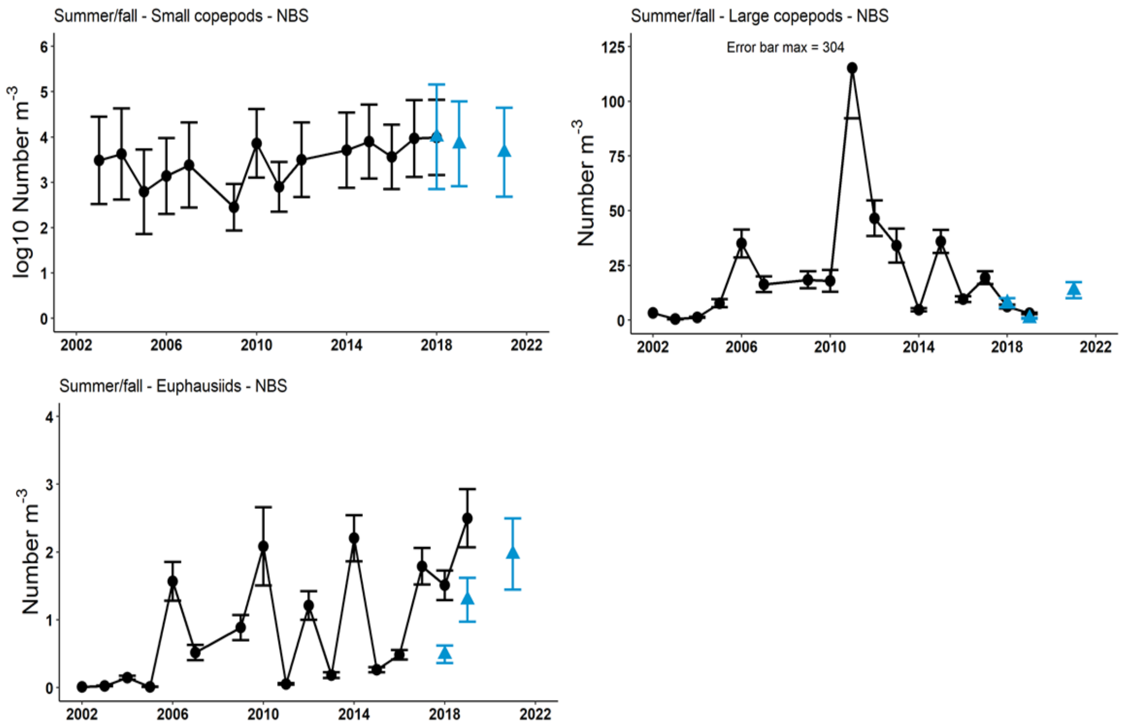


Figure 9. -- Abundance of small copepods (log(n/m^3)), large copepods (n/m^3), and euphausiids (n/m^3) determined by rapid zooplankton assessment methods (blue triangles) and standard laboratory zooplankton assessment protocols (black circles) sampled during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2002-2021.

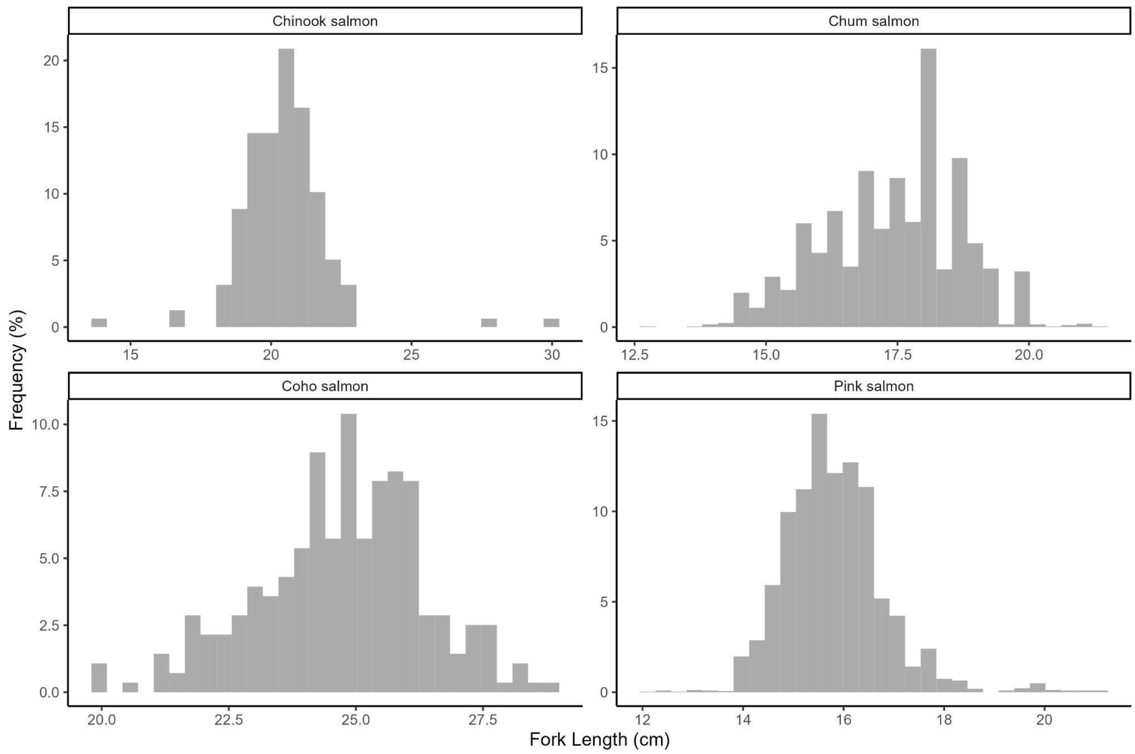


Figure 10. -- Length (fork length) frequency distributions of the most abundant juvenile (< 30 cm) salmon species captured during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2021.

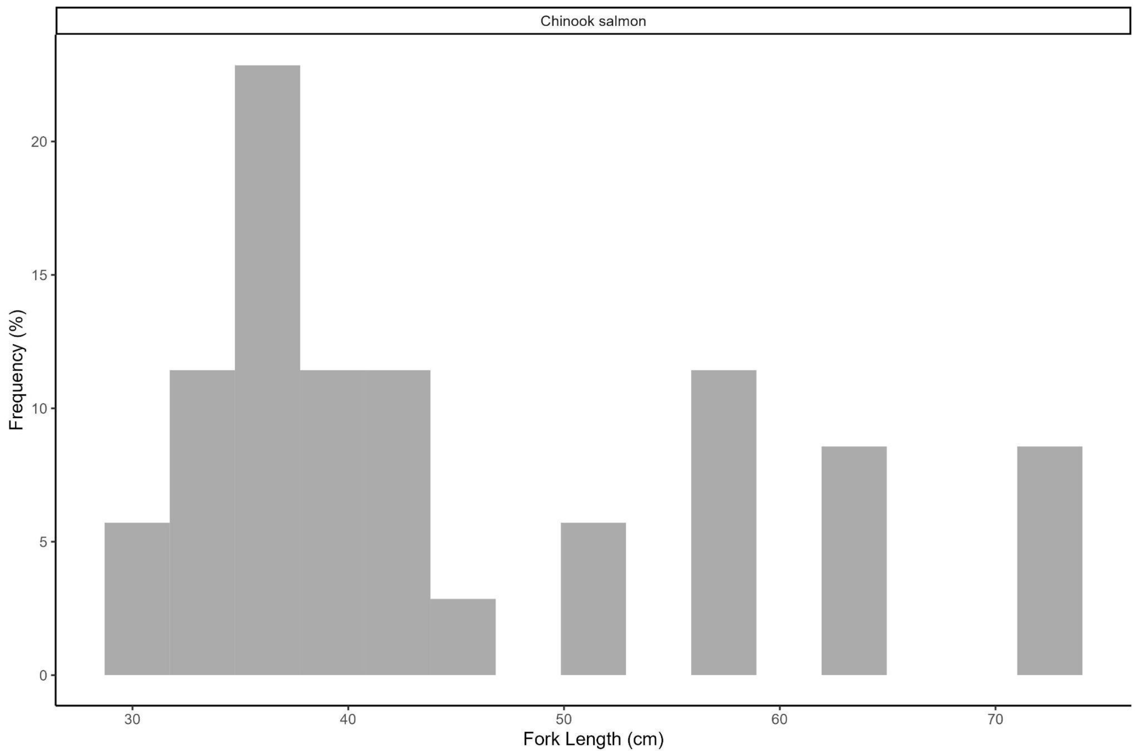


Figure 11. -- Length (fork length) frequency distributions of immature (>= 30 cm) Chinook salmon captured during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2021.

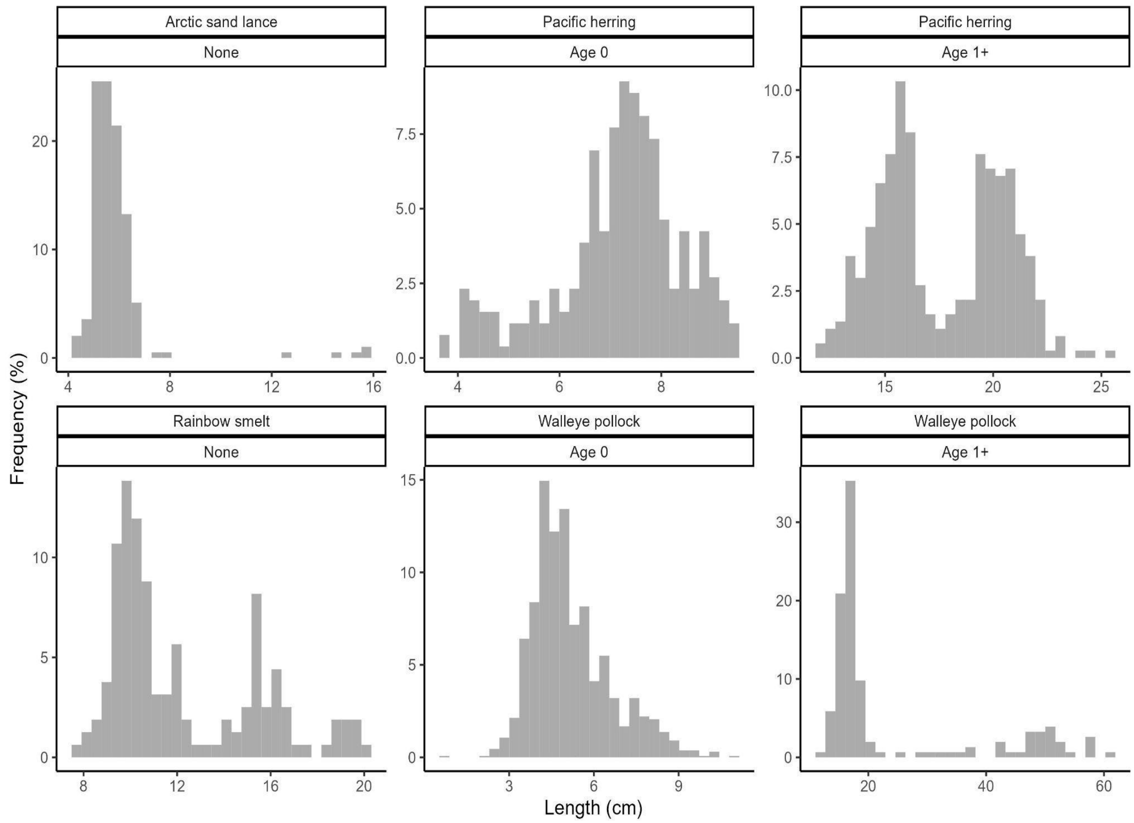


Figure 12. -- Length frequency distributions of Arctic sand lance (fork length), Pacific herring (fork length), Rainbow smelt (fork length), age 0 Walleye pollock (standard length), and age 1+ walleye pollock (total length) sampled during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2021. Pacific herring and walleye pollock lengths are separated into Age 0 and Age 1+ life-history stages. Arctic sand lance and rainbow smelt did not have pre-assigned life-history subcategories (None) and distributions include all lengths measured during the survey.

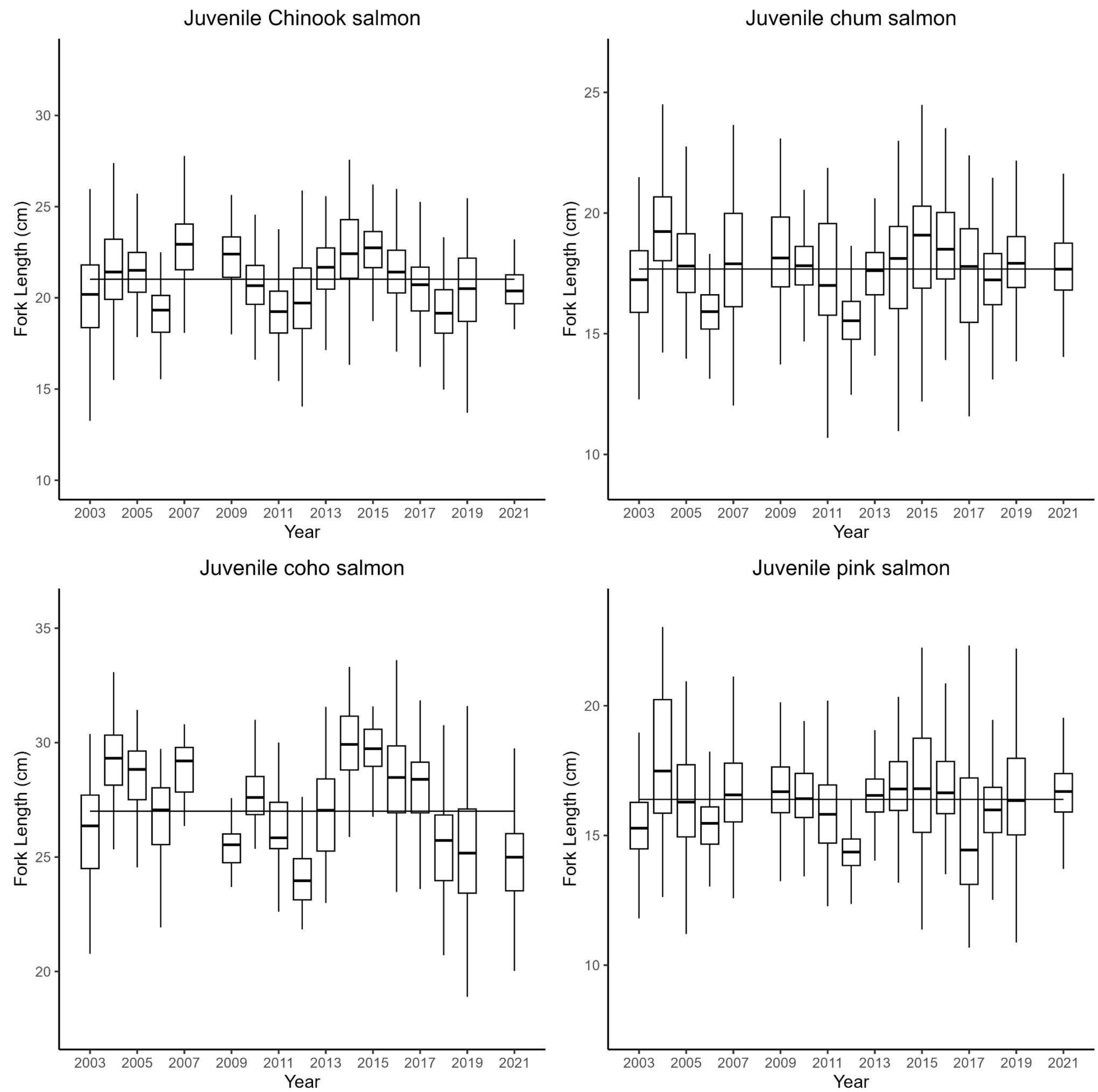


Figure 13. -- Box plots of date-adjusted juvenile salmon fork lengths (cm) sampled during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2003-2019. The solid line in each figure indicated the overall mean. Sockeye salmon lengths are not shown due to the limited number of years where at least 20 lengths were measured.

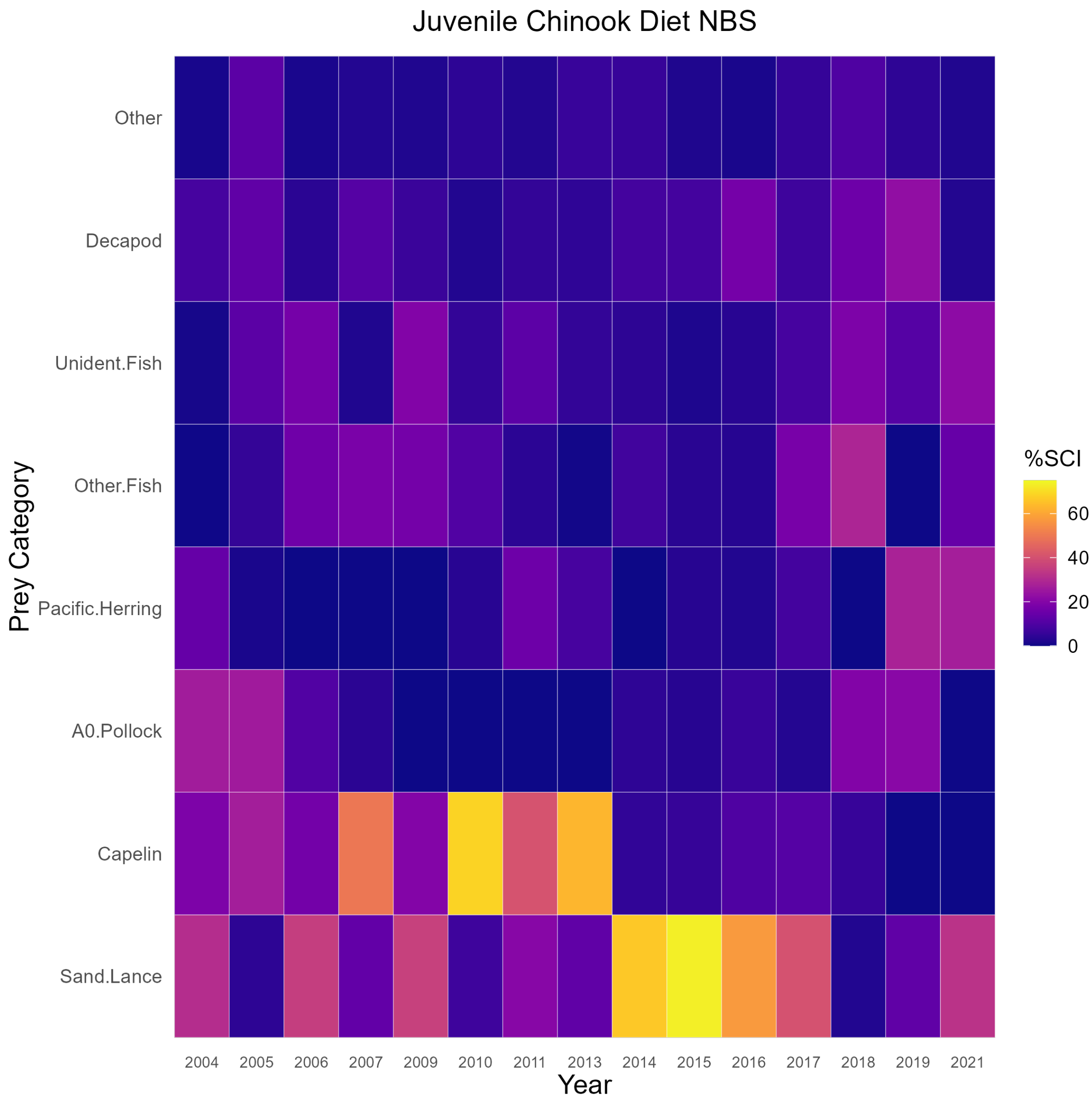


Figure 14. -- The percent of taxonomic prey groups by stomach content index in the stomachs of juvenile Chinook salmon sampled from the Northern Bering Sea Ecosystem and Surface Trawl survey, 2004-2021.

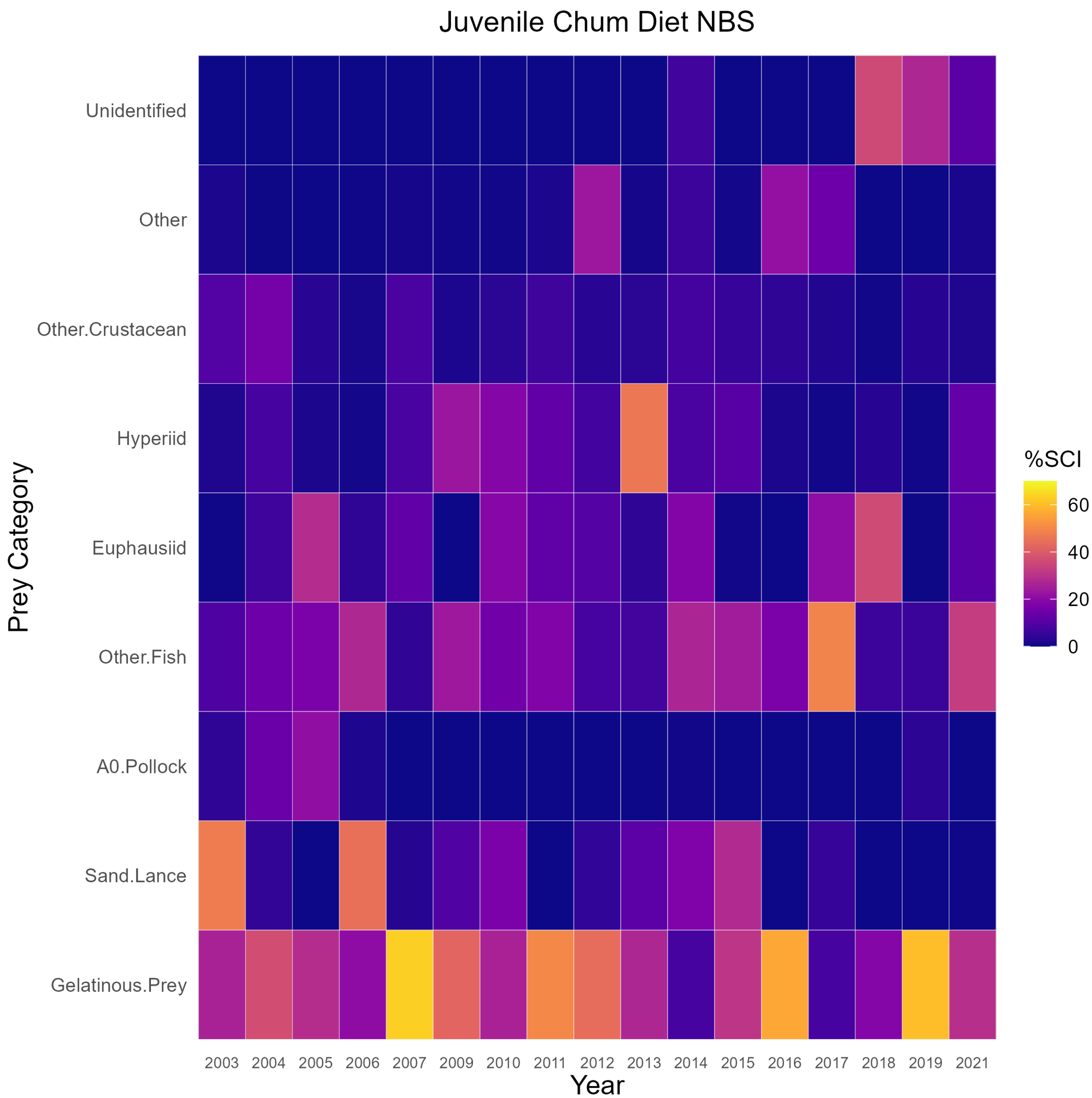


Figure 15. -- The percent of taxonomic prey groups by stomach content index in the stomachs of juvenile chum salmon sampled from the Northern Bering Sea Ecosystem and Surface Trawl survey, 2003-2021.

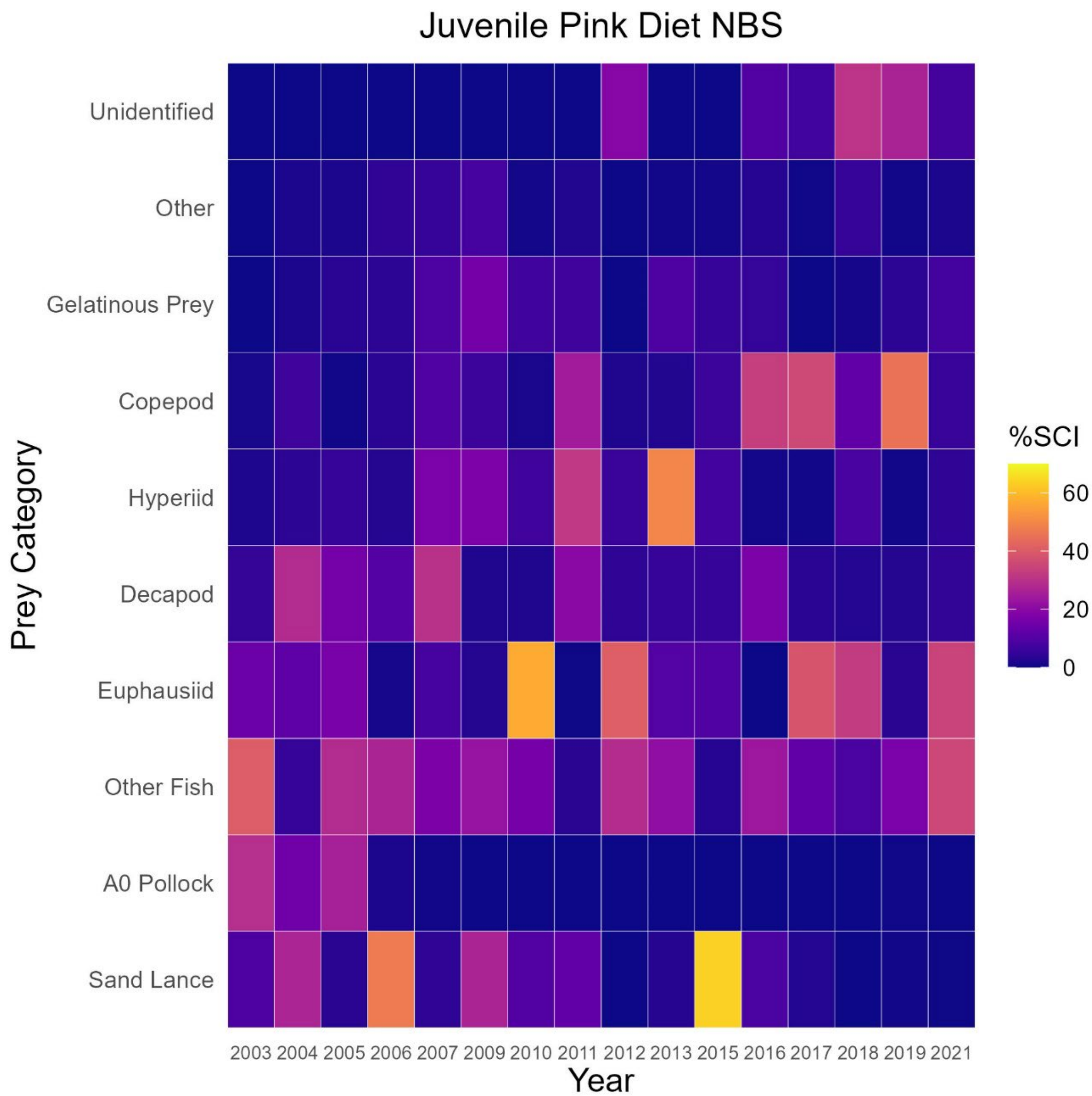


Figure 16. -- The percent of taxonomic prey groups by stomach content index in the stomachs of juvenile pink salmon sampled from the Northern Bering Sea Ecosystem and Surface Trawl survey, 2003-2021.

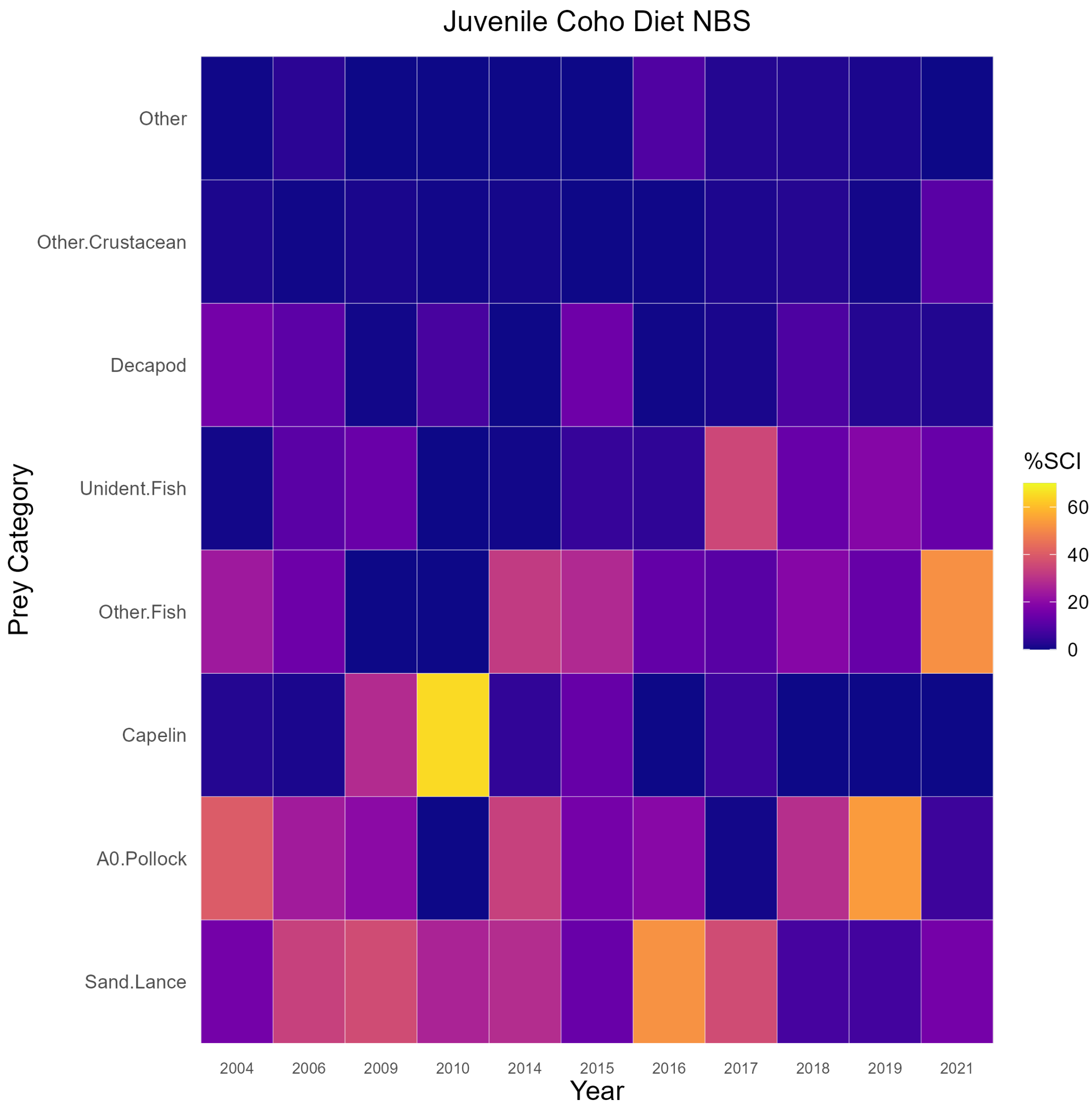


Figure 17. -- The percent of taxonomic prey groups by stomach content index in the stomachs of juvenile coho salmon sampled from the Northern Bering Sea Ecosystem and Surface Trawl survey, 2004-2021.

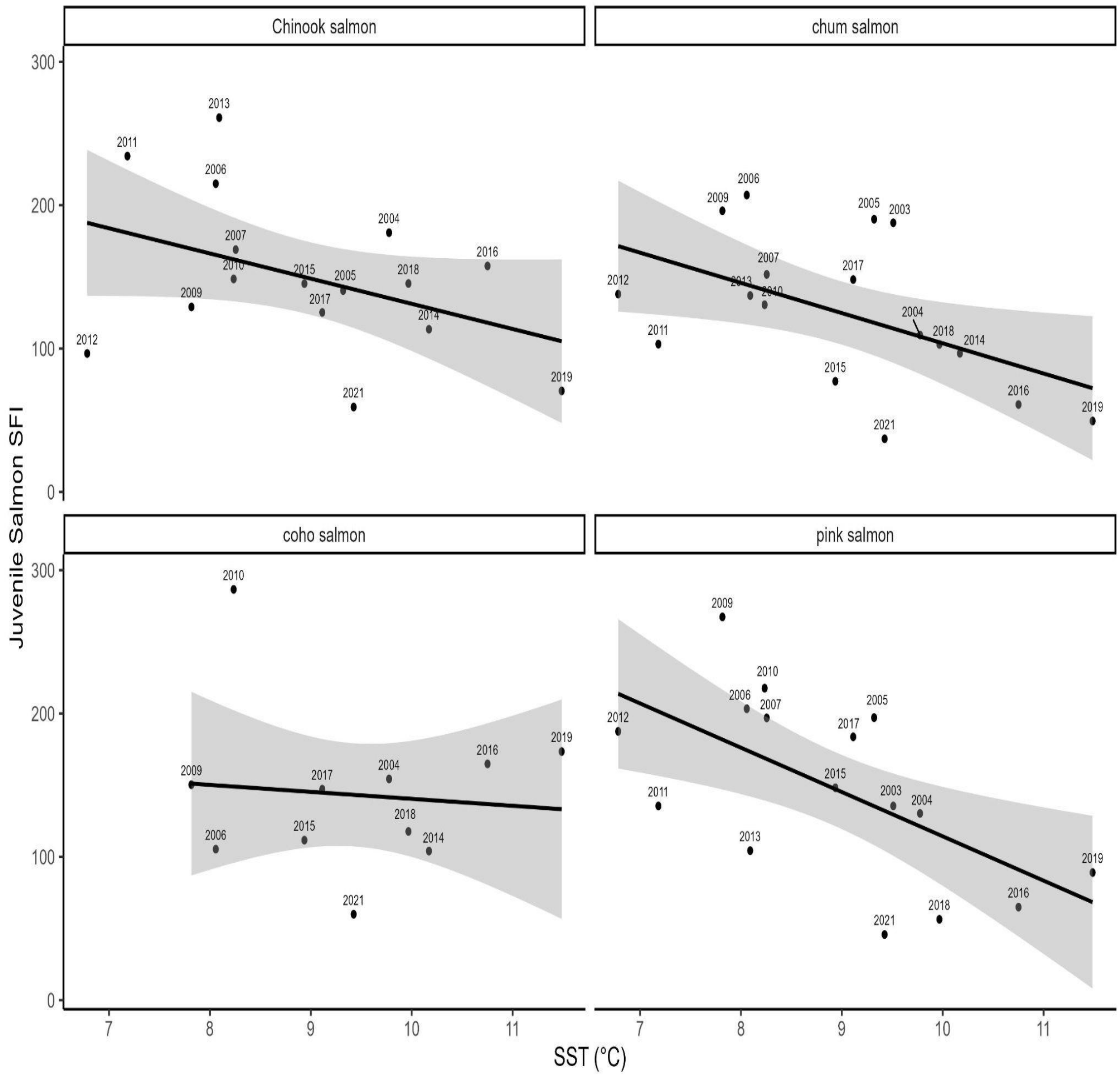


Figure 18. -- Linear regression model fits (black lines) with 95% confidence intervals (shaded regions) between the average stomach fullness index (SFI) of juvenile salmon and sea surface temperature (SST) sampled during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2004-2021. Each point is labeled with the sample years where diet information was available for a minimum of five stations.

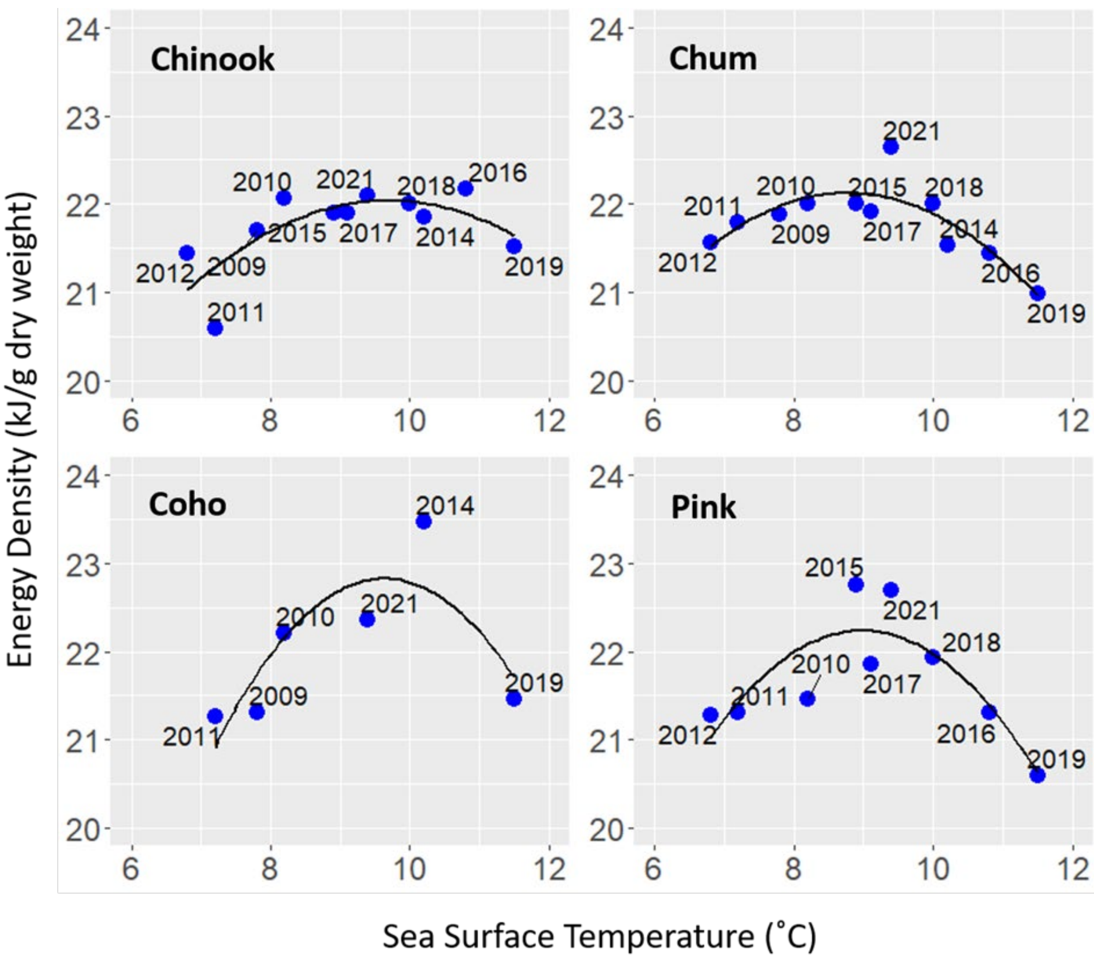


Figure 19. -- Relationship between mean annual whole-body energy density (kJ/g dry tissue mass) and sea surface temperature of juvenile salmon sampled during the Northern Bering Sea Ecosystem and Surface Trawl surveys, 2009-2021. Respective best-fit polynomial curves for Chinook, chum, coho and pink salmon were $y = -0.1217x^2 + 2.3581x + 10.614$ R^2=0.56), $y = -0.1563x^2 + 2.7418x + 10.106$ ($R^2 = 0.72$), $y = -0.3228x^2 + 6.2173x - 7.114$ (R^2=0.65), and $y = -0.2554x^2 + 4.5877x + 1.6376$ ($R^2 = 0.71$).

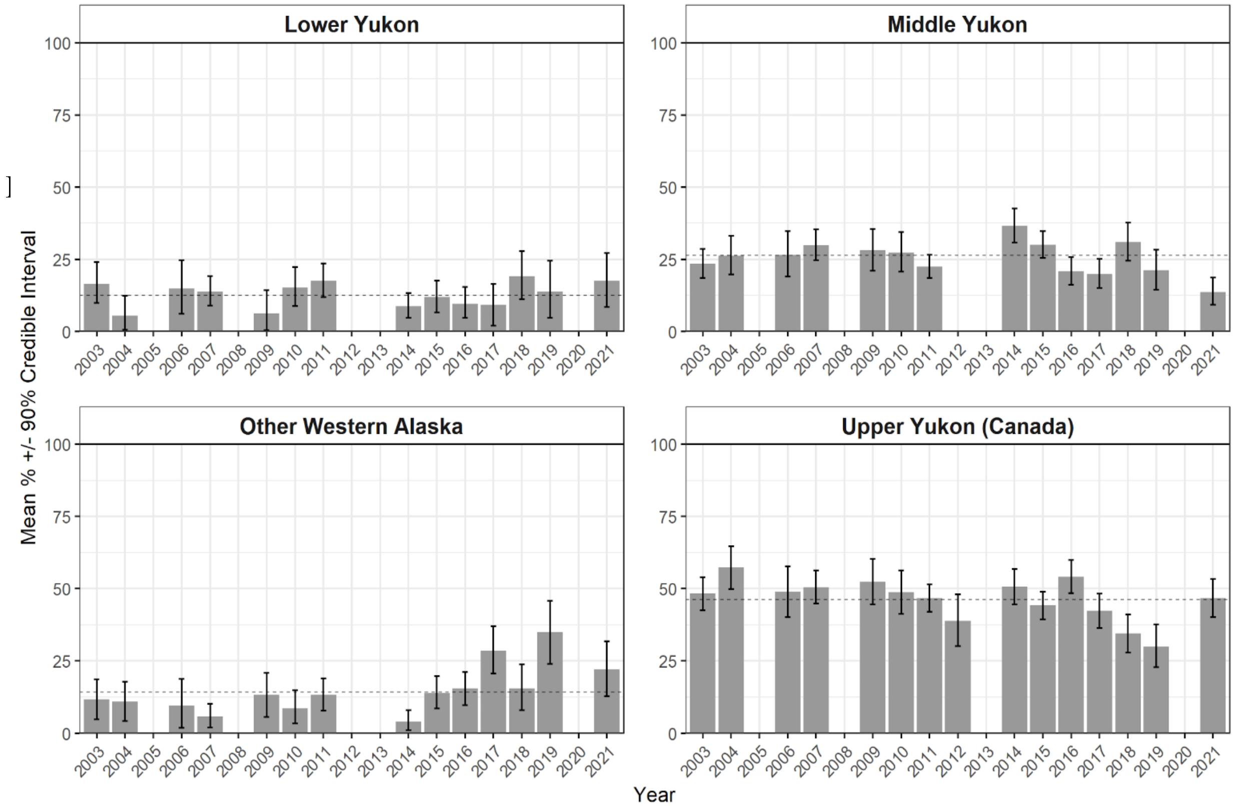


Figure 20. -- Genetic stock proportions of juvenile Chinook salmon (four reporting groups) captured during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2003-2021. Average stock proportions (dashed line) are included for each stock group.

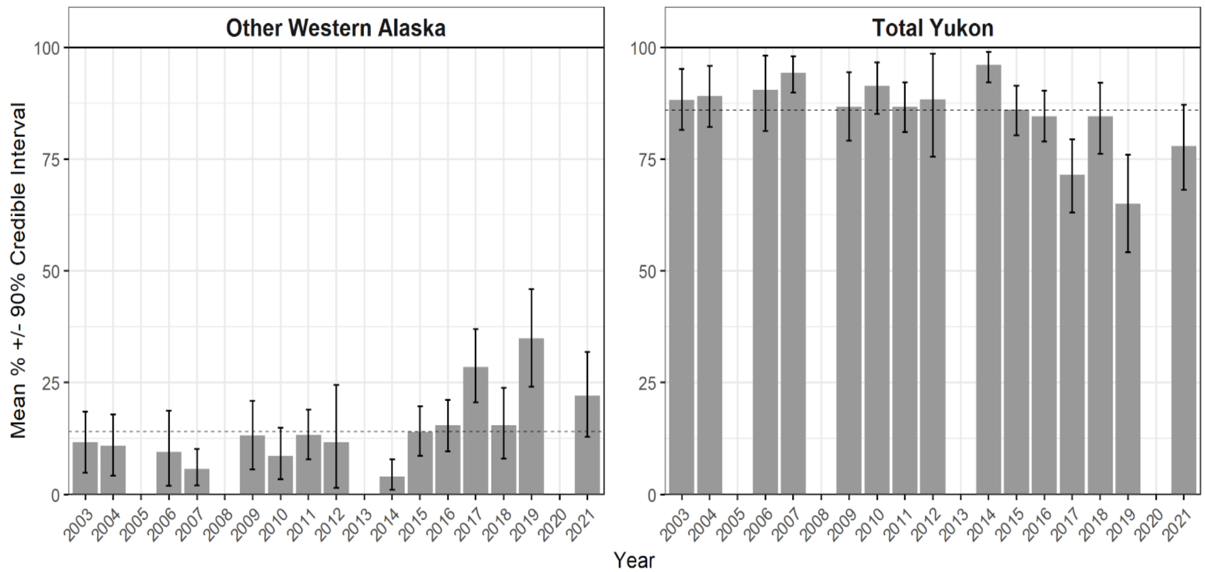


Figure 21. -- Genetic stock proportions of juvenile Chinook salmon (two reporting groups) captured during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2003-2021. Average stock proportions (dashed line) are included for each stock group.

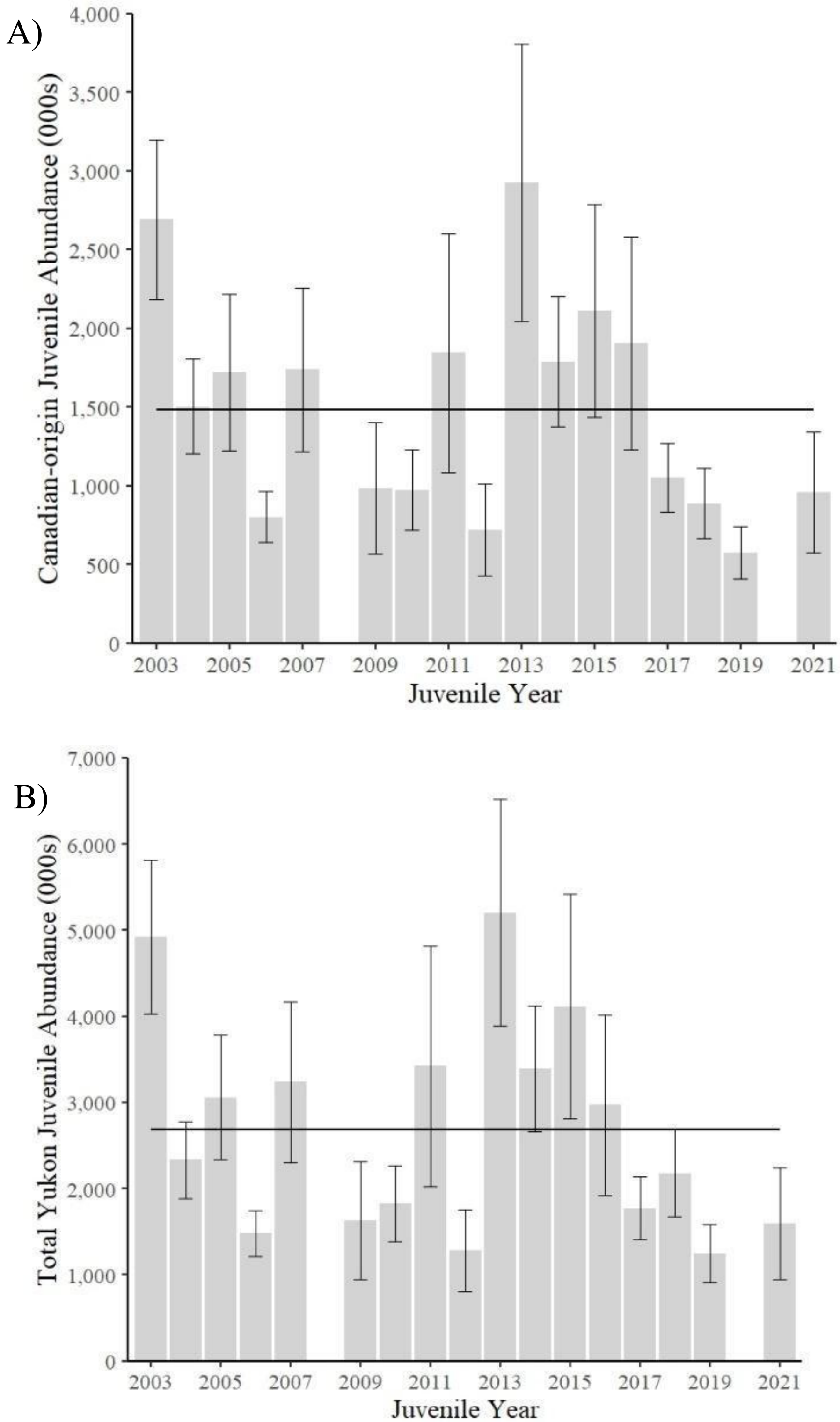
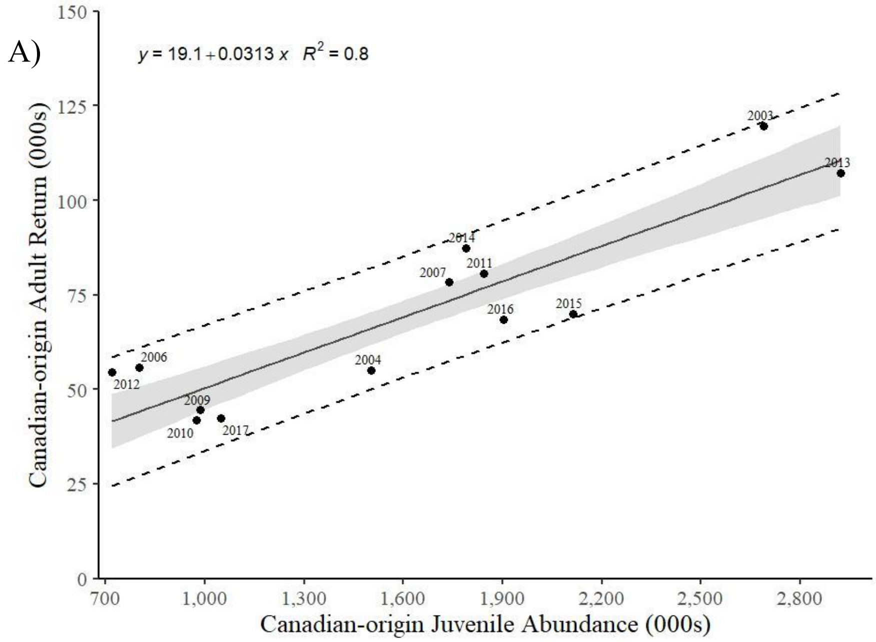


Figure 22. -- Stock-specific abundance estimates of Yukon River Canadian-origin (A) and Total Yukon (B) stock groups of Chinook salmon during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2003-2021. Average abundance for each stock group (solid line) is included.



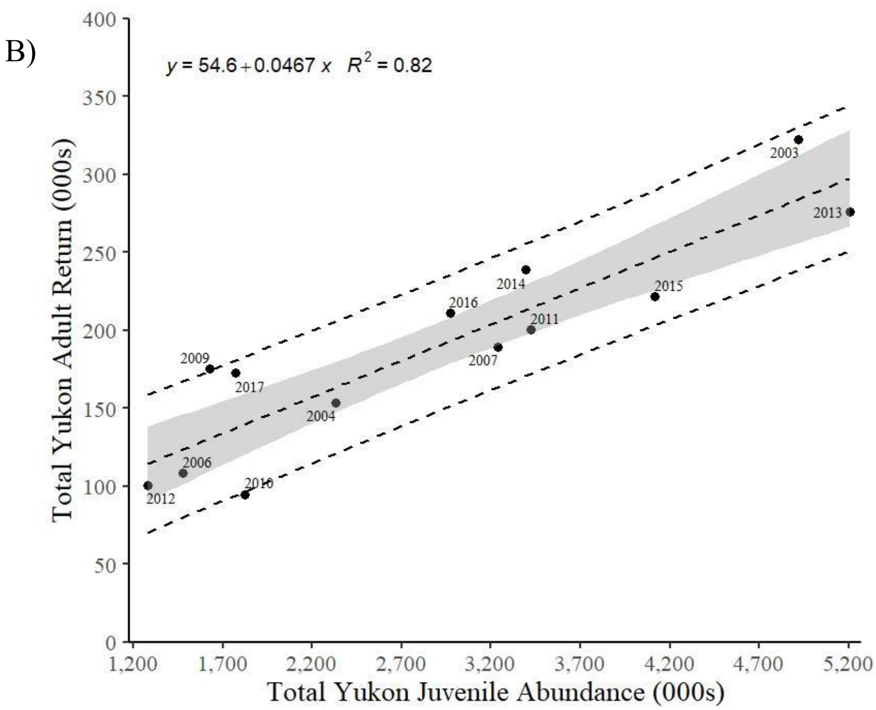


Figure 23. -- Relationships between juvenile abundance and resulting adult returns of (A) Yukon River Canadian-origin and (B) Total Yukon stock groups of Chinook salmon, 2003-2017. The fitted relationship (solid line), 80% prediction interval (dashed lines), 80% confidence interval (shaded region), and survey years (labels) are included.

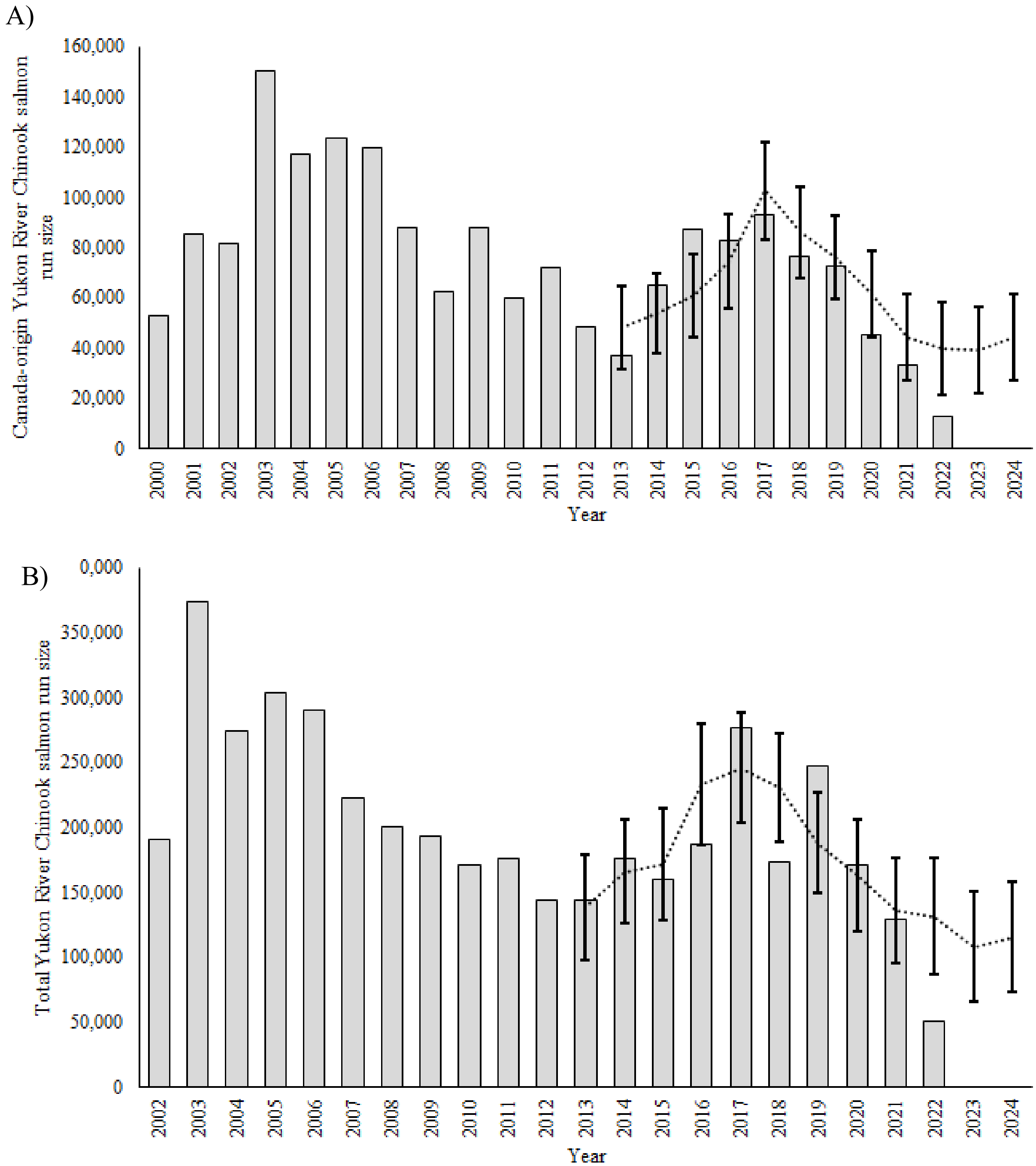


Figure 24. -- Observed (gray bars) and 80% predicted intervals of projected run sizes (black error bars) for (A) Yukon River Canadian-origin and (B) total Yukon stock groups of Chinook salmon, 2003-2024.

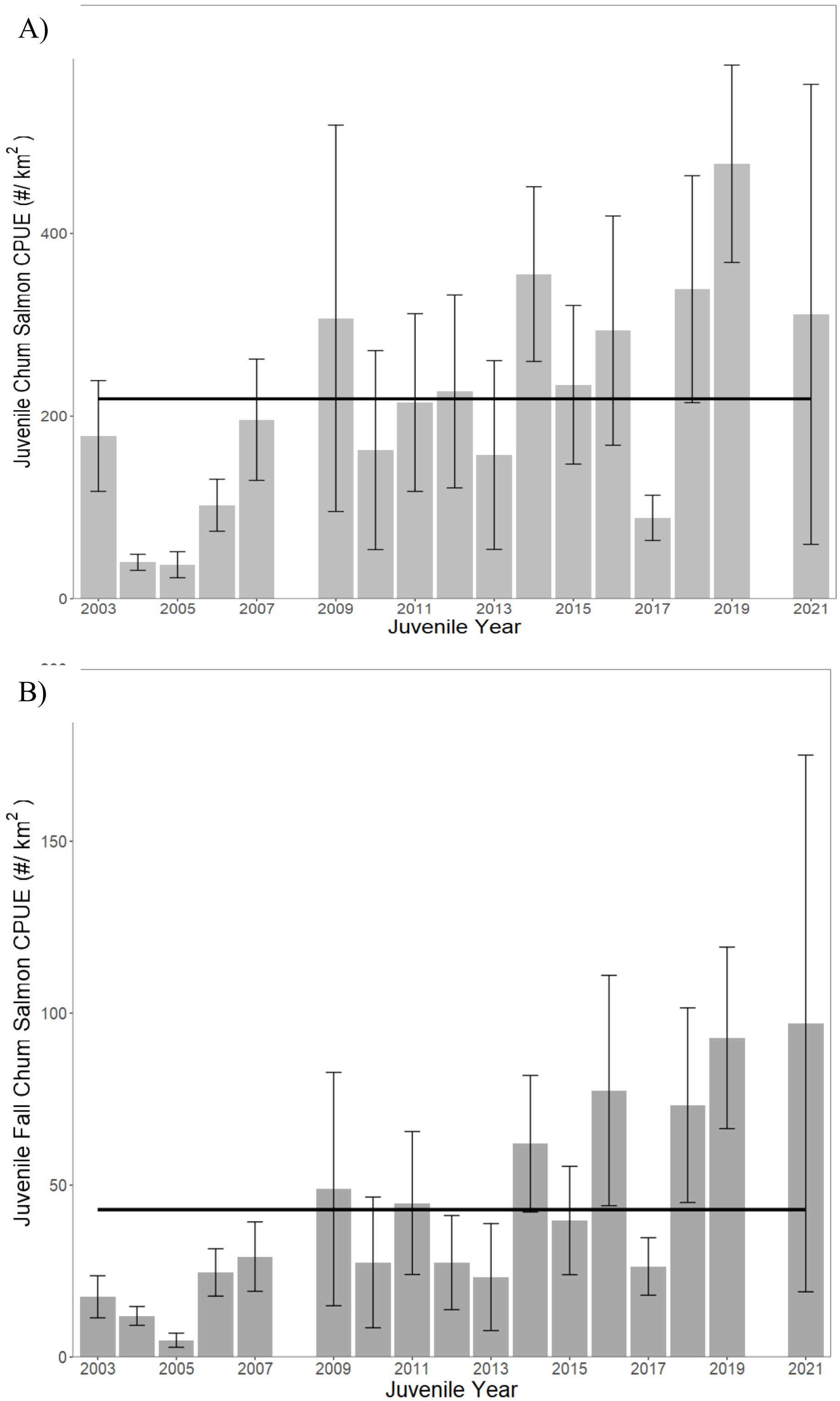


Figure 25. -- Juvenile chum salmon abundance indices for mixed stocks (A) and the fall chum salmon stock group (B) during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2003-2021. Error bars show one standard error above and below the point estimate. Average abundance for each stock group (solid line) is included.

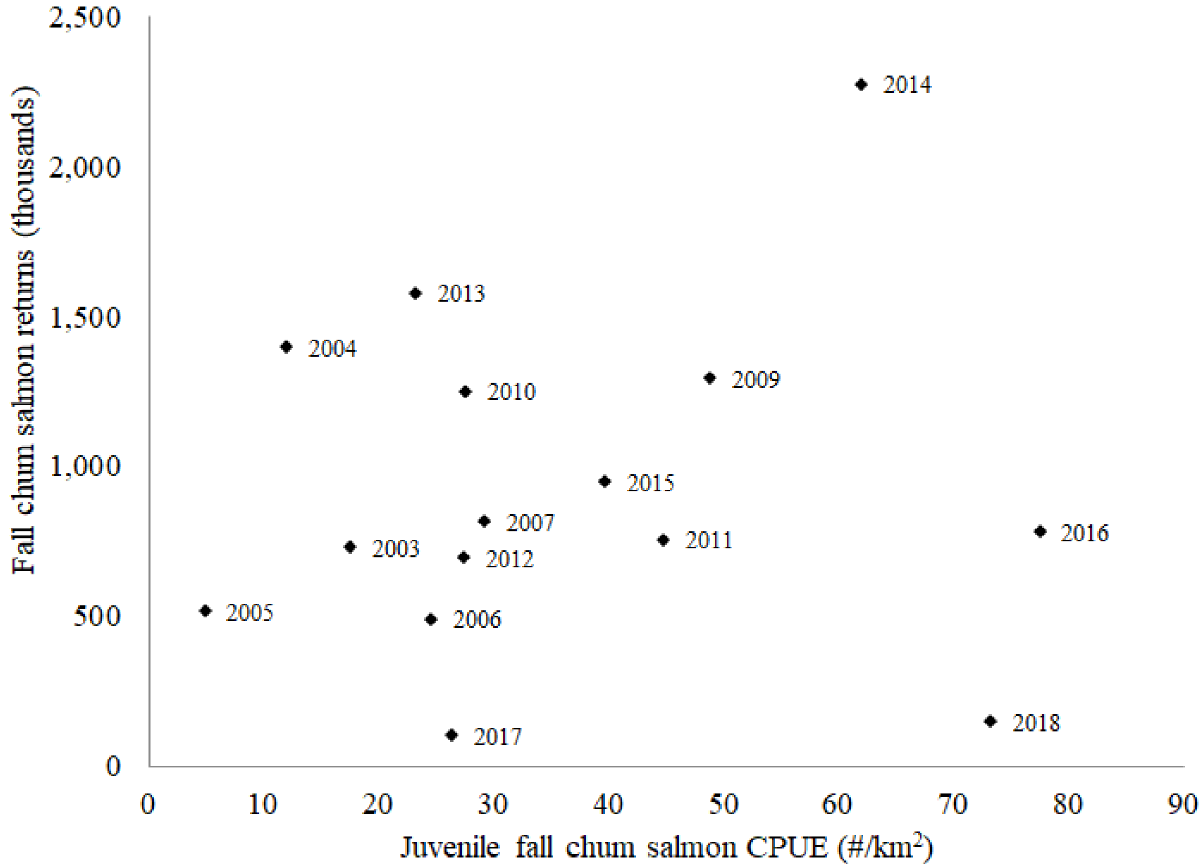


Figure 26. -- Relationship between juvenile fall chum salmon abundance and resulting adult returns of adult fall chum salmon to the Yukon River. Figure labels show the juvenile year (brood year = juvenile year - 1).

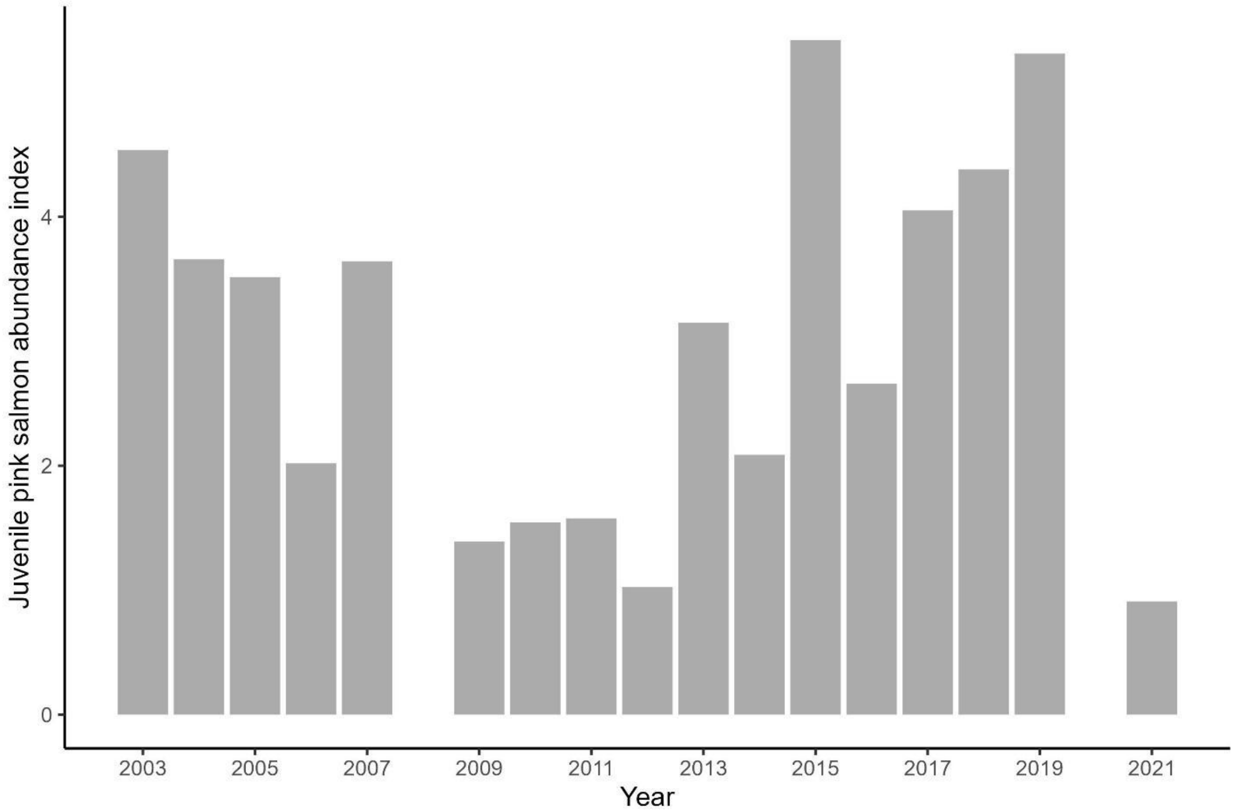


Figure 27.. -- The juvenile pink salmon abundance index from the Northern Bering Sea Ecosystem and Surface Trawl survey, 2003-2021.

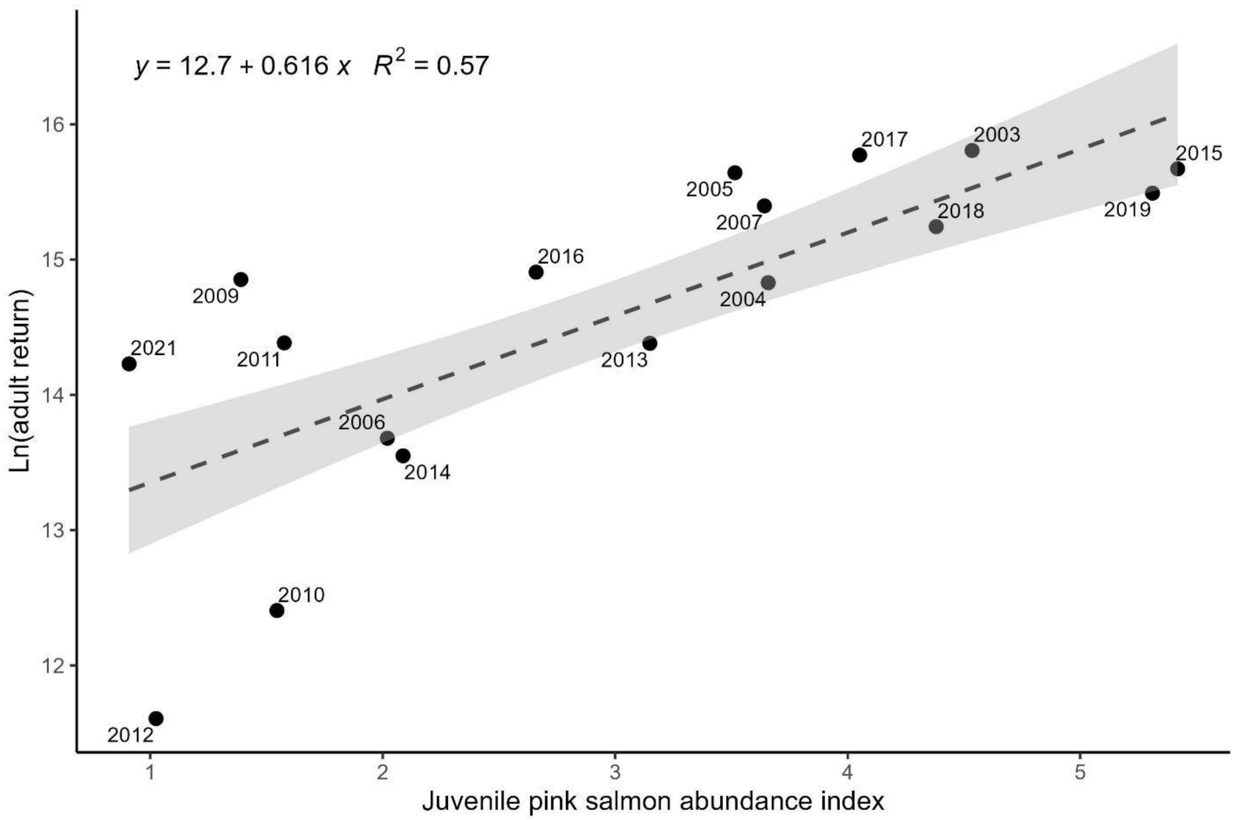


Figure 28. -- A linear regression model fit (black line) with 80% confidence interval (shaded region) between the juvenile pink salmon abundance index from the Northern Bering Sea Ecosystem and Surface Trawl survey (black dots; 2003-2021) and the natural log of adult pink salmon returns to the northern Bering Sea (Yukon River and Norton Sound).

APPENDIX A
Collection Protocols

Water Collection Protocol

Depth	GFF Every station	>10 Large Diameter Every Station	Nut Every station	Salinity (1/day, alternate surface/deep)	Phyto preservation Every Station	GFF and >10 Duplicates 1/day	Fatty Acid Samples Beam Trawl Station Only	HABs Samples Every station	eDNA (phyto and fish) 2nd Station each day	Blanks Every other day
0	X		X	X (OR) ↓				X		
10	X	X	X		X	X (OR) ↓	X	**X	X	
20	X	X	X			X (OR) ↑				
30	X	X(Beam trawl stn only)	X							
40	X (OR) ↓		X (OR) ↓						X (OR) ↓	
50	X (OR) ↑									
60										
70			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)				** HAB samples collected at 0 and 10m for first two stations each day, and only at 0m for the Beam Trawl station.						

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

Van Veen Grab Collection Protocols

Sediment Samples for quantitative cyst counts- *(Lefebvre)* Please collect sediment via Van Veen Grab at all available stations. The goal is to generate a cyst map in the Bering Strait/Bering sea region. We will provide a sediment sampling kit, coolers, and a laminated detailed protocol sheet to take on the cruise. Sediment samples need to be stored in the dark at 1 – 4˚C (in the refrigerator NOT frozen). We will also include a HOBO continuous temperature logger to keep with the sediment samples.

Sediment samples process: Use a cut syringe to pull a 0-3 cm plug from the surface of the sediment in the grab. Stir the plug with a spatula and pack it into a 10 ml vial, leaving NO air (tap the vial gently on the benchtop to remove air bubbles). Fill jars as completely as possible and seal with parafilm. Label each sample with Cruise ID (NBS21), Station #, Collection date, and sample type (sediment). A sheet of labels will be provided with the sediment sampling kit. A detailed protocol for sediments is included in the sediment sampling kit.

Sediment Samples for fatty acids-*(Copeman)* Please collect surface sediment from the Van Veen Grab at each station. Scoop surface sediment from the 0-3 cm surface layer and place into the 15 mL falcon tubes provided. This can be done using a clean spatula or spoon. Fill to 12 mL or near the top but allowing room for freezing. Label each sample with Station #, and Collection date. Place immediately inside a hard case marked Marine Lipid Lab sediment samples stored in the -40 ℃ freezer.

HABs biomarkers in Benthic Clams (from Beam Trawl & Benthic grabs)- *(Lefebvre)* Please collect 5-10 clams as available from any sediment sampling. We are mostly interested in *Macoma calcarea*, but will take any clams available. Minimum size is ½ inch in diameter. Larger clams are better. Place clams in plastic bags sorted by species & label the bag with Cruise name (NBS21), Station #, Haul #, Collection date, and Species (if possible). Freeze clams in bags ASAP and do not allow them to thaw (-20 ˚C).

Fatty Acids in benthic clams from the benthic grab (optional)-*(Copeman)* Please rinse the benthic clams well with seawater before sampling for lipids. Sample 10 clams per station from the benthic grab. Clams can be IDed, weighted and measured in the Marine Lipids Lab. Place clams in a whirl pack bag Label each sample with Station #, and Collection date. Freeze immediately in the -40 ℃ freezer.

Salmon Collection Protocol

The juvenile life-history stage assignments of catch and specimen data are based on length and are approximately <300 mm. However, juvenile Chinook and coho salmon can be larger than 300 mm and therefore the length frequency distribution is also used to assign life-history and otoliths need to be collected to validate age and life-history. Unless otherwise noted, these sample sizes are per station. Take lengths and weights of 50 of each species. Note any fin clips, scarring, parasites, or skeletal deformities. Photograph unusual features with notation in CLAMS. Scan Chinook salmon for adipose fin clips and CWT. Note the presence of ad-clip and CWT in notes and add CWT label to juveniles with CWT.

For juvenile Chinook and coho, remove caudal fin clips for genetics at sea, then store fish frozen and transport to ABL. All other Chinook and coho dissections and processing for diet, energetics, and age will be done at ABL. For juvenile sockeye, chum, and pink when > 15 fish are caught, save 5 average-sized fish for energetics, and 10 for diets. When <15 fish are caught, save minimum 2 for energetics and remainder for diets, or split available fish evenly between energetics and diets.

Juvenile Chinook (*Oncorhynchus tshawytscha*) Process subyearlings first.

- **Genetics:** *(Garcia/Murphy):* All juveniles. Remove a caudal fin clip and place on a separate Whatmann sheet at each station. Place Whatmann sheet in desiccant container to dry. Note the barcode number range for the specimens collected at the station. Barcode numbers 1-600
- **Diet** *(Moss)*: Fish 1-10. Remove stomachs from up to 10 fish 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.
- **Energetics** *(Sewall)*: 2-5 Fish AVG size and all <18cm. Freeze whole. Flag energetics ("ENRG"/ "NUT") in CLAMS.
- **Age:** (*Murphy)*: Collect heads from all fish. Save whole or cut heads and barcode. Wrap heads in plastic wrap with barcode, freeze at -20, and flag Head collection in CLAMS.
- **Icthyophonus:** (*Fergusson/Clark*): Either remove hearts from frozen whole fish saved for diet analysis in the lab, or remove hearts from fish that have stomachs removed for diet analysis in the field. This will provide up to 10 heart samples at each station. Place hearts in vial labeled with barcode number and fix with ethanol.

Juvenile Coho (*Oncorhynchus kisutch*)

- **Genetic origin:** *(Garcia):* up to 50 juveniles per station. Remove a caudal fin clip and place on a separate Whatmann sheet at each station. Note the barcode number range for the specimens collected at the station. Place Whatmann sheet in desiccant container to dry. Tag numbers 601-900
- **Diet** *(Moss)*: Remove stomachs from up to 10 fish at each station. Place stomachs in a soil bag, label with station and preserve in 5-gallon bucket of 10% formalin. Flag Stomach in CLAMS.
- **Energetics** *(Sewall)*: Wrap 2-5 average sized whole fish in plastic wrap with barcodes and freeze at each station. Flag energetics ("ENRG"/ "NUT") in CLAMS.
- **Age:** (*Murphy)*: Collect heads from all fish not saved whole for otoliths. Wrap heads in plastic wrap with barcode tag, freeze at -20, and flag Head collection in CLAMS.

Sockeye (*Oncorhynchus nerka*)

- **Genetic origin:** *(Dann):* up to 50 juveniles per station. Remove a caudal fin clip and place on a separate Whatmann sheet at each station. Note the barcode number range for the specimens collected at the station. Place Whatmann sheet in desiccant container to dry. Tag numbers 901-1200
- **Diet** *(Moss)*: Remove stomachs from up to 10 fish 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.
- **Energetics** *(Sewall)*: Wrap 2-5 average sized whole fish in plastic wrap with barcodes and freeze at each station. Flag energetics ("ENRG"/ "NUT") in CLAMS.
- **Age:** (*Murphy)*: Collect heads from all fish not saved whole for otoliths. Wrap heads in plastic wrap with barcode tag, freeze at -20, and flag Head collection in CLAMS.
- **Neurology:** *(Yopak)*: Collect 12 whole juveniles in formalin with soil bags and barcodes across the juvenile size spectrum (90 – 150 mm: n=3, 150 – 200 mm: n=3, 200 – 250 mm: n=3, and 250 – 300 mm: n=3). Place soil bags in a 1 or 2 liter Nalgene jar with buffered formalin. Collect 12 juveniles regardless of length if you do not encounter the full size range.

Juvenile Chum (*Oncorhynchus keta*)

- **Genetic origin:** (*Garcia)*: Collect and freeze caudal fin clips, wrap in plastic wrap "burrito style". Label with station number, cruise, species and freeze at -40. Collect additional fin clips as time permits.
- **Diet** *(Moss)*: Remove stomachs from up to 10 fish 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 CLAMS.
- **Energetics** *(Sewall)*: Wrap 2-5 average sized whole fish in plastic wrap with barcodes and freeze at each station. Flag energetics ("ENRG"/ "NUT") in CLAMS.

Juvenile Pink (*Oncorhynchus gorbuscha*)

- **Genetic origin:** *(Habicht):* Collect and freeze caudal fin clips, wrap in plastic wrap "burrito style". Label with station number, cruise, species and freeze at -40. Collect additional fin clips as time permits.
- **Diet** *(Moss)*: Remove stomachs from up to 10 fish 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.
- **Energetics** *(Sewall)*: Wrap 2-5 average sized whole fish in plastic wrap with barcodes and freeze at each station. Flag energetics ("ENRG"/ "NUT") in CLAMS.

- **HABs** *(Lefebvre):* Collect 4 whole pink salmon with barcodes at each station. Flag Habs in CLAMS.

Immature/maturing chum, Chinook , coho, sockeye (>300 mm) Record length, weight of up to 50 individuals per species.

- **Chinook Genetics** (*Garcia/Murphy*): Fish 1-50, Assign barcode numbers to genetic tissues, record sex and maturity (all will be immature). Remove pelvic fin clip and add to the Chinook Whatmann sheet at that. Note barcode range for immature Chinook.
- **Chum Genetics** *(Kondzela*): Fish 1-50. Remove pectoral fin from immature/mature chum and wrap in plastic wrap and bag by station. Freeze at -40.
- **Diet** (*Moss*): Fish 1-10, Remove stomachs, combine in a single soil bag and add to 5 gallon bucket of buffered Formalin.
- **Sockeye Neurology** *(Yopak):* Collect 12 immature sockeye heads in soil bags with barcodes across the size range of immature sockeye. Place heads in a 1 liter or 2 liter Nalgene bottle with buffered formalin. Collect 12 immature heads regardless of length if you do not encounter the full size range.

Non-Salmon Collection Protocol

Unless otherwise noted, sample sizes are per station. Length and weigh up to 50 individuals. 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. For non-salmon with diets and energetics requested, when > 15 fish are caught, save 5 average-sized fish for energetics, and 10 for diets. When <15 fish are caught, save minimum 3 for energetics and remainder for diets, or split available fish evenly between energetics and diets. For rare species (e.g., Arctic cod, saffron cod, Pacific cod, sand lance), freeze all whole fish from survey for diet and energetic processing at ABL.

Arctic Cod (*Boreogadus saida*)

- *Moss:* preserve 10 whole age 1+ fish in a single soil bag, flag diet in CLAMS
- *Sewall:* 3-5 age 0 and 3-5 age 1+ fish; freeze with barcode, flag nutrition ("ENRG"/ "NUT") in CLAMS
- *Pinger*: collect 1 small and 1 large fish; freeze with barcode, flag nutrition ("Thiaminase") in CLAMS

Saffron Cod (*Eleginus gracilis*), Walleye Pollock (*Gadus chalcogrammus*), Capelin (*Mallotus villosus*)

- *Moss:* 10 whole age-0 fish in formalin (soil bag), remove stomachs from age 1+ and individually bag, flag diet in CLAMS
- *Sewall:* 3-5 average sized age-0 fish and 3-5 age1+ fish; freeze with barcode, flag nutrition ("ENRG"/ "NUT") in CLAMS
- *Pinger*: collect 1 small and 1 large fish; freeze with barcode, flag nutrition ("Thiaminase") in CLAMS. Collect up to 10 Capelin.
- *Lefebvre:* 4 fish frozen whole in -20, put in station bag with date and location.

Pacific Cod *(Gadus macrocephalus)*

- *Moss:* 10 whole age-0 fish in formalin (soil bag), remove stomachs from age 1+, individually bag, flag diet in CLAMS
- *Sewall:* 3-5 age-0 fish and 3-5 age1+ fish; freeze with barcode, flag nutrition ("ENRG"/ "NUT") in CLAMS

Herring (*Clupea pallasii)*

- *Moss:* preserve 10 whole age-0 fish in formalin in a single soil bag, preserve 10 whole age 1+ herring in a single soil bag, flag diet in CLAMS
- *Sewall:* 3-5 average sized age0 fish, freeze individually with barcode, flag nutrition ("ENRG"/ "NUT") in CLAMS
- *Pinger*: collect 1 small and 1 large fish; freeze with barcode, flag nutrition ("Thiaminase") in CLAMS
- *Lefebvre:* 4 age-0 and 4 age1+ fish, frozen whole in -20, put in station bag with date and location. (total< 100)

Sand lance (*Ammodytes hexapterus)*, Arrowtooth flounder (Atheresthes stomias), Sablefish (Anoplopoma fimbria)

- *Moss:* 10 whole age-1+ fish in formalin (soil bag), flag diet in CLAMS
- *Sewall:* 3-5 average sized fish, freeze individually with barcode, flag nutrition ("ENRG"/ "NUT") in CLAMS
- *Pinger*: collect up to 10 fish; freeze with barcode, flag nutrition ("Thiaminase") in CLAMS

Rainbow smelt (*Osmerus mordax),*

- *Moss:* 10 whole age-1+ fish in formalin (soil bag), flag diet in CLAMS
- *Pinger*: collect 1 small and 1 large fish; freeze with barcode, flag nutrition ("Thiaminase") in CLAMS

Ninespine stickleback (Pungitus Pungitius), Atka mackerel (Pleurogrammus monopterygius), Pacific sandfish (Trichodon trichodon), Rockfish (Sebastes spp.),

- *Moss:* 10 whole age-1+ fish in formalin (soil bag), flag diet in CLAMS

Squid (Gonatus spp.) *Pinger*: collect 3-5 small age-0 fish and 3-5 large age-0 fish; freeze with barcode, flag nutrition ("Thiaminase") in CLAMS

Bering Cisco (Coregonus laurettae) *Pinger*: collect 3-5 small age-0 fish and 3-5 large age-0 fish; freeze with barcode, flag nutrition ("Thiaminase") in CLAMS

Lamprey (*Lethenteron camtschaticum* and *Entosphenus tridentatus*) *Sutton:* Freeze all specimens individually with barcode

Salmon Shark (*Lamna ditropis*) *Garcia:* Tag salmon shark with pop-up tag and SPOT tag. Collect a muscle biopsy plug and a fin clip for genetic analysis.

Beam Trawl Collection Protocol

Sort all fish and commercial crab species (*Chionoecetes spp*. <15mm grouped as one species) to the species level, or voucher for species ID. The other invertebrates will be sorted to general taxonomic groups.

Length and weigh up to 30 individuals. Do not collect individual weights for fish (e.g. age-0) that are too small to accurately measure individual weights (most fish caught in the beam trawl). 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.

Beam Trawl Specimen collection overview

***Chionoecetes* crab <15mm Carapace Width**

- *Copeman:* Freeze up to 30 per station (Freeze crab from station all in one bag. Do not use individual bags). Freeze ASAP and keep in -40 freezer. Store in whirlpack bag inside sample box to avoid crushing and leg removal. . Label bag with cruise, station, event, and species (if possible).

Two most abundant clam species per station

- *Copeman*: Freeze 5 of each species together in a single bag for each species. Freeze ASAP and keep in -40. Freezer. Label bag with cruise, station, event, and species (if possible).
- *Lefebre*: Freeze 5-10 (>1/5" diameter) of each species together in a single bag for each species. Freeze ASAP and store in -20. Label bag with cruise, station, event, and species (if possible).

Macoma calcarea

- *Lefebre*: Freeze 5-10 (>1/5" diameter) of each species together in a single bag for each species. Freeze ASAP and store in -20. Label bag with cruise, station, event, and species.

Pacific cod, yellowfin sole <120 mm TL, northern rock sole <120 mm TL

- *Copeman, Sewall:* Individually bag and barcode (up to 10 per haul) and freeze ASAP in -40. Flag in CLAMS.

Arctic cod	**Pollock (YOY)**	**Saffron cod**	**Sablefish**
Sand lance, both species	**Capelin (juv, adult)**	**Pacific herring (YOY)**	**Arrowtooth fl. (YOY, juv)**

- *Sewall:* 5 per station. High priority fish for energetics. Individually barcode and flag for energetics in CLAMS. Freeze -20.

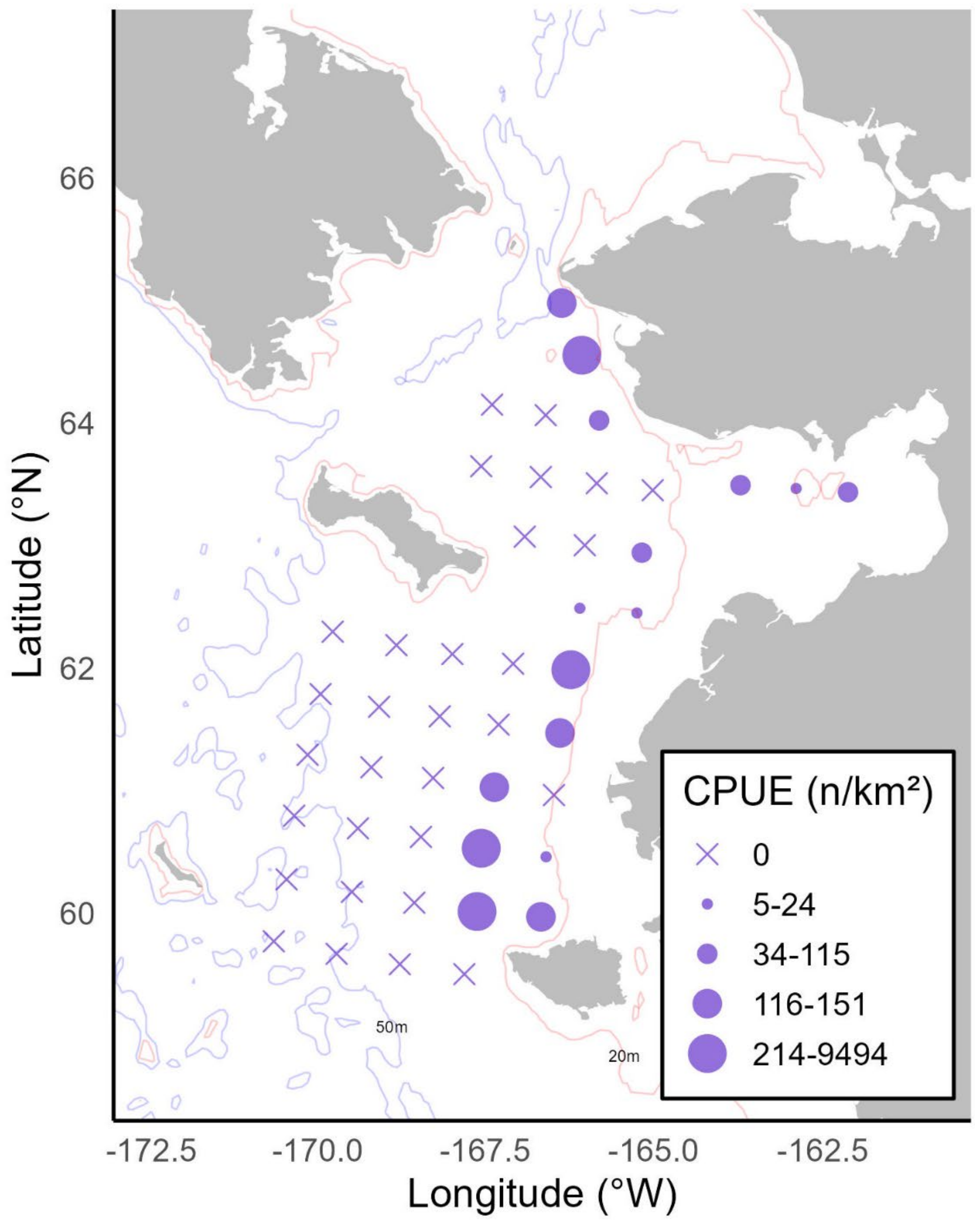
Top 10 most abundant remaining demersal species caught, for example:
Flatfishes (except northern rock sole and yellowfin sole < 120mm), **Eelblennies** (e.g., slender, stout) (YOY, juv, adult), **Sculpins** (e.g., Arctic staghorn, hamecon) (YOY, juv, adult), **Snake prickleback / Lumpenus sp**. (YOY, juv, adult), **Eelpouts** (e.g., polar, Canadian) (YOY, juv, adult), **Snailfishes** (e.g., variegated) (YOY, juv, adult)

- Sewall: 5 per station. Low priority fish for energetics. Individually barcode and flag for energetics in CLAMS. Freeze -20.

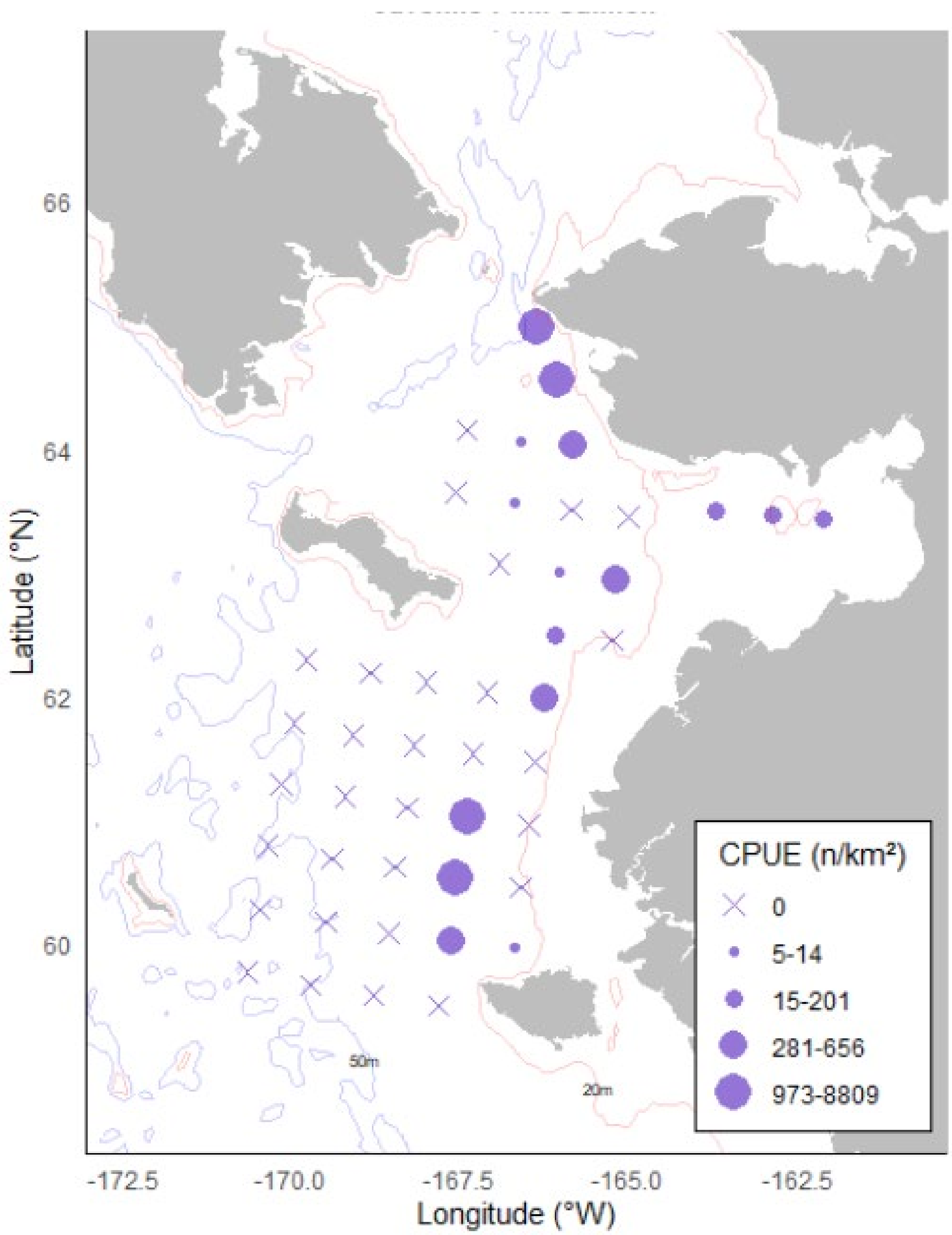
Purple-orange sea star (*Asterias amurensis*)

- *Miller:* Freeze a total of 5 for the entire survey. Flag for stable isotopes in CLAMS

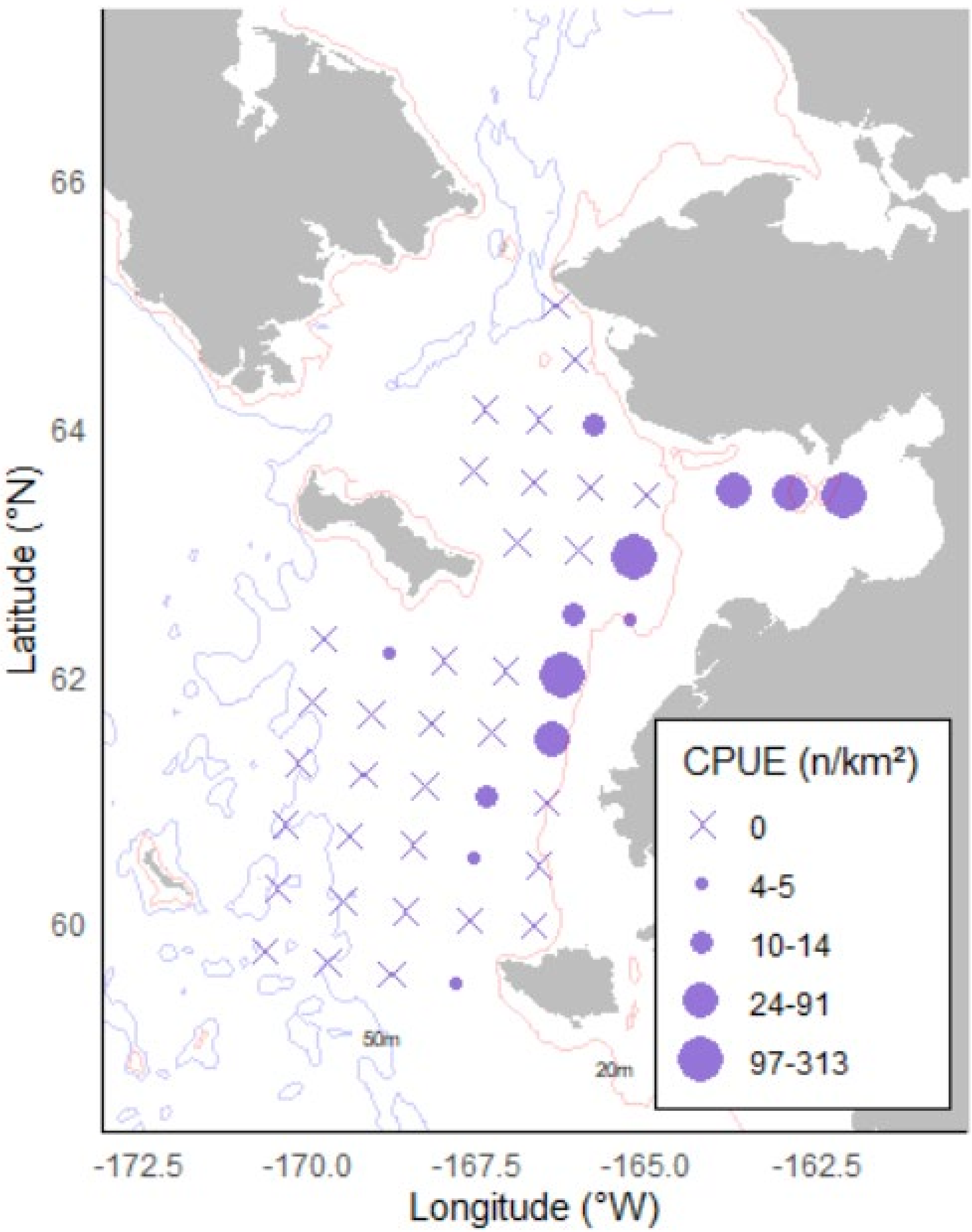
APPENDIX B
Spatial Distribution of Surface and Beam Trawl Catch



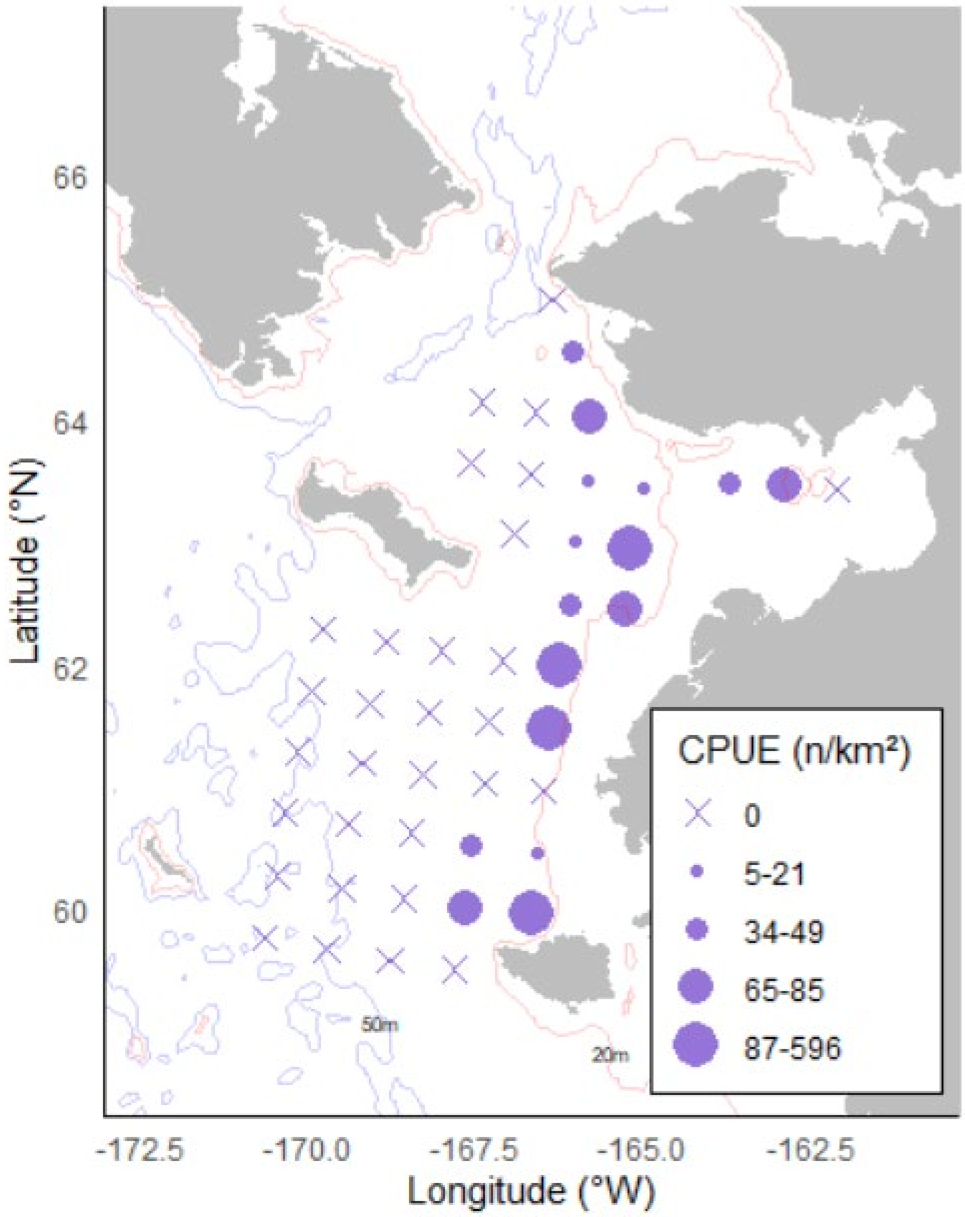
Appendix Figure B1. -- Surface trawl catch rates of juvenile chum salmon (CPUE, n/km^2) during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2021.



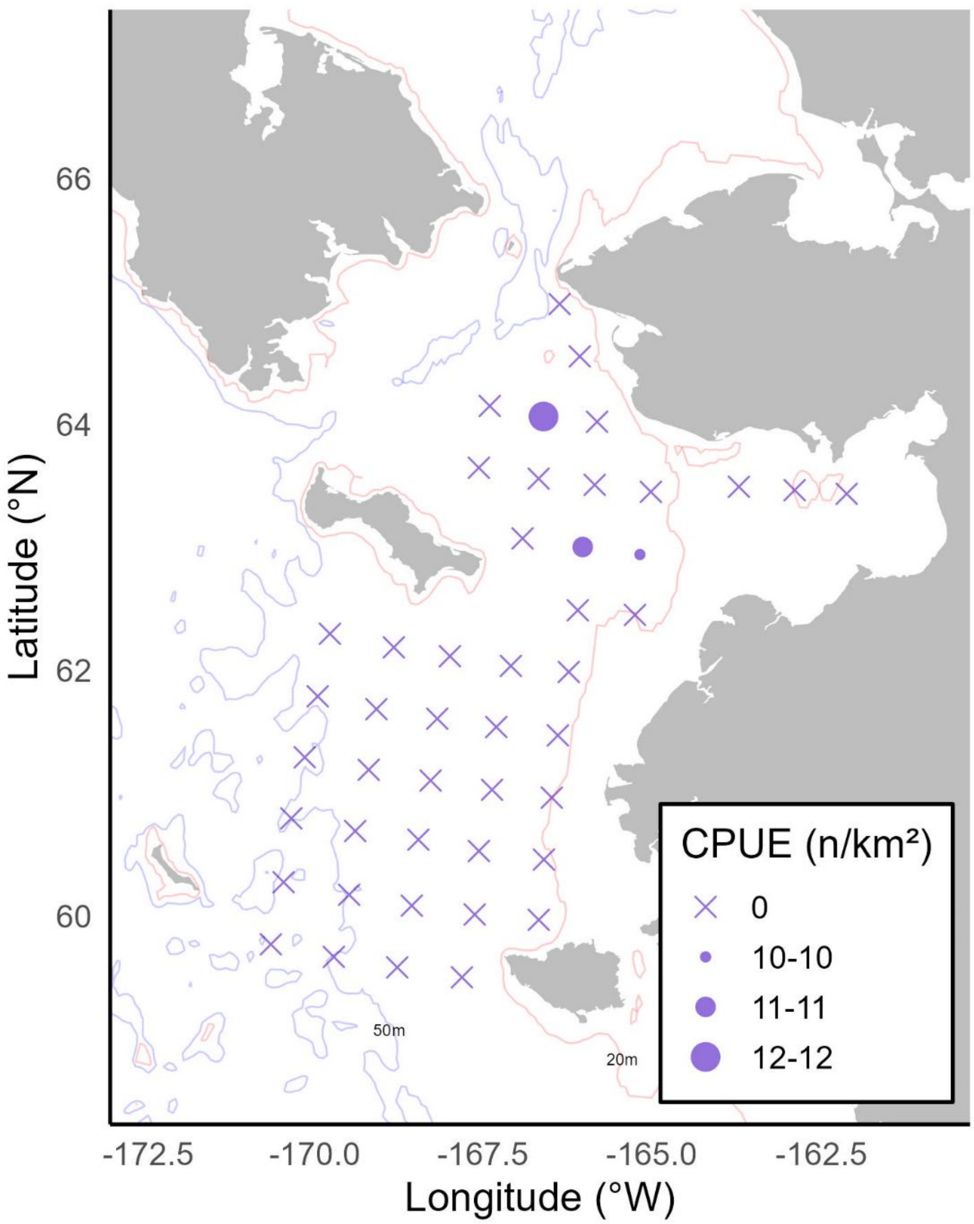
Appendix Figure B2. -- Surface trawl catch rates of juvenile pink salmon (CPUE, n/km^2) during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2021.



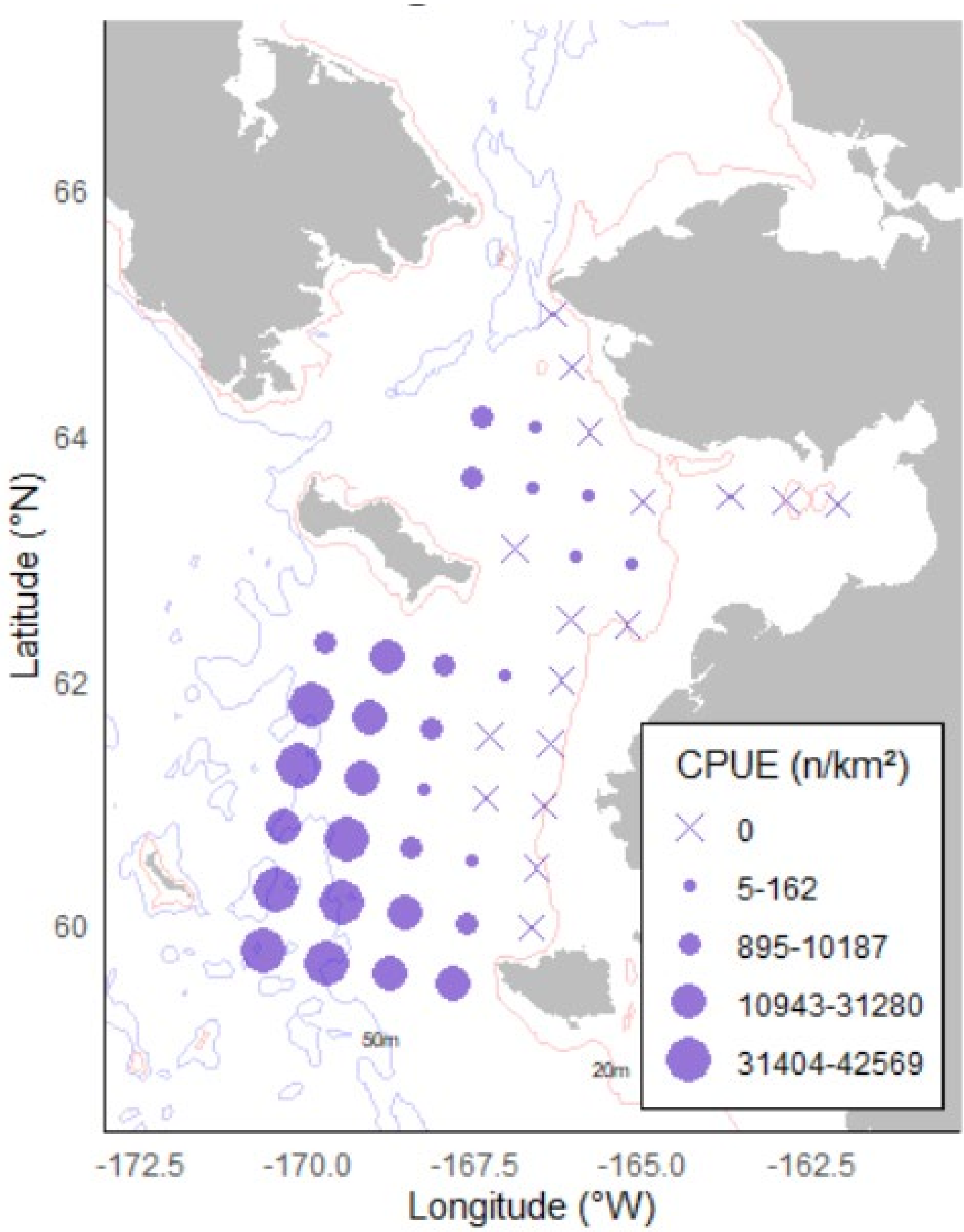
Appendix Figure B3. -- Surface trawl catch rates of juvenile Chinook salmon (CPUE, n/km^2) during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2021.



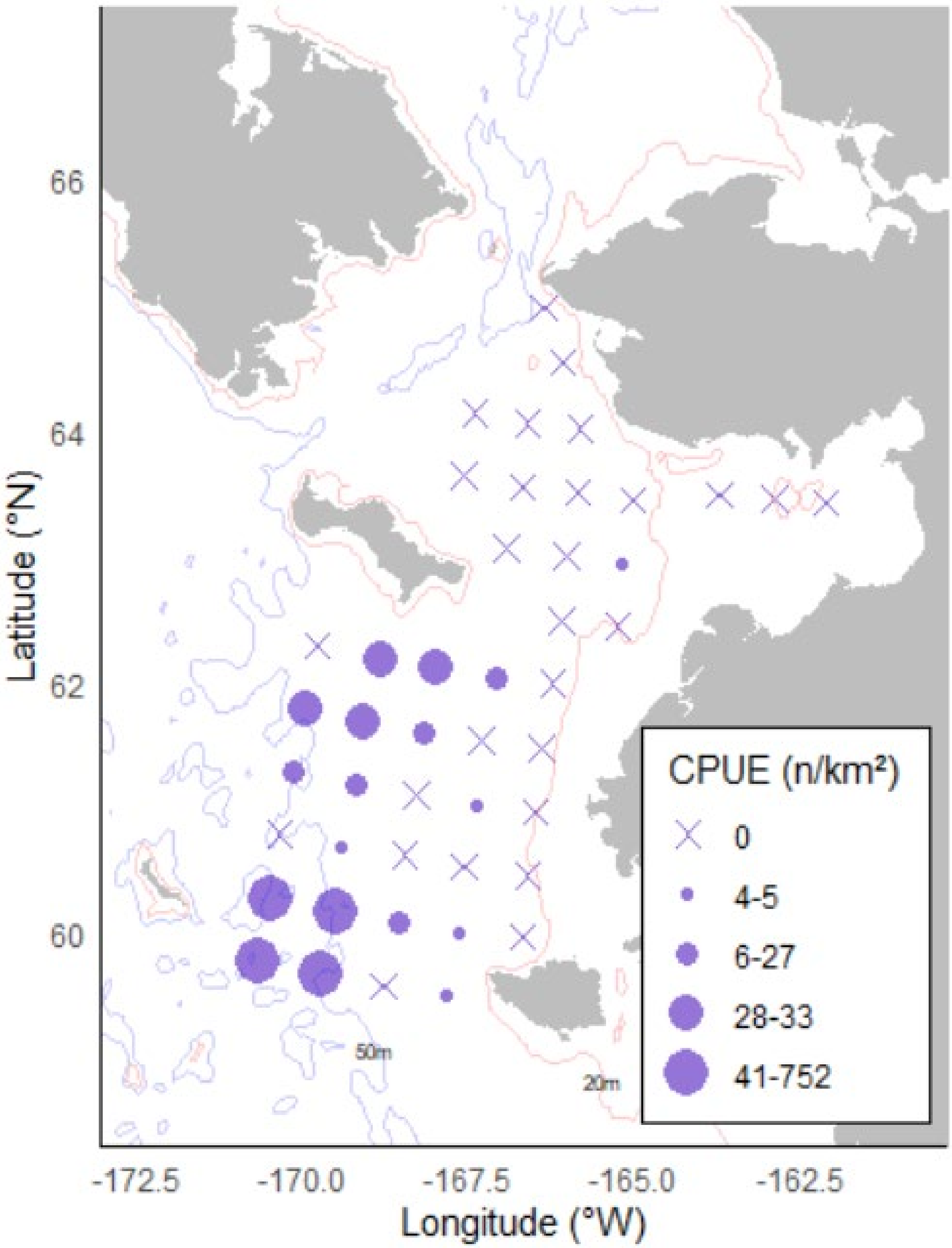
Appendix Figure B4. -- Surface trawl catch rates of juvenile coho salmon (CPUE, n/km^2) during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2021.



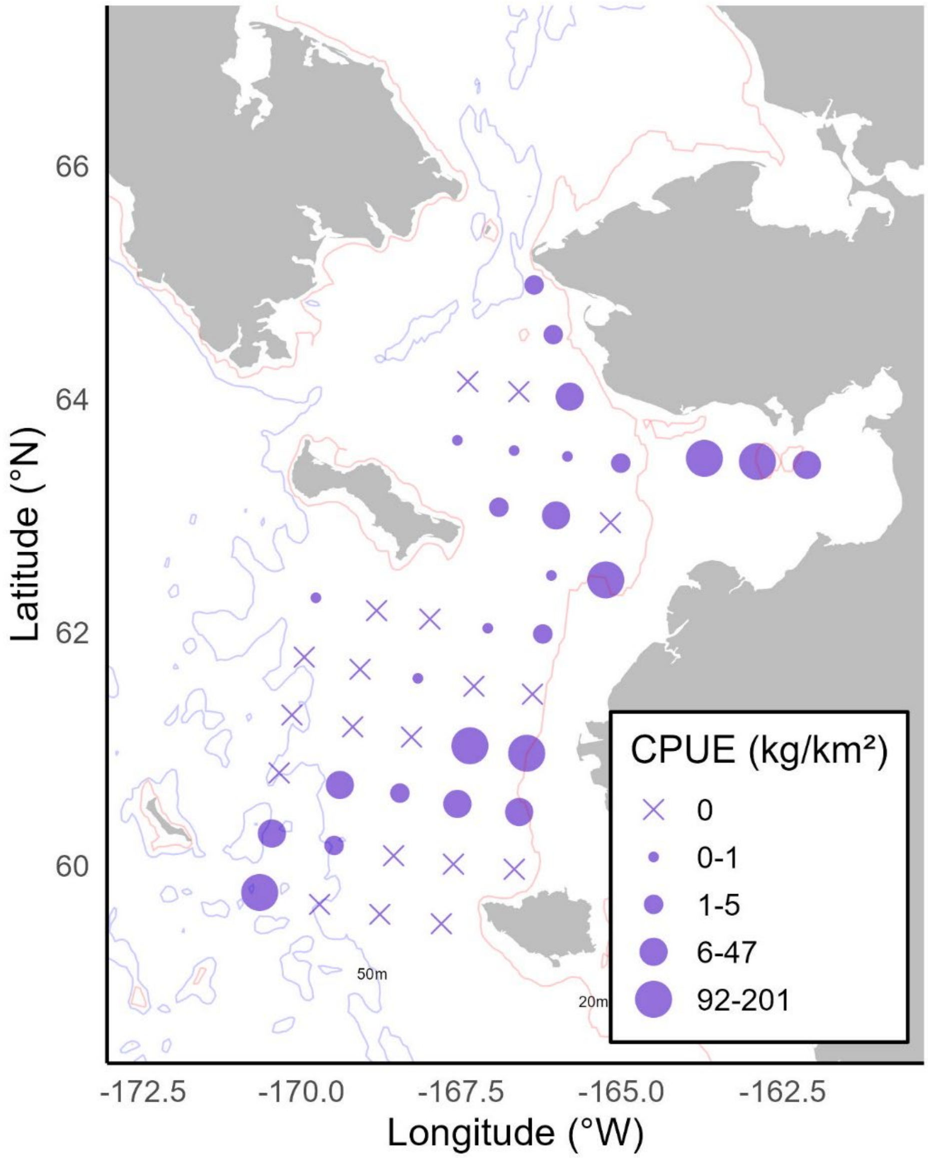
Appendix Figure B5. -- Surface trawl catch rates of juvenile sockeye salmon (CPUE, n/km^2) during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2021.



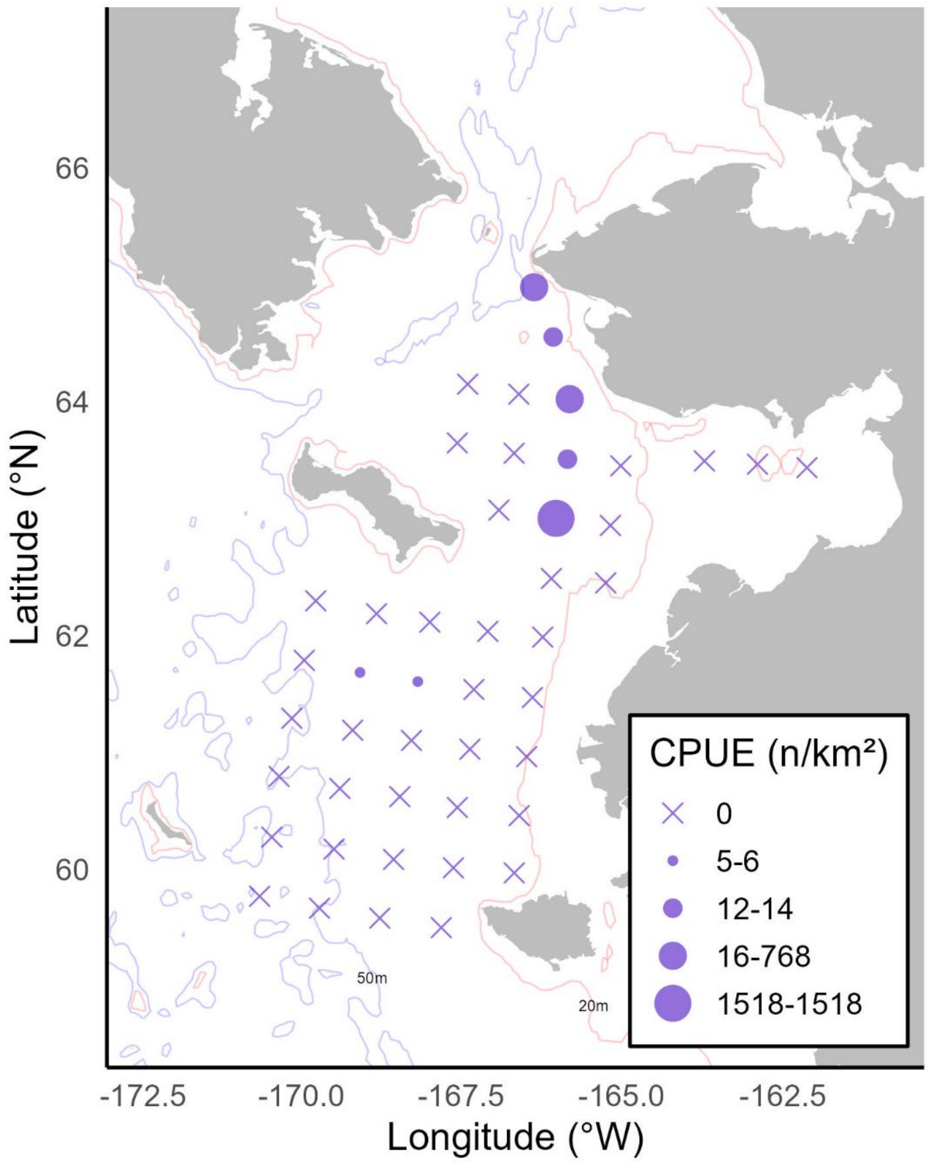
Appendix Figure B6. -- Surface trawl catch rates of age-0 walleye pollock (CPUE, n/km^2) during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2021.



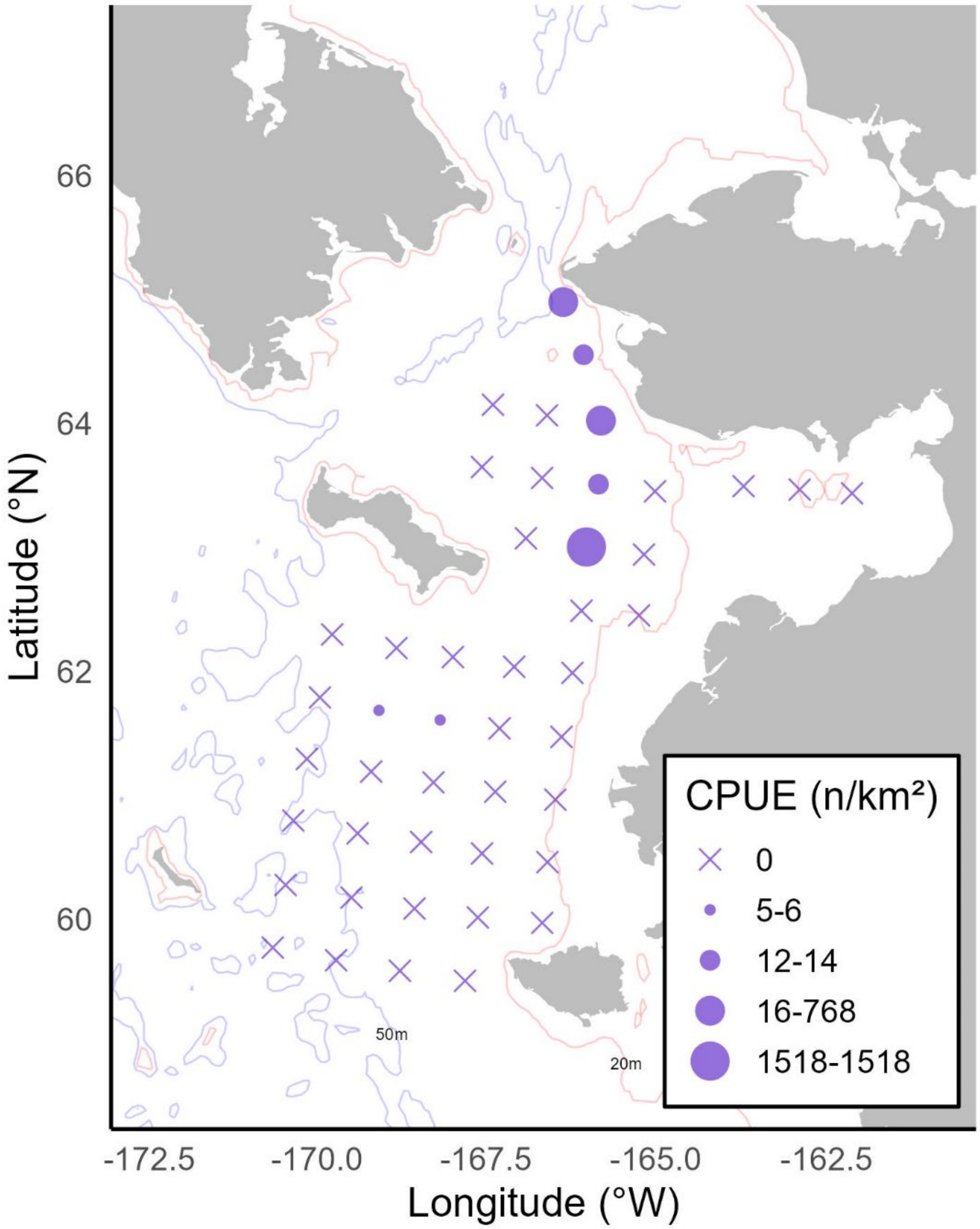
Appendix Figure B7. -- Surface trawl catch rates of age-0 Pacific cod (CPUE, n/km^2) during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2021.



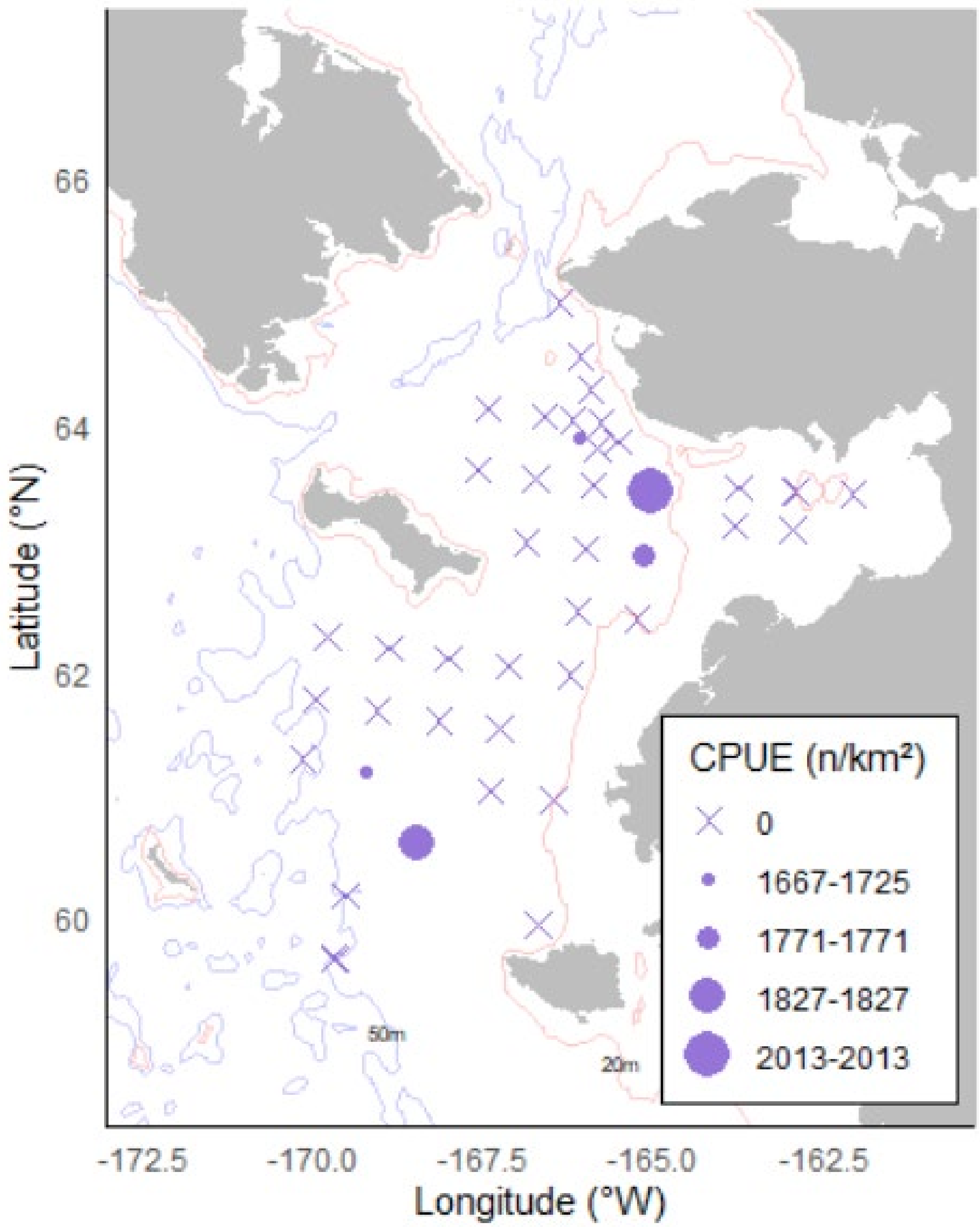
Appendix Figure B8. -- Surface trawl catch rates of Pacific herring (CPUE, kg/km^2) during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2021.



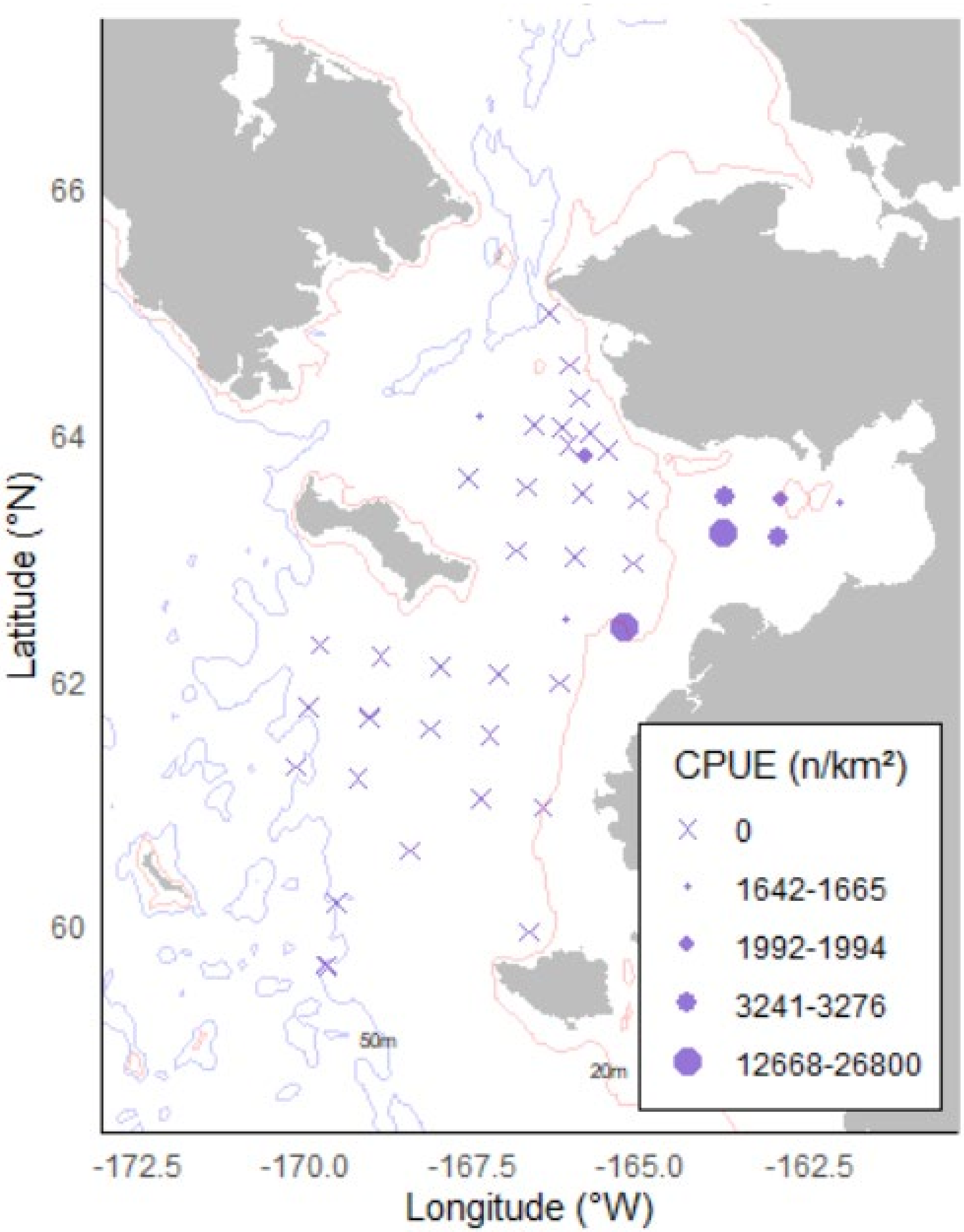
Appendix Figure B9. -- Surface trawl catch rates of Arctic sand lance (CPUE, n/km^2) during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2021.



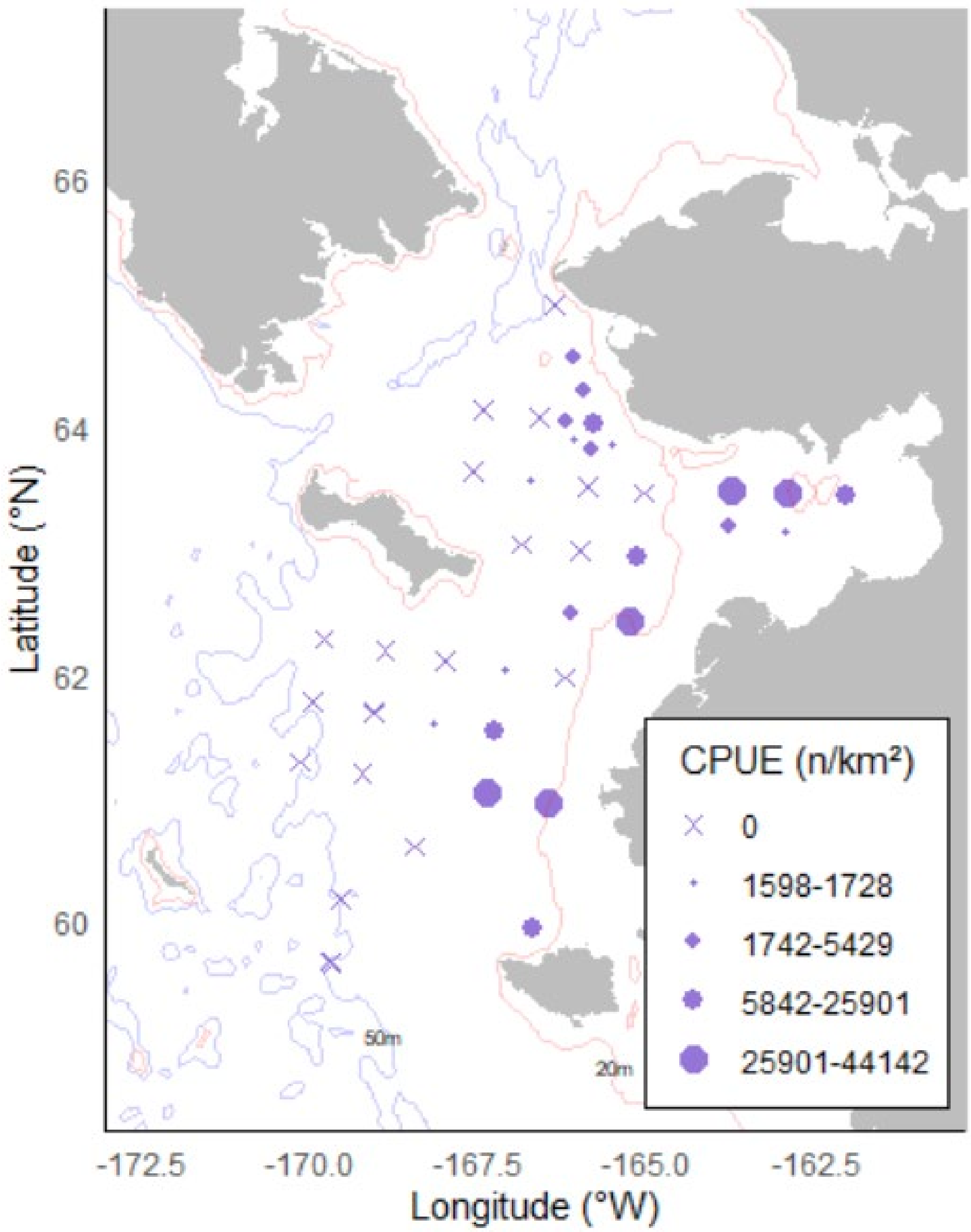
Appendix Figure B10. -- Surface trawl catch rates of capelin (CPUE, n/km^2) during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2021.



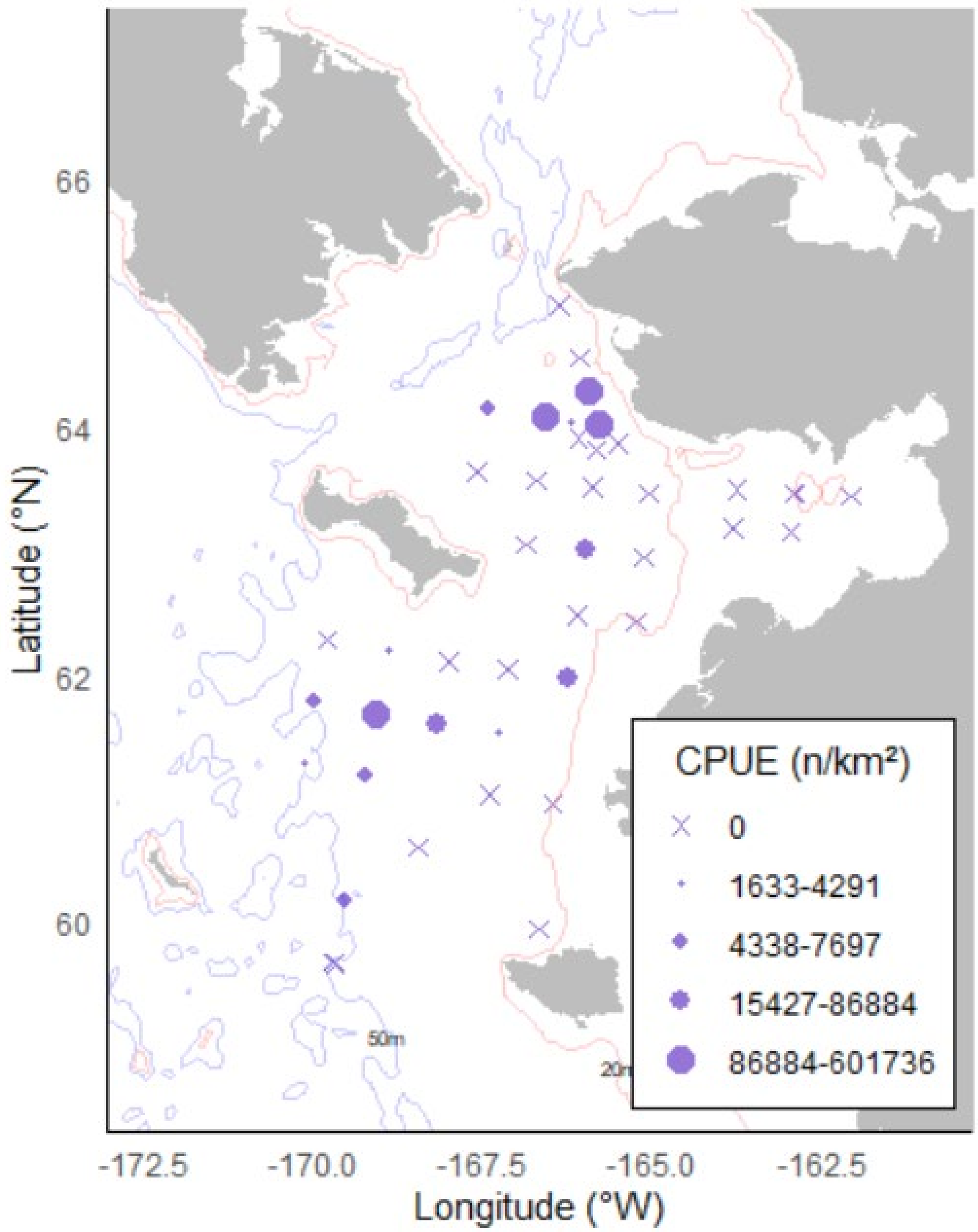
Appendix Figure B11. -- Beam trawl catch rates of age 0 Pacific cod (CPUE, n/km^2) during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2021.



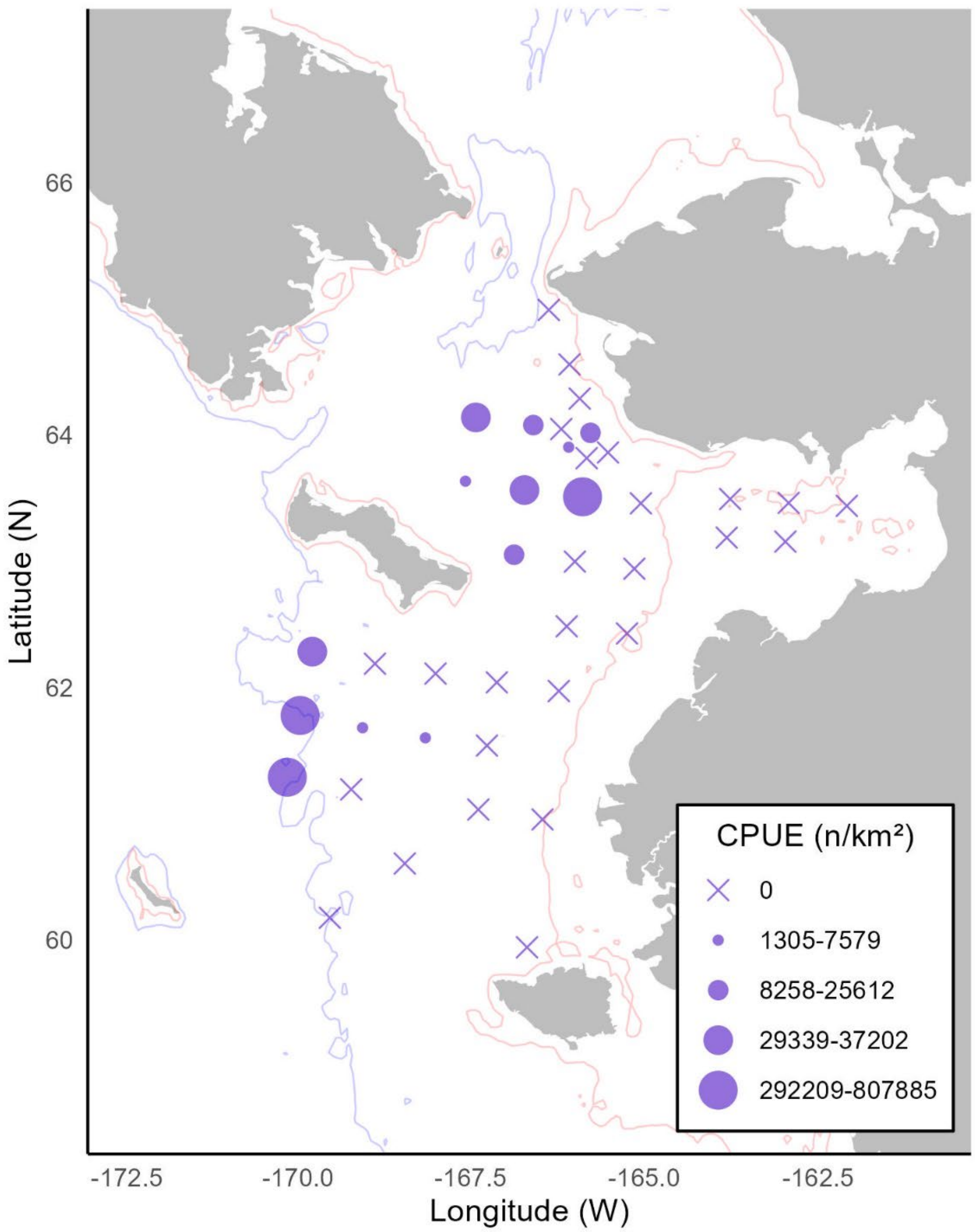
Appendix Figure B12. -- Beam trawl catch rates of all life-history stages (LHS) of saffron cod (CPUE, n/km^2) during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2021.



Appendix Figure B13. -- Beam trawl catch rates of yellowfin sole (CPUE, n/km^2) during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2021.

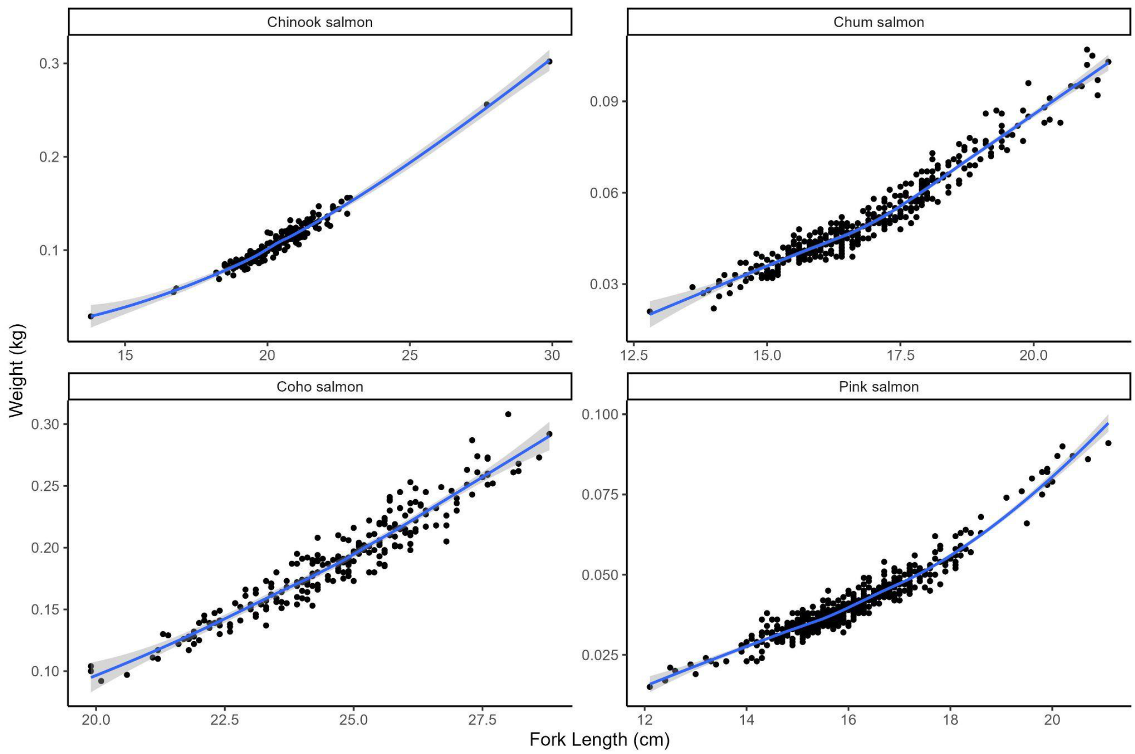


Appendix Figure B14. -- Beam trawl catch rates of snow crab (CPUE, n/km^2) with carapace widths (CW) less than 15mm during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2021.

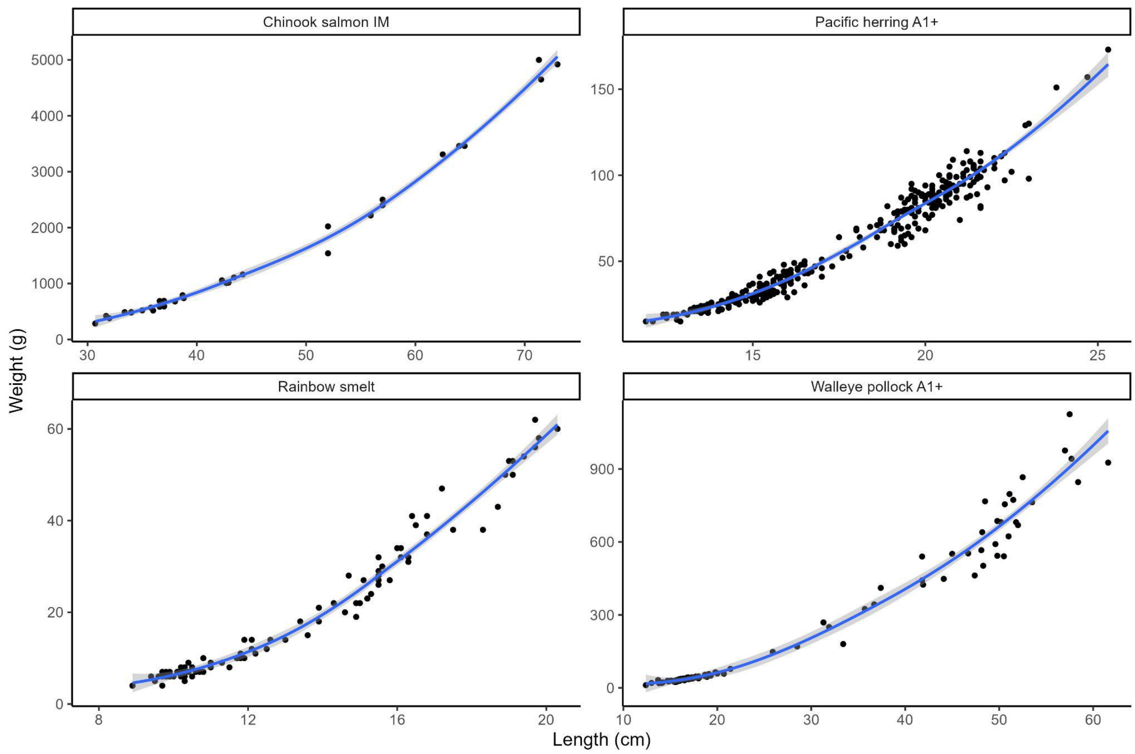


Appendix Figure B15. -- Beam trawl catch rates of snow crab (CPUE, n/km^2) with carapace widths (CW) greater than or equal to 15 mm and less than 45 mm during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2021.

APPENDIX C
Length-Weight Relationships



Appendix Figure C1. -- Length-weight relationships of juvenile salmon species sampled during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2019. Lines and shaded regions are from a local regression model (loess) fit and standard error.



Appendix Figure C2. -- Length weight relationships of abundant species other than juvenile salmon sampled during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2019. Lines and shaded regions are from a local regression model (loess) fit and standard error.

APPENDIX D
Juvenile Salmon Diet

Appendix Table D1. -- Juvenile Chinook, coho, chum, pink, and sockeye salmon sample size by number of stations (n), number of stomachs (n), and the mean stomach fullness index (SFI) sampled during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2003-2021.

	Chinook Salmon			Coho Salmon			Chum Salmon		
Year	Stations (n)	Stomachs (n)	Mean SFI	Stations (n)	Stomachs (n)	Mean SFI	Stations (n)	Stomachs (n)	Mean SFI
2003	--	--	--	--	--	--	12	93	187.73
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	207.08
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	24	109	145.36	24	132	117.73	24	227	102.89
2019	10	44	70.47	17	84	173.49	27	252	48.21
2021	12	112	97.3	11	97	125.37	12	113	123.64

	Pink Salmon			Sockeye Salmon		
Year	Stations (n)	Stomachs (n)	Mean SFI	Stations (n)	Stomachs (n)	Mean SFI
2003	6	60	135.52	--	--	--
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	--
2013	21	188	104.33	0	0	--
2014	0	0	--	0	0	--
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	31	277	56.43	7	30	37.90
2019	32	320	86.72	13	126	42.84
2021	11	106	138.02	0	0	--

Appendix Table D2. -- Juvenile Chinook salmon diet expressed as percent stomach content index (SCI) during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2004-2021. Chinook salmon diets were not available from 2003.

Year	Sand Lance	Capelin	Age-0 Pollock	Pacific Herring	Other Fish	Decapod	Other	Unident. Fish
2004	30.75	18.52	26.29	14.01	0.16	8.21	1.11	0.94
2005	3.97	26.63	25.84	1.27	5.14	12.99	12.05	12.11
2006	35.24	16.69	10.22	0	15.95	3.58	1.37	16.95
2007	13.33	49.60	3.62	0	18.03	10.81	2.52	2.11
2009	35.76	19.79	0	0	16.78	6.14	2.03	19.50
2010	6.89	68.39	0	3.24	10.16	2.35	4.02	4.95
2011	20.52	40.65	0	15.38	3.71	5.03	2.50	12.22
2012	0	0	0	0.00	0	4.22	1.00	94.78
2013	12.93	63.05	0	8.33	0.57	4.31	5.86	4.95
2014	66.46	4.68	4.10	0	7.35	7.97	5.52	3.92
2015	73.43	5.44	3.07	3.04	3.37	7.93	1.91	1.82
2016	57.29	9.90	6.06	2.31	2.95	17.01	1.29	3.19
2017	40.37	11.00	2.67	7.95	17.61	6.81	5.30	8.29
2018	2.39	5.59	19.50	0	28.70	15.46	9.79	18.56
2019	12.98	0	21.00	28.08	0	22.78	4.18	10.99
2021	32.45	0	0.012	26.91	14.16	2.44	2.15	21.77

Appendix Table D3. -- Juvenile coho salmon diet expressed as percent stomach content index (SCI) during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2004-2021. Coho diets were not available in 2003.

Year	Age-0 Pollock	Capelin	Decapod	Other	Other Crustacean	Other Fish	Sand Lance	Unident. Fish
2004	40.07	2.43	15.71	0.3	1.5	23.75	15.69	0.55
2005	0	0	0.23	3.35	0	95.22	0	1.19
2006	24.35	1.35	11.56	3.44	0.36	14.46	33.36	11.13
2007	0	23.88	14.04	0	0	34.35	22.19	5.53
2009	20.1	28.35	0.42	0	1.21	0	36.18	13.75
2010	0	65.06	8.07	0	0.45	0	26.41	0
2011	0.23	44.41	1.95	0	0	9.35	43.47	0.59
2012	0	0	0	0	0.2	0	0	99.8
2013	0	0	0.17	0.16	0	11.18	88.35	0.14
2014	33.47	4.38	0.09	0.05	0.73	32.09	28.65	0.5
2015	15.92	13.28	14.58	0	0.11	27.66	13.56	5.09
2016	19.48	0	0.36	9.27	0.27	12.75	51.99	4.17
2017	0.59	6.22	1.23	2.46	1.65	10.68	36.36	35.13
2018	29.2	0	8.89	2.21	2.56	19	7.69	13.38
2019	53.93	0	2.51	1.37	0.62	13.28	7.22	18.86
2021	6.17	0	2.14	0	10.96	51.52	15.82	13.39

Appendix Table D4. -- Juvenile chum salmon diet expressed as percent stomach content index (SCI) during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2003-2021.

Year	Gelatinous Prey	Sand Lance	Age-0 Pollock	Other Fish	Euphausiid	Hyperiid	Other Crustacean	Other	Unident.
2003	26.07	47.43	3.87	9.25	0.26	1.95	9.83	1.34	0
2004	36.91	4.64	13.72	14.47	6.38	7.84	15.97	0.08	0
2005	28.74	0	21.1	17.04	28.51	1.56	3.05	0	0
2006	20.49	44.64	1.76	27.34	3.88	0.67	1	0.22	0
2007	63.29	2.72	0	4.23	12.31	8.26	8.4	0.79	0
2009	42.23	9.44	0	23.5	0	22.97	1.54	0.33	0
2010	26.07	16.87	0	15.07	19.08	18.86	3.46	0.59	0
2011	49.91	0	0	17.87	11.97	12.37	6.56	1.33	0
2012	43.81	4.32	0	7.8	10.29	7.27	3.2	23.31	0
2013	27.13	11.29	0	6.95	4.03	46.42	3.38	0.8	0
2014	7.73	17.7	0.51	26.7	18.59	8.36	7.42	6.11	6.88
2015	30.65	27.9	0	24.56	0.55	10.61	5.09	0.64	0
2016	56.1	0	0	16.96	0	1.37	4.02	21.55	0
2017	7.86	5.2	0	48.89	20.88	0.41	2.27	14.48	0
2018	18.86	0	0	6.22	35.88	2.92	0.41	0.03	35.67
2019	60.28	0	3.65	5.7	0.06	0.32	2.92	0.01	27.08
2021	29.4	0.23	0	32.62	10.97	12.56	1.97	1.08	11.17

Appendix Table D5. -- Juvenile pink salmon diet expressed as percent stomach content index (SCI) during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2003-2021.

Year	Age-0 Pollock	Copepod	Decapod	Other	Gelatinous Prey	Other Fish	Sand Lance	Euphausiid	Hyperiid	Unident.
2003	29.18	0.96	4.75	0	0	40.46	8.66	14.19	1.8	0
2004	14.98	6.55	28.36	1.47	1.4	5.07	26.75	11.83	3.59	0
2005	25.46	0.4	15.86	1.58	3.36	28.19	3.15	16.65	5.35	0
2006	1.48	3.28	10.16	4.21	3.59	26.53	47.26	0.89	2.59	0
2007	0.37	9.5	29.96	5.24	8.97	17.11	3.96	7.86	17.05	0
2008	0	0	30	0	0	0	50	0	20	0
2009	0	6.03	1.92	7.64	15.72	22.27	26.64	2.47	17.32	0
2010	0	1.16	1.96	0.62	6.75	16.3	9.7	56.78	6.72	0
2011	0	24.38	19.73	2.14	6.39	3.14	12.55	0.12	31.55	0
2012	0	1.96	3.95	0	0	28.43	0	40.91	5.72	19.01
2013	0	2.16	5.09	0.56	9.04	21.01	2.69	9.88	49.57	0
2015	0	6.21	5.21	0.73	5.02	2.65	63.49	9.44	7.24	0
2016	0	33.11	17.2	2.62	4.92	23.34	8.47	0	0.61	9.71
2017	0	35.78	3.31	0.25	0	12.24	2.35	38.56	0.59	6.93
2018	0	12.54	2.34	5.08	0.79	8.34	0	32.32	8.24	30.35
2019	0.27	45.45	2.52	0.56	3.73	16.88	0.52	3.15	0.47	26.46
2021	0	5.54	4.61	1.39	7.36	35.23	0.1	34.18	4.09	7.51

Appendix Table D6. -- Juvenile sockeye salmon diet expressed as percent stomach content index (SCI) during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2004-2021. Sockeye diets were not available from 2003.

Year	Copepod	Sand Lance	Age-0 Pollock	Other Fish	Thysanoessa spp.	Decapod	Other Crustacean	Other	Unident.
2004	3.68	7.87	61.15	0.44	5.17	14.78	4.63	1.55	0.74
2005	0	0	0	0	0	0	0.96	30.03	69.01
2006	0	0	0	0	33.04	47.5	4.73	14.72	0
2007	26.97	0	0	0.49	4.83	0.65	12.08	55.03	0
2009	0	100	0	0	0	0	0	0	0
2010	0	0	0	0	95	0	0	5	0
2011	0	0	0	70	0	30	0	0	0
2015	5.91	0	9.44	0	0.2	73.57	9.45	0.24	1.19
2016	1.42	4.33	4.17	0	2.12	11.85	7.26	36.05	32.8
2017	0	0	0	0	77.67	1.68	0.27	0	20.38
2018	2.98	0	0	1.92	41.9	3.34	1.14	4.05	44.67
2019	7.86	0	17.71	4.19	5.2	12.67	1.49	9.01	41.86

APPENDIX E
Ichthyophonus

Appendix Table E1. -- Individual data of lifestage, fork length, weight, and Ichthyophonus intensity by qPCR for Chinook salmon sampled from the Northern Bering Sea, 2021.

Barcode	Tube #	Lifestage	Fork length (cm)	Weight (kg)	*Ichthyophonus* (gene copies/g)
2	1	Immature	35.8	0.57	0
3	2	Immature	33.4	0.488	Borderline
4	3	Immature	34	0.48	Borderline
5	4	Immature	37	0.59	0
6	5	Immature	62.5	3.31	4.86E+07
7	6	Immature	73	4.92	0
8	7	Immature	36.6	0.584	0
9	8	Immature	42.3	1.057	1.50E+07
10	9	Immature	43.4	1.109	2.23E+07
11	10	Immature	36.6	0.687	1.45E+08
12	11	Immature	52	2.023	2.90E+06
13	12	Immature	55.9	2.218	4.66E+06
14	13	Immature	44.2	1.162	0
15	14	Immature	38.8	0.739	1.77E+07
16	15	Immature	38.7	0.775	5.74E+07
17	16	Immature	38.7	0.791	Borderline
22	17	Immature	42.7	1.01	4.71E+06
23	18	Immature	57	2.5	Borderline
24	19	Immature	64	3.46	4.29E+04
25	20	Immature	52	1.54	Borderline
26	21	Immature	37	0.69	0
27	22	Immature	34	0.49	0
28	23	Immature	38	0.68	1.26E+07
29	24	Immature	32	0.38	0
30	25	Immature	55.9	2.23	1.18E+08
31	26	Immature	31.7	0.42	Borderline
32	27	Immature	71.3	5	Borderline

* Note: Tube #'s for sample Barcodes 31 & 32 were transposed when referencing the field data spreadsheet that was provided. These discrepancies are highlighted in blue with Tube and Barcode #'s in red text

Appendix Table E1 (cont.). -- Individual data of lifestage, fork length, weight, and Ichthyophonus intensity by qPCR for Chinook salmon sampled from the Northern Bering Sea, 2021.

Barcode	Tube #	Lifestage	Fork length (cm)	Weight (kg)	*Ichthyophonus* (gene copies/g)
41	28	Immature	64.5	3.46	2.98E+07
42	29	Immature	57	2.4	Borderline
43	30	Immature	37	0.6	Borderline
51	31	Immature	35	0.52	2.80E+08
52	32	Immature	36	0.518	1.36E+08
54	33	Immature	71.5	4.65	5.31E+06
60	34	Juvenile	19.9	0.1	Borderline
61	35	Juvenile	19.5	0.088	Borderline
62	36	Juvenile	19.3	0.092	Borderline
63	37	Juvenile	19.2	0.086	0
64	38	Juvenile	20.4	0.108	0
65	39	Juvenile	19.8	0.104	0
66	40	Juvenile	18.8	0.08	0
67	41	Juvenile	21.5	0.132	0
68	42	Juvenile	20.2	0.092	0
69	43	Juvenile	20.7	0.104	0
70	44	Juvenile	19.3	0.092	0
71	45	Juvenile	18.6	0.076	0
72	46	Juvenile	19.5	0.094	Borderline
73	47	Juvenile	21.3	0.114	0
76	48	Immature	30.7	0.285	0
83	50	Juvenile	22.1	0.128	Borderline
84	51	Juvenile	19.6	0.093	0
85	52	Juvenile	20.3	0.105	0
86	53	Juvenile	22.9	0.156	0
87	54	Juvenile	19.9	0.102	0
88	55	Juvenile	21.2	0.118	0

*Note: There was no Tube #49 so tube numbering and Barcode numbers were off by a factor of 1 starting with this Tube #. These discrepancies are highlighted in blue with Tube and Barcode #'s in red text to indicate the discrepancy between sample identification on the tube compared to what was provided in the field data spreadsheet.

Appendix Table E1 (cont.). -- Individual data of lifestage, fork length, weight, and Ichthyophonus intensity by qPCR for Chinook salmon sampled from the Northern Bering Sea, 2021.

Barcode	Tube #	Lifestage	Fork length (cm)	Weight (kg)	*Ichthyophonus* (gene copies/g)
89	56	Juvenile	19.8	0.088	0
90	57	Juvenile	21.7	0.129	0
91	58	Juvenile	21.8	0.138	0
92	59	Juvenile	20.7	0.115	0
93	60	Juvenile	22.3	0.147	Borderline
94	61	Juvenile	18.5	0.083	0
95	62	Juvenile	19.7	0.099	0
96	63	Juvenile	19.3	0.093	0
97	64	Juvenile	19.3	0.094	Borderline
98	No label	Juvenile	20.3	0.113	0

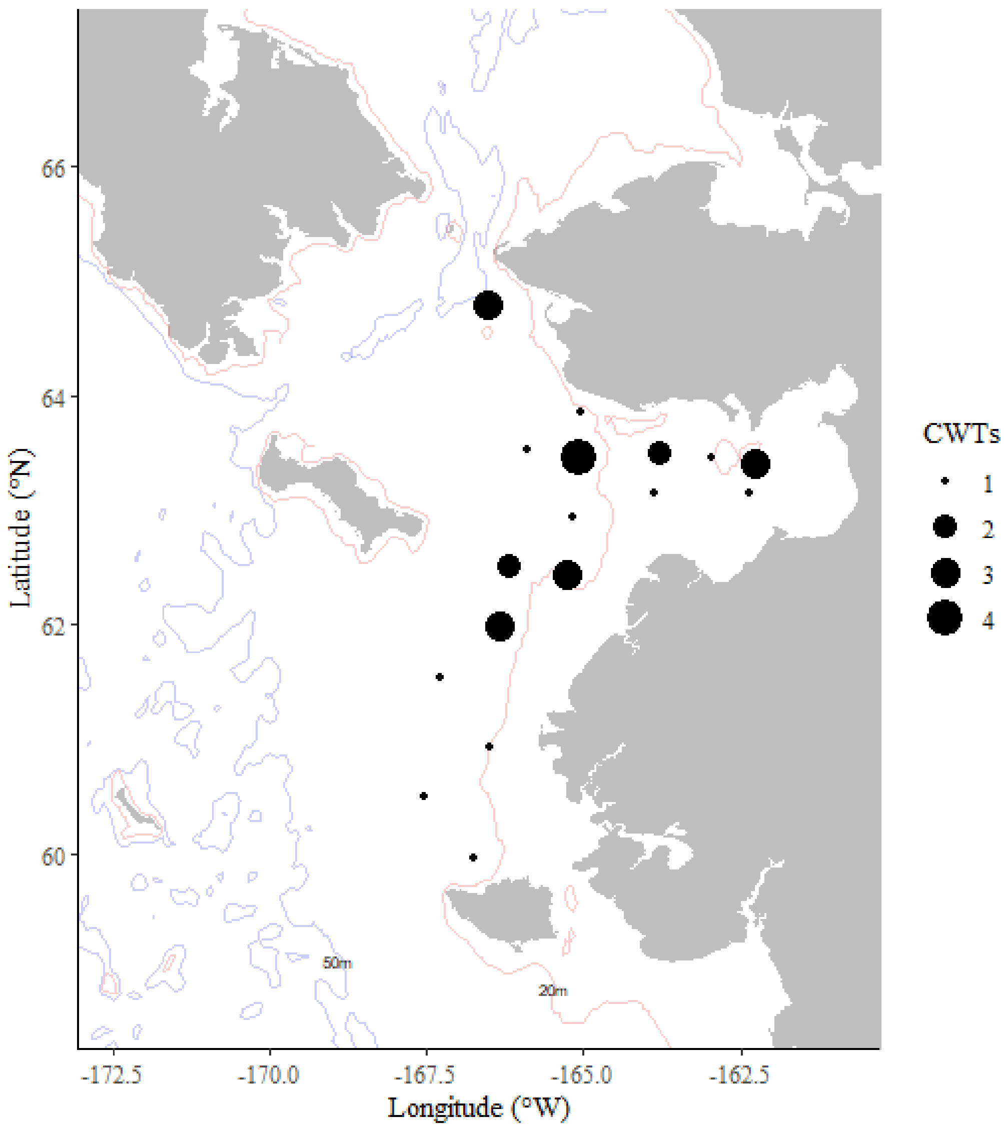
*Note: There was no Tube # for Barcode 98, so this was assumed to be Tube #65. These discrepancies are highlighted in blue with Tube and Barcode #'s in red text to indicate the discrepancy between sample identification on the tube compared to what was provided in the field data spreadsheet.

APPENDIX F

Coded-Wire Tag Recoveries

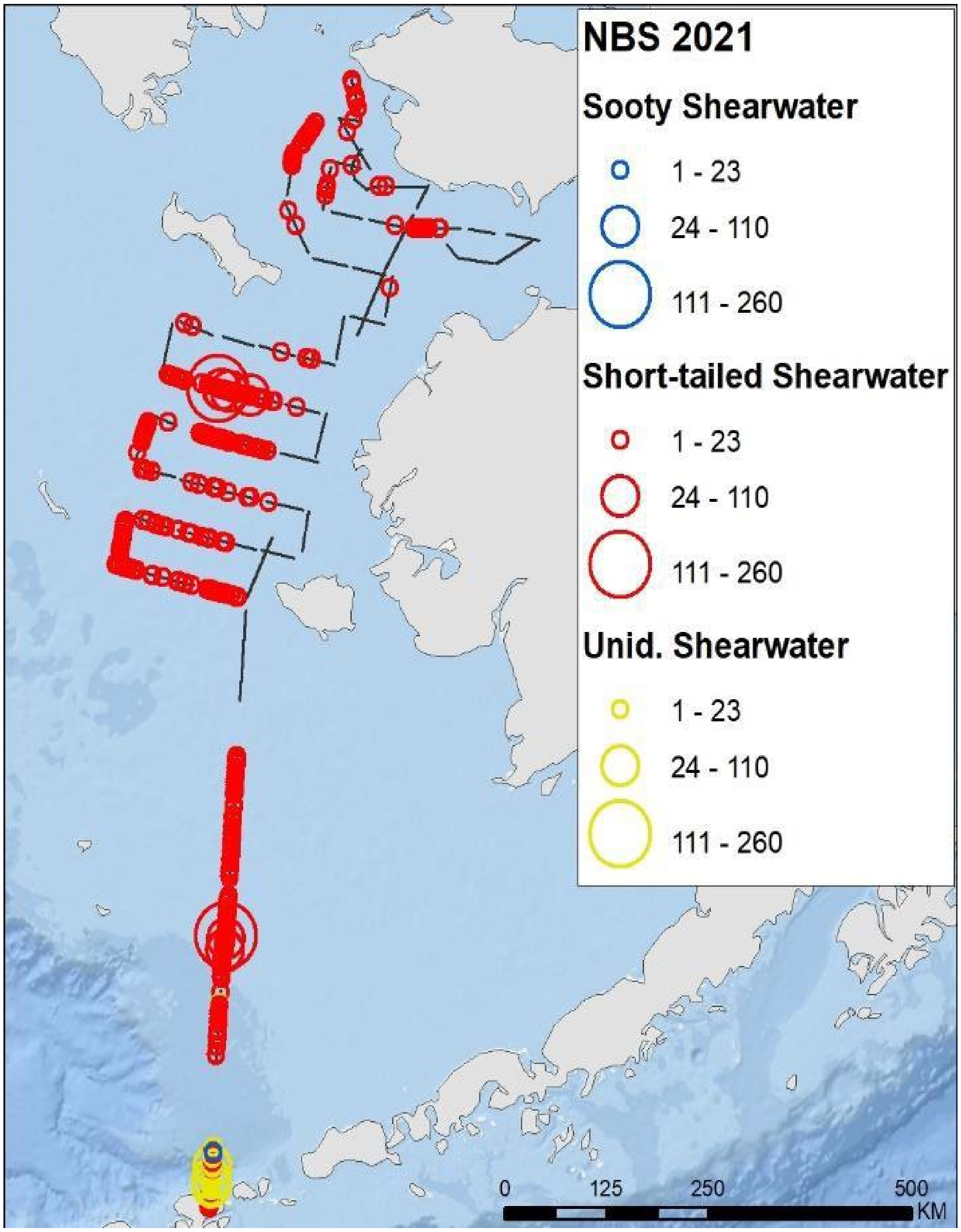
Appendix Table F1. -- Coded-wire-tag (CWT) recovery information from Whitehorse Rapids Fish Hatchery (WRFH) Chinook salmon captured during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2002-2021. CWT tag code of 18 were half tags with just a country code. Ad-clipped juveniles without a tag are assumed to be from WRFH but have shed their CWT.

CWT or Ad-Clip	Brood Year	Release Date	Recovery Date	Latitude (N)	Longitude (W)	Fork Length (mm)	Weight (g)
185106	2001	6/10/2002	10/4/2002	64.1	-164.52	193	79
185102	2001	6/2/2002	10/4/2002	64.1	-164.52	155	46
185061	2001	6/10/2002	10/4/2002	63	-165.97	161	49
18	2006		9/13/2007	65.2	-168.1	125	18
18	2006		9/13/2007	65.2	-168.1	176	58
18	2006		9/13/2007	65.2	-168.1	179	58
18	2009		9/25/2010	64.07	-162.72	164	50
181374	2011	6/6/2012	9/22/2012	61.48	-167	138	28
181779	2011	6/6/2012	9/24/2012	64.1	-163.55	160	45
181779	2011	6/6/2012	9/24/2012	60.98	-168	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	62.5	-167.08	192	75
183187	2013	6/6/2014	9/14/2014	62.5	-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	-166.02	120	18
183186	2014	6/8/2015	9/14/2015	64	-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	-166.02	129	24
184593	2016	6/7/2017	9/3/2017	62	-168	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			10/5/2002	63	-167.48	134	23
ad-clip			9/25/2010	63.82	-162.78	190	87
ad-clip			9/12/2012	64.4	-166.07	185	75
ad-clip			9/24/2013	60.52	-167.05	207	108
ad-clip			9/16/2013	63.77	-164.57	183	70
ad-clip			9/19/2013	62.52	-167.03	202	94
ad-clip			9/13/2015	64.02	-167	113	15
ad-clip			9/10/2018	63.5	-166	127	22

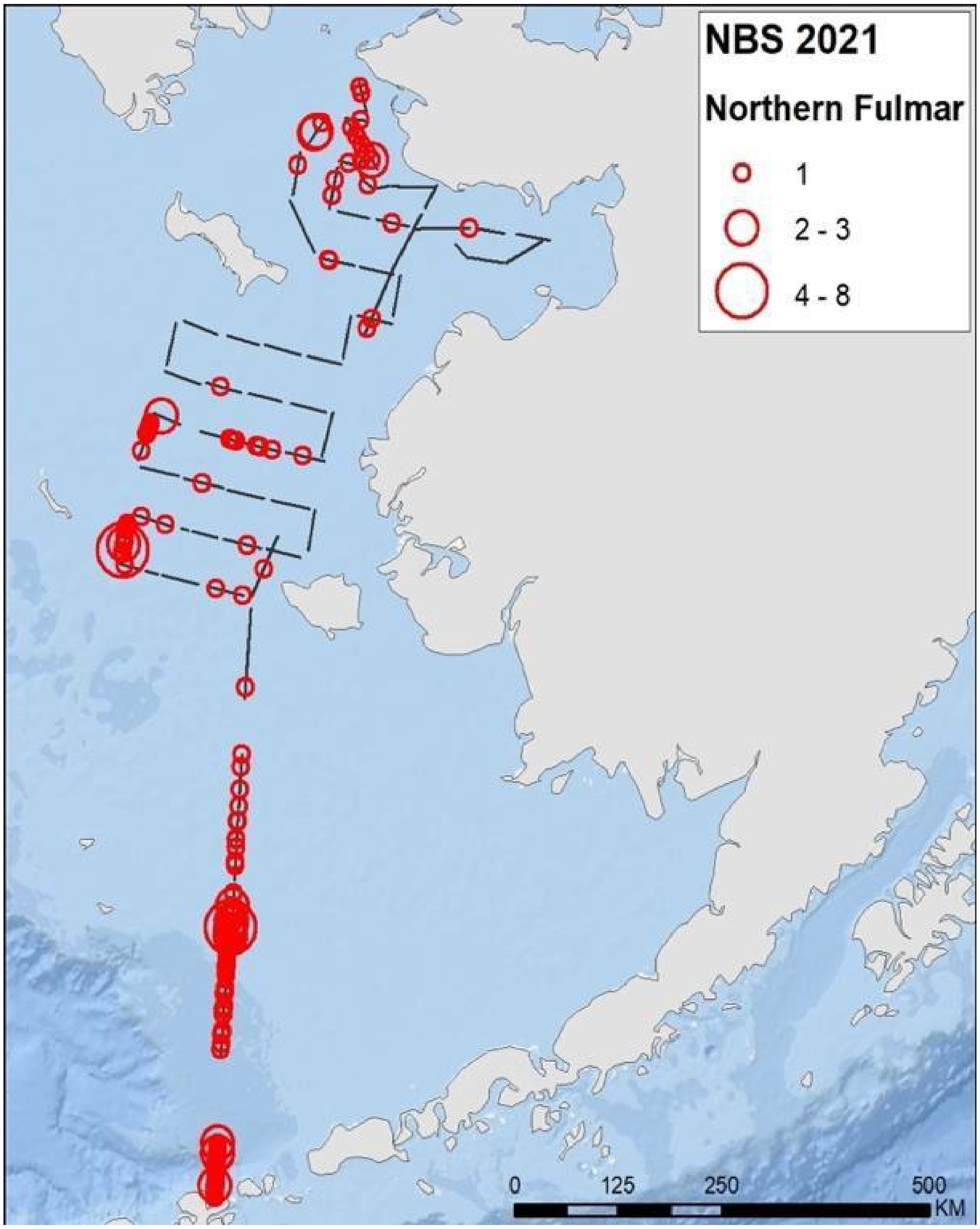


Appendix Figure F1. -- Location of CWTs recovered from Whitehorse Rapids Fish Hatchery Chinook salmon during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2002-2021.

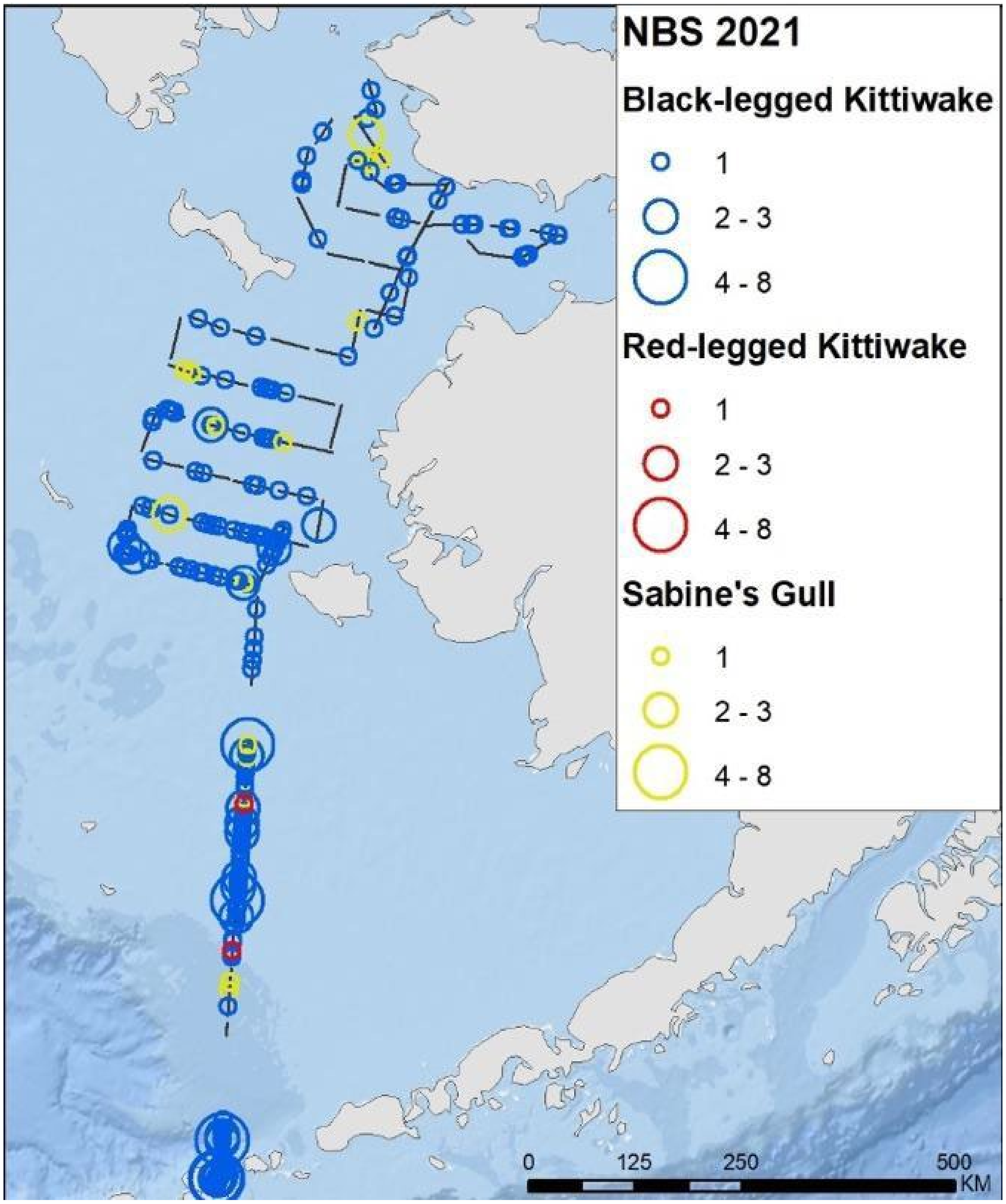
APPENDIX G
Seabird Distributions



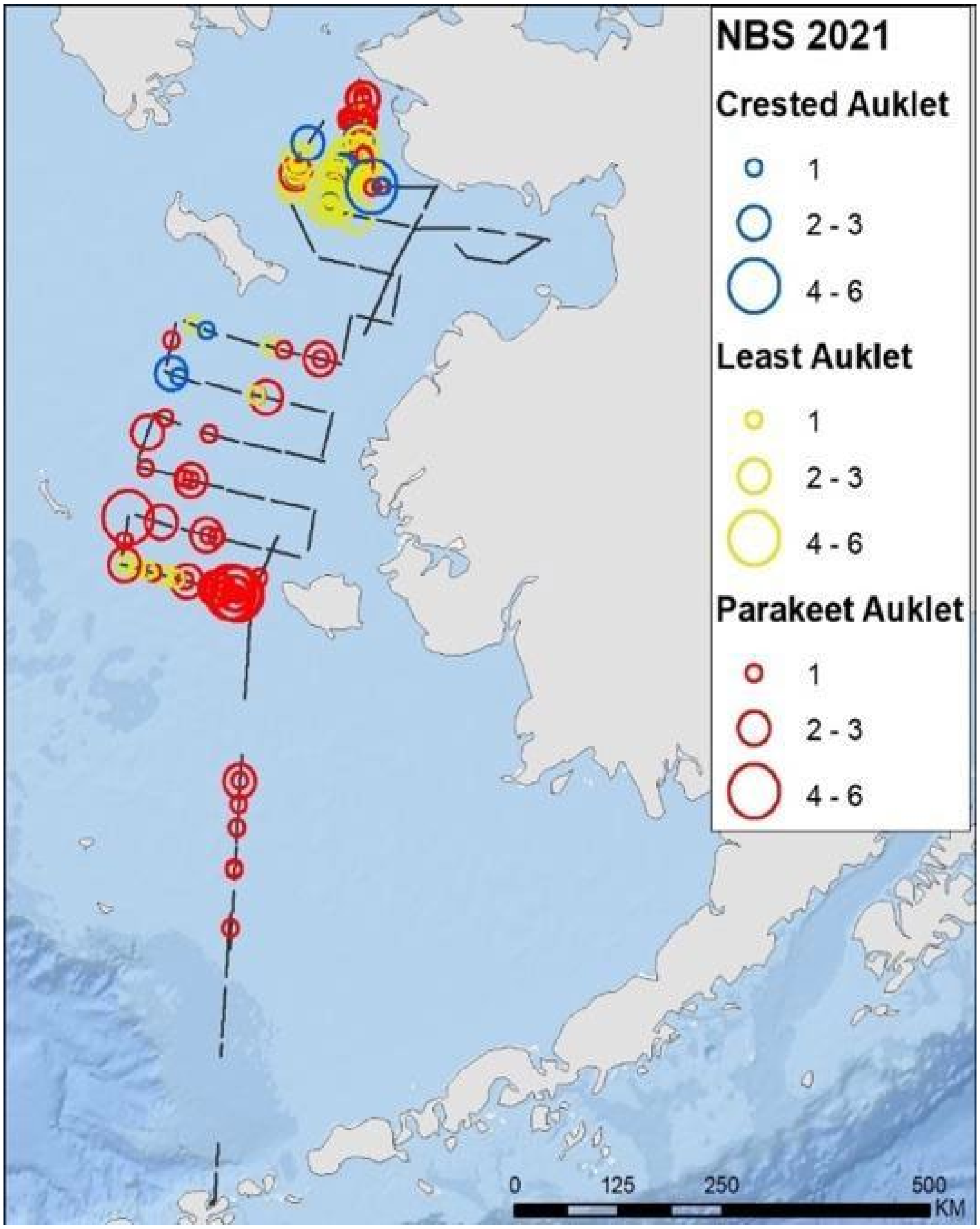
Appendix Figure G1. -- Distribution of shearwaters during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2021.



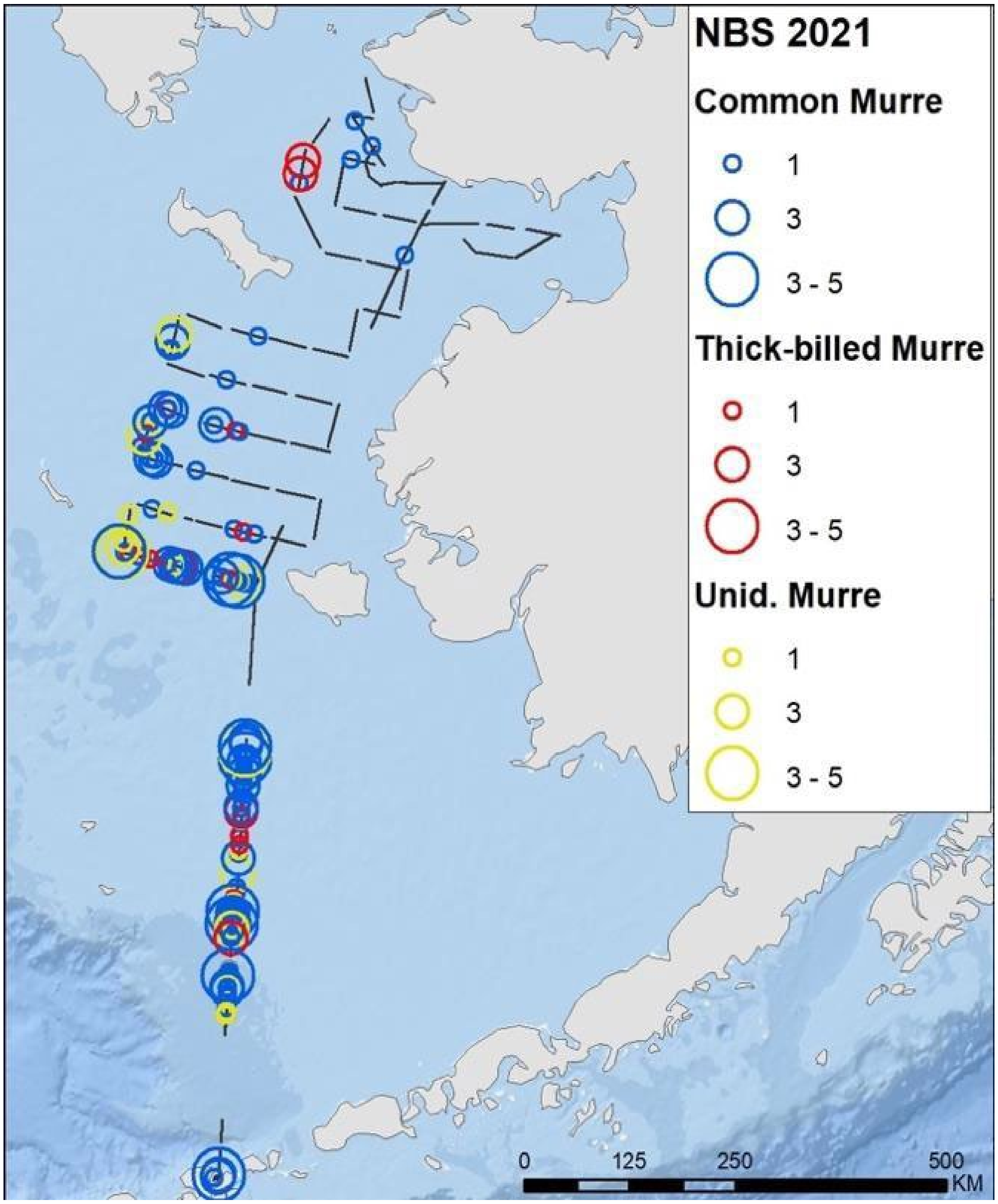
Appendix Figure G2. -- Distribution of northern fulmars observed during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2021.



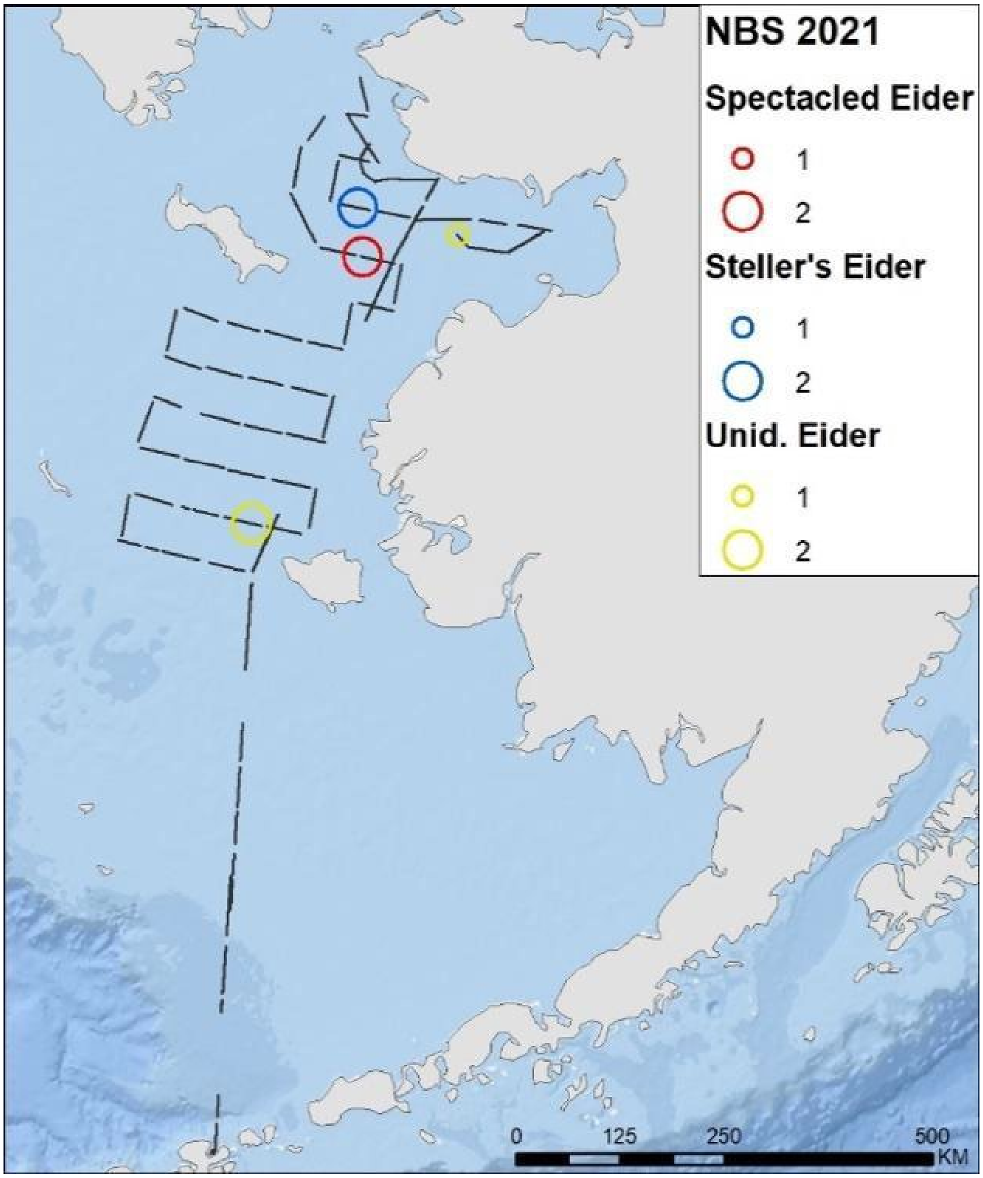
Appendix Figure G3. -- Distribution of small gull species observed during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2021.



Appendix Figure G4. -- Distribution of auklet species during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2021.



Appendix Figure G5. -- Distribution of murre species during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2021.



Appendix Figure G6. -- Distribution of eider species during the Northern Bering Sea Ecosystem and Surface Trawl survey, 2021.

U.S. Secretary of Commerce
Gina M. Raimondo

Under Secretary of Commerce for
Oceans and Atmosphere
Dr. Richard W. Spinrad

Assistant Administrator, National Marine
Fisheries Service.
Janet Coit

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7600 Sand Point Way N.E.
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