Expedition to study the winter ecology of Pacific salmon in Gulf of Alaska using gillnet and longline gear fished from FV Raw Spirit, February 25 – March 25, 2022

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Science Branch, Pacific Region
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Nanaimo, British Columbia
V9T 6N7

2023

**Canadian Technical Report of
Fisheries and Aquatic Sciences 3524**

Fisheries and Oceans Canada Pêches et Océans Canada

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Canadian Technical Report of Fisheries and Aquatic Sciences

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Fisheries and Aquatic Sciences 3524

2023

EXPEDITION TO STUDY THE WINTER ECOLOGY OF PACIFIC SALMON IN GULF OF ALASKA USING GILLNET AND LONGLINE GEAR FISHED FROM FV *RAW SPIRIT*, FEBRUARY 25 – MARCH 25, 2022

by

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Cat. No. Fs97-6/3524E-PDF ISBN 978-0-660-47434-2 ISSN 1488-5379

Correct citation for this publication:

Neville, C., Banks, M., Bouillon, D., Esenkulova, S., LaForge, R., Lewis, B., Martynuik, G., Schubert, A., Riddell, B., and Beamish, R. 2023. Expedition to study the winter ecology of Pacific salmon in Gulf of Alaska using gillnet and longline gear fished from FV *Raw Spirit*, February 25 – March 25, 2022. Can. Tech. Rep. Fish. Aquat. Sci. 3524: vi + 62 p.

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ABSTRACT

Neville, C., Banks, M., Bouillon, D., Esenkulova, S., LaForge, R., Lewis, B., Martynuik, G., Schubert, A., Riddell, B., and Beamish, R. 2023. Expedition to study the winter ecology of Pacific salmon in Gulf of Alaska using gillnet and longline gear fished from FV *Raw Spirit*, February 25 – March 25, 2022. Can. Tech. Rep. Fish. Aquat. Sci. 3524: vi + 62 p.

In the winter of 2022, the Canadian commercial fishing vessel *Raw Spirit* was chartered to study the winter ecology of Pacific salmon in the Gulf of Alaska. This was the third privately funded study with the first two conducted in 2019 and 2020. The 2022 survey was part of a multi-vessel study organized by the North Pacific Anadromous Fish Commission for the International Year of the Salmon (IYS). The *Raw Spirit* used experimental Japanese research gillnets and longline fishing gear. An objective was to compare catches with the trawl net surveys in 2019, 2020 and with the trawl net catch of the Canadian Coast Guard trawl vessel, *Sir John Franklin*, that was participating in the IYS survey. The gillnet and longline gear fished by the *Raw Spirit* also provided an opportunity to compare the catch composition with historic surveys in the 1960s that used similar gear. The *Raw Spirit* completed 19 gillnet and 17 longline sets between February 27 to March 23, 2022. Oceanographic sampling (vertical bongo and CTD) and eDNA samples were also completed at each station. Eighteen species were sampled including six *Oncorhynchus* species (57 steelhead, 53 sockeye, 51 coho, 30 chum, 10 pink and one Chinook salmon). Total catches of Pacific salmon between the two vessels (*Raw Spirit and Sir John Franklin*) were similar with the exception of steelhead which were only caught in the surface gillnet gear.

RÉSUMÉ

Neville, C., Banks, M., Bouillon, D., Esenkulova, S., LaForge, R., Lewis, B., Martynuik, G., Schubert, A., Riddell, B., and Beamish, R. 2023. Expedition to study the winter ecology of Pacific salmon in Gulf of Alaska using gillnet and longline gear fished from FV *Raw Spirit*, February 25 – March 25, 2022. Can. Tech. Rep. Fish. Aquat. Sci. 3524: vi + 62 p.

Au cours de l'hiver 2022, le navire de pêche commerciale canadien *Raw Spirit* a été affrété pour une étude de l'écologie hivernale des saumons du Pacifique dans le golfe d'Alaska. . Il s'agissait de la troisième étude financée par des fonds privés, les deux premières ayant été menées en 2019 et 2020. Le relevé de 2022 faisait partie d'une étude multi-navires organisée par la Commission des poissons anadromes du Pacifique Nord dans le cadre de l'Année internationale du saumon). Le *Raw Spirit* utilisait des filets maillants de recherche expérimentaux japonais et des engins de pêche à la palangre. L'un des objectifs était de comparer les prises avec celles des relevés au chalut effectués en 2019 et 2020 et avec les prises au chalut du navire de pêche au chalut de la Garde côtière canadienne (NGCC), le Sir John Franklin, qui participait au relevé effectué dans le cadre de l'Année internationale du saumon. La pêche au filet maillant et à la palangre effectuée au moyen du navire de pêche *Raw Spirit* a également permis de comparer la composition des prises de ce relevé avec des relevés historiques des années 1960 utilisant des engins similaires. Le *Raw Spirit* a effectué 19 traits de filet maillant et 17 traits de palangre entre le 27 février et le 23 mars 2022. Des échantillons océanographiques (trait vertical d'un filet de type « Bongo » et équipement CTP) des échantillons d'ADN environnemental ont également été effectués à chaque station. Dix-huit espèces ont été échantillonnées, dont six du genre *Oncorhynchus* (57 saumons arc-en-ciel, 53 saumons rouges, 51 saumons cohos, 30 saumons kétas, 10 saumons roses et un saumon chinook). Les prises totales de saumons du Pacifique entre les deux navires (*Raw Spirit* et *Sir John Franklin*) étaient similaires, à l'exception du saumon arc-en-ciel qui n'a été capturé que dans le filet maillant de surface.

1 INTRODUCTION

This was the third survey to study the winter ecology of Pacific salmon in the Gulf of Alaska (Riddell et al. 2022). A major objective was to better understand the mechanisms that regulate ocean survival of Pacific salmon. In 2022, this survey chartered the Canadian commercial fishing vessel (FV) *Raw Spirit*, that was modified to fish gillnet and longline gear. The organizers of the charter vessel, Dr. Richard Beamish and Dr. Brian Riddell of Canada, who had independently secured funding for the 2019 and 2020 winter trawl surveys in the Gulf of Alaska (Beamish and Riddell 2020; NPAFC Secretariat 2018; Pakhomov et al. 2019; Somov et al. 2020), also secured the funding for the *Raw Spirit* in 2022. Funding for this third survey was from industry and government and managed through the Pacific Salmon Foundation. This third survey was also part of the International Year of the Salmon (https://yearofthesalmon.org/2022expedition/). Major objectives for the International Year of the Salmon were to identify the winter distribution of Pacific salmon from all salmon producing countries and to study the winter ecology of salmon.

The objectives for the gillnet/longline survey were to continue the studies carried out in the 2019 and 2020 surveys as well as to contribute to the International Year of the Salmon. An objective was to compare the catches in the gillnets and longlines with the trawl catches by the Canadian research ship, CCGS *Sir John Franklin,* and with catches in our previous surveys in 2019 and 2020. The use of gillnets and longlines also provided a comparison with historic surveys in the 1960s that used similar (non-trawl) gear.

Fishing with gillnets and longlines also provided an opportunity to collect scales as Pacific salmon that are caught in trawls lose most of their scales. Pacific salmon caught in gillnets and longlines had minimal scale loss allowing scales to be examined to determine ages and winter growth patterns. An important component of the surveys was the identification of potential Pacific salmon predators which may not be caught in the trawl fishing gear. A tool used to provide more information on the presence of predators was eDNA.

This report provides a summary of fishing and oceanographic operations completed during the survey. Additionally, we include available analysis of salmon ages, diets and stock composition.

2 METHODS

2.1 SURVEY AREA

The survey was from February 25 to March 25, 2022. We planned to fish similar areas to the *Sir John Franklin* to compare catches between the trawl net and the gillnets/longlines (Figure 1A). As gillnets required a fishing period of approximately 12 hours and the trawl net was fished for one-hour sets, it was expected that only about half of the stations fished by the *Sir John Franklin* could be fished by the *Raw Spirit*. The southern stations were scheduled to be fished during the first half of the survey by each vessel and the northern stations in the second half of the survey (Figure 1A), with a port call for refueling by both vessels mid-trip. The initial plan was modified, and the *Raw Spirit* fished in the southern region during both legs due to poor weather conditions, especially in the north, during the second leg of the survey.

2.2 SCIENCE TEAM AND VESSEL CREW

The scientific crew on the vessel included six Canadian researchers and two commercial fishermen from Canada (Table 1, Figure 2). The two commercial fishermen that were part of the science team were the leads for the longline fishing operations. The vessel crew of ten people included the bridge officers and fishing master (Table 1).

2.3 FISHING GEAR AND OPERATIONS

2.3.1 Gillnet

The gillnets were 2.4 km long research gillnets imported from Japan (Nichimo Company, Tokyo). The nets consisted of panels 50 m in length and 8 m in depth (Figure 3). At each end of the gillnet were nine panels of commercial gillnet (115 mm). Between these panels were three panels of each 48, 55, 63, 72, 82, 93, 106, 121, 138, 157 mm panels. The panels were not in order of size but were mixed across the 2.4 km in the order shown in Figure 3.

Recovery of the net was conducted by retrieving the net up the stern ramp and onto a trawl drum. To reduce snagging of the gillnet, guide rails were added to the stern deck of *the Raw Spirit* (Figure 4A, B). Additionally, spooling gear was added to the drum to manage the gillnet and reduce backlash occurrences (Figure 4A). Although hauling the net up the stern ramp was effective for removing fish from the net, this method put additional stress on the gear compared to hauling methods used by Japanese gillnet research vessels. To accommodate for the added stress on the net, the headrope was reinforced with 9-11 mm Spectra rope. Additionally, 8 m spacers made of 9 mm poly were added to the footrope between each net panel to ensure tension during hauling was maintained on the headrope and specifically the Spectra rope, rather than on the web or the footrope.

The net was marked with a flagpole floated off each end of the 2.4 km gillnet along with 2-3 Scotchman floats. Additional floats were added along the length of the headrope. These floats were connected with a quick snap between panels. The number of Scotchman floats used along the 2.4 km length varied (4-12) over the survey. It was anticipated that wave height would be a limiting factor for gillnets that would require seas less than 3 m to fish effectively. The vessel crew added additional Scotchman floats along the headrope to reduce net tangling during rough weather events and increase fishing opportunities. At each location where a Scotchman float was attached to the headrope, a small weight (< 2.5 kg) was added to the spacer line on the footrope to help spread the net vertically. This weight also helped to reduce tangling of the gear during weather events.

A satellite tracker (MetOcean, https://metocean.com/) in a mesh net bag was attached to the flagpoles at each end of the net and a third was placed on the headrope about mid-net. These floating satellite trackers were on a 3 m line and attached to the gear with a carabiner. The trackers allowed the net to be followed during the extended soak periods and during darkness. Additionally, the satellite trackers allowed the vessel crew to know the orientation of the net during monitoring in darkness and when approaching for recovery. Sensors recording temperature and depth were attached to both the headrope and the footrope of the net. These sensors were a combination of RBR duet[3]'s (rbr-global.com) and onset HOBOs (www.itm.com). These small, self-contained instruments recorded temperature and depth during fishing operations and data was downloaded between fishing stations. The fishing period (soak time) for the gillnet was targeted pre-dusk to post-dawn (overnight). Recorded soak time for the gillnet was the time between the completion of setting the gear and the initiation of hauling the gear.

To ensure fish were tracked to the capture web size, the web panels and the totes used for collecting catch were colour coded (Figure 5). The totes were sampled in the order of the mesh size that came on board. In addition to separating catch by web size, the vertical location of fish in the net and the spacing between fish was recorded by dividing the net into four quadrants with Q1 representative of the surface quarter of net and Q4 the bottom quadrant (Figure 3).

2.3.2 Longlines and fishing operations

The longlines were 1.5 km long with 350-500 baited hooks (size 4, 5, 6) on 1 m leads spaced with quick snaps along the length of the longline. The use of quick snaps to attach baited hooks to the long line resulted in variability in the number of hooks fished during each set. The bait included salted anchovy, salted herring and squid.

A modification to the vessel for fishing the longline gear included a second drum mounted to the upper port trawl deck (Figure 4C). From this drum, the longline ran through two blocks to transfer the longline from the upper port trawl deck to the main trawl deck. During setting of the gear, the longline passed through a baiting table that was placed just forward of the wave gate (Figure 4C). During hauling of the longline, the baiting table was replaced by a guide for the longline mid-deck. This guide helped reduce lateral movement of the longline during retrieval.

The ends of the longline were marked with flagpoles, Scotchman floats and with satellite trackers. Scotchman floats were also placed along length of longline to ensure the longline remained at the surface. Temperature gauges including RBR duet[3]'s (rbr-global.com) and onset HOBOs (www.itm.com), were placed at the Scotchman floats and along the longline to record temperature variability over the fishing areas.

It was anticipated that the longline gear would be less impacted than gillnets by sea state and would be able to be fished in poorer weather than the gillnets. The targeted soak time for the long lines was 1-4 hours. Setting pre-dawn to fish over dawn was targeted based on results in the 1960s (Turner and Aro 1968). However, a smaller number of daytime and evening sets were also planned. Recorded soak time for the longline was considered to be the time between the completion of setting the gear and the initiation of hauling the gear.

The information collected for the longline operations included the number of hooks fished, the bait type and hook size fished and as much detail as possible on the hooks that caught fish. The approximate amount of bait remaining on the hooks at gear retrieval was also recorded to help determine if fish were being lost after hooking. During hauling of the longline gear, fish that were observed falling from the hooks were noted.

2.4 PROCESSING CATCH

2.4.1 Catch processing - Pacific salmon species

The term salmon is used in this report to include all species in the genus *Oncorhynchus* including Chinook salmon, *O. tshawytscha*, coho salmon *O. kisutch*, chum salmon *O. keta*, pink salmon *O. gorbuscha*, sockeye salmon *O. nerka*, and steelhead *O. mykiss*. Steelhead may have a common name that includes "trout", however, the American Fisheries Society book on the common and scientific names of fishes does not include "trout" in the accepted common name (Page et al. 2013). Prior to any sampling, all Pacific salmon had a uniquely numbered Floy tag attached to the caudal peduncle and the catch in each web size was documented. Fork and total length (mm), round weight (g), sex and observations of wounds, parasites, and general condition were recorded for each salmon, including examining for adipose fin clips and coded wire tags (CWTs). The stomach, liver, female gonads and muscle samples were removed and individually frozen. The stomach was removed from just posterior to the gill arch to the start of the small intestine and was frozen for analysis in the lab. Otoliths were removed and stored dry and scale samples were stored in gummed scale books. The remaining carcass of the sampled salmon was bagged with the Floy tag and frozen.

2.4.2 Catch Processing - Other species

All catch was examined and either sampled at sea or frozen whole for sampling in the lab on land. Squid were identified to species, measured (mantle length, mm), tissue for DNA analysis was collected and the body was frozen. A similar process was followed for the remaining by-catch of fish.

2.5 OCEANOGRAPHY/ZOOPLANKTON/eDNA

Oceanographic and plankton sampling was conducted off the upper starboard trawl deck of the ship where a third drum was mounted (Figure 6A). This small drum was used for the deployment of both the CTD and a bongo net. Both gear types were deployed independently to a depth of 350 m. Additionally, for the collection of water samples for eDNA sampling, a Niskin bottle was added to the wire during CTD deployment (Figure 6B). The water samples for eDNA were collected at 5 m depth.

The bongo net had 253 µm cod ends and flowmeter. The plankton sample from one cod end was preserved in 3.7% formalin for identification and enumeration of species in the lab on land. The second cod end was size fractioned through five mesh panels (1.5 cm – 150 µm) and the plankton from each size fraction was frozen in pre-weighed plastic bags for laboratory analysis.

A Seabird CTD was deployed at each station to 350 m. The CTD was equipped with pressure, temperature, salinity and oxygen sensors. Sample for eDNA collection was obtained using about 10 L of water collected with two Niskin bottles deployed to 5 m depth during the CTD set. The water samples were filtered on the vessel in a 'clean room' on the ship. This 'clean room' was a region in the lab (~ 4 m^2) isolated using plastic sheeting that extended from floor to the ceiling. The inside of this 'room' and all equipment was disinfected between sets with 10% bleach and 10% sodium thiosulphate. The Niskin bottles were secured outside the 'clean room'. A sterilized hose extended through the wall of the 'clean' room and attached to the Nisken bottles and transferred the collected water to the high-performance filtration system. Then 10 L of water was run through duplicate 0.22 µm Sterivex cartridge filters in the filtration system. Once filtration was complete and air was used to purge excess water from the filters, the filters were filled with RNA*later*, placed in labeled whirl-packs and zip lock bags and then stored in the dark at 4 C°.

2.6 BIRD AND MAMMAL OBSERVATIONS

Bird observations were conducted throughout the survey, both during fishing and *ad hoc* while travelling. During the setting and hauling of fishing gear that occurred in daylight hours, an observer was positioned on the gantry above the stern deck. When weather prohibited safe observations from the gantry, observations were made from the wheelhouse. The purpose of these observations was to document interaction between the fishing gear and the birds.

Records of marine mammals were made by the vessel bridge crew throughout the survey. Identification and numbers were provided when possible and the general position of vessel at time of observation was recorded. Marine mammals observed around gear were also recorded. Photos of birds and mammals were obtained when possible.

Birds that were captured in the net were released alive when possible. If dead, the birds were identified, measured and frozen whole.

2.7 ANALYSIS

For this report, catch per unit effort (CPUE) for the gillnet was considered a set regardless of soak time. The CPUE for the longline was standardized to catch per 1000 hooks to be consistent with analysis conducted in the 1960s (Turner and Aro 1968). The condition of Pacific salmon was estimated using Fulton's Condition Factor *K* calculation:

$$K = 10^5 W / L^3$$

The combination of the analysis of the scales and length of fish was used to estimate number of winters in the ocean. In this report, a salmon in its first winter at sea was considered an ocean age 1 fish.

DNA was analyzed by the Molecular Genetics Laboratory at the Pacific Biological Station of Fisheries and Oceans Canada in Nanaimo, British Columbia, using microsatellite analysis (Beacham et al. 2005) or single nucleotide polymorphisms (SNPs; Beacham et al. 2022). We summarized DNA results to a regional or stock level based on probabilities of 70% or greater.

Stomach analysis was conducted by an expert with over 25 years of experience in the identification of stomach contents from Pacific salmon and other pelagic species (Zotec Services, Nanaimo, British Columbia). Items were identified to the lowest taxonomic level possible, but in this report were grouped into general categories. Photographs of identifiable features on the squid remains in the stomachs were examined by a cephalopod expert (Michael Zuev of the Russian Federal Research Institute of Fisheries and Oceanography). When possible, he identified the squid to species using these photographs. Stomachs were classified as empty when the volume of stomach contents was less than 0.1 cc.

3 RESULTS

3.1 FISHING OPERATIONS

The Raw *Spirit* conducted 17 longline sets and 19 gillnet sets at 16 stations (Tables 2, 3, 4; Figure 1B). The weather on the first leg of the survey (February 25-March 11, 2022) was good with seas mostly less than two meters in height during fishing operations (Table 3). The exception was the more westerly transect line (145^{0}W), which had poorer weather and larger seas that prohibited fishing with gillnets or longline gear. Fishing was instead conducted at three stations south of the planned survey area (station 8-10; Figure 1B). In total, during the first leg, 15 gillnets and 13 longline sets were completed at 11 stations (Table 3). Fishing times over a 24-hour period are listed in Table 3. The average soak period of the gillnets was nine hours and the average soak time of the longlines was three hours (Table 3). It had been anticipated that gillnets would be set around dusk; however, due to travel time between stations, gillnets were often not set until later in the evening (Table 3) and resulted in shorter soak times. In addition to the fishing operations, CTD casts were conducted at each of the 11 stations. Plankton was collected with the bongo net at 9 stations and eDNA water samples (Nisken bottle) were collected at 10 stations (Table 3).

Refueling of the vessel occurred March 14, 2022, in Port Hardy, British Columbia (Table 2). Forecasted poor weather in the northern region for the following 4-7 days exceeded the levels that could be effectively fished by the *Raw Spirit* and resulted in the modified plan to repeat fishing in the southern portion of the survey area. However, weather during the second leg of survey was still poor, with seas regularly over three meters, and resulted in reduced fishing opportunities compared to the first leg of the survey.

During the second leg of the survey (March 15-24, 2022), five stations were sampled with four longline and four gillnet sets completed (Tables 3, 4). Four of these stations had been fished during the first leg of the survey and were given a unique station number when fished during the second leg. Gillnets were deployed at two of the repeated locations (stations 14, 15; Figure 1B) but only longlines could be deployed at the third (station 12, Figure 1B). At the fourth station (station 13), no fishing gear could be deployed due to high seas. The poor sea states also reduced the soak time possible for the gillnet sets to an average of 4 hours (Table 3). The longline sets had an average soak time of three hours and were set as described in Table 3. One station fished (station 16) was east of the planned survey area and outside of the Canadian exclusive economic zone (Figure 1B).

Weather during the second leg of survey caused extensive damage to the gillnets, including one gillnet breaking in half during its soak. Although both halves of the gear were recovered, it demonstrated the limitations of the gear in large seas. Oceanographic sampling was also impacted during this leg of the survey. The CTD and water sample for eDNA were collected at each station. However, due to poor weather, the bongo was only deployed at two stations (Tables 2, 3).

During fishing operations, the gillnets drifted 0.3 to 1.3 km/hr. The longline movement was slightly less, ranging from 0.4 to 0.95 km/hr. The largest movement of the gillnet occurred at station 1, set 2, and at station 7, set 16 (Figure 1B) when the gear travelled 6.5 km during the soak. These sets soaked for 16 hours and 9 hours, respectively, resulting in movement of the net from 0.4 – 0.7 km/hr. The largest movement of the longline gear occurred at station 7, set 18 (Figure 1B), where it travelled 3.3 km during a 262 minute soak. Typically, the gear moved toward the east (002-143^0, 78%), although some movement to the northwest (290-346^0) also occurred.

3.2 SALMON CATCH IN GILLNETS

There were 202 salmon caught in total during the survey. Of these, 193 salmon were caught in the gillnet, which consisted of 50 sockeye salmon, 46 coho salmon, 29 chum salmon, 10 pink salmon, one Chinook salmon and 57 steelhead (Tables 4, 5). On the longline gear, nine salmon were landed including five coho, three sockeye and one chum salmon (Tables 4, 5). Several (eight) other salmon were observed on the longline during hauling but were lost prior to landing. These salmon could not be identified to species (Table 5).

3.2.1 Chum salmon

There were 29 chum salmon caught in 11 sets with 15 (52%) of these fish caught in two sets at two stations (Figures 7A, 8; Table 5). The catch of chum salmon ranged from the most northerly station (50^{o}N; station 2) to just south of the planned survey area (station 8; 46^{o}N; Figures 1B, 8). All chum salmon were caught in the upper half of the gillnet (surface 4 m). The average length and weight were 36 ± 11.6 cm and 645 ± 709 g (Figures 9A, 10A; Table 6). The average condition (K) was 0.98 ± 0.09 (Figure 10B).

Preliminary age estimates, using a combination of the scales collected and fish length, indicated a mixture of fish that had been at sea from one winter to four winters, with most (18) in their first winter at sea (ocean age 1). Twelve of these fish were caught in the two sets with the largest catches. However, there was a mixture of other age classes also present in these sets. The average size of the ocean age 1 fish was 28 ± 2.5 cm and 233 ± 72 g. These fish had an average condition (*K*) of 0.98 ± 0.08. About 90% of the first winter fish were captured in gillnet mesh sizes 63 mm and smaller. There was a positive relationship between the length of the chum salmon and the mesh size of the gillnet panel with larger fish captured in larger mesh sizes (r^2 = 0.63; Figure 11A). Overall, all chum salmon were caught in eight of the 11 mesh sizes with no chum salmon caught in the 106 mm mesh size or mesh sizes greater than 121 mm.

Most the chum salmon (28) were caught in nets with soak periods over dusk, including the two largest sets. This included the one gillnet that was set in the afternoon but that was fished until after dusk (set 3). At the two locations that had gillnets deployed during both legs of the survey (station 6, 14; station 11, 15), there was variability in the catch of chum salmon. At stations 6 and 14, there was one chum salmon caught during the two sets conducted on March 5 compared to nine chum salmon caught in the two sets conducted two weeks later on March 20 (Figure 7A, Table 5). At stations 11 and 15, there was one chum salmon caught in a single gillnet on March 11, but there were no chum salmon caught in the single gillnet on March 22 (Figure 7A; Table 5).

There was evidence that the chum salmon were in schools. In set 31, seven chum salmon of similar size were caught in a gillnet area of less than two meters square (Figure 12). The school was in the net at a depth of approximately 4 m.

3.2.2 Coho salmon

There were 46 coho salmon caught in 13 sets at ten stations (Tables 4, 5; Figures 7B, 13). Overall, coho salmon were broadly distributed, with recoveries at all locations where gillnets were fished with the exception of the most southerly location (station 9; Figure 13). The catch by set ranged from one to 14 (Figure 7B; Table 5) with the largest set (set 12) catching 29% of all coho salmon.

Four of the coho salmon were preyed on in the gillnet and only a portion of the body was recovered. The average length and weight of the 42 coho salmon that could be measured was 39 ± 3.4 cm and 634 ± 164 g (Table 6; Figures 9B, 10C). The average condition (*K*) of the coho salmon was 1.04 ± 0.07 (Figure 10D). Seven of the coho salmon had adipose fin clips and two of these coho salmon also had CWTs. These marked fish were caught in five different sets and four different stations. The CWTs identified the two tagged fish as originating from the Quinault hatchery and released in Cook Creek on the northern coastal region of Washington State (CWT tag 056281) and the Quinsam Hatchery on the east coast of Vancouver Island, British Columbia (CWT tag 183478). There was no significant difference between the size and condition of the marked fish and the remaining coho salmon in the catch (t-test, $p > 0.05$).

All coho salmon caught in the gillnet were caught in sets that fished over dawn or dusk. Most (90%) of the coho salmon were caught in the surface 4 m of the gillnet. The remaining coho salmon were caught in quadrant 3 of the gillnet (Figure 3). In general, the coho salmon caught within a single set were not in close proximity to each other. However, coho salmon were caught in a broad range of mesh sizes with catches in all but the smallest (48 mm) and one of the two largest (138 mm) web sizes. Within a single set they were regularly distributed over two or more web sizes (Figure 7B). Additionally, there was no relationship between the size of the coho salmon and the capture mesh size (Figure 11B). In the largest catch (Set 12), the coho salmon were distributed over six different web sizes, or over three quarters of the extent of the net (Figure 7B), indicating that coho salmon were present over a distance of at least 2 km at this station.

The two locations from the first leg of the survey that were also sampled during the second leg had different catch rates. Station 6, fished on March 5, had the largest catches with the two sets catching a total of 19 coho salmon (Table 5; Figures 7B, 13). Comparatively, when re-sampled on March 20 (set 14), only one coho salmon was caught in two sets (Figures 7B, 13). At stations 11 and 15, there was one coho salmon caught in a single gillnet on March 11, but there were no catches in the single gillnet on March 22 (Figure 7B).

3.2.3 Pink salmon

Ten pink salmon were caught in seven sets and at six stations (Figures 7C, 14; Tables 4, 5). They were distributed mostly in the eastern portion of the sampling area and ranged from the most northerly station (station 2) to station 8 in the south (Figure 14). Pink salmon were caught in one of the three stations fished south of the standard survey area (Figure 14). Catches with more than one fish all occurred in the most southerly sets. All pink salmon were caught in the surface 4 m of the gillnet.

The average length and weight of the pink salmon was 30 ± 1.7 cm and 257 ± 42 g (Table 6; Figures 9C, 10E). Their average condition (*K*) was 0.94 ± 0.05 (Table 6). There was a weak negative relationship between condition and the length of the pink salmon, however this relationship was not significant (Figure 10F). Pink salmon were caught in the three smallest mesh sizes (63 mm or less) and, in general, the size of fish increased with web size (Figure 11C).

3.2.4 Sockeye salmon

Fifty sockeye salmon were caught in six sets across six stations (Figures 7D, 15; Tables 4, 5). The catch by set ranged from 1-29 (Table 5; Figure 7D). Sixty percent of the sockeye salmon were caught in one set (set 5, station 2) and at the most northerly location fished during the survey, and 88% were caught north of 48^{o}N (Figure 15).

Three sockeye salmon were preyed on while in the net. The average length and weight of the remaining 47 sockeye salmon was 43 ± 4.9 cm and 872 ± 310 g (Table 6, Figures 9D, 10G) and the average condition (*K*) of the sockeye salmon was 1.04 ± 0.06 (Table 6). There was no relationship between the length of the sockeye salmon and the condition of the fish (Figure 10H). Preliminary examination of scales and length of fish for age indicated that all sockeye salmon sampled were in their second or third winter in the ocean.

All sockeye salmon were caught in sets that fished over dusk or dawn. Sockeye salmon were observed in all depth quadrants of the net, with about 70% caught in the surface 4 m of the net. The sockeye salmon were caught across all mesh sizes except the smallest two (48 mm, 55 mm). When more than one sockeye salmon was in a net, they were caught within three to nine different mesh sizes. Even in sets with small catches (n = 4-6 fish), there were sockeye salmon in three to four of the different mesh sizes (Figure 7D). In the largest catch (n = 29; set 5), there were sockeye salmon recovered from nine different mesh sizes and in over 80% of the length of the entire 2.4 km net (Figure 7D). Although there was no obvious grouping of the sockeye salmon within a set, they were typically encountered in the smaller mesh sizes (72 mm, 82 mm, 93 mm) and in a variety of mesh sizes within a set. However, there was only a very weak relationship with high variability between fish length and the mesh size it was captured in (Figure 11D).

The two locations that were fished on the first leg of the survey that were also fished on the second leg had similar catch rates. At one location (stations 6, 14), sockeye salmon were not caught during either fishing event. At the second location (stations 11, 15) catches were small on both March 11 and March 23, with one and four sockeye salmon caught, respectively (Figure 7D; Table 5).

3.2.5 Steelhead

The 57 steelhead caught in the gillnet represented the largest catch of all salmon and were the most widely distributed Pacific salmon in the survey (Table 4). Steelhead were encountered in 15 of the 19 sets and at 12 of the 13 stations fished with gillnets (Table 5). They were caught from the most northerly to the most southerly locations fished, and the largest catches were on the eastern side of the survey area (Figure 16). The catch per set ranged from one to 14 (Figure 7E). Two sets (17 and 26) caught 21% and 25% of all steelhead, respectively, and were both on the eastern longitude (135^{o}W) of the study area (Figures 7E, 16; Table 5).

Some of the steelhead were not measured due to predation or damage in the net. The average length and weight of the remaining steelhead was 50 ± 10.4 cm and 1382 ± 977 g (Table 6; Figures 9E, 10I). The average condition (K) of the steelhead salmon was 0.98 ± 0.09 (Table 6; Figure 10J). Ten (18%) of the steelhead had adipose fins removed but no CWTs were present. There was no significant difference in the size or condition of the ten fish with adipose fin clips and the total catch (t-test, $p > 0.05$).

The length distribution of the steelhead (Figure 9E) suggested that multiple age classes were present. Preliminary aging using the scales supported this interpretation. Due to the complexity of steelhead life history, with a mix of freshwater and saltwater ages and the possibility of repeat spawning, ages have not yet been finalized for these steelhead.

The steelhead were captured in all mesh sizes except for the smallest (48 mm) and the largest (157 mm). In 80% of the sets with two or more steelhead, the fish were caught in multiple mesh sizes (Figure 7E). The steelhead were predominantly caught (66%) in the surface quarter of the net. Only three steelhead were caught below 4 m and none were caught below 6 m. In five sets, two steelhead were caught within 3 m of each other. Additionally, due to the catch of steelhead in multiple web sizes in a single net, they were caught over an extended area. For example, in set 17, station 7, the 13 steelhead were caught in five different mesh sizes (Figure 7E), including the commercial 115 mm web at both ends of net, suggesting steelhead were along the 2.4 km area that was being fished by the gear. The relationship between the length of the steelhead and the capture mesh size was weak (Figure 11E) and some of the larger steelhead were captured in the smallest mesh sizes.

The two locations that were fished in both legs of the survey caught steelhead during both periods (Figures 7E, 16). Steelhead were caught in similar numbers in both sets conducted at station 6 (March 5; n = 4, 2) and station 14 (March 20; n = 3, 2). Additionally, at the location for station 11 (March 11) and station 15 (March 21), only one set was conducted on each date. During these two fishing days, 14 and 6 steelhead were caught, respectively, and these catches were both part of the three largest catches of steelhead during the survey.

3.2.6 Chinook salmon

One Chinook salmon was caught at station 2 (Figure 1B). This unmarked fish was 42.5 cm in length and weighed 911 g.

3.3 SALMON CATCH ON LONGLINE

Nine salmon (5 coho, 3 sockeye and 1 chum salmon) were recovered on the longline gear (Tables 4, 5; Figures 8, 13, 15). An additional 8 salmon, or about 50% of the salmon catch on this gear, was observed falling off the hooks as the gear was being hauled (Table 5). This loss of fish typically happened in larger seas. The pressure of the vessel on the longline would result in multiple hooks (> 6) being out of the water to the stern of the vessel with any catch hanging below the longline. Waves would either knock the fish off the hook or the jarring of the line due to wave actions would allow the fish to fall off. All salmon were caught on size 4 or 5 hooks with anchovy or herring used as bait. Observations of bait retention during hauling indicated that the majority of hooks still had bait.

Due to the low catch rate, comparisons between the time of day fished and between gear types, was limited. One of the coho salmon had an adipose fin clip but no CWT. There was no difference in the size of the coho or sockeye salmon caught on longlines or in the gillnets ($p > 0.05$). The chum salmon was one of the three largest chum salmon (55 cm, 1,573 g) caught on the survey and was in its fourth winter at sea. Except for at station 16, the salmon species caught on the longline were also observed in the gillnet catch at the same location.

The CPUE (catch/1000 hooks) was highest for coho salmon at 0.7. Sockeye salmon CPUE was 0.4 and chum salmon was 0.1.

3.4 DNA ANALYSIS

At the time of publication of this report, DNA analysis for stock origin is complete for coho, sockeye and chum salmon (Table 7). Results of DNA analysis for steelhead, Chinook and pink salmon are not yet available.

3.4.1 Chum salmon

DNA analysis identified most of the chum salmon as originating from British Columbia (n = 12; Table 7), with 9 from northern British Columbia. Six of the salmon (20%) were identified as originating from Alaska including western, central and southeast Alaska. Four (13%) of the chum salmon were from coastal Washington State and Puget Sound, and four were identified as originating from Japan (2) and Russia (2). Four chum salmon could not be assigned a stock of origin with a 70% or greater probability.

The four chum salmon originating from Japan and Russia were all in at least their second winter at sea. The remaining chum salmon in their second winter or more at sea originated from northern British Columbia (4) and western (2) and central (1) Alaska. One of the fish in this age group could not be assigned to stock origin at 70% probability. In contrast, the ocean age 1 chum salmon included all fish that originated from southern regions, including the southern United States (4) and southern British Columbia (3). The remaining age 1 chum salmon originated from northern British Columbia (5), and southeast (2) and central (1) Alaska. There were no age 1 chum salmon identified from western Alaska or Asia. The seven chum salmon that were caught in a school in set 31 originated from central Alaska (1), southeast Alaska (2), and northern British Columbia (2). The remaining two chum salmon could not be assigned to a region at 70% or greater probability.

3.4.2 Coho salmon

DNA analysis for coho salmon identified fish from the Columbia River through to Alaska (Table 7), with the largest contribution originating from Canada (n = 16; 31%). Of these fish, the majority (13) were from north-central British Columbia (Table 7). Two coho salmon were identified as originating from the Quinsam River, on eastern Vancouver Island in southern British Columbia. This DNA assignment agreed with the CWT tag that was recovered from one of these fish. The second fish was not tagged or adipose fin clipped. One final fish identified as originating from British Columbia could not be assigned to a specific area at 70% probability.

Coho salmon from the southern United States were the second most abundant stock type (n = 15; 29%). These included nine from coastal Washington and six from Oregon and the Columbia River. Three of the six coho salmon from Oregon and the Columbia River were adipose fin clipped. Five of the nine fish identified as coastal Washington were adipose fin clipped with one of these having a CWT from this region (Quinault hatchery, Washington State).

Similar numbers of coho salmon were identified as originating from Alaska (n = 13; 25%) and included fish from the Kodiak Peninsula to southeast Alaska. In addition, there were 4 (8%) coho salmon that originated from transboundary rivers shared by Alaska and northern British Columbia. Three coho salmon could not be identified to origin at 70% probability.

The coho salmon were extensively mixed. Sets that caught more than three coho salmon had representation from the southern United States to Alaska in the catch. Additionally, there was no difference in the average length of the coho salmon from each of these three regions (ANOVA; $p = 0.67$).

3.4.3 Sockeye salmon

DNA analysis was conducted on 53 sockeye salmon (Table 7). The majority of the fish were identified as originating from Alaska (32) with many from Cook/Norton Sound (10) or the Kodiak Peninsula (7; Table 7). There was also a large number (11) that could not be assigned to a specific region within Alaska at 70% probability. Nineteen of the sockeye salmon were identified as originating from British Columbia with most (15) originating from the Fraser River. Of the Fraser River fish, 12 were identified as summer-run fish (Chilko and Mitchell) and two as late-run timing stocks. One fish could only be classified as originating from the Fraser River but not to a specific run timing, at 70% probability. The remaining four sockeye salmon from British Columbia included three from Vancouver Island (Sproat Lake) and one from the north coast (Babine). One sockeye salmon was identified as originating from the southern United States (Big Creek, Washington State) and another from Osoyoos, British Columbia, on the upper Columbia River. There was no relationship between stock origin and where the sockeye salmon were caught, indicating that sockeye salmon were extensively mixed throughout the survey area.

3.5 DIET OF SALMON

3.5.1 Chum salmon

Most (57%) of the chum salmon had empty stomachs, and these were observed in 70% of the sets where chum salmon were captured. The empty stomachs were observed both in fish that were in their first ocean winter (8) as well as in older chum salmon (9).

Of the 13 chum salmon that had food in their stomachs, there were nine prey groups. The most common, by volume, was the tunicate *Oikopleura* (35%). However, this prey was only observed in three fish. Other items that represented more than 5% of the diet by volume included squid

(10%), polychaetes (7%), and hyperiid amphipods (6%). Squid was only observed in one of the stomachs and was identified as *Okutnia anonycha*. The remaining items that could be identified (10%) included jellyfish (3%), fish remains (3%), pteropods (3%), isopods (2%) and euphausiids (1%). A large percentage (32%) of the prey in chum salmon stomachs was too digested for identification. These unidentifiable prey items were observed in 70% of the chum salmon stomachs.

3.5.2 Coho salmon

Diet analysis was conducted on 47 stomachs from coho salmon and identified 28 (60%) of the stomachs as empty. The fish with empty stomachs were distributed across 70% of the sets that caught coho salmon, but were more likely to be from southern rivers. Coho salmon identified as originating from the Columbia River and Oregon all had empty stomachs.

In the 19 coho salmon stomachs that contained prey, the average volume of prey in the stomach was 5 cc (range 0.5 to 24 cc). By percent volume, the most common diet item was squid and cephalopods (72%) and included *Boreoteuthis borealis, O. anonycha* and *Onychoteuthis borealijaponica*. This was also the most common prey type by occurrence being identified in 68% of the stomachs. The mantle length of the observed squid ranged from 31–71 mm. Fish remains were important by volume (27%) but were found in only seven of the stomachs. Of the fish remains that could be identified, the blue lanternfish *Tarletonbeania crenularis*, was the most common. The remainder of the stomach contents (~1%) was too digested for identification.

3.5.3 Sockeye salmon

Most (78%) of the 45 stomachs analyzed from sockeye salmon were empty and the proportion of empty stomachs was similar across the survey area. In the sockeye salmon that were feeding, the average volume of the diet contents was 3.9 cc with no fish having more than 9 cc of food in their stomachs. The most common prey item was squid, by volume and occurrence (90% of volume, 80% of stomachs). Four species of squid were identified including *B. borealis*, *Gonatus onyx, G. madokai* and *O. borealijaponica*. Although most were highly digested, there were some mantles that could be measured and these ranged in length from 38-52 mm. *Oikopleura* and unidentified fish remains represented 6% and 3% of the stomach contents, respectively. The remaining contents were too digested and could not be identified.

3.5.4 Pink salmon

Only two of the pink salmon had prey in their stomachs and the remaining eight (80%) were empty. The two stomachs that had prey contained euphausiids (40%), pteropods (22%), hyperiids (22%), chaetognaths (11%) and ostracods (5%). Euphausiids were dominated by *Euphausia pacifica.*

3.5.5 Steelhead

Twenty (41%) of the 49 steelhead stomachs examined were empty and the empty stomachs were observed in 67% of the sets. The average volume of the remaining 20 stomachs sampled was 3.2 cc (range 0.3-14.7 cc). The most common diet item, by volume, was squid (47%). When the squid were combined with items that could only be classified down to the level of cephalopod, they represented 48% of the total volume. About half of all fish that were feeding had squid or cephalopod remains in the stomach. The size of the squid mantles ranged from 42-60 mm. The species of squid identified in the stomach, in descending order of frequency of occurrence, included *Boreoteuthis berealis, O. anonycha, G. onyx* and *C. calyx*. By volume in the stomachs, *O. anonycha* was the most abundant and *G. onyx* was the least abundant. Fish remains were also important in the diet representing, by volume, 30% of the diet. In the fish remains, myctophids including *Tarletonbeania crenularis* were the most common. Euphausiids were the most commonly identified prey item in 66% of the fish that were feeding. The species identified included *E. pacifica* and *Thysanoessa spinifera*. However, by volume, they were only 10% of the diet. Unidentified eggs averaging 2.5 mm in diameter were encountered in one steelhead stomach that also had both fish and crustacean remains. The eggs and crustacean remains represented 4% and 3% of the stomach contents by volume, respectively. The remaining 5% of stomach contents were comprised of hyperiids, shrimp, gammarids, isopods, and other matter that was too digested for identification.

3.6 PREDATION, PARASITES AND FISH HEALTH

3.6.1 Predation

The occurrence of predation wounds and scars on the salmon was low with 3% having evidence of predation prior to capture (three steelhead (5%), two sockeye salmon (4%), and one chum salmon (3%)). The predation of salmon while they were entangled in the gillnets was more commonly observed. This included slashes and open wounds from birds, to large portions of the body or stomach being removed by birds or larger predators. Eight of the coho salmon (16%), four sockeye salmon (8%) and four steelhead (7%) had recent predation wounds.

3.6.2 Parasites

Sea lice were observed on 27 (13%) of the salmon. All sea lice were identified as the salmon louse (*Lepeophtheirus salmonis*) and over half were gravid females. The number of sea lice on an individual fish ranged from one to five. Steelhead had the highest prevalence of sea lice (22%) with an average of 1.6 lice per infected fish (range 1-3). The prevalence and numbers on coho and pink salmon were similar (20%, 1.5 sea lice per infected fish). Coho salmon had sea lice numbers ranging from one to five and pink salmon had one to two sea lice per fish. Only one louse was observed on one sockeye salmon during the survey.

3.6.3 Fish Health

Four fish (3 sockeye salmon, 1 steelhead) with internal lesions or pustules were documented and samples of internal organs and tissues were preserved in formalin for analysis at the Fish Health Laboratory in Nanaimo, British Columbia. In addition to these lesions and pustules, a number of the salmon were documented with adhesion of the pyloric caeca (Figure 17) . This was observed in all salmon species except pink and chinook salmon. However, it was most common in sockeye with over 50% of the samples recorded as having some level of adhesion. In several instances, especially in sockeye salmon, the adhesions were severe with the pyloric caeca adhered to the body wall and around the internal organs. Six of the sockeye salmon from station 2 were frozen whole to allow a more detailed analysis by the Fish Health Laboratory in Nanaimo, British Columbia.

3.7 NON-SALMON CATCH

Sixteen species other than salmon were caught or encountered in the survey and are listed in Table 4. Fourteen different species were caught in the gillnet, one was caught on the longline, and one was caught in both gear types. Three of the species were not landed but were observed either within the gear or tangled in the buoy lines and escaped or were lost prior to landing. These included the larger fish and mammal species. Four species of birds were caught in the gear and were released unharmed when possible.

3.7.1 Black rockfish

There were 25 black rockfish (*Sebastes melanops*) caught in nine gillnet sets (Figure 18; Tables 4, 5). All black rockfish were caught on the first leg of the survey (Figure 18).

Two of the black rockfish were mangled in a net rollup and were not measured. The average length and weight of the remaining 24 black rockfish was 45 ± 4.4 cm and 1,492 ± 531 g. They were caught in 8 mesh sizes ranging from 48 mm to 138 mm (Figure 19A) and were typically caught in more than one mesh size when catch was greater than one. There was no relationship between the size of the black rockfish and the mesh size in which the fish was caught. They were located at all depths within the net, from headrope to footrope, and there was no observed catch pattern within the gear.

DNA, otoliths, and scales were collected from all of the black rockfish. In addition, seven fish were dissected with the stomachs, gonads and muscle samples frozen and returned to the lab for analysis. The bodies of all other fish were retained and frozen for subsequent analysis.

3.7.2 Pacific spiny dogfish

Pacific spiny dogfish (*Squalus suckleyi*) were caught both in gillnet (16) and longline (4) gear (Table 4). Most of the Pacific spiny dogfish were caught south of 47°N (Figure 20) and when more than one was caught in a gillnet, they were located in multiple mesh sizes (106 mm and larger; Figure 19B). There was one Pacific spiny dogfish caught on the longline at station 2 at the northern extent of the survey area.

The average length of the Pacific spiny dogfish was 100 ± 10.0 cm (Figure 21). Most were female (12), and these were larger on average (104 cm) than the males (89 cm). Spines and muscle were frozen from 14 Pacific spiny dogfish. Six fish were frozen whole and returned to the lab. Of the fish sampled at sea, two stomachs contained food remains. One Pacific spiny dogfish had a *Chiroteuthis calyx* squid in the stomach and one contained unidentified fish flesh (frozen and returned to the lab).

3.7.3 Pacific sardine

Fourteen Pacific sardine (*Sardinops sagax*) were captured in one gillnet set (set 23, Table 5) at the most southerly station fished (Station 9; Figure 1B). These fish were captured across three web sizes (115, 106 and 63 mm). The fish caught within an individual panel were within 2 m of each other and in the same area of the net. The fish ranged from 15-28 cm in length, with an average of 17 ± 3.2 cm. There was one larger fish in the sample that was 28 cm in length and weighed 232 g. All Pacific sardines were frozen and returned to the lab.

3.7.4 Boreal clubhook squid

Fourteen boreal clubhook (*Onychoteuthis borealijaponica*) squid were captured in eight gillnet sets and in mesh sizes from 48-115 mm (Figure 22). The mantle lengths ranged from 16.0 - 28.4 cm with an average of 22.4 cm. The average weight was 263 g. Samples were frozen and returned to the lab.

3.7.5 Salmon shark

Two salmon sharks (*Lamna ditropis*) were encountered in two different gillnet sets (stations 6 and 15; Figures 1B, 23). In both encounters, the sharks escaped from the trawl ramp as the gear was being hauled.

3.7.6 Other fish

A single juvenile skilfish (*Erilepis zonifer*) was caught in the gillnet at station 8 in the southern region of sampling (Figure 1B). This fish was 31.3 cm in length and weighed 491 g. During the same set a longnose lancetfish (*Alepisaurus ferox*) was also captured. The fish was 112 cm long and weighed 2,195 g. The gillnet caught jellyfish, but they were poorly retained. Therefore, the occurrence and numbers of the jellyfish species are under-reported. Due to this, jellyfish were only reported as present (P) in Table 5. The samples that were recovered included fried-egg jellyfish (*Phacellophora camtschatica*), water jellyfish (*Aequorea* spp.) and moon jellyfish (*Aurelia labiate*).

3.7.7 Birds

Birds were not common in the catch of the gillnet and were never caught on the longline gear. A horned puffin (*Fratercula corniculate*; set 19, station 8), and a tufted puffin (*F. cirrhata*; set 31, station 14) were captured in the survey (Table 5). After identification, the puffins were measured (wing length and span), weighed and frozen whole. Two storm petrels (*Hydrobates* spp.) were also caught in the gillnets (station 7, set 17; station 15, set 34). One of these birds (station 15) was successfully untangled from the gillnet and released. A Laysan albatross (*Phoebastria immutabilis*) was tangled in one gillnet (station 14) and successfully released.

3.7.8 Marine mammals

Two Dall's porpoises (*Phocoenoides dalli*) were entangled in the gillnet gear at two stations (station 1, set 2; station 15, set 34; Figure 24). In both instances these mammals escaped from the net prior to landing. No measurements or sex were available for either specimen.

Additionally, during the final day of fishing, large schools of Dall's porpoises were observed at station 16. The gillnet set was immediately cancelled, relocated about 2 km south of the original fishing location (Figure 1B), and successfully fished.

A northern fur seal (*Callorhinus ursinus*) was entangled in buoy line at station 6 in set 12 (Figure 24). The mammal was not harmed and successfully swam free as the line attached to the flagpole was pulled to the stern of the vessel. No biological information is available for this mammal.

3.8 OCEANOGRAPHY/ZOOPLANKTON/eDNA

The surface temperatures recorded during the survey ranged from 6.6 ^{o}C at station 2 in the northern part of area fished, to over 15 ^{o}C in stations south of 46^{o}N. The highest temperatures (15.6 ^{o}C) recorded by a RBR duet[3] temperature recorder was at station 10. However, temperatures around 15 ^{o}C were also observed at stations 8 and 9. Temperatures declined with depth and at stations from 46^{o}N and southward were on average 9 ^{o}C at 5 m.

Zooplankton samples (preserved and frozen) will be processed as part of the IYS expedition. Water samples for eDNA analysis were collected during every deployment of the CTD. The filters from the filtered water were returned to the Molecular Genetics Lab at the Pacific Biological Station in Nanaimo for analysis. Results of these samples will be combined and reported in combination with samples from the other vessels.

3.9 VISUAL OBSERVATIONS OF BIRDS AND MAMMALS

Observations of birds and mammals are provided in Table 8. These observations were taken during daylight hours and when crew were available, and are therefore not a complete list of birds and mammals in the study area.

An unexpected sighting occurred during transit to the study area at approximately 49.15^{o}N, 131.07^{o}W. A bird landed on the bow in the evening and remained there for several hours. Photos of the bird suggest that it was either a Masked (*Sula dactylatra*) or Nazca (*Sula granti*) booby. Either species would be rare for the area as they are generally observed much further south, off California.

3.10 COMPARISONS WITH OTHER SURVEYS

3.10.1 CCGS *Sir John Franklin*

No direct comparison of catch between the *Raw Spirit* and the Sir *John Franklin* can be made due to the time lag between fishing events at various locations and a minimum of five days separating fishing events by these two vessels. However, even with this lag in timing, more general comparisons of catch rates can be made. To minimize variation, our comparisons use sets conducted during the first leg of the *Raw Spirit* survey with *Sir John Franklin* catches (King et al. 2022). During this period, seven locations were fished by both vessels (Figure 25).

Pacific salmon were caught by both vessels at each location although only the gillnets caught steelhead. Excluding the steelhead that were caught in these 7 sets (n = 40), the catch of other Pacific salmon by the two gear types was similar (gillnet = 107, trawl = 91). This suggests that the two gear types were similarly effective at catching all species of Pacific salmon except steelhead. There is variability in the number of each species caught by the two vessels (Figure 26A). This may be due to the lag in fishing time between the vessels or due to the time of day that fishing occurred. If we remove the day/night variability and only compare sets fished at a similar time of day (n = 2, stations 1, 4), there were five days between fishing events by each vessel and the total catch between the trawl gear and gillnets, with exception of steelhead, were similar (Figure 26B). Additionally, the general distribution patterns for each species of Pacific salmon provided by King et al. (2022) were similar to the distribution patterns of Pacific salmon observed in this survey (Figures 8, 13, 14, 15).

3.10.2 1960s surveys

As part of the high seas tagging program in the 1960s, longlines were set in January/February and then in April and subsequent months. We conducted a comparison of our longline catches of Pacific salmon with catches reported by the FV *G.B. Reed*, one of the vessels that consistently participated in the surveys in the 1960s (Turner and Aro 1968). For the comparison we used the fishing years 1963, 1964, and 1965, when fishing was conducted in both January and April.

The most commonly caught Pacific salmon in 1963 to 1965 was sockeye salmon. The average CPUE of sockeye salmon was similar in January (38.2 fish/1000 hooks) and April (32.8 fish/1000 hooks) with the largest catches in 1965 (Table 9; Figure 27). The sockeye salmon CPUE in 2022 was significantly smaller at 0.4 fish/1000 hooks.

The average CPUE of chum salmon in January 1963, 1964, and 1965 was 0.5 fish/1000 hooks and ranged from 0.3 to 0.7. The catch increased substantially by April with an average CPUE of 7.9. The CPUE of chum salmon in 2022 was 0.1 fish/1000 hooks (Table 9; Figure 27).

The CPUE of coho salmon from 1963 to 1965, in both January (average of 0.2) and April (average of 0.8), was similar to the CPUE in March 2022 (0.7 fish/1000 hooks). There was also more variability in the historic catches with coho salmon absent from some surveys in January 1963 and 1965 (Table 9; Figure 27).

3.11 ISSUES TO CONSIDER FOR FUTURE SURVEYS

3.11.1 Longline

An issue with the longline fishing was the inability of the vessel to pull the gear vertically. As the gear was being hauled from the stern, and due to lack of bow thrusters or means to keep the weight of the vessel from pulling on the gear, there was often multiple hooks (more than five) out of the water during gear recovery. When fish were on these hooks they were getting hit by waves or simply falling off the gear prior to it reaching the vessel. This is expected to have reduced the overall catch with this gear. However, since most hooks retained bait when recovered, it is not anticipated that the loss of fish from fishing operations would have changed our interpretation of what was present.

3.11.2 Gillnet

The gillnet was effective in seas less than 3 m and waves with a long frequency. However, segments of the second leg were lost to sampling due to larger seas. It is recommended that the gillnet is used as a secondary gear on future trawl surveys. It could be set in fair seas or in areas where large salmon catches are encountered by the trawl gear. The gillnet caught a broader range of fish species, including possible salmon predators, than the trawl gear. It is, therefore, an important gear type to use in future research. It is also important for studies of steelhead as it was the only gear demonstrated as being effective in catching these surface-oriented fish.

4 DISCUSSION

The results of this survey and the surveys in 2019 and 2020 (NPAFC 2022) provided new information about the ocean ecology of Pacific salmon in the winter in the Gulf of Alaska. In all years, the catches of salmon were very patchy and less abundant than expected, indicating that there are vast areas in the Gulf of Alaska that have relatively low salmon abundances.

The catch of pink salmon in 2022 remained low. It appears that pink salmon were farther south than was surveyed in 2019, 2020 and 2022. Pink salmon distributions also had very little overlap with sockeye salmon in these surveys. This is important because it has been suggested that because of the similarity in diets, there may be a density dependent competition that would result in hatchery pink salmon competing for food and reducing sockeye salmon survival in some years. If this density dependent competition occurs, it would have to occur before or after the winter, because it appears that pink salmon are distributed much farther south in the winter than sockeye salmon. Understanding where the pink salmon are rearing in the winter is a necessary requirement to be able to identify mechanisms regulating their survival.

We did not find that specific aggregate populations of sockeye salmon occupied specific rearing areas as we expected prior to these surveys. This is important because it may indicate that the mechanisms regulating different ocean survivals may originate during the coastal period prior to the first ocean winter. We found that winter surveys can provide advance estimates of total sockeye salmon returns. In 2022, with the exception of steelhead in the gillnet catches, sockeye salmon dominated catches both in this survey and in the survey by the *Sir John Franklin* (King et al. 2022). The 2022 sockeye return year to the Fraser River in British Columbia was expected to be dominated by Adams River or late-run sockeye salmon and this run cycle is typically the largest of a four-year cycle. The pre-season forecast anticipated a stronger return of the summer-run sockeye salmon to the Fraser River (see http://www.psc.org/FRPWeb/Status/FRP_Fraser_sockeye_pink_status.pdf), but still forecasted the late-run timing group to be about 38% of the returns. All sockeye salmon catches in our survey in 2022 were in at least their second winter at sea and would be expected to return to their natal rivers that fall. However, of the 15 Fraser River sockeye salmon identified in the catch, only two were late-run, and not Adams River fish. The majority of the sockeye salmon sampled and originating from the Fraser River were summer-run. The catches of these summer-run fish were much more abundant than the late-run sockeye salmon and more closely reflected the actual returns in 2022 than the pre-season forecast.

The catch of chum salmon in this survey was low. Additionally, there were very few chum salmon older than age 2 in the catch. Chum salmon have traditionally been the largest commercial fishery, by weight, in British Columbia. Chum salmon from British Columbia were not abundant in their second, third and fourth ocean years compared to chum salmon from Alaska, Russia and Japan in the 2019, 2020 and 2022 surveys. This appears to relate to the poor returns in British Columbia in the past four years. Juvenile chum salmon studies in the Strait of Georgia show that abundances of juveniles in the ocean in the first five months have not declined (Neville 2022), possibly indicating that the poor survival is related to open ocean conditions in the first marine year.

We found chum salmon in a small school. It has always been believed that salmon do not school in the open ocean. The small school of chum salmon were in their first ocean year with individuals originating from rivers that were widely separated from northern British Columbia to Alaska. We also found a small school of coho salmon in our 2019 survey and a larger school of coho salmon in the 2020 survey (Beamish et al. 2022). The school of coho salmon in 2020 contained populations from Oregon to Alaska. There must be a genetically controlled behaviour that "directs" chum and coho salmon to school in the winter, possibly to reduce the effects of predation and improve feeding efficiency in the winter by minimizing metabolic costs.

Steelhead were effectively caught in the gillnet gear. They were only caught in the gillnets and not in the trawls that were also fishing at the surface. This is the first time in over 50 years that steelhead have been effectively studied in the Gulf of Alaska in the winter. Our catches and the absence of catches by the other ships fishing as part of the International Year of the Salmon show that steelhead were confined to the surface few meters. There is literature that shows steelhead probably are in the surface waters for their entire ocean life (Nielsen et al. 2011). This makes them susceptible to ocean changes at the surface that affect their food and this behaviour may help explain the large-scale decline in recent years.

Our studies show that winter is a distinct period in the ocean life of Pacific salmon. Like other animals, Pacific salmon may be cued by external factors to adjust their behaviour and metabolism to better survive the winter. The external cue could be day length and the winter solstice. We know from circuli patterns on scales that winter is a period of reduced growth. In this survey, the percent of empty stomachs ranged from 80% for pink salmon to 41% for steelhead with an average of 63.2 % for all species. For comparison, the percent of empty stomachs for juvenile pink, chum, coho and Chinook salmon in the Strait of Georgia in September range from 1-28% but typically average 5-15%. One explanation for the relatively large percent of empty stomachs in the winter and the reduced growth as indexed by scales is a reduced abundance of prey. However, another explanation/hypothesis could be a reduced feeding behaviour. We propose that the reduced catches by the longlines compared to the catches in the gillnets may be related to a reduced feeding response. We see that after the winter annulus is formed on coho salmon there is an abrupt return to rapid growth, which could be related more to an external stimulus (e.g., day length) than to an abrupt increase in prey. If winter is a distinct period in the life of Pacific salmon, it should be apparent that a much better understanding of how ocean and climate changes are affecting salmon survival is needed in order for us to be responsible stewards in a future of climate related changes in the ocean ecosystem.

5 FUTURE RESEARCH

The new information that has been discovered in three years of winter surveys in the Gulf of Alaska highlight the need for additional future research. At present there are no winter surveys planned for the Gulf of Alaska by government agencies in 2023; however, a fourth privately funded and organized expedition is being considered.

6 ACKNOWLEDGEMENTS

Thank you to the crew of the *Raw Spirit* for finding the fair seas and ensuring that we maximized the fishing opportunities we could within our survey area. We want to especially thank the many businesses that provided financial support for this research. This included, in alphabetical order, Aero Trading; Alaska General Seafoods; Canadian Fishing Company; Copper River Seafoods; E&E Foods, Inc.; French Creek Seafoods; Keltic Seafoods; Leader Creek Fisheries; North Pacific Seafoods; OBI Seafoods; Parkland (fuel); Premium Brands Group; Trident Seafoods Corp.; Unican Industries; UniSea, Inc.; and West Coast Reduction. We also want to thank the Government and Foundations that also provided funding (cash or in-kind) including Great Pacific Foundation; BC Northern Development & Innovation Trust; BC Salmon Restoration and Innovation Fund; Fisheries and Oceans Canada; Great Bear (Central Coast First Nations); North Pacific Anadromous Fish Commission; and Pacific Salmon Foundation.

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8 TABLES

Table 1. Science team and vessel crew that participated in the Gulf of Alaska survey on the FV *Raw Spirit* February 25 – March 25, 2022.

Name	Role
Chrys Neville	Chief Scientist
Mike Banks	Science team
Dan Bouillon	Science team
Svetlana Esenkulova	Science team
Rebecca LaForge	Science team
Brendon Lewis	Science team
Geoffrey Martynuik	Science team
Aidan Schubert	Science team
Hans-Peter Jesson	Captain
Matt Roszmann	Fishing Master
Roman Moizis	Chief Engineer
Eden Thibideau	Bridge officer
Wayne Edwards	Second Engineer
George Boutilier	Deck crew
Kyle Erickson	Deck crew
Dustin McDonell	Deck crew
Stephane Tourangeau	Deck crew
Chris Shufelt	Galley
Marlowe Mathieson	Steward

Table 2. Travel and fishing activity by day during the FV *Raw Spirit* gillnet and longline survey 2022. Fishing activity is listed as the day the gear is set but may not have been hauled until the following day. Detailed bridge log information is provided in Table 3.

Date	Activity	Fishing Station	Set initiated	Gear used
25-Feb	Leave Port Alberni/Travel			
26-Feb	Travel			
27-Feb	Fishing starts	1	1-3	Longline, gillnet, CTD, Bongo
28-Feb	Fishing	1	4	Longline
1-Mar	Fishing	2	5-6	Longline, gillnet, CTD, Bongo, Nisken
2-Mar	Fishing	3	7-8	Longline, gillnet, CTD, Bongo, Nisken
3-Mar	Fishing	4	9	Gillnet, CTD, Nisken
4-Mar	Fishing	5	10-11	Longline, CTD, Bongo, Nisken
5-Mar	Fishing	6	12-15	Longline, gillnet, CTD, Bongo, Nisken
6-Mar	Fishing	7	16-17	Gillnet, CTD, Bongo, Nisken
7-Mar	Fishing	7	18	Longline
	Fishing	8	19-20	Gillnet, CTD, Bongo, Nisken
8-Mar	Fishing	8	21	Longline
	Fishing	9	22-23	Gillnet, CTD, Nisken
9-Mar	Fishing	9	24	Longline
	Fishing	10	25	Gillnet, CTD, Bongo, Nisken
10-Mar	Travel			
11-Mar	Fishing	11	26-28	Longline, gillnet, Bongo, CTD, Nisken
12-Mar	Travel/weather			
13-Mar	Travel/weather			
14-Mar	Fuel in Port Hardy			
15-Mar	Travel/weather wait			
16-Mar	Weather wait/Travel			
17-Mar	Travel			
18-Mar	Fishing	12	29	Longline, CTD, Nisken
19-Mar	Oceanography only	13		CTD, Nisken
20-Mar	Fishing	14	30-31	Gillnet, CTD, Nisken
21-Mar	Fishing	15	32	Longline
22-Mar	Fishing	15	33-34	Longline, gillnet, CTD, Bongo, Nisken
23-Mar	Fishing	16	35-36	Longline, gillnet, CTD, Bongo, Nisken
24-Mar	Travel			
25-Mar	Travel/Return to Port Alberni			

Table 3. Bridge log data for the FV *Raw Spirit* gillnet and longline survey 2022. Location is the latitude (°N) – longitude (°W) of the station.

Set	Station	Location (°N - °W)	Set Date	Gear type	Bait type/Hook size (A= anchovy, H=herring, S=squid)	Set time (PST)	Retrieval time (PST)	Soak time (minutes)	Time of day	Sea state (m)	Wind direction	Wind Speed
1	1	49-135	27-Feb	Longline	A,S/4	12:26	15:50	204	day	2	-	-
2	1	49-135	27-Feb	Gillnet		13:40	7:46 (+1)	1086	dusk/dawn	2	-	-
3	1	49-135	27-Feb	Gillnet		15:06	18:00	174	day	2	-	-
CTD-1	1	49-135	27-Feb	CTD		18:00				2	-	-
B-1	1	49-135	27-Feb	Bongo		18:20				2	-	-
4	1	49-135	28-Feb	Longline	A,S/4	6:48	10:09	201	dawn	1	-	-
5	2	50-138	1-Mar	Gillnet		1:06	8:43	457	night/dawn	0.5-1.5	ENE-NE	5-15
6	2	50-138	1-Mar	Longline	A,S/4	6:43	11:16	273	dawn	1-2	ENE-N	10-20
CTD-2	2	50-138	1-Mar	CTD		7:09				1.5	ENE-N	10-20
B-2	2	50-138	1-Mar	Bongo		7:29				1.5	ENE-N	10-20
7	3	49-141	2-Mar	Gillnet		1:37	8:02	385	night/dawn	0.5-1.5	N-W	5-10
CTD-3	3	49-141	2-Mar	CTD		1:40				1	N-W	5-10
B-3	3	49-141	2-Mar	Bongo		2:05				1	N-W	5-10
8	3	49-141	2-Mar	Longline	A,S/4	6:29	9:47	198	dawn	1-1.5	W-SW	5-10
9	4	48-138	3-Mar	Gillnet		0:26	7:54 (+1)	448	night/dawn	1.5-3	SW-W	20-25
CTD-4	4	48-138	3-Mar	CTD		0:39				3	W	>20
10	5	47-141	4-Mar	Longline	A/3,4,5	6:55	9:33	158	dawn	2-1	SW	5-8
11	5	47-141	4-Mar	Longline	A/4	9:08	11:09	120	day	1	SW	5-10
CTD-5	5	47-141	4-Mar	CTD		9:15				1	SW	5-10
B-5	5	47-141	4-Mar	Bongo		9:45				1	SW	5-10
12	6	47-138	5-Mar	Gillnet		0:37	8:16 (+1)	399	night/dawn	1	SW-S	5
CTD-6	6	47-138	5-Mar	CTD		0:53				1	SW	5
B-6	6	47-138	5-Mar	Bongo		1:20				1	SW	5
13	6	47-138	5-Mar	Longline	A/3,4,5	6:33	10:03	210	dawn	0.5	S	3-10
14	6	47-138	5-Mar	Longline	A/3,4,5	7:15	11:23	248	day	0.5	S	5-10
15	6	47-138	5-Mar	Gillnet		13:35	8:12 (+1)	1117	dusk/dawn	0.5-1	SSW-SSE	5-10
16	7	47-135	6-Mar	Gillnet		22:37	7:38	541	night/dawn	0.5-1	SE-SW	5-6
17	7	47-135	6-Mar	Gillnet		23:46	9:10	564	night/dawn	0.5-1	SSW-SW	4-7
CTD-7	7	47-135	7-Mar	CTD		0:30				1	SSW	4
B-7	7	47-135	7-Mar	Bongo		1:03				1	SSW	4
18	7	47-135	7-Mar	Longline	A/3,4,5	6:31	10:53	262	dawn	0.5	SW-WSW	5-12
19	8	46-135	7-Mar	Gillnet		19:31	8:16	645	night/dawn	1-1.5	SW	4-10
CTD-8	8	46-135	7-Mar	CTD		20:02				1.5	SW	10
B-8	8	46-135	7-Mar	Bongo		20:20				1.5	SW	10

Table 3. Bridge log data for the FV *Raw Spirit* gillnet and longline survey 2022. Location is the latitude (°N) – longitude (°W) of the station.

Set	Station	Location (°N - °W)	Set Date	Gear type	Bait type/Hook size (A= anchovy, H=herring, S=squid)	Set time (PST)	Retrieval time (PST)	Soak time (minutes)	Time of day	Sea state (m)	Wind direction	Wind Speed
20	8	46-135	7-Mar	Gillnet		21:35	11:45	850	night/dawn	1-1.5	SW	4-10
21	8	46-135	8-Mar	Longline	A/3,4,5	6:38	10:08	210	dawn	1-2	W-WSW	10
22	9	45-135	8-Mar	Gillnet		19:45	7:36	711	night/dawn	1.5-2.5	WSW-SW	2-15
CTD-9	9	45-135	8-Mar	CTD		19:54				2	SW	12-15
B-9	9	45-135	8-Mar	Bongo		20:21				2	SW	12-15
23	9	45-135	8-Mar	Gillnet		21:59	9:31	692	night/dawn	1-2.5	WSW-SW	lt airs - 10
24	9	45-135	9-Mar	Longline	A,S,H/3,4,5	6:36	10:43	247	dawn	1.5-2	W	lt var-12
25	10	46-138	9-Mar	Gillnet		2:34	7:54	320	dusk	1-2.5	SW-S	20-25
CTD-10	10	46-138	9-Mar	CTD		2:50				2.5	S	20-25
26	11	48-135	11-Mar	Gillnet		11:02	20:12	550	dusk	1.5-2.5	SW-E	10-17
27	11	48-135	11-Mar	Longline	A,S,H/3,4,5	11:55	13:10	75	day	1.5	W	8-10
CTD-11	11	48-135	11-Mar	CTD		12:10				1.5	W	10
B-11	11	48-135	11-Mar	Bongo		12:35				1.5	W	10
28	11	48-135	11-Mar	Longline	A,S,H/3,4,5	18:05	22:07	242	night	1	E	23-30
29	12	47-135	18-Mar	Longline	A,S,H/3,4,5	18:57	20:32	95	night	4-5	SE-SW	13-35
CTD-12	12	47-135	18-Mar	CTD		19:05				4-5	SE-SW	13-35
CTD-13	13	46-138	19-Mar	CTD		16:21				4-5	SW	25-35
30	14	47-138	20-Mar	Gillnet		13:17	16:11	174	day	3.5	W	10-25
CTD-14	14	47-138	20-Mar	CTD		13:27				3.5	W	10-25
31	14	47-138	20-Mar	Gillnet		18:17	21:11	174	dusk	2.5-3	W	10-25
32	15	48-135	21-Mar	Longline	A,S,H/3,4,5	13:10	15:06	116	day	4	SW	20-25
33	15	48-135	22-Mar	Longline	A,S,H,F/3,4,5	7:00	10:04	184	day	3	SW-W	10-28
CTD-15	15	48-135	22-Mar	CTD		11:16				3	SW	28
B-15	15	48-135	22-Mar	Bongo		11:29				3	SW	28
34	15	48-135	22-Mar	Gillnet		13:28	20:18	410	dusk	2-3	SE-SW	15-30
35	16	48-133	23-Mar	Longline	A,S,H,F/3,4,5	6:34	10:47	253	dawn	2.5	SW	15-25
CTD-16	16	48-133	23-Mar	CTD		9:05				2-3	SW	25
B-16	16	48-133	23-Mar	Bongo		9:35				2-3	SW	25
36	16	48-133	23-Mar	Gillnet		17:11	20:56	225	dusk	2-3	W-S	15-30

*(+1) indicates retrieval is +1 day.

Table 4. Total catch by species in the gillnet and longline gear from most common to least common in catch.

Species or group		Gillnet	Longline
Steelhead	*Oncorhynchus mykiss*	57	
Sockeye salmon	*Oncorhynchus nerka*	50	3
Coho salmon	*Oncorhynchus kisutch*	46	5
Chum salmon	*Oncorhynchus keta*	29	1
Black rockfish	*Sebastes melanops*	25	
Pacific spiny dogfish	*Squalus suckleyi*	16	4
Pacific sardine	*Sardinops sagax*	14	
Boreal clubhook squid	*Onychoteuthis borealijaponicus*	14	
Pink salmon	*Oncorhynchus gorbuscha*	10	
Dall's porpose[1]	*Phocoenoides dalli*	2	
Salmon shark[1]	*Lamna ditropis*	2	
Storm petrel[2]	*Hydrobates* spp.	2	
Chinook salmon	*Oncorhynchus tshawytscha*	1	
Horned puffin	*Fratercula corniculata*	1	
Laysan albatross[2]	*Phoebastria immutabilis*	1	
Longnose lancetfish	*Alepisaurus ferox*	1	
Skilfish	*Erilepis zonifer*	1	
Tufted puffin	*Fratercula cirrhata*	1	
Northern fur seal[1]	*Callorhinus ursinus*		1
Moon jellyfish	*Aurelia labiata*	Present	
Fried egg jellyfish	*Phacellophora camtschatica*	Present	
Water jelly	*Aequorea*	Present	

[1] Escaped prior to landing

[2] One or more released live from deck

Table 5. Catch of Pacific salmon and other species by set and station. Location is the latitude (°N) – longitude (°W) of the station.

Set number	Station number	Location (°N - °W)	Set date	Gear type (GN=gillnet, LL= longline)	Survey Leg	Chum salmon	Coho salmon	Pink salmon	Sockeye salmon	Chinook salmon	Steelhead	Unidentified salmon*	Pacific spiny dogfish	Black rockfish	Boreal clubhook squid	Pacific sardine	Longnose lancetfish	Skillfish	Salmon shark*	Moon jellyfish	Fried egg jellyfish	Water jelly	Dall's porpoise*	Northern fur seal*	Puffin	Storm petrel	Laysan albatross*
1	1	49-135	27-Feb	LL	1	1																					
2	1	49-135	27-Feb	GN	1	7	2	1						3						P			1*				
3	1	49-135	27-Feb	GN	1						4																
4	1	49-135	28-Feb	LL	1																						
5	2	50-138	1-Mar	GN	1	4	2	1	29	1	2				1					P							
6	2	50-138	1-Mar	LL	1				1				1														
7	3	49-141	2-Mar	GN	1		1	1	9		1				1					P							
8	3	49-141	2-Mar	LL	1																						
9	4	48-138	3-Mar	GN	1		3		6					3													
10	5	47-141	4-Mar	LL	1							2															
11	5	47-141	4-Mar	LL	1							2															
12	6	47-138	4-Mar	GN	1		14				2																
13	6	47-138	5-Mar	LL	1		2					2												1*			
14	6	47-138	5-Mar	LL	1		1						1														
15	6	47-138	5-Mar	GN	1	1	5				4		7	2	1				1*								
16	7	47-135	6-Mar	GN	1	2	4	3			1		3	2	1												
17	7	47-135	6-Mar	GN	1	1	1	1	1		12		1	5	1											1	
18	7	47-135	7-Mar	LL	1		1					1	1														
19	8	46-135	7-Mar	GN	1	2	4	2					1		3				1*						1		
20	8	46-135	7-Mar	GN	1	1	4				1		2	1			1	1									
21	8	46-135	8-Mar	LL	1																						
22	9	45-135	8-Mar	GN	1						1			1	1												
23	9	45-135	8-Mar	GN	1										3	14											
24	9	45-135	9-Mar	LL	1																						
25	10	46-138	9-Mar	GN	1		4				1		1	2													
26	11	48-135	11-Mar	GN	1	1	1	1	4		14			6							P						
27	11	48-135	11-Mar	LL	1																						
28	11	48-135	11-Mar	LL	1				1																		
29	12	47-135	18-Mar	LL	2							1	1														
30	14	47-138	20-Mar	GN	2	1					3																
31	14	47-138	20-Mar	GN	2	8	1				2		1		2										1		1*
32	15	48-135	21-Mar	LL	2																						
33	15	48-135	22-Mar	LL	2																						
34	15	48-135	22-Mar	GN	2						5									P		P	1*			1*	
35	16	48-133	23-Mar	LL	2				1																		
36	16	48-133	23-Mar	GN	2	1	1		1		4																
Total in gillnet						29	46	10	50	1	57	0	16	25	14	14	1	1	2	P	P	P	2		2	2	1
Total on longline						1	5		3		0	8	4											1			
Total Catch						30	51	10	53	1	57	8	20	25	14	14	1	1	2	P	P	P	2	1	2	2	1

P indicates present in set but no counts

*Escaped or released

Table 6. Average length (cm) , weight (g) and condition (*K*) of Pacific salmon caught in the gillnet. The N value is less than total catch for some fish were not measured due to damage in fishing gear.

Species	N	Average length (cm)	SD	Weight (g)	SD	Condition (*K*)	SD
Chum salmon	29	36.4	11.64	645	709	0.98	0.07
Coho salmon	42*	39.3	3.38	634	164	1.04	0.07
Pink salmon	10	30.1	1.72	257	42	0.94	0.05
Sockeye salmon	47	43.3	4.92	872	310	1.04	0.06
Steelhead	55*	49.5	10.40	1382	977	0.98	0.09

*42 coho salmon measured for length, 39 for weight and condition

*55 steelhead measured for length, 51 measured for weight and condition

Table 7. Stock origin for coho, sockeye and chum salmon caught in the survey based on DNA analysis. Probability of assignment is 70% or greater.

Species	Area	Number
Coho salmon	Alaska – Cook/Norton	2
	Alaska – Kodiak Peninsula	5
	Alaska – Southeast Alaska	4
	Alaska – general	2
	Transboundary – Taku/Alsek	4
	Northern British Columbia	12
	Central British Columbia	1
	South British Columbia	2
	Canada General	1
	Coastal Washington	9
	Columbia/Oregon	6
	Unknown	3
Sockeye salmon	Alaska – Bering	3
	Alaska - Cook/Norton	10
	Alaska – Kodiak Peninsula	7
	Alaska – Southeast Alaska	1
	Alaska – general	11
	Northern British Columbia	1
	South British Columbia - Fraser River	15
	South British Columbia - Other	3
	Washington State	1
	Columbia - Okanogan	1
Chum salmon	Alaska – western	2
	Alaska – central	2
	Alaska – Southeast Alaska	2
	Northern British Columbia	9
	Southern British Columbia	3
	Southern US – Puget Sound	1
	Southern US – Coastal Washington	3
	Russia	2
	Japan	2
	Unidentified	4

Table 8. Observations of birds and mammals during survey not associated with fishing activity. Date and general location are provided.

Date	Time (PST)	Latitude (°N)	Longitude (°W)	Species	Photos (y/n)	Comments
25-Feb-22	1506	48.80	-123.50	Whales – no ID	no	2x blow ~ 1km of port
26-Feb-22	738	48.93	-128.78	Porpoise – no ID	no	
26-Feb-22	845	~49.0	-128.91	black footed albatross	no	
26-Feb-22	845	~49.0	-128.91	Shearwaters	no	
26-Feb-22	845	~49.0	-128.91	Northern fulmar	no	
26-Feb-22	1030	49.14	-129.14	Albatross	no	
26-Feb-22	1043	49.15	-129.17	Eared seal	no	northern fur seal? N=2
26-Feb-22	1146	49.21	-123.34	Black footed albatross	no	
26-Feb-22	1310	49.20	-129.64	Black footed albatross	no	
26-Feb-22	1433	49.19	-129.95	Black footed albatross	no	
26-Feb-22	1900	49.15	-131.05	Boobie	yes	landed on bow. Remained ~ 5 hrs
27-Feb-22	1010	49.01	-134.66	Baleen whale – no ID	yes	
27-Feb-22	1348	48.99	-135.07	Baleen whale – no ID	no	
28-Feb-22	941	49.00	-134.95	Sea lion	no	species not determined
28-Feb-22	1212	49.09	-135.10	Porpoise – no ID	yes	
2-Mar-22	daytime	48.70	-140.11	Albatross	no	
2-Mar-22	daytime	48.38	-139.15	Albatross	no	
3-Mar-22	735	48.03	-137.91	Albatross	no	
3-Mar-22	1050	47.94	-138.05	Albatross	no	
3-Mar-22	1508	47.62	-138.74	Albatross	no	n=6 in group
3-Mar-22	1844	47.46	-139.30	Albatross	no	n=2
4-Mar-22	836	47.00	-140.99	Albatross	no	
4-Mar-22	935	~47.0	-141.00	Albatross	no	
4-Mar-22	1402	47.01	-140.50	Albatross	no	
4-Mar-22	1549	47.00	-140.03	Albatross	no	
5-Mar-22	600			Laysan albatross	no	10 while fishing at station 6
5-Mar-22	1300	47.01	-137.63	Black footed albatross	no	n= 3
5-Mar-22	1300	47.01	-137.63	Northern fulmar	no	1
5-Mar-22	1300	47.01	-137.63	Black legged kittiwake	no	n=3
5-Mar-22	1605	47.01	-137.98	Black legged kittiwake	no	
5-Mar-22	1642	46.99	-137.98	Whales – no ID	no	
6-Mar-22	1109	47.01	-137.63	Whales – no ID	no	
7-Mar-22	1153	46.98	-134.97	Humpback whale	yes	
7-Mar-22	1235	~47.0	-134.96	Northern fulmar	no	
7-Mar-22	1535	46.52	-135.05	Porpoise – no ID	no	
8-Mar-22	1312	45.98	-135.05	Pinniped – no ID	no	n=2
8-Mar-22	1340	45.90	-135.05	Dall's porpoise	no	pod swimming off bow
8-Mar-22	1346	45.89	-135.05	Whales – no ID	no	
9-Mar-22	1229	45.06	-135.11	Dall's porpoise	yes	
11-Mar-22	1622	48.01	-134.98	Humpback whale	yes	playing in surface waters
13-Mar-22	1130	50.79	-128.47	Grey whale	yes	species not absolute.
13-Mar-22	1256	50.89	-128.27	Sea otter	no	
13-Mar-22	1350	50.96	-128.11	Sea otter	yes	n=2
13-Mar-22	1400	50.97	-128.10	Sea otter	yes	multiple
13-Mar-22	1542	50.96	-127.76	Porpoise – no ID	no	
15-Mar-22	1847	54.29	-131.89	Baleen whale – no ID	no	
15-Mar-22	2004	54.29	-132.22	Whales – no ID	no	
	1849	53.74	-133.54	Whales – no ID	no	
	1950	53.57	-133.60	Whales – no ID	no	low blows off at angle. 4 whales
20-Mar-22	1945	47.01	-137.98	Albatross	no	n=26
22-Mar-22		47.99	-134.98	Dall's porpoise	no	
22-Mar-22	1815	48.00	-135.03	Whales – no ID	no	
23-Mar-22	1250	47.99	-133.00	Dall's porpoise	yes	
24-Mar-22	1250	48.35	-129.28	Dall's porpoise	yes	
25-Mar-22	1000	48.80	-125.93	Sea gull		first sighting on return

Table 9. CPUE of Pacific salmon on longline by the *G.B. Reed* in January and April 1963-1965 and by the *Raw Spirit* in March 2022.

				CPUE					
Year	Vessel	Month	Gear	Sockeye	Pink	Chum	Coho	Chinook	Steelhead
1963	*G.B. Reed*	January	longline	26.5	0.6	0.6	0.0	0.0	0.4
1964	*G.B. Reed*	January	longline	28.5	1.1	0.3	0.7	0.0	1.3
1965	*G.B. Reed*	January	longline	59.5	1.9	0.7	0.0	0.0	0.2
1963	*G.B. Reed*	April	longline	10.8	10.1	4.8	0.8	0.0	3.4
1964	*G.B. Reed*	April	longline	0.1	30.4	3.0	1.6	0.0	1.1
1965	*G.B. Reed*	April	longline	87.3	6.4	15.9	0.1	0.1	0.4
2022	*Raw Sprit*	March	longline	0.4	0.0	0.1	0.7	0	0

9 FIGURES

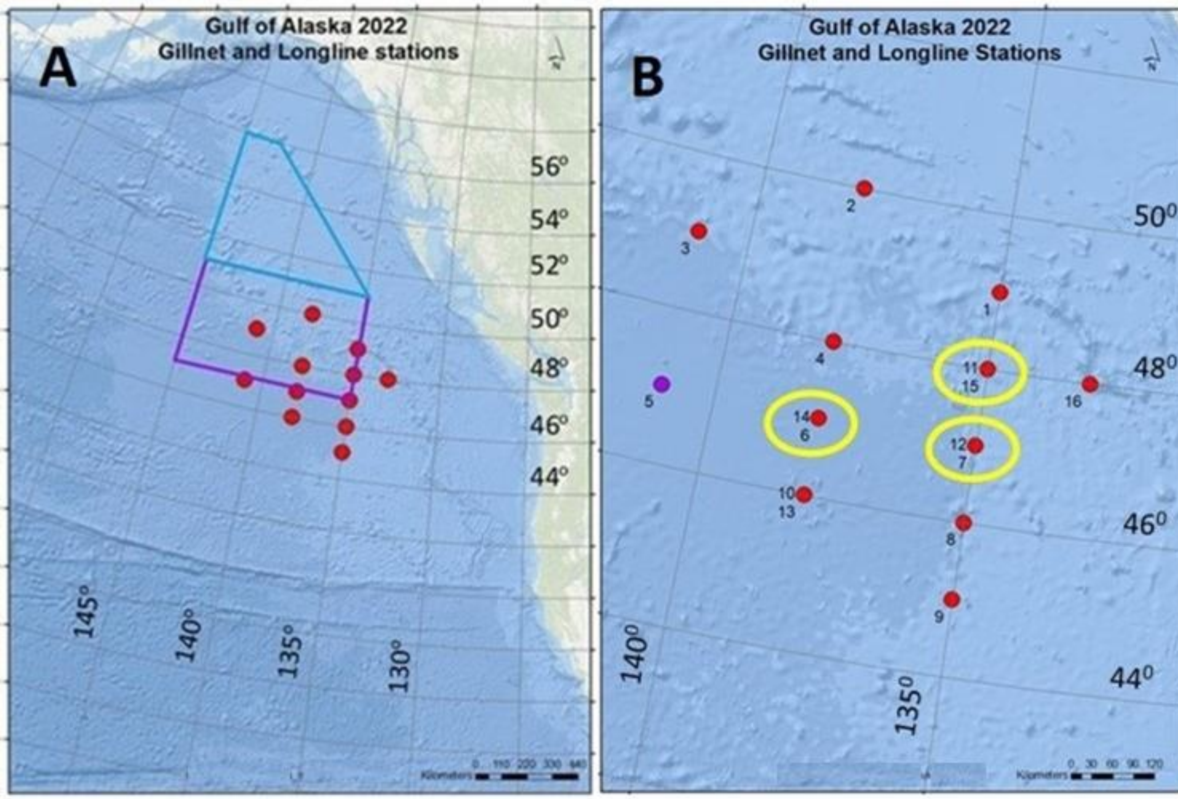

Figure 1. (A) Study area for 2022 survey by *Raw Spirit* and *Sir John Franklin* (purple polygon – southern stations, blue polygon – northern stations). The red dots are the stations that were sampled by the *Raw Spirit*. All sampling was conducted in the southern region of study area (purple polygon) or to the south or east of this primary study area. The area in the north (blue polygon) was not fished by the Raw *Spirit* due to weather. (B) Station numbers sampled by *Raw Spirit*. The red dots indicate locations where gillnets and longlines were fished. The purple dot is station where only longlines were fished. Four locations were sampled on both legs of the survey and have two unique station numbers. Three of these locations were fished on both legs (yellow ovals). The fourth location had only CTD sampling conducted on the second leg due to weather (station 13).

Figure 2. Science team. From back left: Brendon Lewis, Rebecca LaForge, Chrys Neville, Mike Banks, Geoffrey Martynuik. From front left; Aidan Schubert, Svetlana Esenkulova, Dan Bouillon.

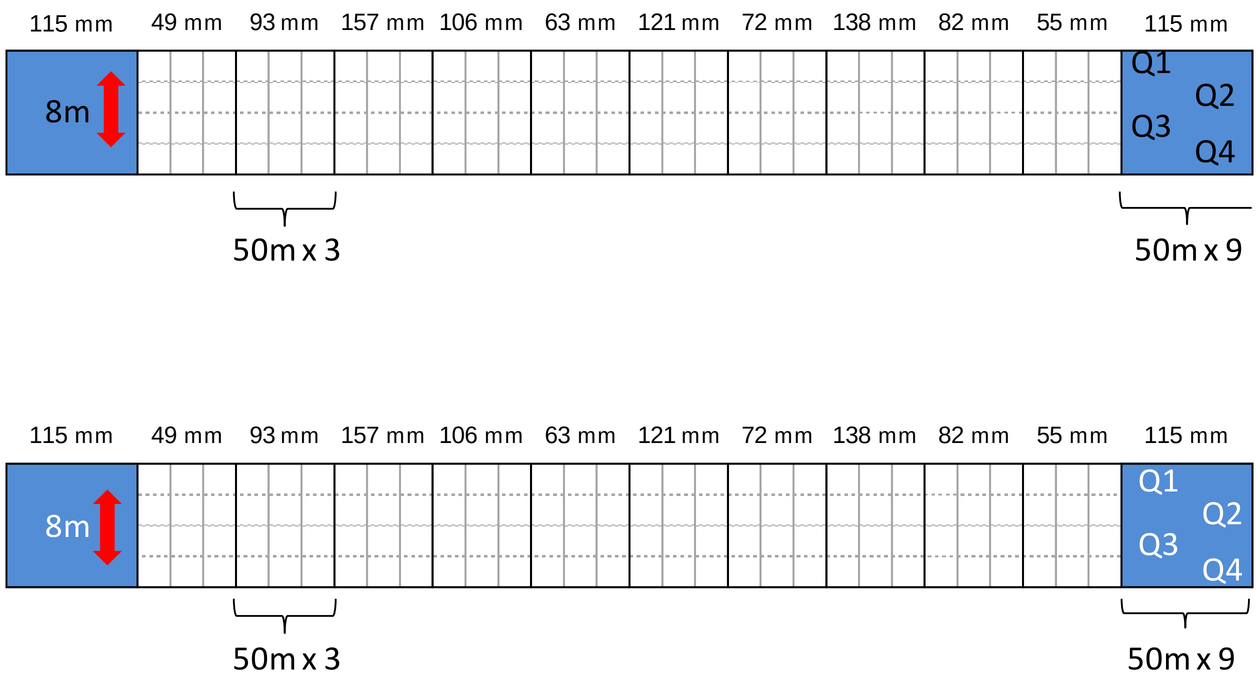

Figure 3. Schematic of gillnet. Web size of each section is shown along top of figure. The blue rectangles represent the nine panels of 115 mm commercial gillnet (115 mm) at each end of gillnet. The variable size mesh panels are between the commercial gillnet and each mesh size has 3 panels. All panels are 50 m in length. Total length of gillnet 2.4 km. Four depth quadrants (Q1, Q2, Q3, Q4), indicated by dotted lines, were used to identify the location of fish caught in the web.

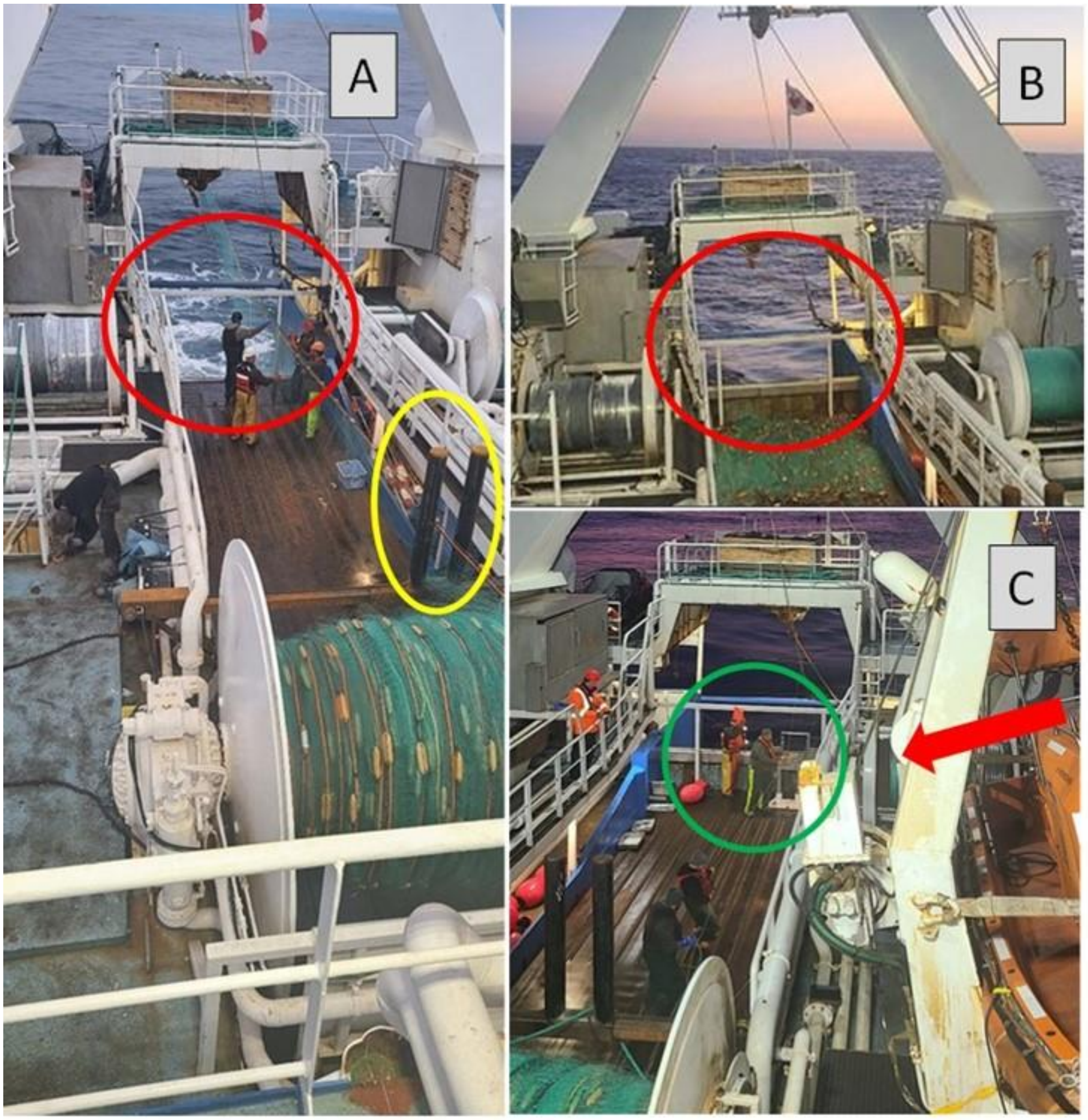

Figure 4. Vessel modification for fishing. Gillnet operations: Guide rails on stern (red circle; panel A, B) to prevent net from catching on sides of vessel or from moving vertically when setting/hauling during larger seas. Roller bars on drum (yellow circle; panel A) to direct net onto drum and reduce backlashes. Longline operations: Baiting station moved to stern deck during setting (green circle; panel C). Drum for longline on upper port trawl deck (red arrow; panel C).

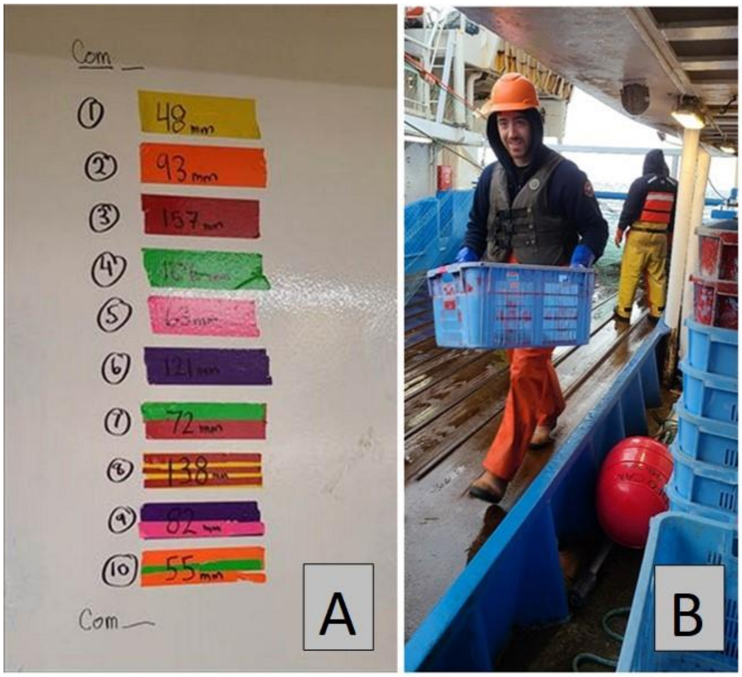

Figure 5. Tracking the catch by gear size. Colour coding of gillnet web size was used on the headrope of gillnet and on all totes. These totes were moved to the sampling lab regardless of catch.

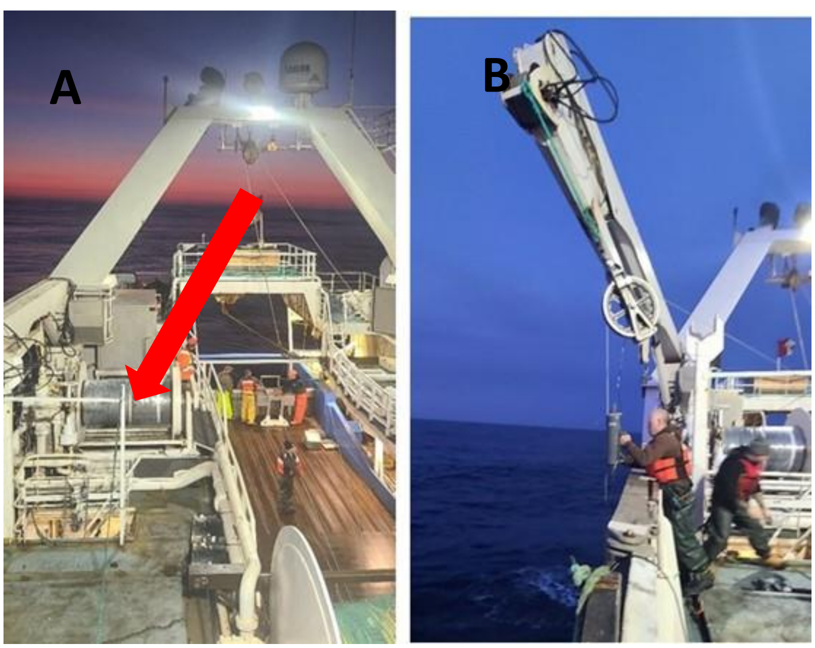

Figure 6. Location of CTD/bongo winch on starboard upper deck (Panel A, red arrow). Both CTD and bongo were deployed off the starboard side using a block on the crane arm to maintain the gear away from the vessel side (Panel B). The Niskin bottle was attached to wire during deployment of CTD to collect water sample for eDNA (Panel B – retrieving Niskin bottle).

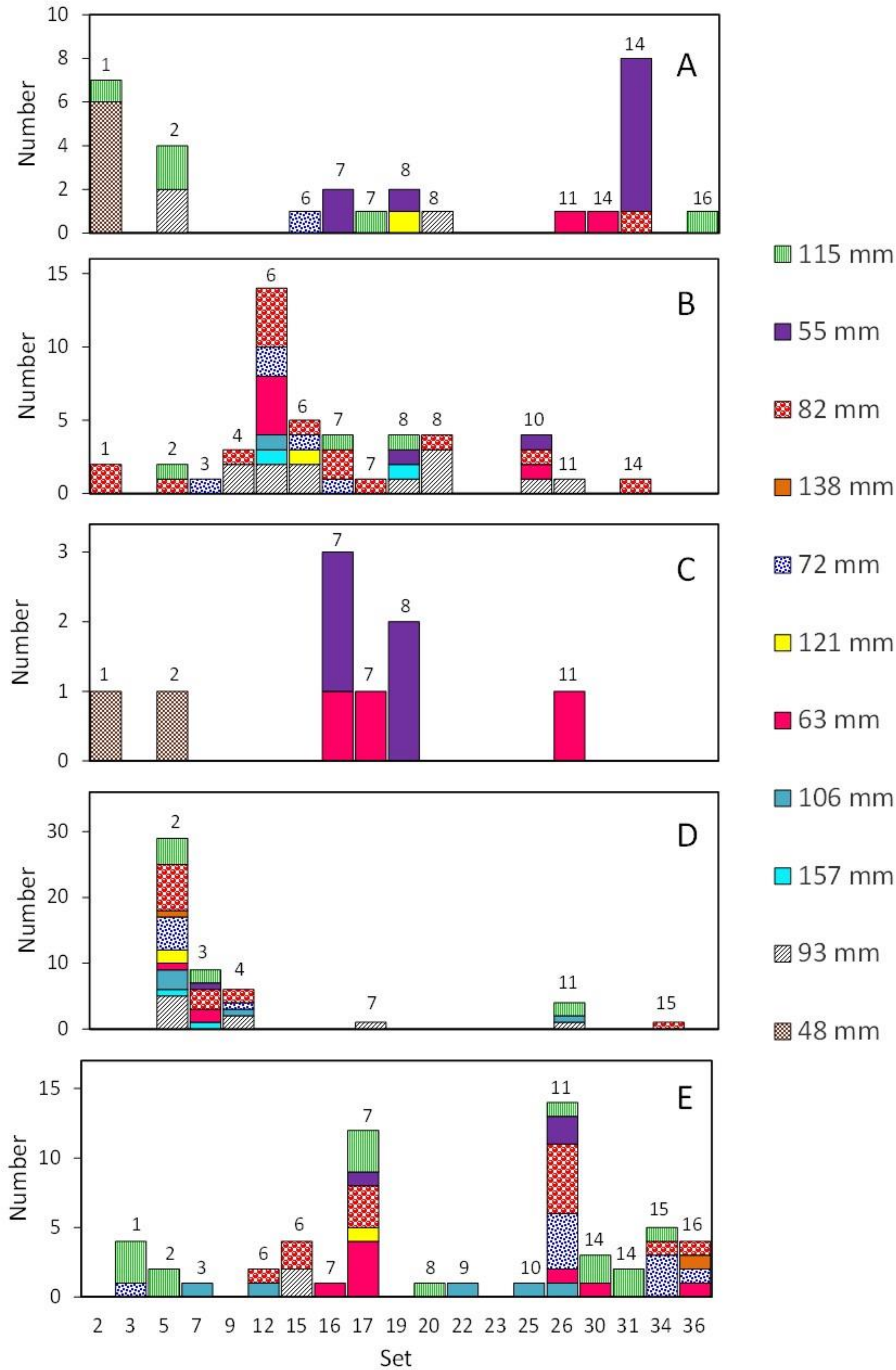

Figure 7. The catch (n) of Pacific salmon (A - chum salmon, B - coho salmon, C - pink salmon, D - sockeye salmon, E - steelhead) by set and mesh size in the gillnet. The station number is listed above the bars.

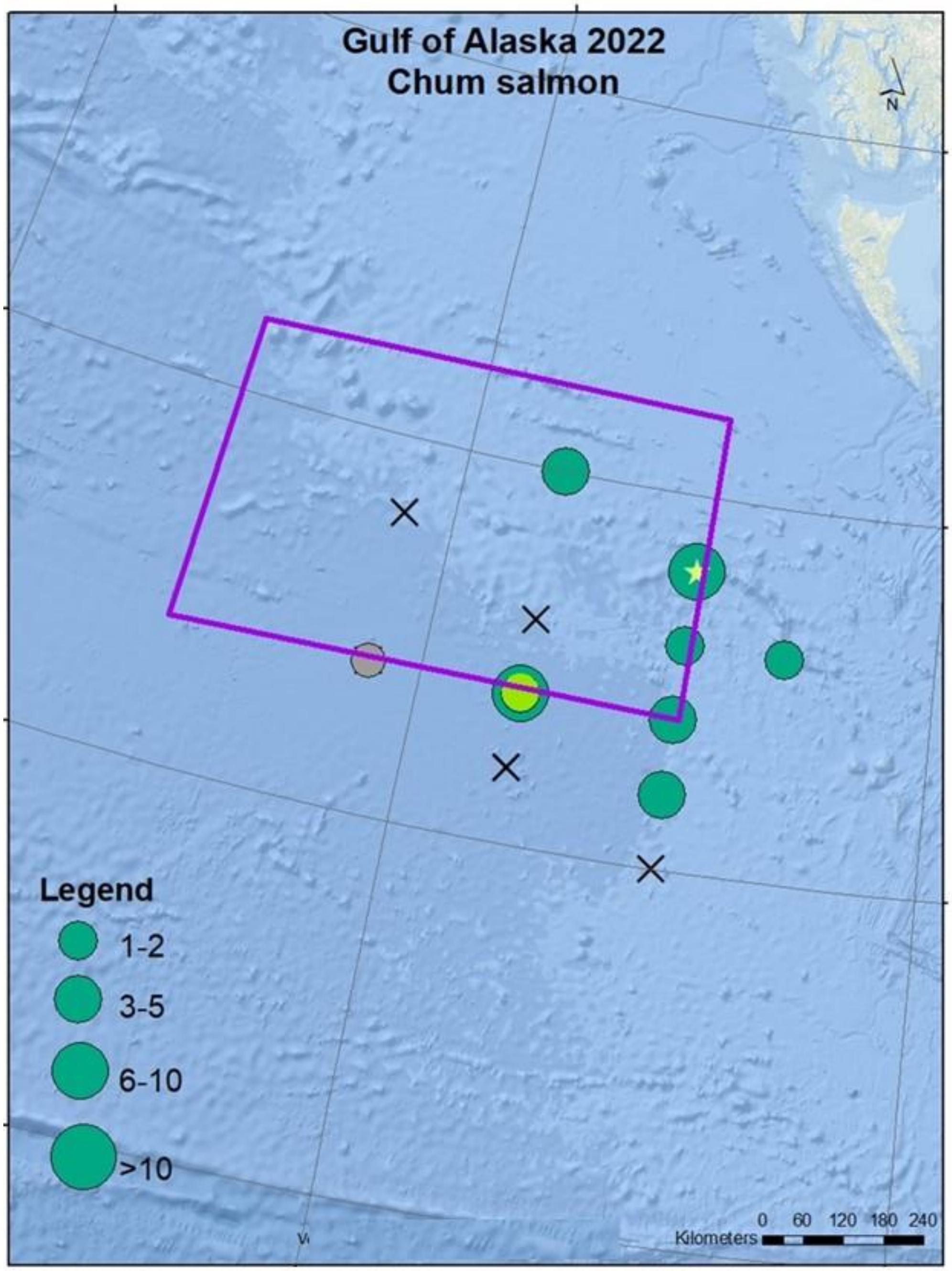

Figure 8. Distribution of chum salmon by station showing relative catch by gillnets. Crosses (X) are stations with no catch of chum salmon. The grey dot indicate station where no gillnet was set. When a location was fished on both legs of the survey the relative catch rates during the different periods are shown by a double circle representing the different days. The lower catch rate for these locations is a lighter shade of green. Yellow star indicates location where chum salmon caught on longline gear. The purple polygon is the perimeter of southern study area (see Figure 1A).

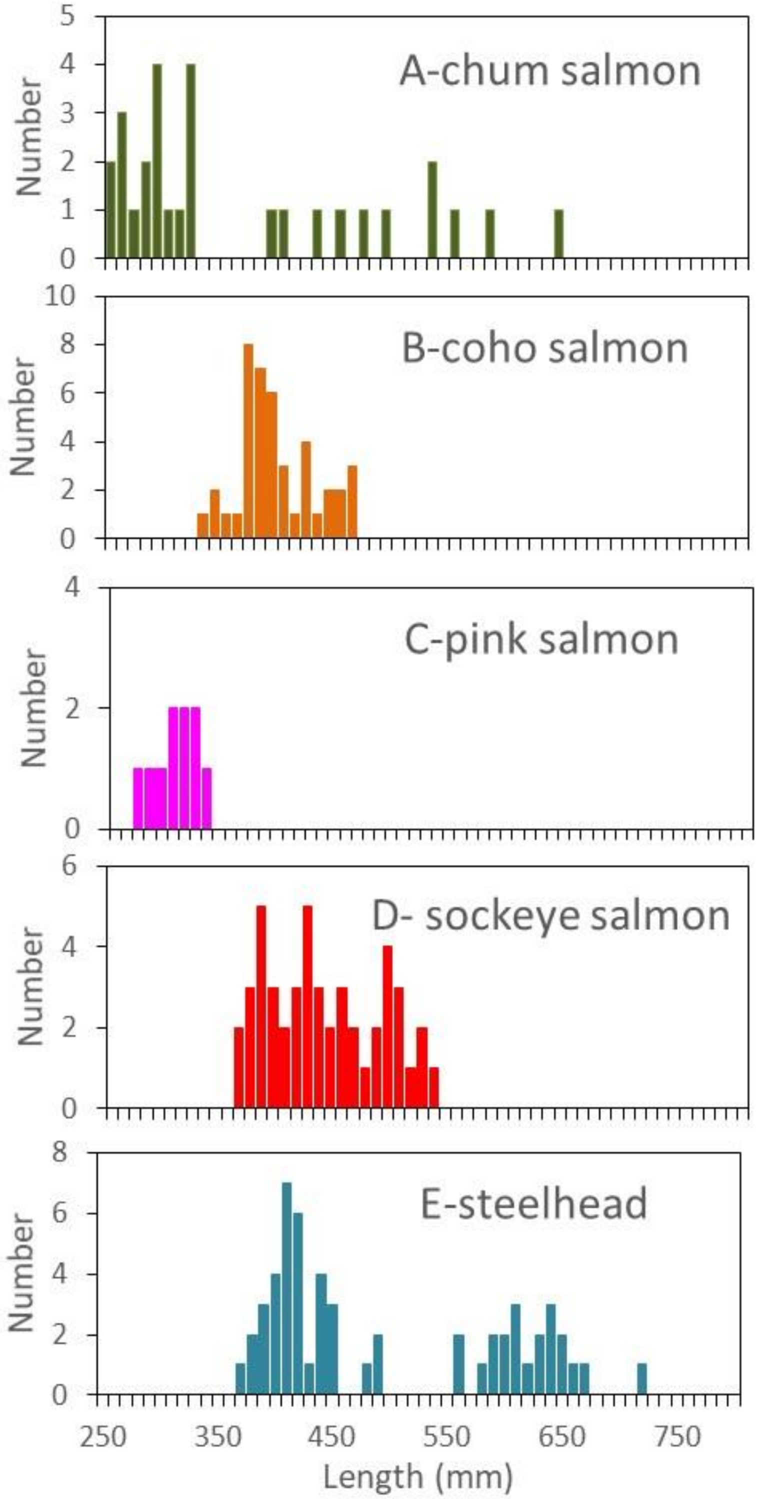

Figure 9. Length frequency of Pacific salmon caught in the gillnet. Note: Y axis varies by species.

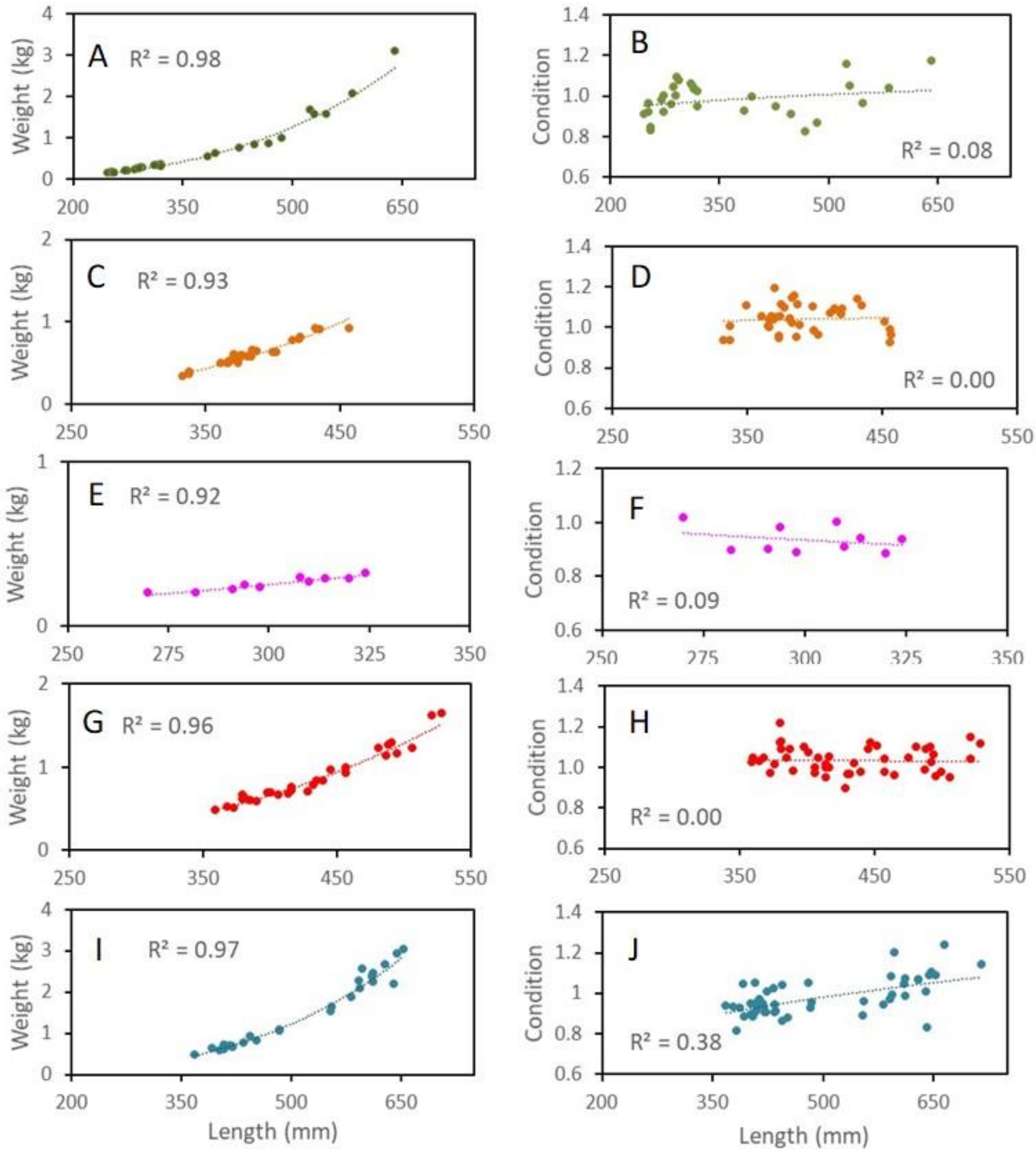

Figure 10. Relationship of length to weight and condition for the Pacific salmon (A, B - chum salmon; C, D - coho salmon; E, F - pink salmon; G, H - sockeye salmon; I, J - steelhead) caught in the gillnets.

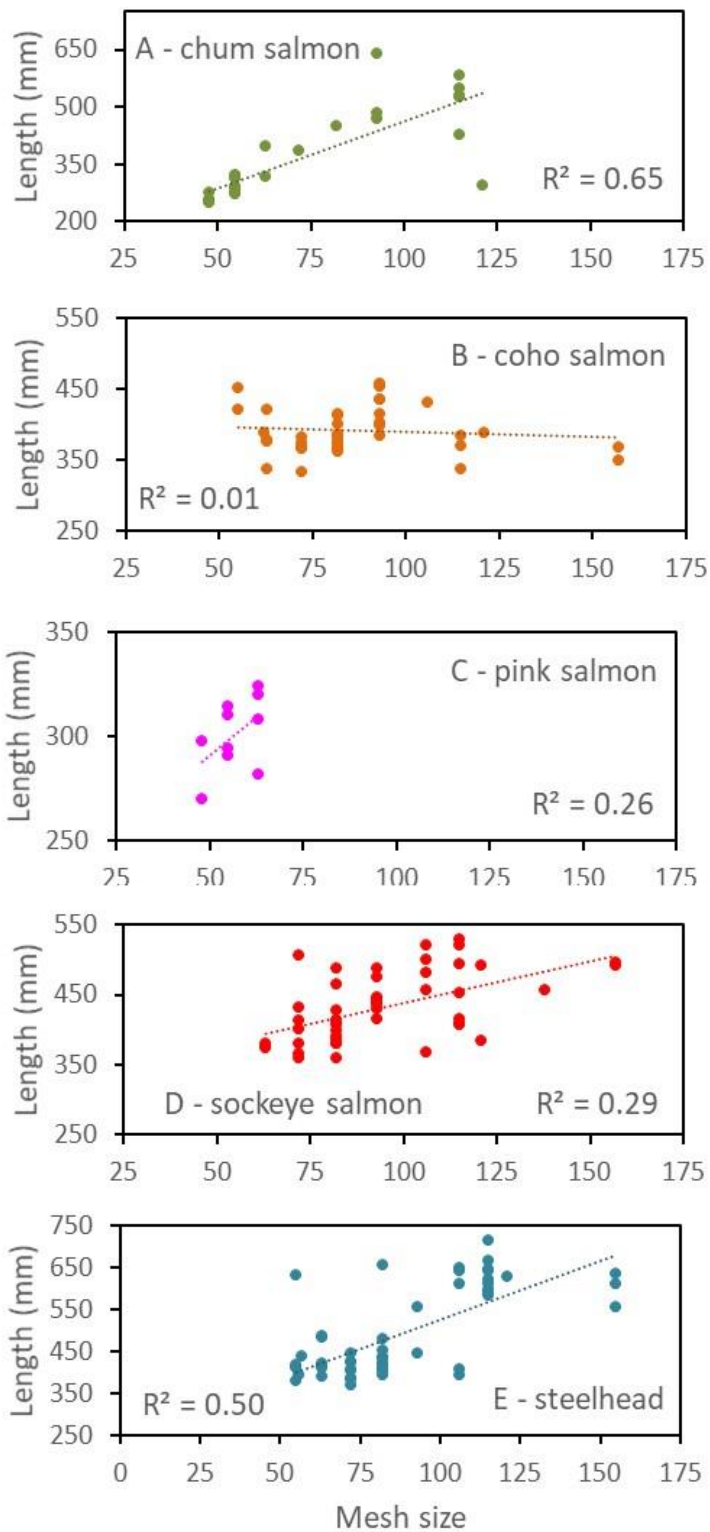

Figure 11. Length of Pacific salmon (A – chum salmon; B – coho salmon; C – pink salmon; D – sockeye salmon; E – steelhead) by mesh size in the gillnet.

Figure 12. Catch of 7 chum salmon in one panel of set 31, station 14, March 20, 2022, showing close proximity and similar size of the fish.

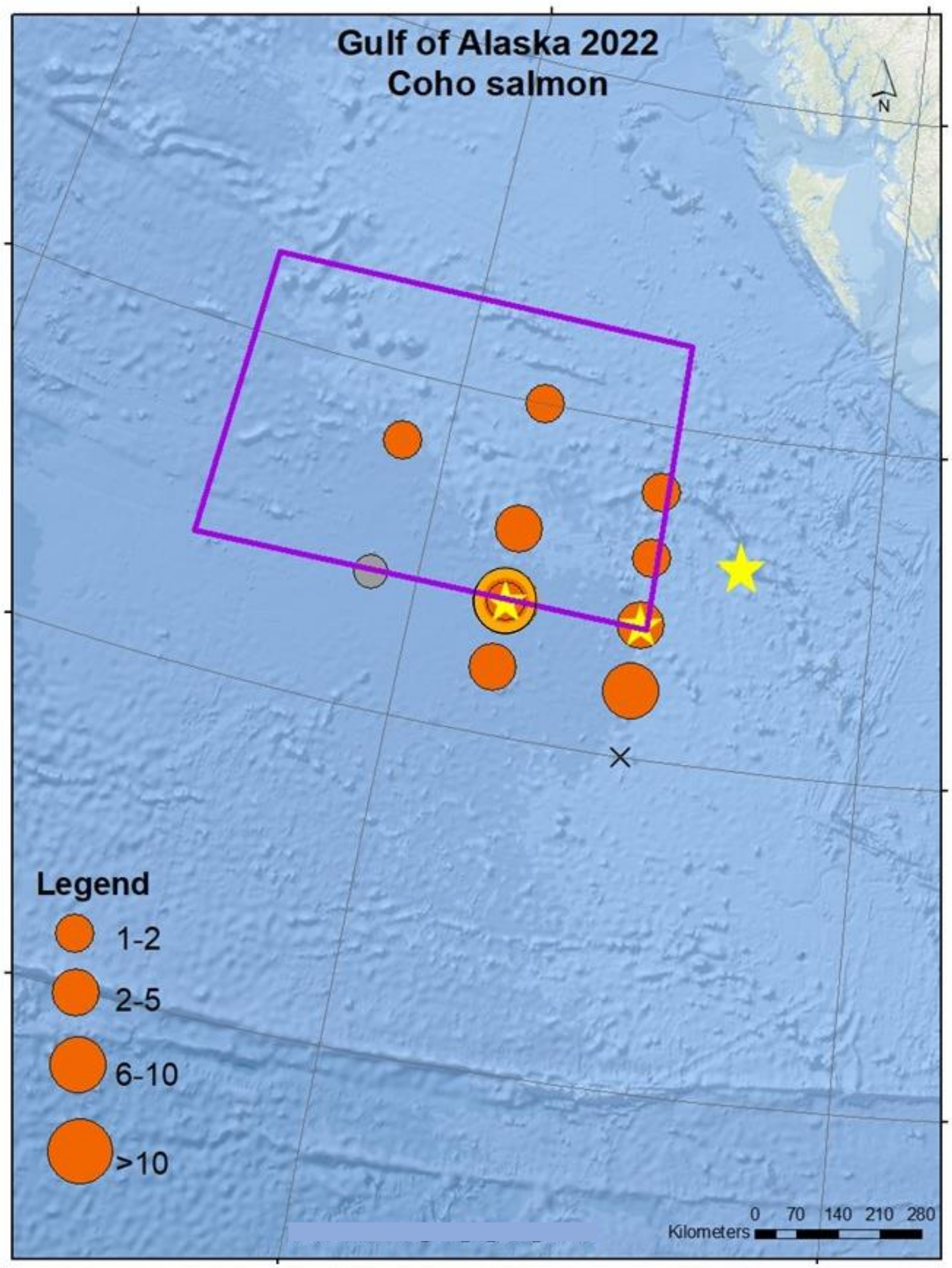

Figure 13. Distribution of coho salmon by station showing relative catch by gillnets over study area. Crosses (X) are stations with no catch of coho salmon. Grey dot is location where no gillnets were set. When a location was fished on both legs of the survey the relative catch rates during the different periods are shown by a double circle representing the different days. The higher catch rate for these locations is a lighter shade of orange. Yellow stars indicates location where coho salmon caught on longline gear. The purple polygon is the perimeter of southern study area (see Figure 1A).

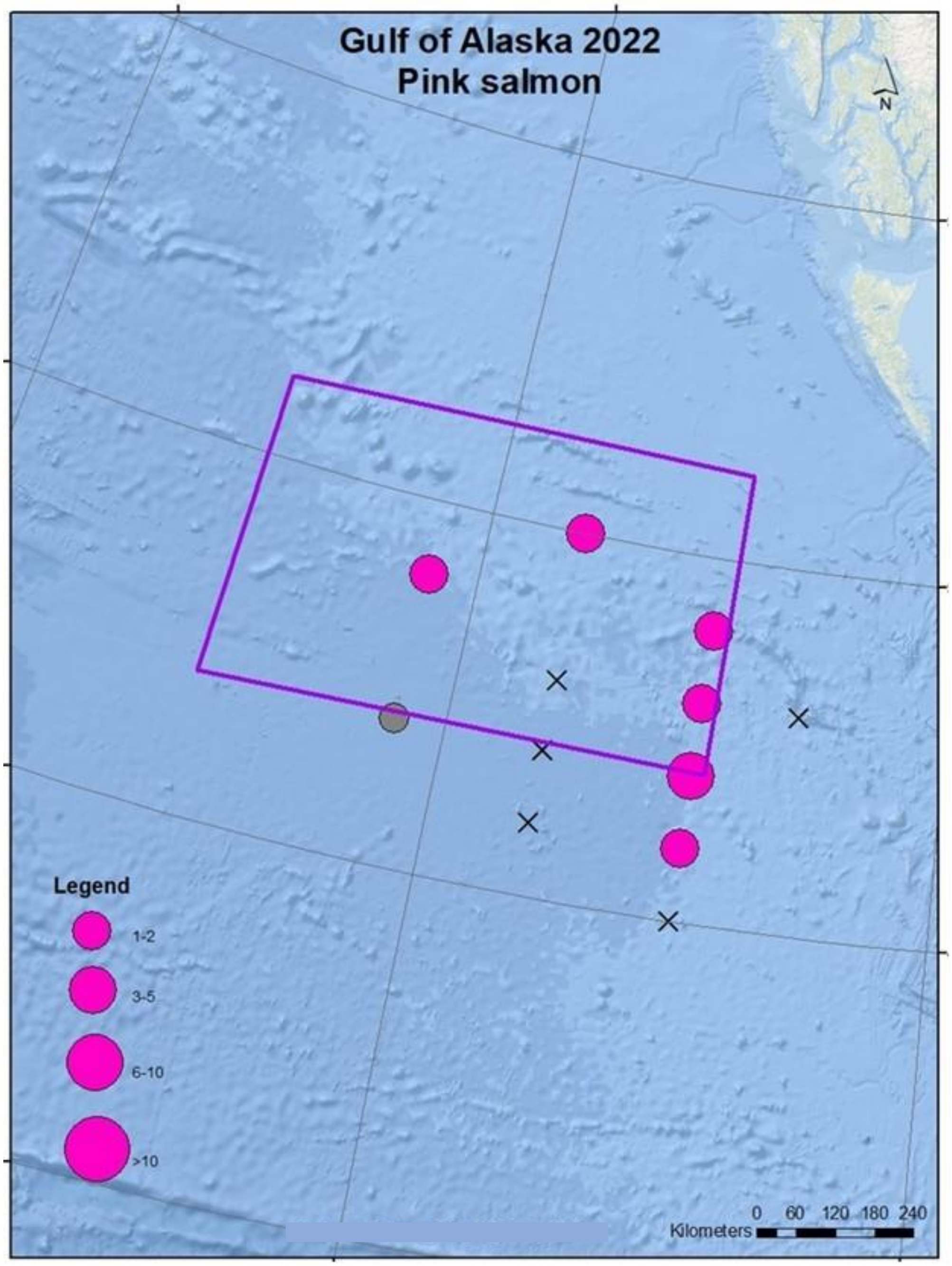

Figure 14. Distribution of pink salmon by station showing relative catch in the gillnets over study area. Crosses (X) are stations with no catch of pink salmon. Grey dot is location where no gillnets were set. No pink salmon were caught on longline gear. The purple polygon is the perimeter of southern study area (see Figure 1A).

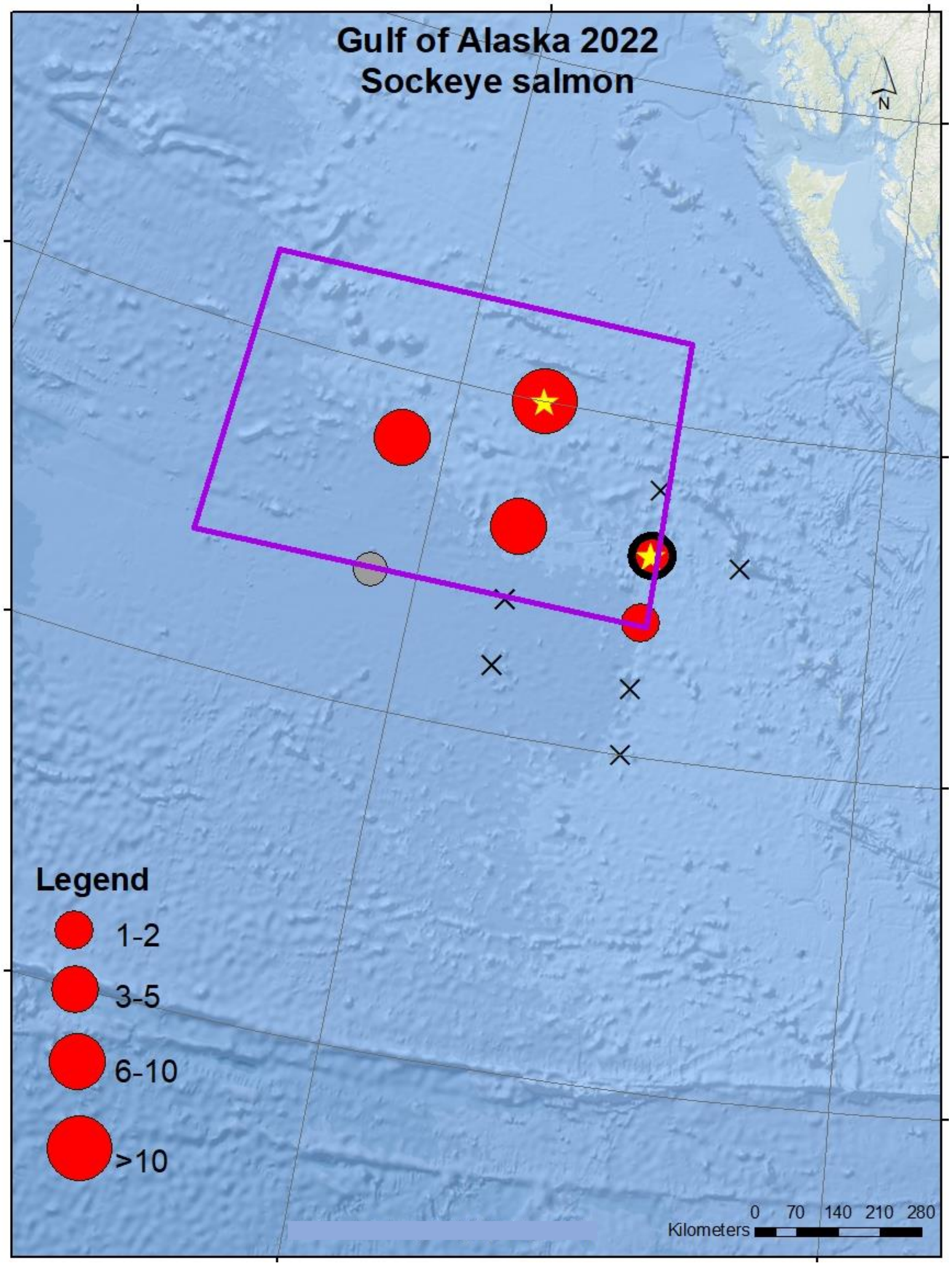

Figure 15. Distribution of sockeye salmon by station showing relative catch in the gillnets over study area. Crosses (X) are stations with no catch of sockeye salmon. Grey dot is station with no gillnet sets conducted. When a location was fished on both legs of the survey the relative catch rates during the different periods are shown by a double circle representing the different days. The higher catch rate for these shown in as a thick black border. A yellow star indicates location where coho salmon caught on longline gear. The purple polygon is the perimeter of southern study area (see Figure 1A).

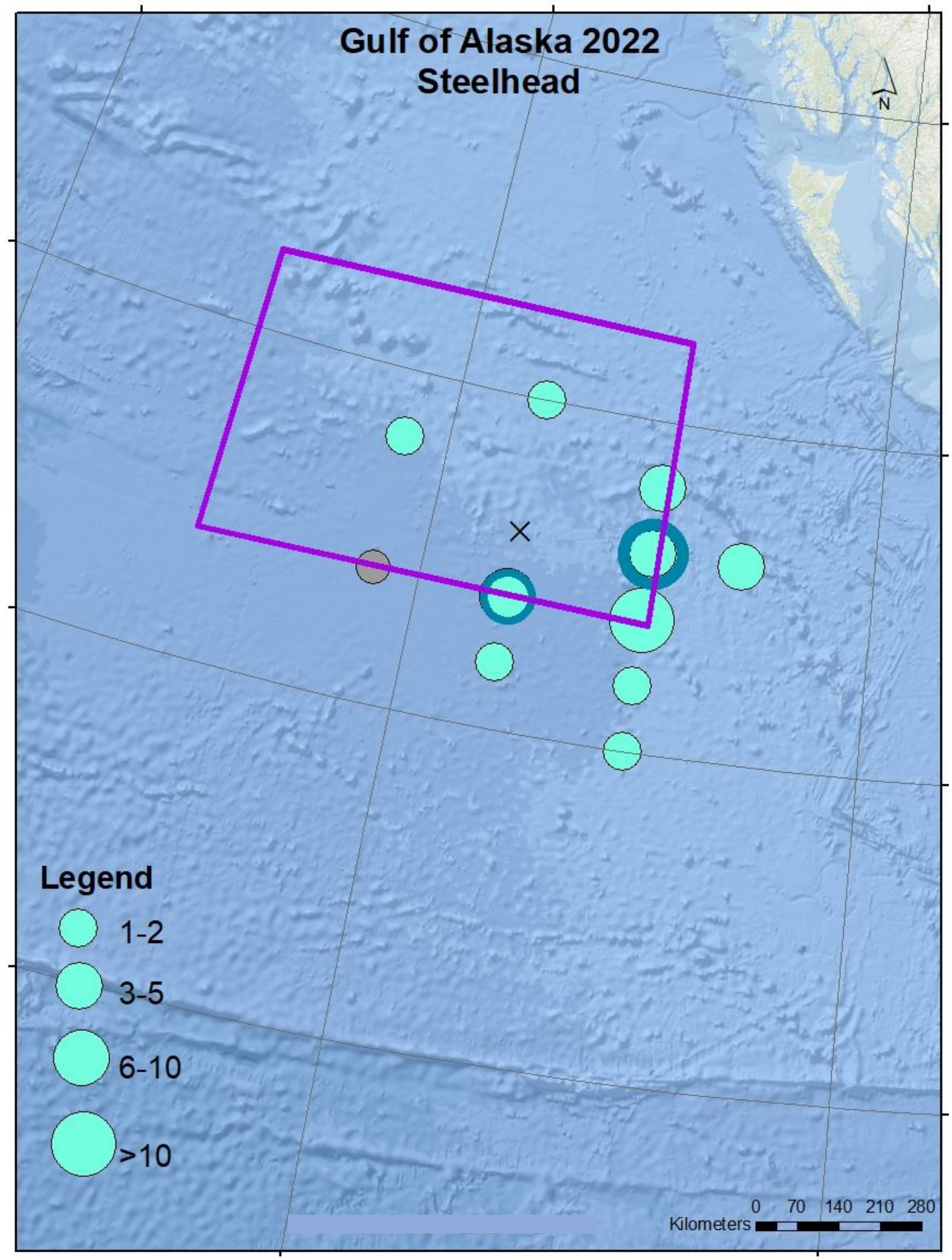

Figure 16. Distribution of steelhead by station showing relative catch in the gillnets over study area. Crosses (X) are stations with no catch of steelhead. Grey dot is station with no gillnet sets conducted. When a location was fished on both legs of the survey the relative catch rates during the different periods are shown by a double circle representing the different days. The higher catch rate for these days is in dark blue. The purple polygon is the perimeter of southern study area (see Figure 1A).

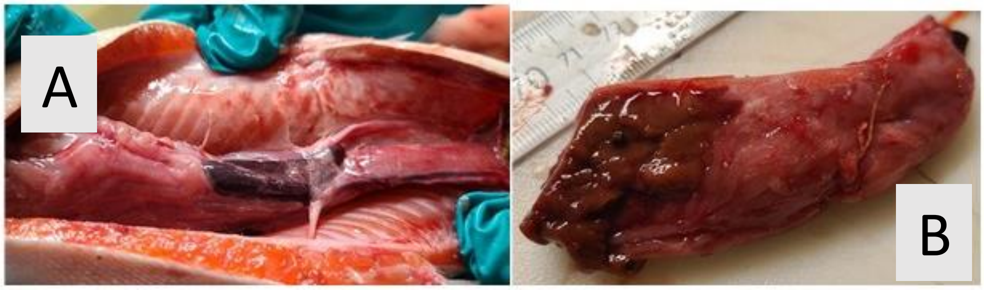

Figure 17. Adhesion in body cavity of two sockeye salmon caught at Station 2, Set 5. Panel A is a view inside the body cavity and Panel B is the stomach and pyloric caeca removed from a fish showing the high level of adhesion around the stomach.

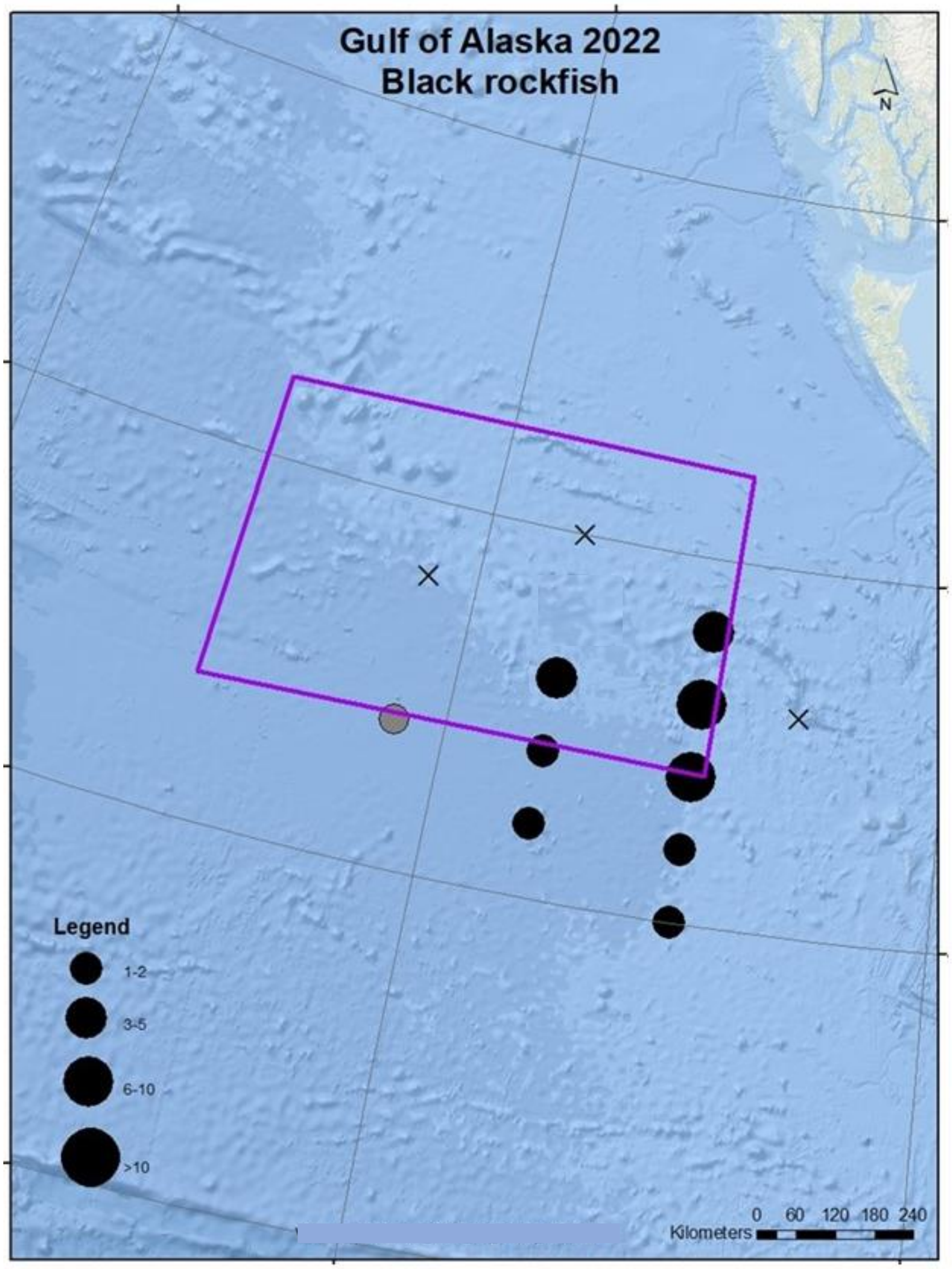

Figure 18. Catch locations and relative catch of black rockfish. The crosses (X) indicate set locations with no catch. The grey circle is the station that was not fished by gillnet. No black rockfish were caught on longline gear. The purple polygon is the perimeter of southern study area (see Figure 1A).

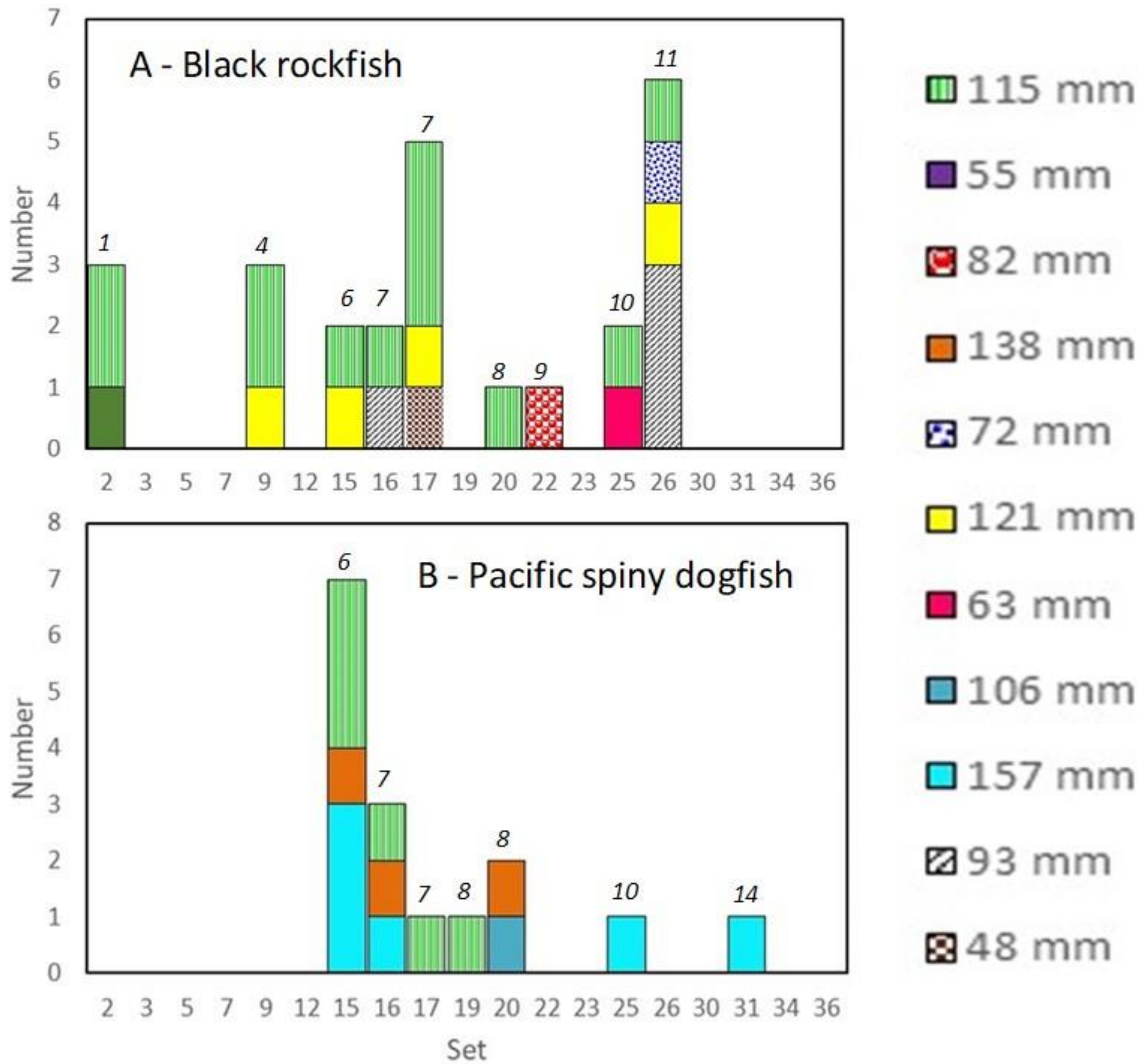

Figure 19. Catch of (A) black rockfish and (B) Pacific spiny dogfish in gillnets shown by set and mesh size. The station number is listed above the bars.

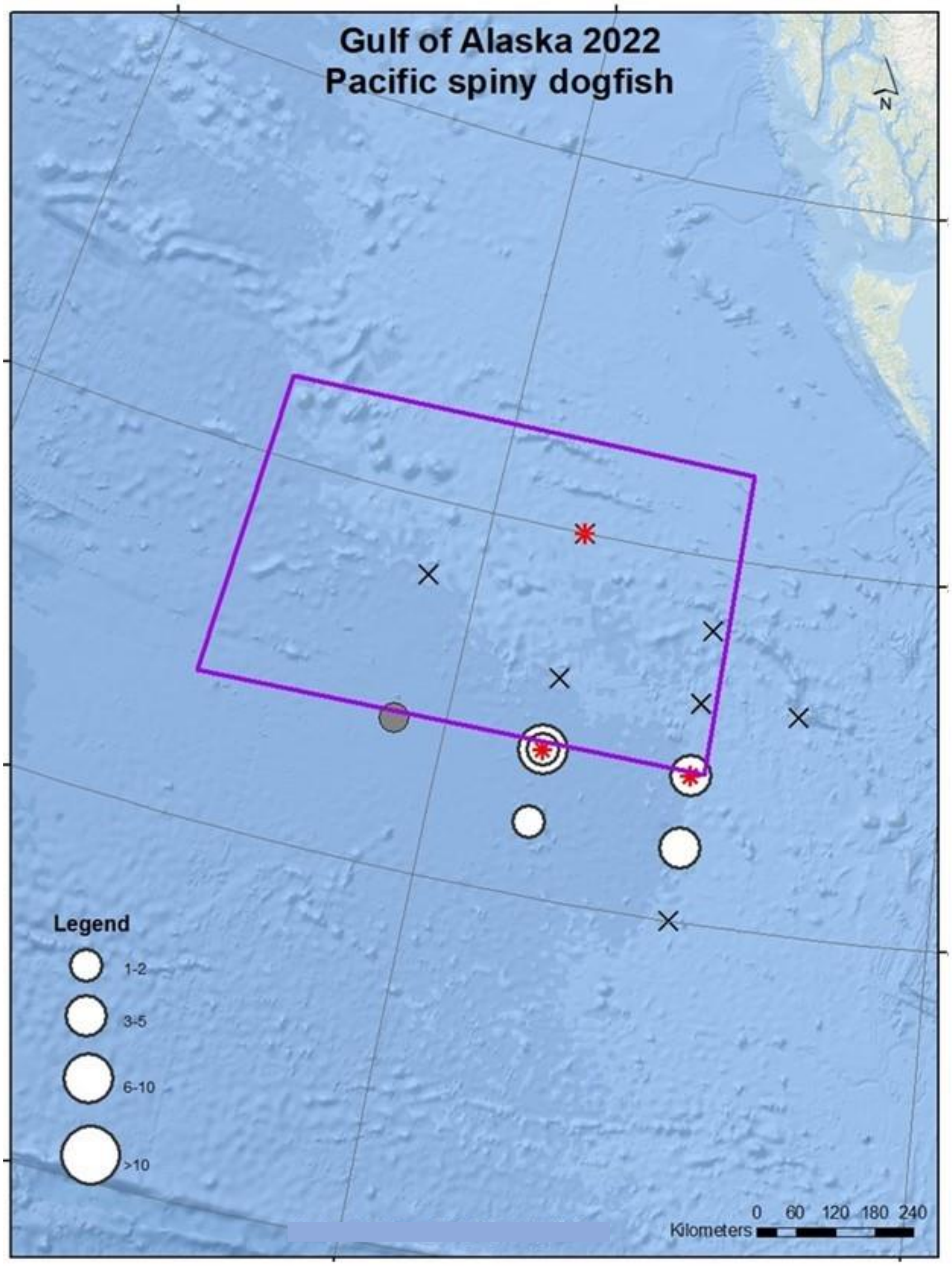

Figure 20. Distribution of Pacific spiny dogfish by station showing relative catch by gillnets over study area. Crosses (X) are stations with no catch of dogfish. Grey dot is location where no gillnets were set. When a location was fished on both legs of the survey the relative catch rates during the different periods are shown by a double circle representing the different days. A red star indicates location where dogfish were caught on longline gear. The purple polygon is the perimeter of southern study area (see Figure 1A).

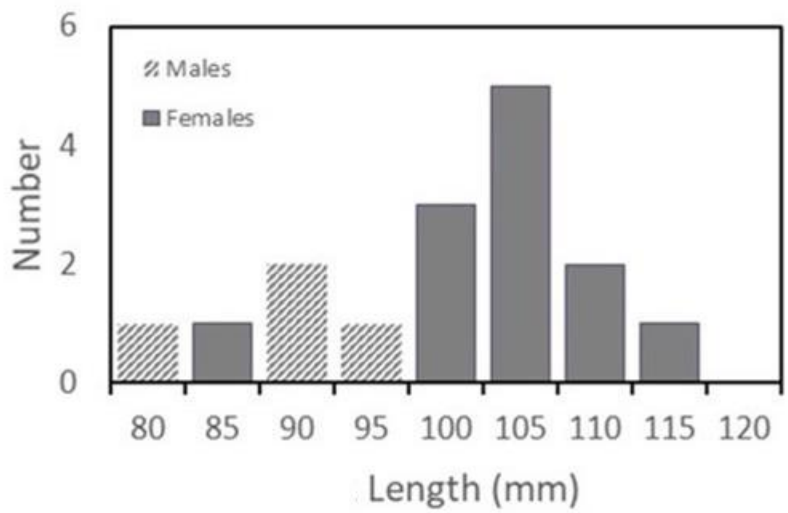

Figure 21. Length frequency of Pacific spiny dogfish. Males (hashed grey lines) and females (dark grey) are indicated in panel A.

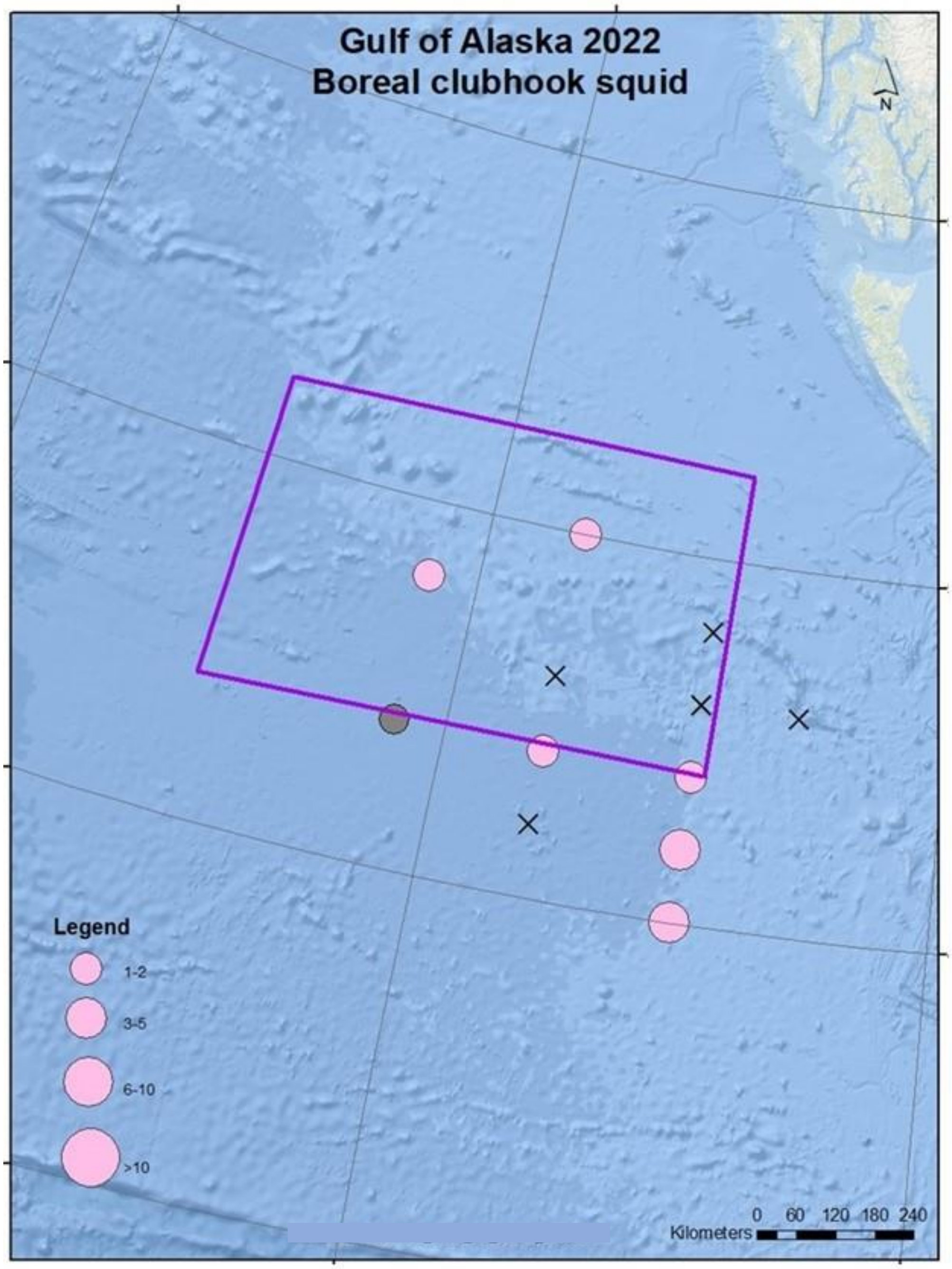

Figure 22. Distribution of Boreal clubhook squid by station showing relative catch by gillnets over study area. Crosses (X) are stations with no catch of squid. Grey dot is location where no gillnets were set. The purple polygon is the perimeter of southern study area (see Figure 1A).

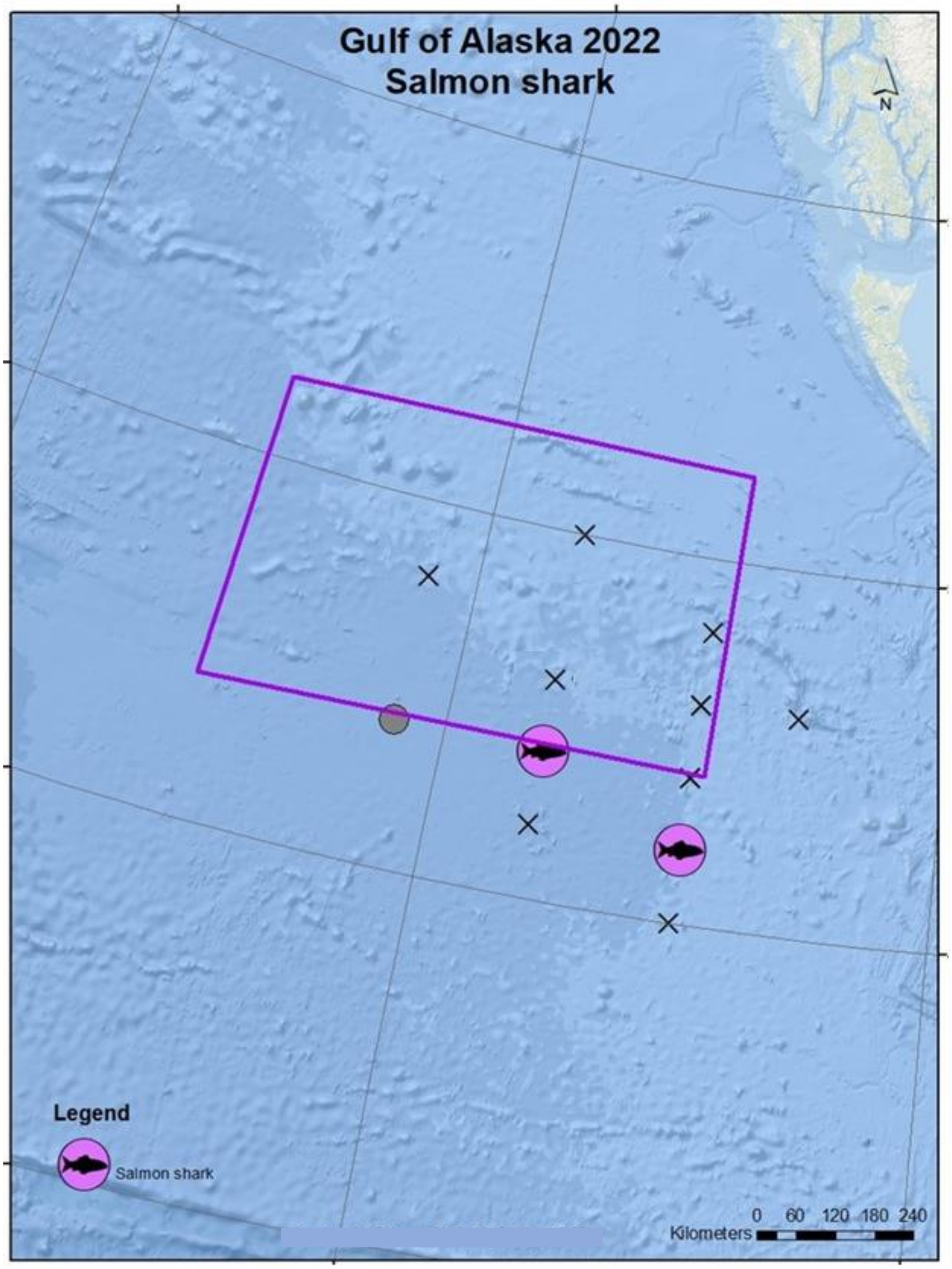

Figure 23. Distribution of salmon sharks by station showing relative catch by gillnets over study area. Crosses (X) are stations with no catch of salmon sharks. Grey dot is location where no gillnets were set. The purple polygon is the perimeter of southern study area (see Figure 1A).

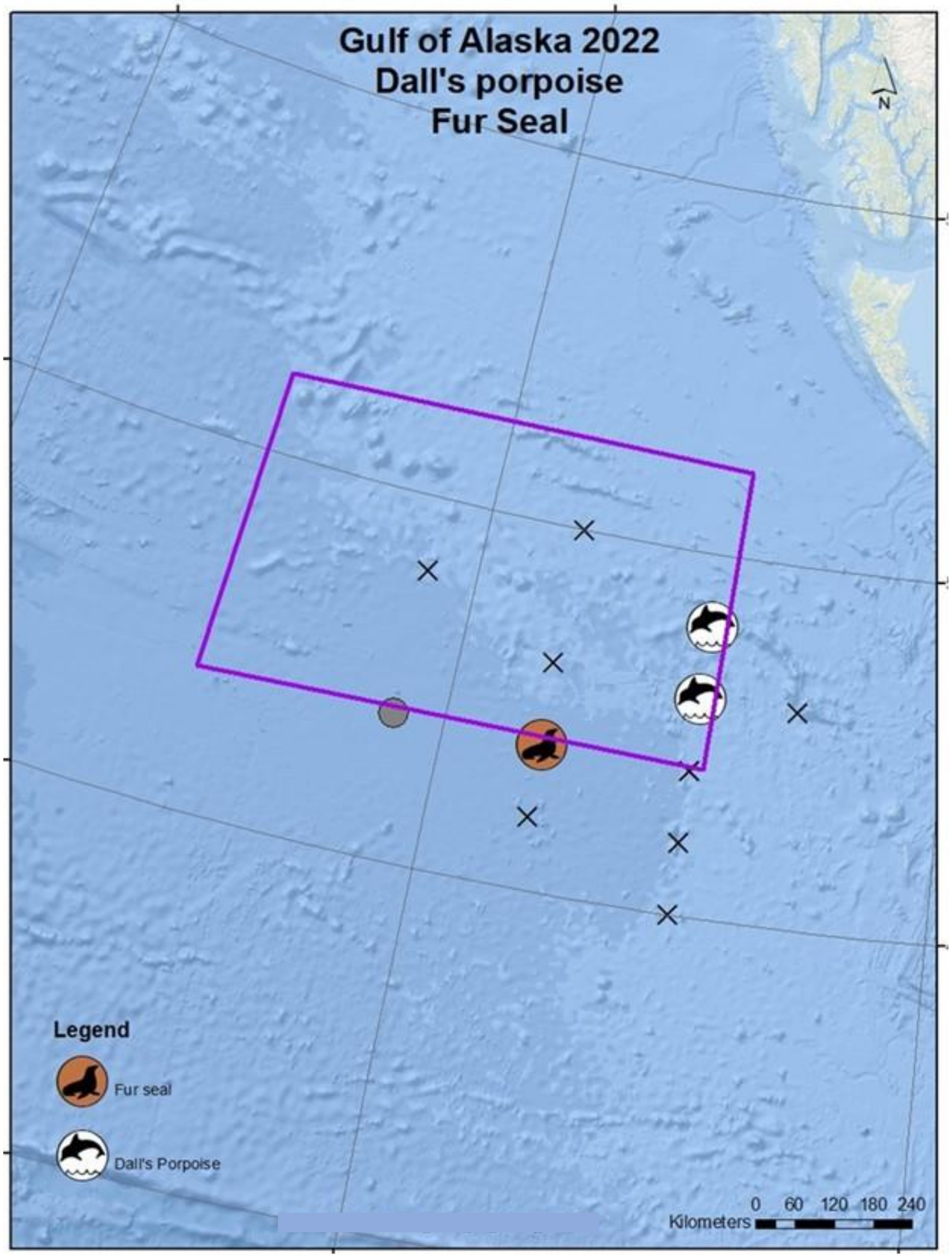

Figure 24. Distribution of marine mammals caught/entangled by station s over study area. Crosses (X) are stations with no catch or entanglement of marine mammals. Grey dot is location where no gillnets were set. The purple polygon is the perimeter of southern study area (see Figure 1A).

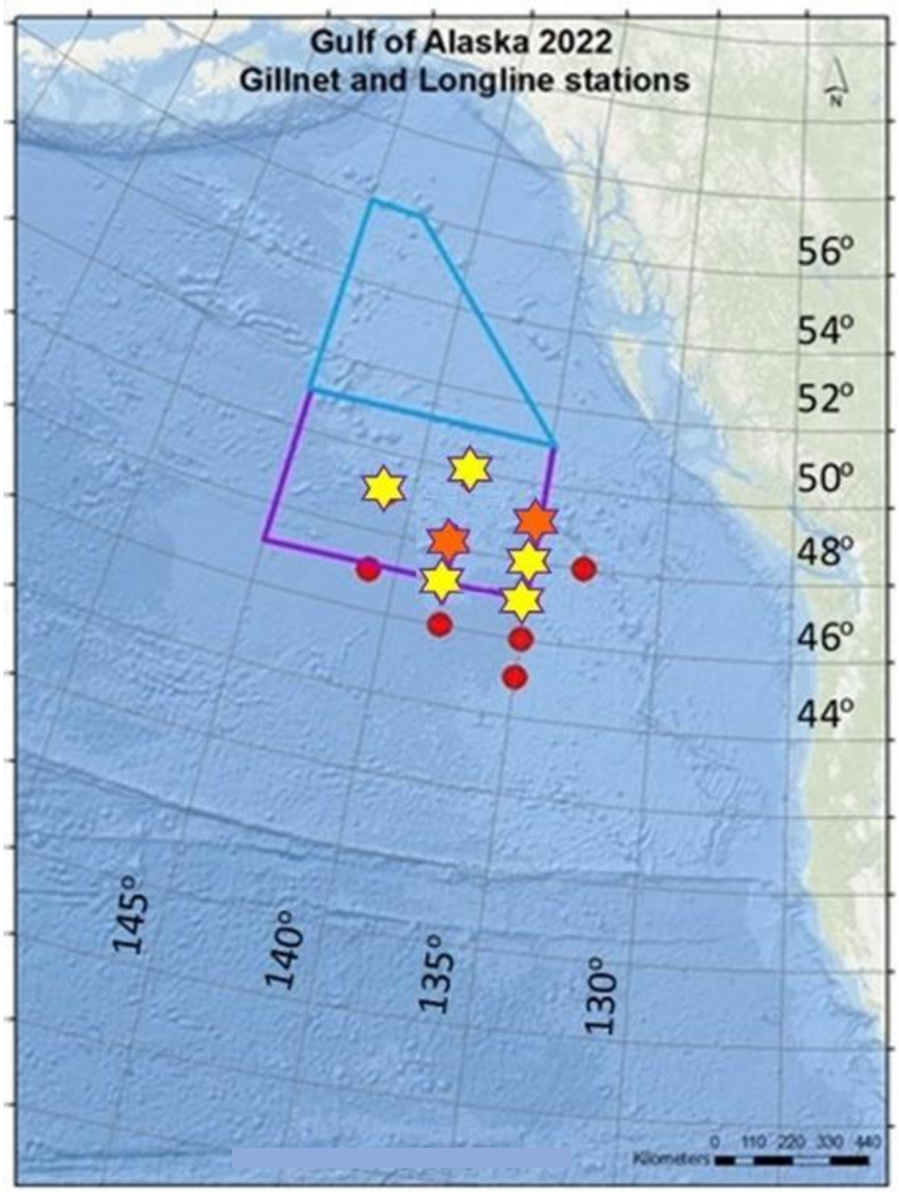

Figure 25. Stars indicate locations fished by both the *Raw Spirit* (gillnets) and *Sir John Franklin*. The orange stars are locations that both vessels fished at night. Data for *Sir John Franklin* from King et al. (2022). The purple polygon is the perimeter of southern study area (see Figure 1A).

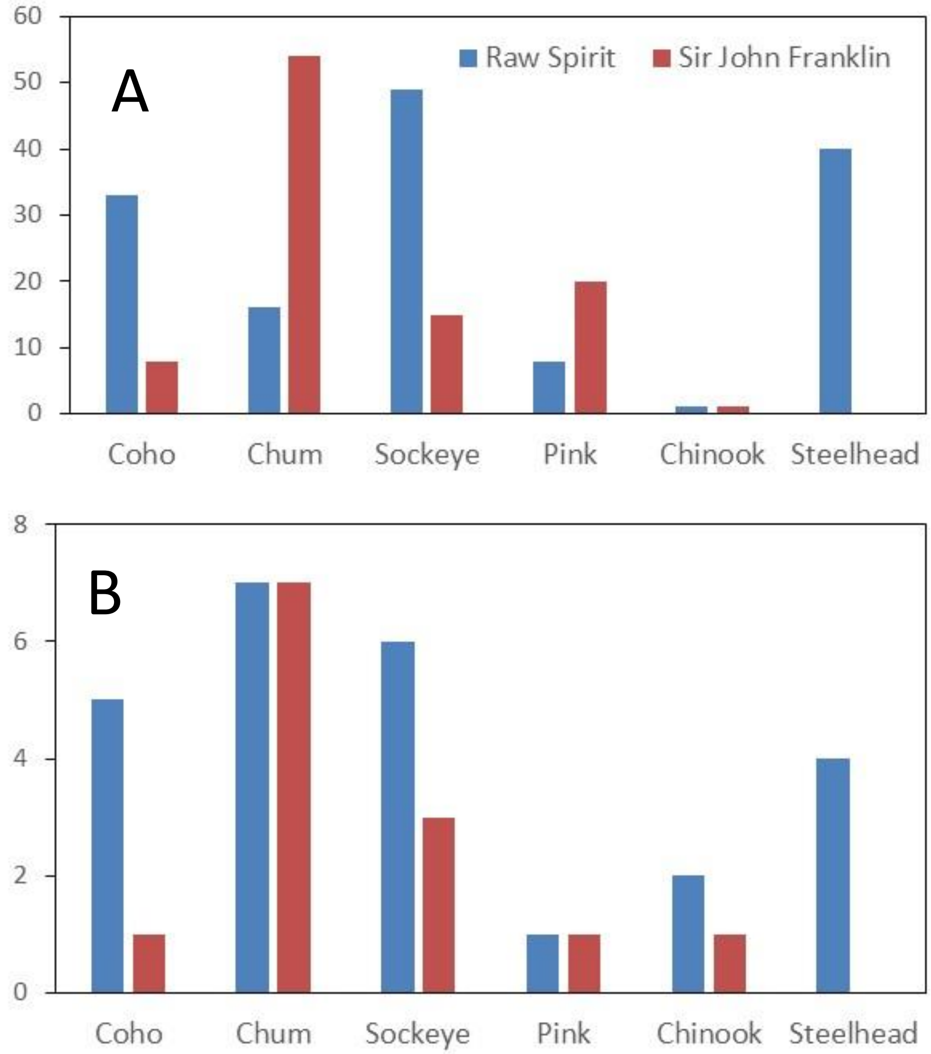

Figure 26. Comparison of catch of salmon in gillnets fished by the *Raw Spirit* (red) and in trawl net by *Sir John Franklin* (blue). Panel A includes the seven locations fished by both vessels and panel B are the two sets that were fished at night by both vessels.

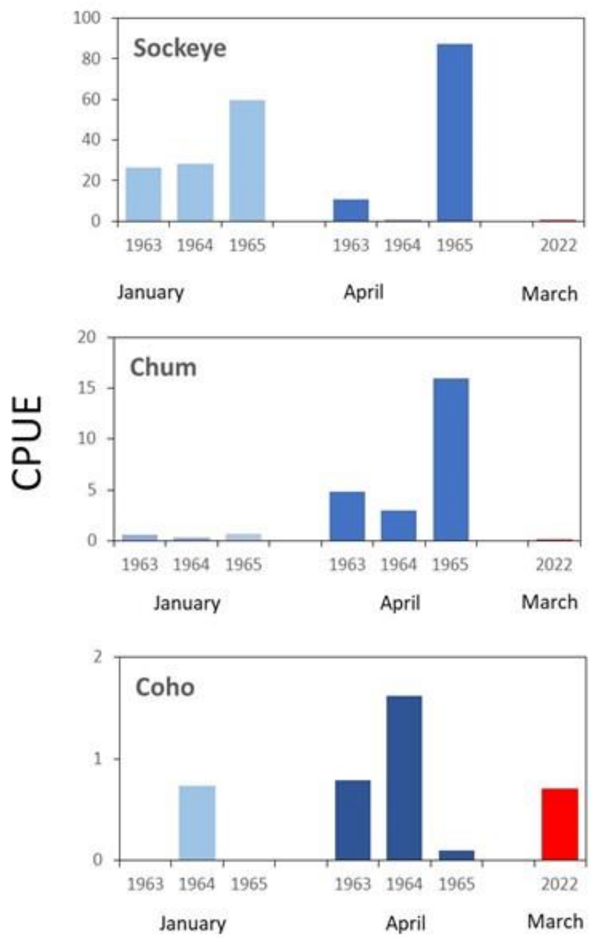

Figure 27. CPUE (fish/1000 hooks) of sockeye, chum and coho salmon caught on longline by the *G.B. Reed* in January and April 1963-1965 and by the *Raw Spirit* in March 2022. There were no pink salmon or steelhead caught on the longline by the *Raw Spirit*.