

**Summary of Preliminary Findings of the International Gulf of Alaska
Expedition Onboard the R/V *Professor Kaganovskiy*
During February 16–March 18, 2019**

by

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Abstract

The international expedition to the Gulf of Alaska was the first large-scale, integrated winter pelagic ecosystem research survey, with a particular focus on Pacific salmon. The expedition covered an area of approximately 700,000 km² between February 16 and March 18, 2019. The research team of 21 included scientists from Canada, Japan, Korea, Russia and the United States of America and was a major contribution to the International Year of the Salmon Program. The expedition leader, Dr. Richard Beamish of Canada, secured funding for the expedition from both governmental organizations and private individuals. The intent of the expedition was to demonstrate that international collaboration could be effective, to provide baseline measurements of major pelagic ecosystem components including abundance of Pacific salmon in the Gulf of Alaska in the winter season and to test key hypotheses on factors regulating salmon survival in the ocean during their seasonal activities. In total, 423 salmon (223 chum, 93 coho, 73 sockeye, 31 pink, and 3 Chinook salmon) were caught during trawl survey. In addition, two coho salmon caught with a live-box were tagged with NPAFC disc tags and released in the eastern Gulf of Alaska. Content below provides an overview of samples collected and some preliminary results from the survey.

Keywords: Pelagic ecosystem, Pacific salmon, Gulf of Alaska, international collaboration

INTRODUCTION

It is currently recognized that during winter about one third of all Pacific salmon inhabit the Gulf of Alaska (GoA), yet factors affecting their survival during the critical winter period have not been studied. In light of changing ocean ecosystems, there is an urgent need to research winter foraging conditions of Pacific salmon, particularly in the northeastern Pacific Ocean. Presently, there is no baseline information on this ecosystem, which adds uncertainty to current forecasts of salmon return and fish behaviour in the changing North Pacific ecosystem. In the short-term, a large number of major salmon related management issues in Alaska and British Columbia (BC) will benefit from the scientific studies in this area.

There is a growing recognition that a size-dependent mortality within the first ocean year regulates Pacific salmon production. A recent large environmental change event called the “Blob” had occurred in the GoA from 2014 to 2016. It has been speculated that poor returns to rivers around the GoA and in BC following this marine heatwave resulted from reduced summer growth and overall fish condition. As new and possibly even more extreme warming events may occur in the future, the expedition to the GoA was a timely study of the ecosystem levels effects on the survival of all Pacific salmon species. The expedition is particularly relevant to Pacific salmon science off the west coast of North America as a “proof of concept” to investigate the application of trawl studies integrated with comprehensive measurement of ocean conditions and prey fields, to determine abundance and distribution of Pacific salmon populations in the open ocean. Similar surveys are routinely carried out in the northwestern Pacific and are successfully used by Russian scientists to forecast salmonid returns. Furthermore, surveys to estimate the abundance and condition of Pacific salmon in their first ocean winter at sea are a logical extension of the early marine survival studies conducted in many nearshore areas.

Currently, there is a controversy about the carrying capacity of the GoA, which is needed to plan the hatchery enhancement programs in the North Pacific. There is a disagreement in opinions to support the large number of hatchery operations. The paucity of the available information calls for basic ecological information about prey availability, diet, species abundances and stock specific rearing areas of Pacific salmon. The expedition is the first major contribution to the International Year of the Salmon announced in the fall of 2018. This international collaboration is deemed to be a springboard for future multi-country, Pan-Pacific collaborative cruises involving all salmon producing nations.

The main objectives of the expedition thus were threefold:

- (a) to demonstrate that scientists from salmon producing countries could work collaboratively to investigate factors regulating marine survival of Pacific salmon in shared international waters;
- (b) to identify the stock specific rearing areas for all species of salmon, their abundances and their condition to test the hypothesis that the abundance of salmon is mostly determined by the end of first ocean winter; and
- (c) to obtain baseline measurements of environmental parameters and ecosystem components in the GoA during winter.

MATERIALS AND METHODS

A trawl survey for overwintering Pacific salmon was conducted in the GoA in February and March 2019 onboard the chartered Russian R/V *Professor Kaganovskiy*, covering ~697,500 km² (Figure 1). Eleven scientists: six from Canada, three from the USA, one from Japan and one from South Korea joined ten Russians scientists already onboard the vessel. The science team included experts in oceanography, chemistry, zooplankton, micronekton and fish biology. The field sampling was designed to allow processing of as many samples onboard of the ship as possible.

The survey area and detailed protocols followed are described in the NPAFC Document 1807 Rev. 1 (NPAFC, 2018). In total, 58 stations were completed in the main research area (Figure 1). In addition, two trawl sets were completed in the Canadian EEZ (not considered as part of the survey grid) and four sets (including 2 of the sets in the Canadian EEZ) were conducted with a modified cod end at the end of the main survey. The modified cod-end was a large aluminum live box designed to capture salmon for tagging and release. These were trial sets with this gear and were 20–30 minutes in length.

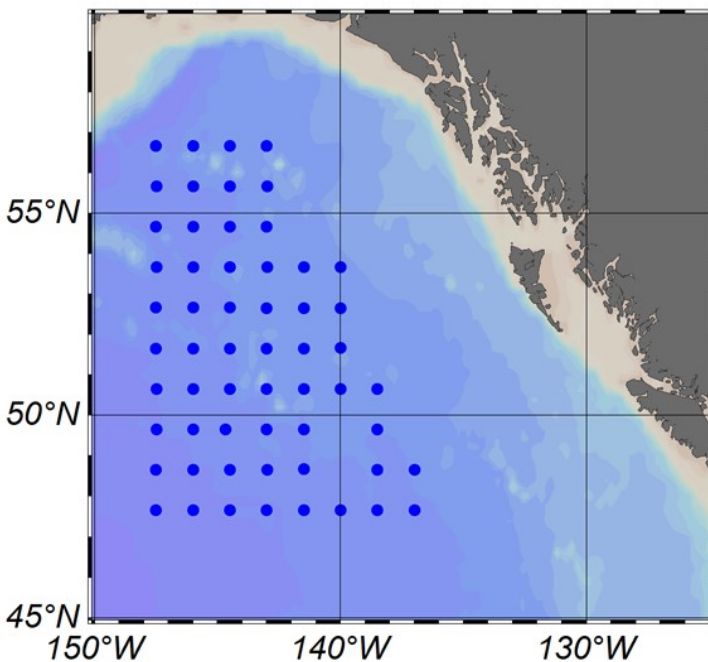


Figure 1. Expedition stations (n=58) sampled during the February–March 2019 in the Gulf of Alaska.

Typical survey stations conducted during both daylight and night times consisted of:

(1) a deployment of a 24-position rosette equipped with a SeaBird CTD 911 plus and Rinko CTD, turbidity, fluorescence and oxygen sensors, to a minimum depth of 600 m. At every other station, the rosette and a SeaBird CTD were deployed to 1000 m. Water samples for measuring salinity, chlorophyll and macronutrients were collected at standard depths of 0, 25, 50, 75, 100, 150, 200, 400, 600, 1000 m. Samples for oxygen concentration measurement were only collected at stations to 1000m;

(2) a vertical deployment of two Juday nets (0.1 m² mouth area, 160 µm mesh) to 50–0 and 200–0 m, and one Bongo net (0.5 m², 236 µm) to 250–0 m;

(3) a deployment of a surface (0–30 m) midwater trawl (~120 m², 30m depth x 40m width) for the duration of one hour at a speed of 4.5 knots.

(4) a deployment of a small neuston net from HydroBios (surface 0–20 cm, mesh size 300 µm) for 15 min at 2.5 knots.

At every trawl station, CTD48Mc (Sea&Sun Technology GmbH) and the ambient temperature by SBE-56 high accuracy thermometer were attached to the trawl.

Oceanographic samples (CTD, nutrients, chlorophyll and oxygen) and Juday net zooplankton samples were processed onboard the vessel. The samples from the Bongo nets were preserved and frozen for analysis at onshore laboratories in Canada. Neuston net samples were collected to provide information on micro-plastics in the surface waters of the GoA. However, in addition, the net provided information on larval and juvenile fish not retained in the larger trawl. These samples were preserved in formalin to be analysed in Canada.

From each trawl, all micronekton and nekton were processed. All salmon were identified and processed for length, weight, DNA, scales, otoliths, energy density, lipids, fatty acids and diet analysis. A subsample of the salmon catch (up to 10 per trawl) was processed for fish health diagnostics. Non-salmon nekton species were identified, enumerated, measured and a subsample was frozen or preserved for subsequent laboratory analysis in Canada and Russia. Micronekton (jellyfish, mesopelagic fish, squid) were identified to the species level, measured, counted, weighed and some frozen for subsequent lab analyses.

Additional sampling or procedures conducted during the survey included at-sea stock identification, macro-plastic enumeration (one hour periods daily), documentation of marine mammals (continuous), nighttime visual jellyfish enumeration (~10-minute intervals during sets), measures of solar radiation and reflectance to calibrate satellite measurement of phytoplankton blooms, and underwater video recording of fishes behaviour within the trawl net in day time (GoPro cameras).

PRELIMINARY FINDINGS

Water Dynamics and Chemistry

In the surveyed region, two current systems of the North-Eastern Pacific: Sub-Arctic Current (SAC) and Alaskan Current were observed, with the main dynamic irregularities shown in the geostrophic currents map (Figure 2). A divergence between currents to the west and east was visible at ~48°N and 50°N on most transects of the survey (Figure 2). Surface temperature and salinity showed a north-south gradient with coldest and saltiest waters at the northwestern part of the grid and warmest and freshest waters in the southeastern grid corner (Figure 3). The surface 7°C isotherm demarcated the boundary between the colder and warmer parts of the survey (Figure 3).

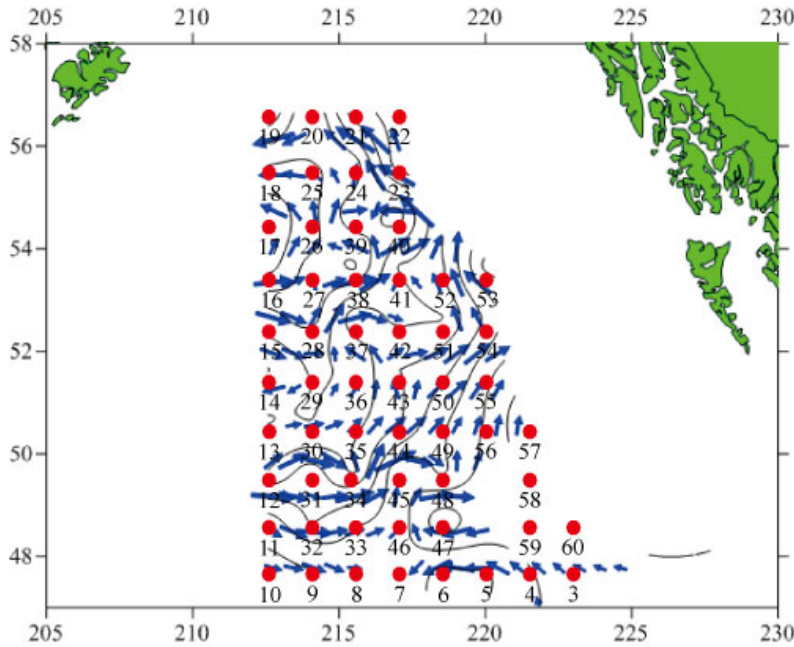


Figure 2. Geostrophic currents (0–1000 m) during February–March 2019 in the Gulf of Alaska.

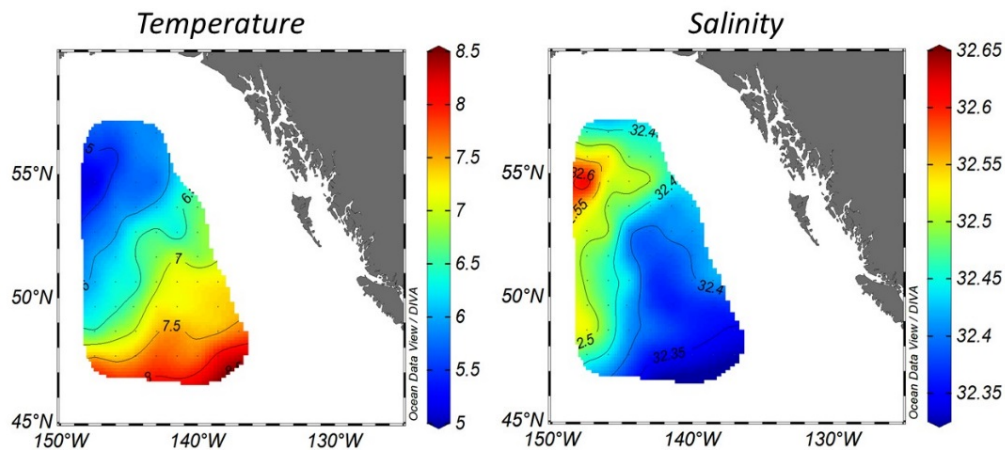


Figure 3. Surface temperature and salinity during February–March 2019 in the Gulf of Alaska.

A notable pattern observed during the grid work was the depth of the 2.5 ml.l^{-1} oxygen horizon. Oxygen concentrations below this level may affect salmon and other micronekton physiological performance. According to our preliminary findings, the depth of the 2.5 ml.l^{-1} threshold gradually increased from < 150 m at the northern part of the grid to ~ 300 m in the south (Figure 4). Other thermodynamics as well vertical stability parameters will be considered in detail in future analyses.

The spatial distribution of dissolve inorganic nitrogen (DIN) and phosphorus (DIP) as well as silica and ammonium showed very similar patterns, being the highest at the northwestern and lowest at the southeastern parts of the grid, closely tracking the coldest and warmest parts of the survey, respectively (Figure 5).

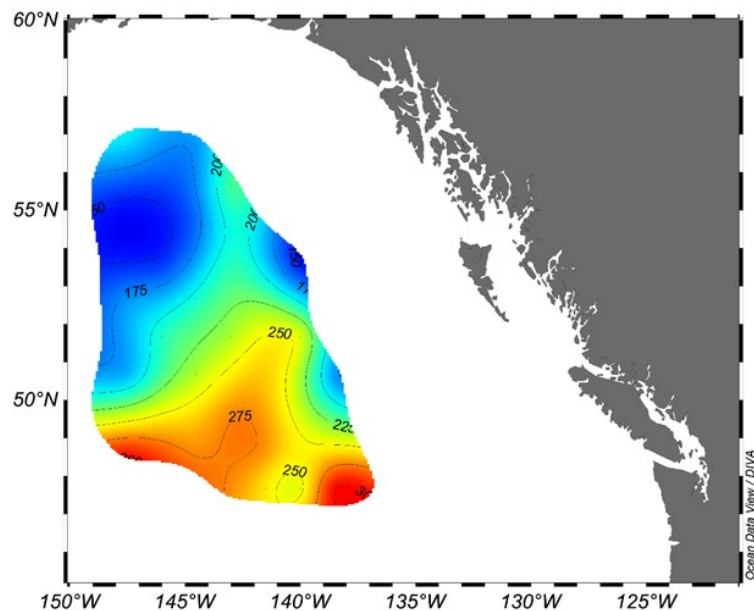


Figure 4. Depth of the 2.5 ml.l⁻¹ oxygen concentration during February–March 2019 in the Gulf of Alaska.

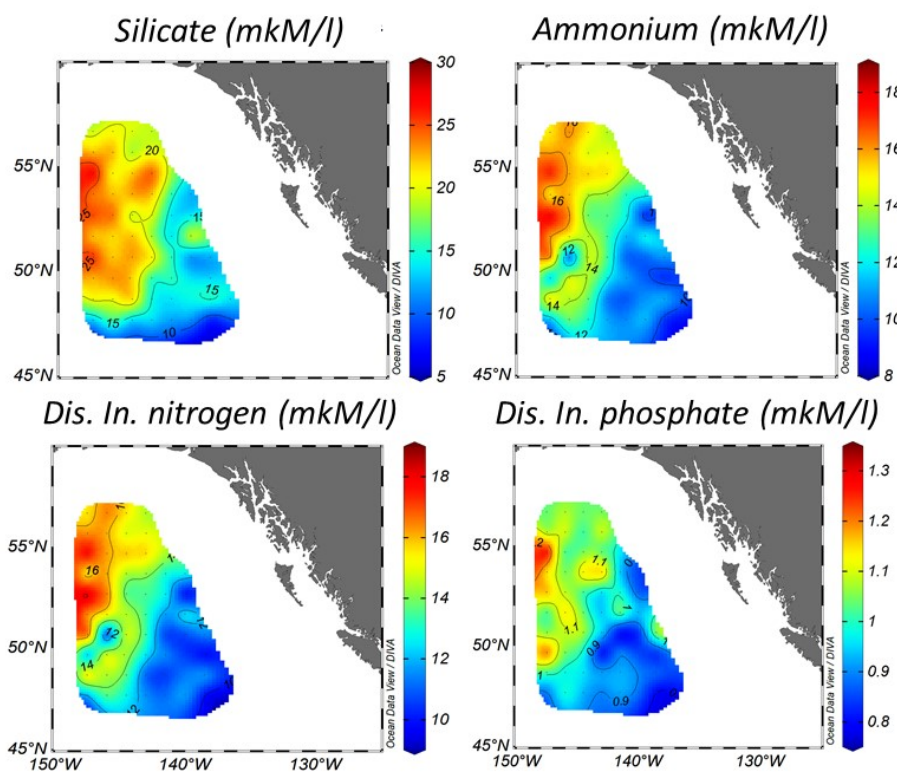


Figure 5. Surface distribution of macronutrients during February–March 2019 in the Gulf of Alaska.

Phytoplankton biomass (expressed as Chlorophyll-*a*)

In general, Chl-*a* concentrations did not exceed 0.9 mgChl-*a*.m⁻³ (or 90 mgChl-*a*.m⁻²) (Figures 6–12). Phytoplankton biomass was unevenly distributed, with regions of high and low biomass across the survey area. In the north, high phytoplankton biomass was measured in the east and west of the survey grid, possibly associated with eddies. Elevated phytoplankton biomass was also observed in the central and

south central part of the survey grid (Figure 6). Figures 7–12 illustrate sections across the depth range of chlorophyll samples (0–150 m) for the six major latitudinal grid lines of the survey. There was usually a subsurface maximum in Chl-*a* concentrations. The sections largely reflected the observations from the surface plots, and additionally demonstrated that elevated phytoplankton biomass in the regions highlighted above extended deep in the water column (to ~ 100 m), e.g., Figure 7 – Section 1, and Figure 9 – Section 3. This was indicative of a deep mixed layer. It appears that phytoplankton bloom development may have been initiated, due to calm weather conditions, in the southern central part of the survey in the beginning of March 2019.

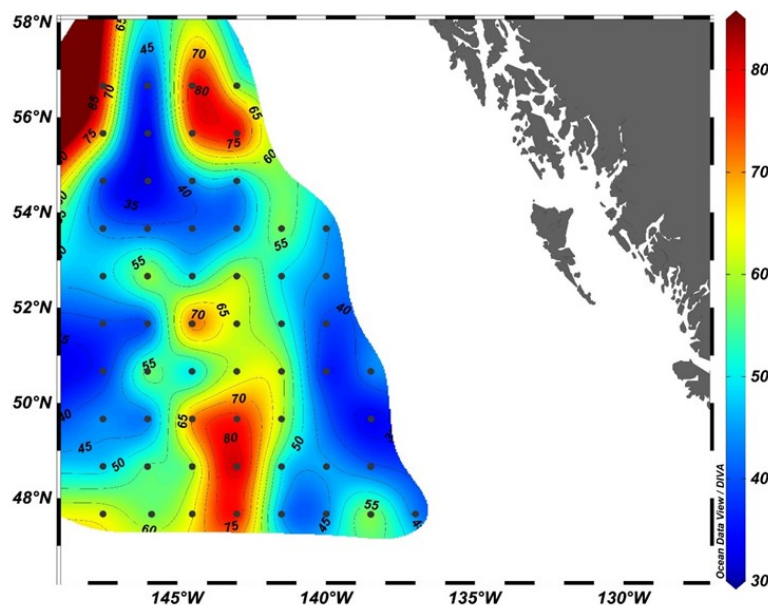


Figure 6. Depth integrated (0–150 m) chlorophyll-*a* concentration (mg Chl.a.m⁻²) during February–March 2019 in the Gulf of Alaska.

Zooplankton biomass

Total and major zooplankton group biomass (corrected for avoidance) from the Juday net are presented on Figure 13. Total zooplankton biomass averaged 164.2 mgWW.m⁻³. Highest biomass was observed at Station 8 (764.3 mgWW.m⁻³) and was largely attributed to an unusually high biomass of chaetognaths (Figure 13A, F). Overall, the major zooplankton groups did not show overlapping distributions, and substantial spatial variation was evident in the distribution of all groups. Copepod biomass was highest in the south of the GoA (Figure 13B). Euphausiid biomass was high in the southeast and north GoA (Figure 13C). Pteropod biomass was high in the northeast, center and south-west of the GoA (Figure 13D). Hydromedusae had highest biomass in the southeast quadrant of the survey area (Figure 13E).

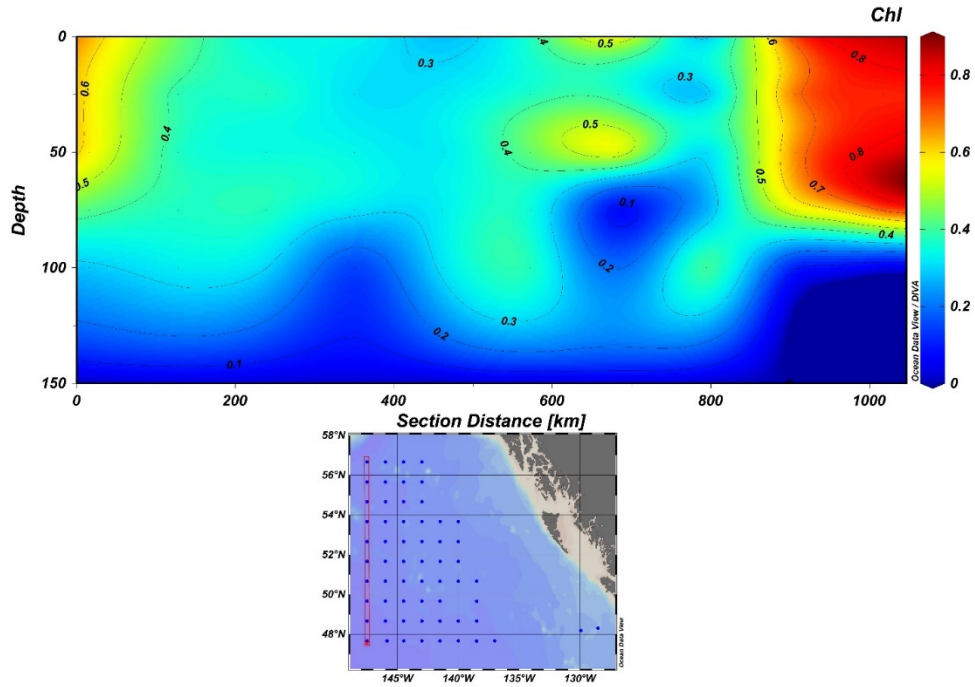


Figure 7. Vertical distribution of Chl-a along the Section 1 during February–March 2019 in the Gulf of Alaska. Section runs from south to north.

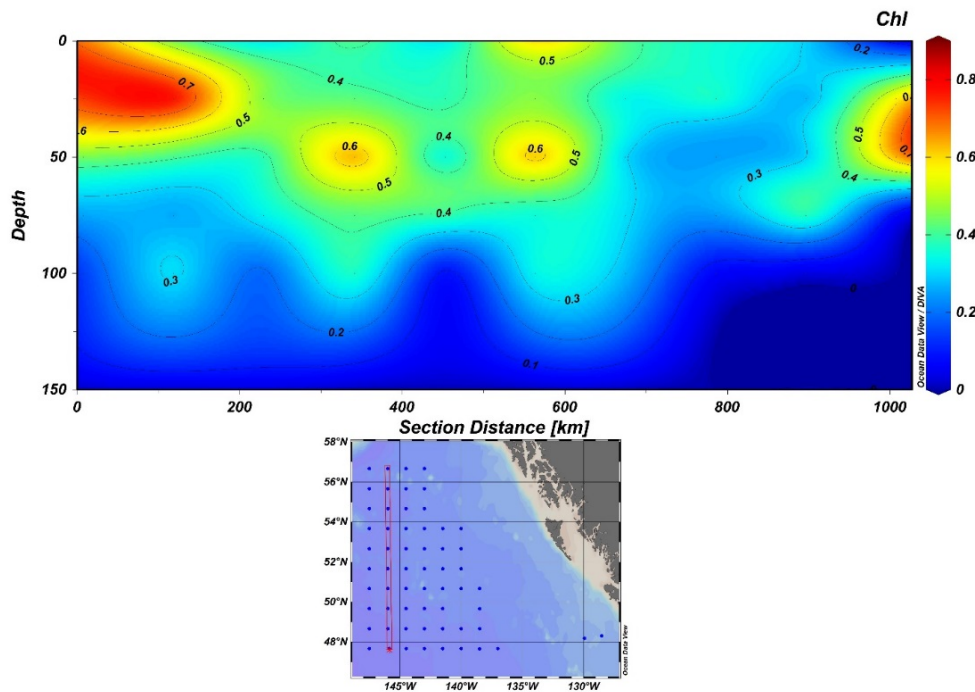


Figure 8. Vertical distribution of Chl-a along the Section 2 during February–March 2019 in the Gulf of Alaska. Section runs from south to north.

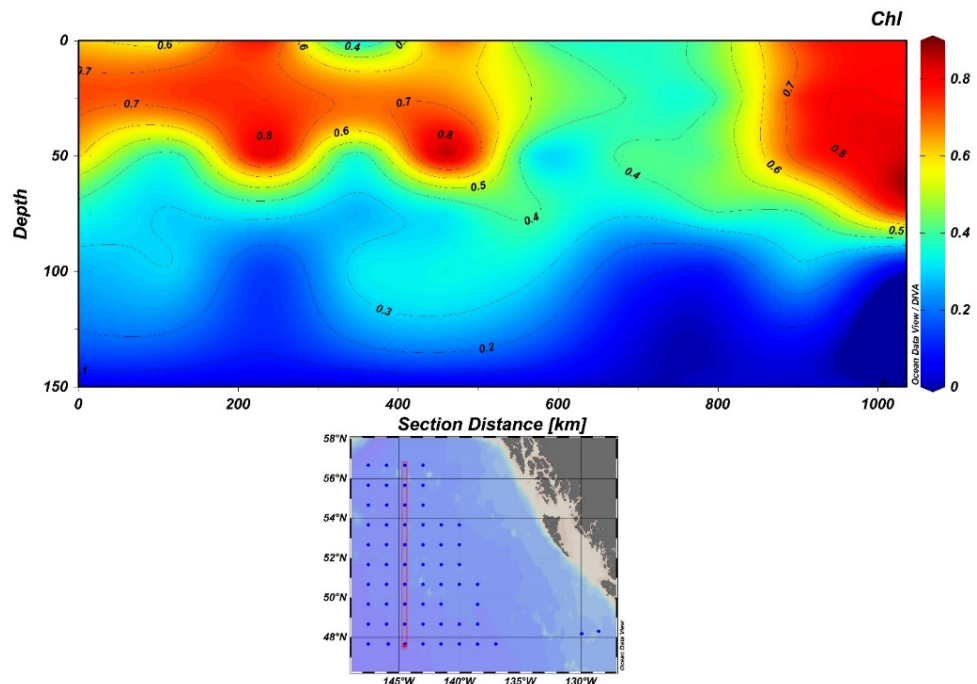


Figure 9. Vertical distribution of Chl-a along the Section 3 during February–March 2019 in the Gulf of Alaska. Section runs from south to north.

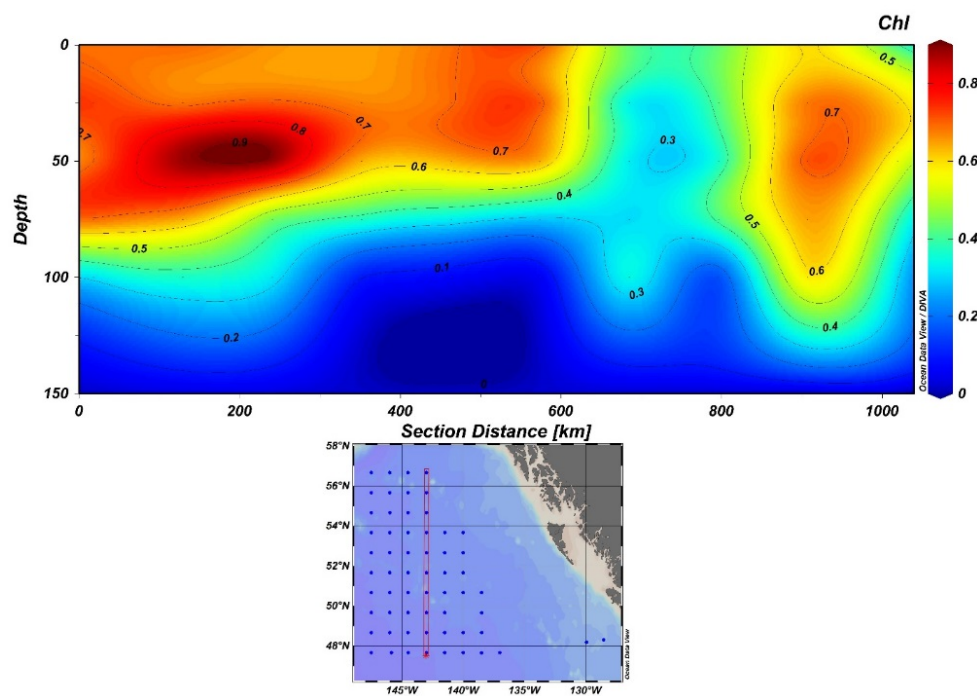


Figure 10. Vertical distribution of Chl-a along the Section 4 during February–March 2019 in the Gulf of Alaska. Section runs from south to north.

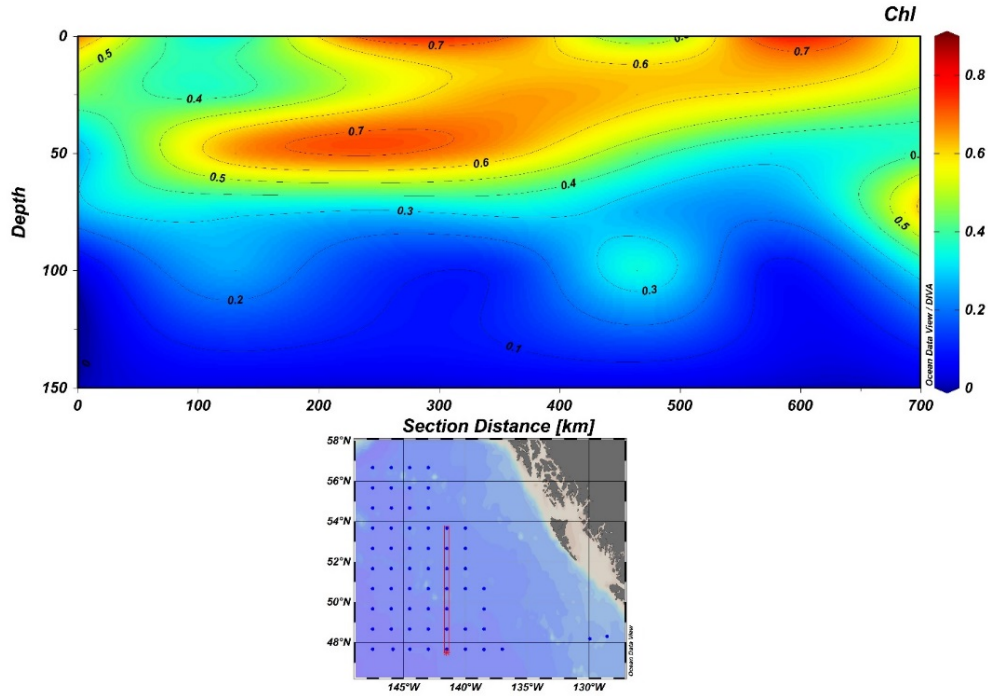


Figure 11. Vertical distribution of Chl-a along the Section 5 during February–March 2019 in the Gulf of Alaska. Section runs from south to north.

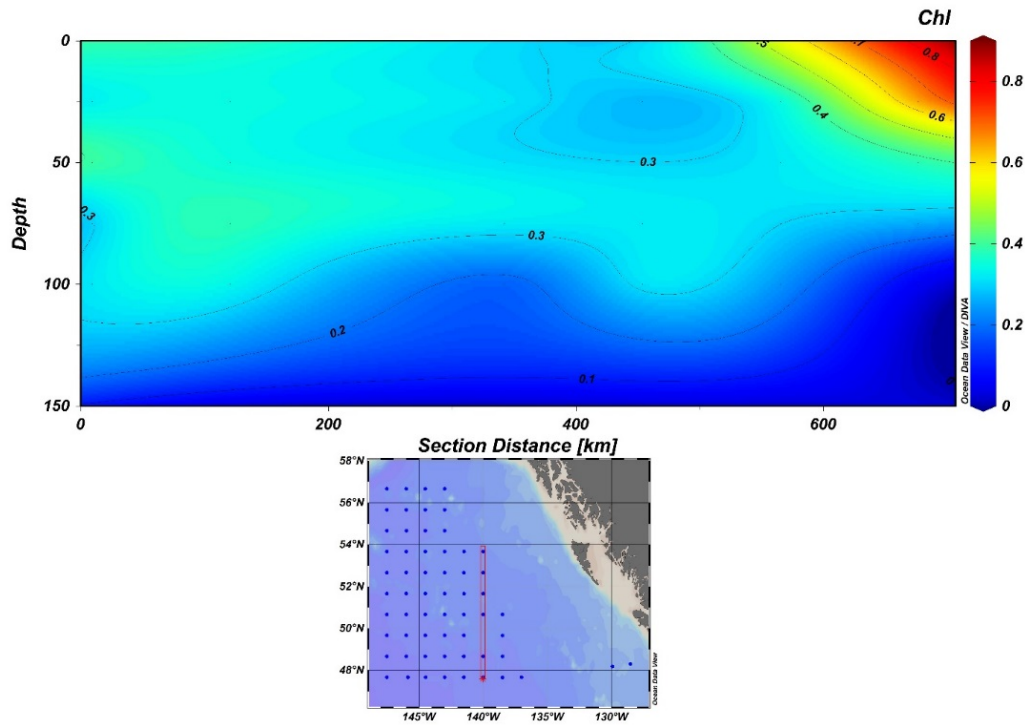


Figure 12. Vertical distribution of Chl-a along the Section 6 during February–March 2019 in the Gulf of Alaska. Section runs from south to north.

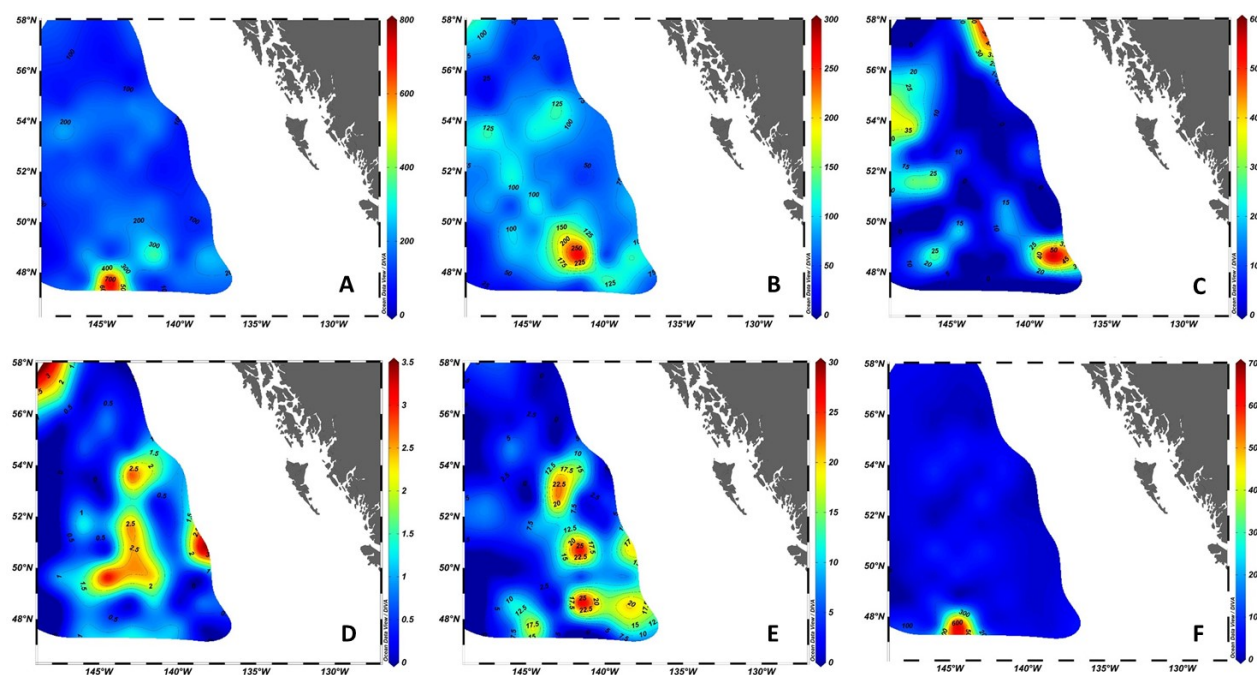


Figure 13. Epipelagic biomass (mgWW.m^{-3}) of total zooplankton (A), copepods (B), euphausiids (C), pteropods (D), hydromedusae (E) and chaetognaths (F) during February–March 2019 in the Gulf of Alaska.

The Bongo net samples were not analysed at sea and treated as follows:

Net 1 of the Bongo was preserved in a 4% formaldehyde seawater solution. At stations 3, 4, 7, and 16 the Net 1 sample was split in two and one half was preserved in 4% formaldehyde and the second half in 95% non-denatured ethanol. These samples are retained for detailed taxonomic analysis.

Net 2 was size fractionated using a sieve set of 4000, 2000, 1000, 500 and 250 μm . Individual organisms in the 4000 μm fraction were measured and transferred to numbered eppendorf tubes or wirtpak bags. We endeavoured to collect triplicate samples of three large calanoid copepods (*Neocalanus* sp.) from as many stations as possible, taking specimens from the 2000 μm fraction when there were none in the 4000 μm fraction. At some stations, this was not possible due to a lack of large calanoid copepods. The remainder of the size fractions were transferred in their entirety to numbered wirtpak bags. All net 2 samples were immediately transferred to a -40°C blast freezer, and 12 hours later to a -40°C storage freezer.

Net 2 samples were transferred to UBC at the end of the voyage. Most of the samples were stored at -20°C . These samples are available for isotope, lipid, and energetic analysis. A subset will be stored at -80°C to be suitable for fatty acid analysis (Samples from Station 3, 7, 8, 10, 12, 14, 19, 21, 22, 25, 26, 29, 31, 36, 43, 45, 54, 58). Stable isotope and fatty acid analyses are described in detail in the report on Biogeochemical Analysis of Food Webs. All size fractions and size fraction components will be weighed and measured to the nearest 0.01 mg prior to biogeochemical analysis. The resulting biomass dataset will be made available to the IYS GoA database.

ADDITIONAL SAMPLING

Particulate Organic Matter (POM) Carbon and Nitrogen Isotopes

These samples were collected at every grid station to (a) provide an isotope baseline for the Gulf of Alaska for application in trophic studies; (b) identify spatial variation in isotope signatures that can be used to trace salmon movement; and (c) validate existing predictive models for Gulf of Alaska isotopes (ISOSCAPES).

Sample collection procedure: approximately 5L of water was collected from the sea surface (~ 2m depth), using the Rosette, at every station. 2000ml was filtered onto a pre-combusted 25mm GF/F filter; and another 2000ml was filtered onto a pre-combusted 25mm GF/F filter and ACIDIFIED by immersion in 1M HCl for 30 seconds on the filter holder. After acidification, the sample was rinsed with 0.7 µm filtered seawater and dried by applying vacuum pressure to the filter. Each filter was transferred to its own Aluminum foil envelope and stored at -20°C. Samples will be stored at UBC at -20°C until processing.

Food web biogeochemistry

Stable carbon and nitrogen isotopes and fatty acids of all components of the pelagic food web in the Gulf of Alaska, representative of sub-regions identified based on physical, chemical and biological variables were collected whenever possible (usually at every grid station).

Sample collection included (all samples will be stored frozen at UBC until the time of analysis):

1. Particulate Organic Matter (POM) – collected at the sea surface using a Niskin rosette at every station (see above).
2. Zooplankton – collected using a Bongo net hauled through the upper 250 m of the water column (see above). Samples were split into size fractions and the largest size fraction (> 4 mm) split into species. The majority of samples will be stored at -20°C but a subset will be stored at -80°C to be suitable for fatty acid analysis.
3. Trawl salmon and bycatch – representative samples of all species in the trawl catch were collected at every station during the survey. The majority of samples will be stored at -20°C but a subset will be stored at -80°C to be suitable for fatty acid analysis.

Environmental DNA

Environmental DNA (eDNA) analysis uses the free DNA shed from organisms and available in the environment to assess fish species diversity and composition. Water samples for eDNA analysis were collected at all 58 stations throughout the cruise using a Niskin bottle mounted on the CTD rosette that was deployed just below the surface at approximately 2–4m of depth. Two litres of subsurface water (~ 2m; in duplicates) were filtered through a Sterivex filtration column and immediately frozen until further analysis in the Pacific Biological Station, Nanaimo. In addition, the eDNA database will provide overall composition of micronekton and zooplankton allowing estimation of salmon prey preferences.

PELAGIC TRAWL

Pacific salmon

Salmon were caught in 48 of the 58 stations fished (Figure 14). Overall, 425 salmon were caught and the largest catches corresponded to the southcentral part of the grid survey (Figure 14F). Chum salmon was the most common species encountered (n=223) and were also encountered in the most sets (81%, Figure 14A). Coho salmon were the second most common salmon species (n=95) with most (95%) caught south of 52°N (Figure 14B). Conversely, the 73 sockeye salmon were primarily caught north of 52°N (84%, Figure 14C). Catches of Chinook and pink salmon were the lowest in the expedition with 3 and 31 caught respectively (Figure 14D, E).

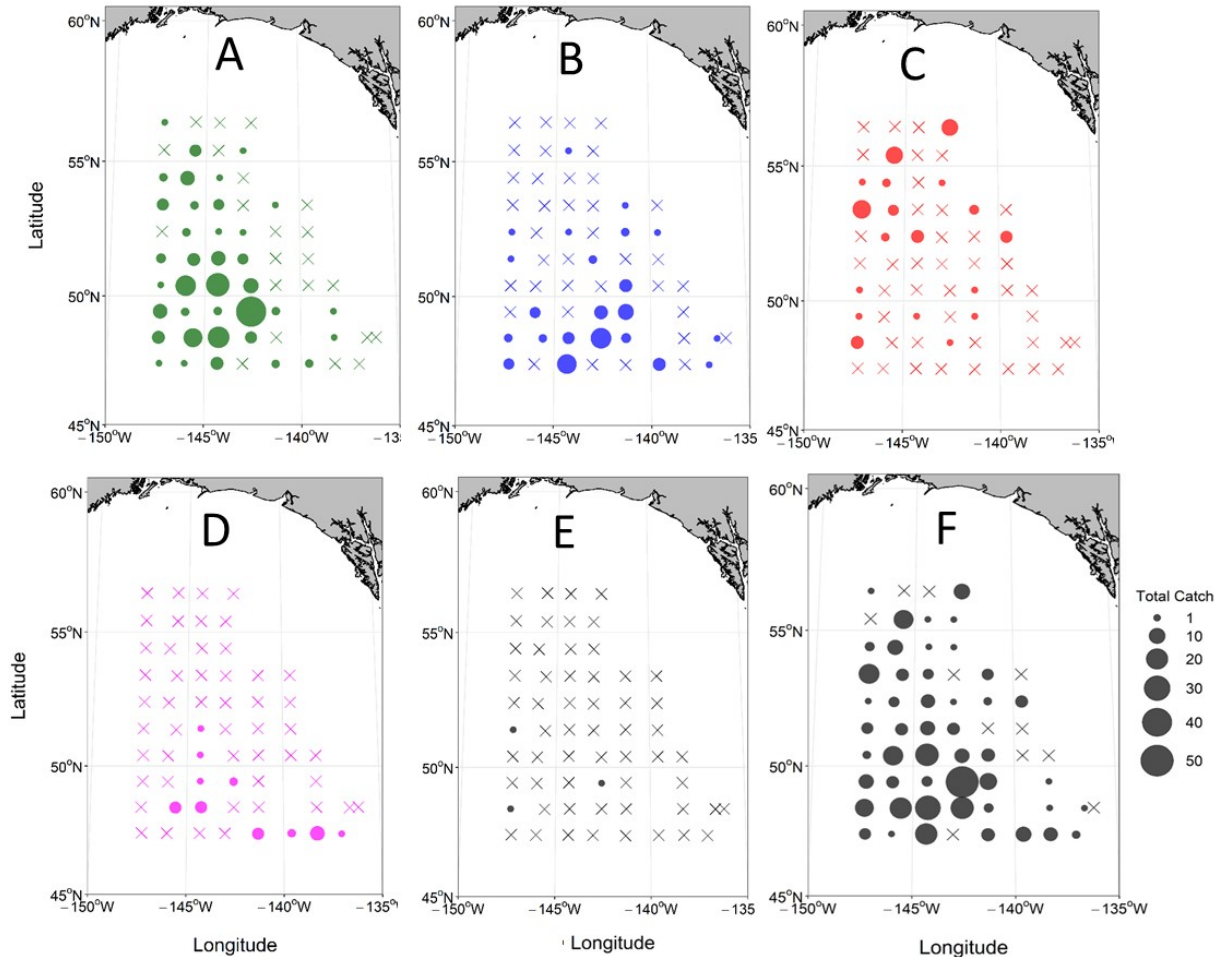


Figure 14. Salmon catches: (A) chum; (B) coho; (C) sockeye; (D) pink; (E) Chinook; (F) all five species; during February–March 2019 in the Gulf of Alaska. An ‘x’ indicates zero catch.

The size of salmon caught ranged from a fork length of 25 cm (chum salmon) to 75 cm (Chinook salmon). The largest salmon caught were Chinook salmon (>71 cm fork length) and the smallest salmon were chum salmon (~24 cm fork length). Based on length data, multiple age classes of chum, sockeye and chinook salmon were caught in the survey (Figure 15). Scale and otolith analysis will be conducted to verify ages of these salmon.

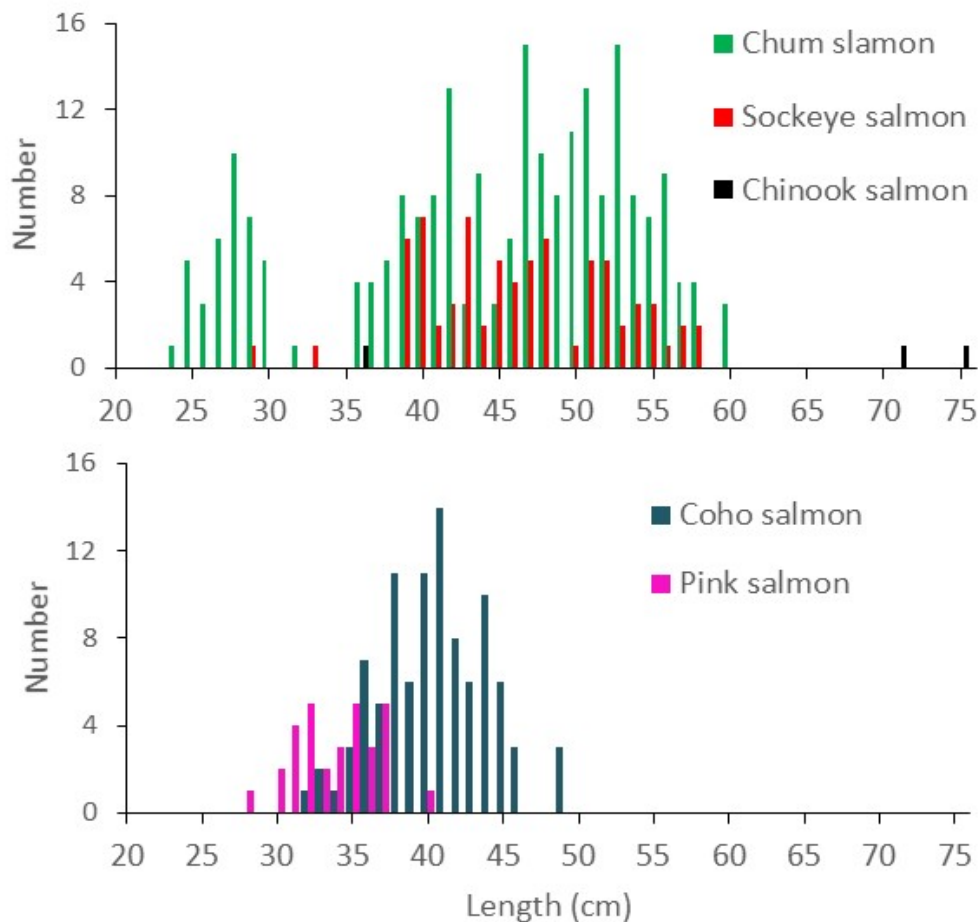


Figure 15. Length frequency of Pacific salmon caught in the Gulf of Alaska expedition February–March 2019.

Stomach analysis to examine salmon diet was conducted on all salmon captured during the survey. Preliminary analysis indicated that key diet categories by volume included euphausiids, pteropods, larval fish, and squid. Stomach contents have been preserved (frozen) and will undergo additional analysis in laboratories in Canada and the US.

Abundance and biomass of Pacific salmon

The survey area calculated with the 30-mile buffer (the half of average distance between neighboring stations) totaled 697,500 km². Fifty-eight stations are regularly distributed throughout the survey area. It is conditionally accepted that the catch value on each station characterises abundance and biomass of fish,

squid and other pelagic animals within the Voronoi polygon calculated for this station. The area of calculated polygons ranged from 10,200 to 16,800 km², with an average of 12,000 km² (Figure 16).

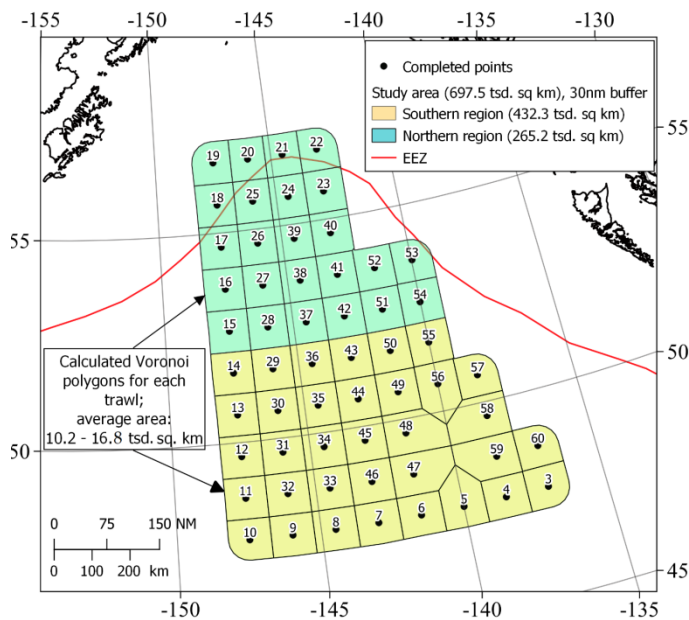


Figure 16. The Gulf of Alaska survey area and integrated survey stations, 21.02–15.03.2019. Red line shows the boundary of Canadian and U.S. exclusive economy zone (EEZ)

Total numbers and biomass of all species in the trawl catches were calculated as a sum of their numbers and biomass within the polygons. Within each polygon, numbers and biomass were calculated as the catch value multiplied by the ratio of polygon area and area swept by the trawl net during one-hour haul divided by species. For some species a group-specific catchability coefficient (q) was applied, e.g., the trawl catchability coefficient for maturing and immature Pacific salmon aged $n.1+$ or older is 0.3; for juvenile salmon of first marine year is 0.4. For quickly growing pink and coho salmon spending one year at sea, the trawl catchability coefficient equals 0.3 (Table 1). The catchability coefficients for major nekton species are presented in Shuntov & Bocharov (2003) and the pros and cons of applied method analysed in Volvenko (1998, 1999).

Chum salmon *Oncorhynchus keta*

Chum salmon was the most abundant salmon species in the Gulf of Alaska during winter 2019. Chum salmon occurred in almost two thirds of trawl catches, and its numbers and biomass exceeded 50% of total Pacific salmon abundance estimates (Table 1). Based on the size of fish, it appears that chum salmon were represented by all marine-age groups including fish of first marine year. Their abundance calculated with the catchability coefficient $q = 0.4$ totaled 3.56 million fish. Based on fish size and the relative size of gonads, maturing fish that will return to spawning grounds later this year were not abundant. Their numbers contributed about 3% of the total estimated abundance.

Although chum salmon distribution undoubtedly continues beyond the western limits of the survey area, within the study area chum salmon distribution was the widest latitudinally of any salmon species and covered the entire area. Chum salmon distribution density was highest in vicinity of 50°N (Figure 17).

Chum salmon occurred in the trawl catches as far south as 46°N near 130°W in April 1990 and 43°N near 150°W in early May 1990.

Table 1. Frequency of occurrence in trawl catches, estimated numbers and biomass of Pacific salmon species in the upper epipelagic layer (0–30 m) throughout the investigated area in the GoA during winter 2019. q is the catchability coefficient

Salmon species	q	Frequency of occurrence (%)	Numbers (million fish)	Biomass (thousand tons)
<i>Oncorhynchus gorbuscha</i>	0.3	17.2	4.21	1.63
<i>Oncorhynchus keta</i>	0.3	55.2	24.17	26.96
	0.4	20.7	3.56	0.74
	total	63.8	27.73	27.70
<i>Oncorhynchus nerka</i>	0.3	31.0	8.94	10.28
	0.4	1.7	0.10	0.02
	total	31.0	9.04	10.30
<i>Oncorhynchus kisutch</i>	0.3	37.9	13.59	10.37
<i>Oncorhynchus tshawytscha</i>	0.3	5.17	0.37	1.32
All species	total	82.8	54.95	51.33

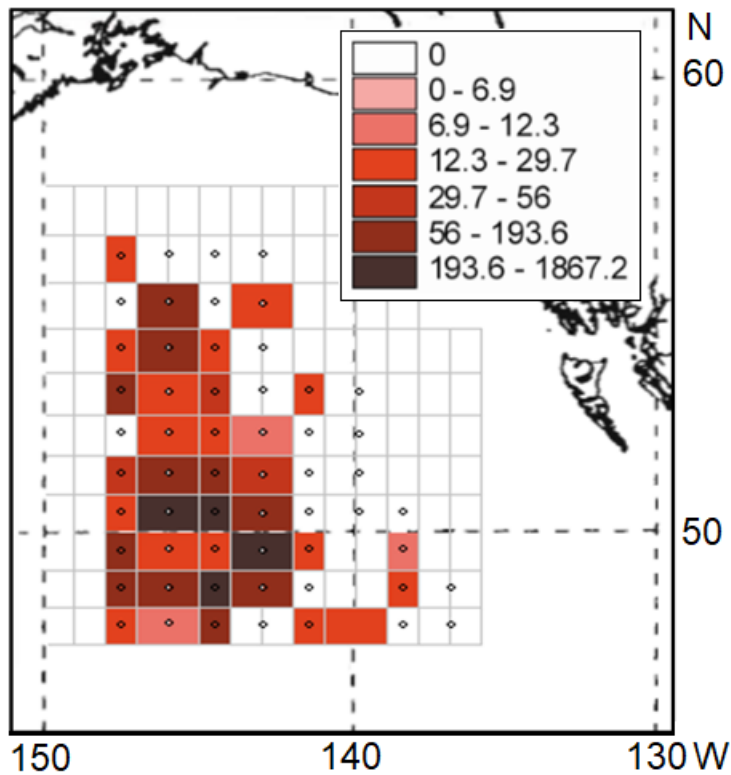


Figure 17. Estimated chum salmon distribution density in the upper pelagic layer in the Gulf of Alaska in winter 2019. The color grade is in fish per km².

Coho salmon *Oncorhynchus kisutch*

Coho salmon were the second most abundant salmon species caught during the survey and their density was higher in southern part of survey area (Figure 18). The total preliminary estimated abundance was 13.6 million fish. These catch levels are high compared to prior studies in the region, which reported coho salmon were minor species (Myers et al. 2016).

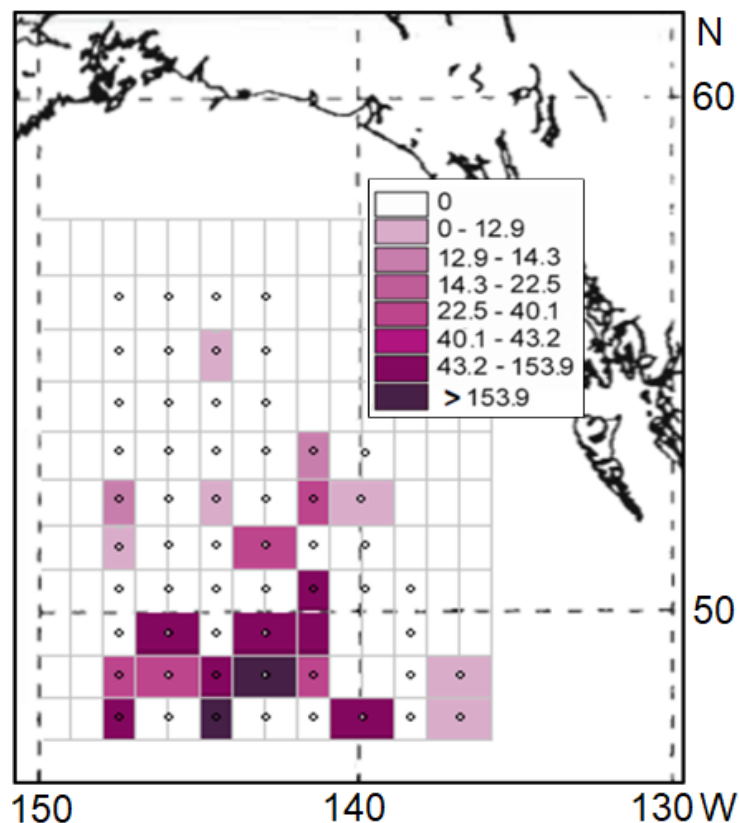


Figure 18. Estimated coho salmon distribution density in the upper pelagic layer in the Gulf of Alaska in winter 2019. The color grade is in fish per km².

Sockeye salmon *Oncorhynchus nerka*

Sockeye salmon mostly occurred in the northern part of survey area with SST less than 7°C. Nine out of ten sockeye catches larger than 1 fish/hour occurred northwards of latitude 52°N (Figure 19). In the northern part of survey area, sockeye salmon estimated abundance contributed 81.3% of total salmon abundance and 87.0% of total estimated salmon biomass.

Catches of sockeye salmon were somewhat lower than expected given the large size (i.e., millions of adults) of sockeye populations in British Columbia and Alaska that may rear in the Gulf of Alaska in winter. It is possible that some sockeye salmon over winter farther west of our survey area. Survey data in the northwestern Pacific collected by TINRO in 1986-1992 and 2009-2010 also revealed significant sockeye concentrations in the central Pacific Ocean in winter. Sockeye salmon appear to have a Pan-Pacific distribution and need ocean surveys that span the Pacific Ocean to fully understand their distributions, abundance, and condition.

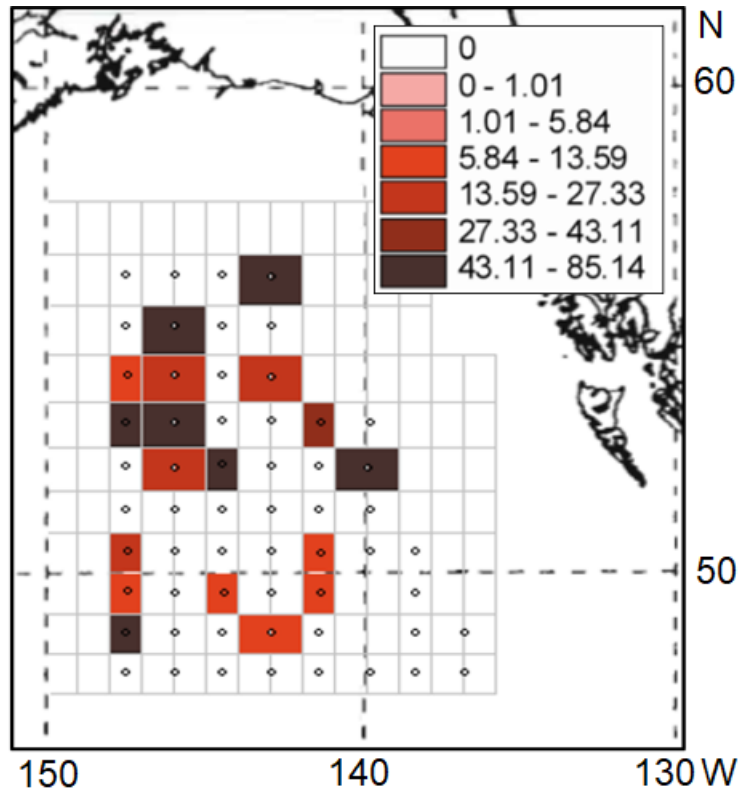


Figure 19. Estimated sockeye salmon distribution density in the upper pelagic layer in the Gulf of Alaska in winter 2019. The color grade is in fish per km².

Pink salmon *Oncorhynchus gorbuscha*

Pink salmon distribution density in the upper pelagic layer of the Gulf of Alaska in winter 2019 was low – from 11.4 to 107.4 fish per km² (Figure 20). In the north-western and central Pacific Ocean, wintering pink salmon dwell in the vicinity of the Subarctic Current with their main concentrations along both the northern and the southern fronts (Radchenko et al., 2018). During this survey, satellite altimetry data showed a well-expressed branch of the Subarctic Current in the south-eastern corner of survey area (Figure 21), where almost all pink salmon specimens were caught. Based on our survey, pink salmon in February-March mainly dwell along the southern branch of the Subarctic Current, and possibly farther south.

Chinook salmon *Oncorhynchus tshawytscha*

Very few Chinook salmon were caught in the study area (n=3). This is likely because Chinook salmon have the deepest distribution in the water column of any salmon and may not be effectively caught by the near-surface trawl. Catches of Chinook salmon were too low to produce reliable estimates of abundance across the study area. We may only conclude that, in the upper epipelagic layer, Chinook salmon remain widely distributed in winter high seas and likely epitomizes the individual (non-schooling) behaviour postulated for Pacific salmon.

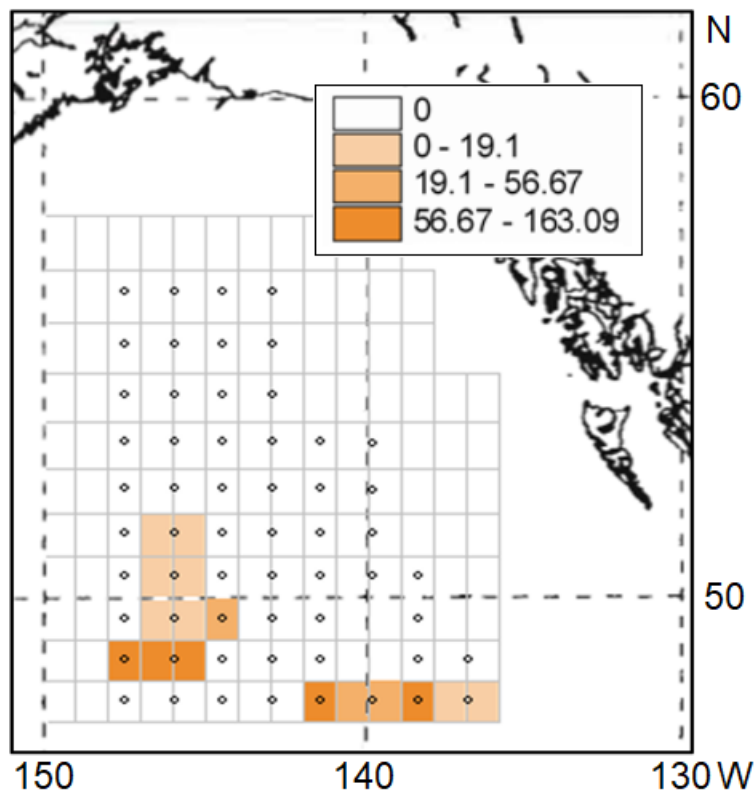


Figure 20. Estimated pink salmon distribution density in the upper pelagic layer in the Gulf of Alaska in winter 2019. The color grade is in fish per km².

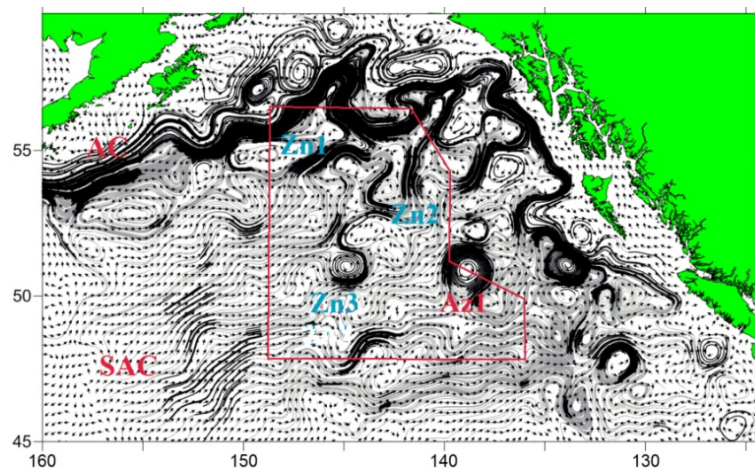


Figure 21. Currents in the Gulf of Alaska in March 2019 based on OSCAR data (<https://www.esr.org/research/oscar/>) SAC – the Subarctic Current, three cyclonic eddies and one anticyclonic eddy are also indicated

In-field genetic stock identification

Among important objectives of the expedition was the deployment and implementation of an in-field genotype-by-sequencing technology for genetic stock identification by single nucleotide polymorphism sequencing (SNP GSI) of salmon utilizing the Oxford Nanopore Technologies minION third generation sequencer. Such technology is desirable to enable next to real-time information for stock specific management and research approaches. This approach currently relies on high throughput genetic stock identification methods that require samples to be transported to a laboratory for analysis.

Preliminary stock composition analysis suggests that coho salmon stocks dominated by populations residing in the close proximity to the study area. These include the coast of British Columbia, with a largest fraction coming from the northern coastal streams, followed by individuals from the further south (Southern coastal Streams, Queen Charlotte Straight, Johnston Straight and Southern Fjords, and Nahwitti). Other contributing stocks covered a broad geographic range from southeast Alaska to Washington State and the Columbia River. Interestingly, stock composition was largely independent of capture site, suggesting that distant stocks readily mix in the open ocean and do not segregate according to origin. The field-based results will be validated with results replicated at the genomics lab at the Pacific Biological Station, DFO, Nanaimo, BC on the established Ion-Torrent based workflow as well as the data read from one of the coded-wire tagged individuals included in this analysis.

DNA tissue samples were also collected from all salmon species and are being processed by laboratories in Canada, the US and Japan to identify stock origin. These results are expected to be available during 2019. Additionally, thermal marks from the otoliths of chum and pink salmon are being assessed by laboratories in Japan and will provide additional information on stock origin.

Biological sampling of salmon to assess fish health

To assess the health of salmon captured during the expedition, tissue samples from all species, up to ten individuals per trawl, were collected during the expedition with the help of other expedition members. A total of 255 salmon (80 coho, 3 Chinook, 27 pink, 61 sockeye, and 84 chum) were dissected and tissue and blood samples collected. Aseptic tissue samples (gills, brain, heart, kidney, liver, spleen, and muscle) were preserved in RNAlater for later analysis of pathogen burden, stress, and inflammation markers on a high throughput nanofluidics qPCR platform. Additionally, samples from the same tissues, as well as pyloric caeca, were also preserved in formalin for histological analysis. Finally, blood was collected from all individuals for assessment of IGF-1 (growth), stress indices (cortisol, glucose, lactate), ionoregulation (osmolality, ions). All samples will be analyzed utilizing the high throughput pipeline established at the Molecular Genetics Laboratory at the Pacific Biological Station in Nanaimo. These results will corroborate data collected by other researcher on the condition of salmon by providing a molecular insight into the infection and inflammation status of individuals.

Additional muscle samples collected from the salmon will be analyzed in laboratories in Canada and the US to measure the energy density, fatty acid composition and stable isotope values.

Tagging experiment

During the last days of the expedition, two coho salmon were captured by a trial of trawl operation with a live box in the cod end. The live coho salmon (both FL= 420 mm) were tagged with NPAFC disc tags (numbers NA6001 and NA6002) and immediately released in the eastern Gulf of Alaska (48°42'N, 134°23'W) on March 15, 2019 (WGSM 2019).

Catch and abundance of non-salmon fish, squid and macroplankton species

Myctophiid species were the most common non-salmon fishes captured in the survey. The species encountered (Table 2) were caught almost exclusively at night. Samples of these groups of fish have been retained and will be further analyzed in laboratories in Canada and Russia. Other fish caught in the survey are listed in Table 2 and include larger mature fish, including *Squalus acanthias* (Spiny dogfish), to larval samples of *Microstomus pacificus* (Dover sole). Samples of these fish have been retained for further analysis in laboratories in Canada, US and Russia.

More than nine species of squid were identified in the catch although *Boreoteuthis borealis* was the most commonly encountered (Table 2). Similar to myctophiids, these were predominantly caught at night. In addition, several gelatinous species and other invertebrates were documented in the catch. The gelatinous species were numerous, especially at night and in some regions. This group included jellyfish, ctenophores, salps and gelatinous gastropods. Other invertebrates captured included pelagic octopods, euphausiids and shrimp (Table 2).

Trawl catch indicates that beside salmon, very few species are present in the upper epipelagic during the day-time but increase substantially during the night (Table 2). During the day, total biomass of non-salmonid fishes, squid and macroplankton species is less than the salmon biomass itself. At night, the abundance of upper epipelagic layer inhabitants increased by more than 700 times and reached at least one animal per sixteen square meters. Considering the amount of sea nettle *Chrysaora melonaster*, observed from visual observations from the vessel at night and which contributed 89.0% of the group biomass, the estimated abundance is likely an underestimate.

Table 2. Catch, catch weight, frequency of occurrence, estimated numbers and biomass for fish (excluding Pacific salmon), squid and macroplankton species in the upper epipelagic layer (0–30 m) throughout the entire study area in the Gulf of Alaska in winter 2019. Species that were primarily caught during day- and night-time trawls are indicated. q is the catchability coefficient.

Species	Catch number	Catch weight	q	Frequency of occurrence (%)	Numbers (million fish)	Biomass (thousand tons)
Day-time species						
<i>Anotopterus nikparini</i>	1	0.018	0.3	1.7	0.14	>0.005
<i>Aptocyclus ventricosus</i>	1	0.057	0.5	1.7	0.08	>0.005
<i>Gasterosteus aculeatus</i>	1	0.002	0.5	1.7	0.07	>0.005

<i>Microstomus pacificus</i> , larv.	20	0.016	0.1	10.3	8.16	0.01
<i>Sebastes melanops</i>	1	3.288	0.5	1.7	0.07	0.22
<i>Squalus acanthias</i>	2		0.5	3.5	0.16	0.72
<i>Thalassenchelys coheni</i> , larv.	1	0.61	0.1	1.7	0.37	0.23
<i>Zaprora silenus</i>	1	0.09	0.5	1.7	0.08	0.01
<u>All fish species</u>			total		<u>9.13</u>	<u>1.20</u>
<i>Gonatus madokai</i>	7	0.254	0.1	8.6	2.60	0.09
<i>Gonatidae</i> gen. sp.	1	0.001	0.1	1.7	0.40	>0.005
<u>All squid species</u>			total		<u>3.00</u>	<u>0.09</u>
<i>Aequorea</i> sp.	26	50.651	0.1	82.8	6.96	16.97
<i>Aurelia labiata</i>	77	12.326	0.1	41.4	27.63	4.21
<i>Aurelia limbata</i>	2	0.639	0.1	3.5	0.74	0.24
<i>Corolla calceola</i>	4	0.003	0.1	5.2	1.86	>0.005
<i>Phacellophora camtshchatica</i>	32	44.558	0.1	29.3	11.05	15.89
<u>All jellyfish species</u>			total		<u>48.24</u>	<u>37.31</u>
All species			total		60.37	38.60
Night-time species*						
<i>Diaphus theta</i>	320	1.077	0.1	27.3	303.32	1.02
<i>Icichthys lockingtoni</i>	1	0.012	0.3	1.7	0.32	0.00
<i>Lestidium ringens</i>	2	0.01	0.2	4.6	0.95	0.01
<i>Lipolagus ochotensis</i>	1	0.01	0.1	4.6	0.48	>0.005
<i>Paralepididae</i> gen. sp., juv.	10	0.02	0.1	4.6	106.05	0.21
<i>Stenobrachius leucopsarus</i>	356	0.319	0.1	31.8	317.66	0.27
<i>Symbolophorus californiensis</i>	3	0.022	0.1	9.1	3.18	0.02
<i>Tarletonbeania crenularis</i>	5337	12.914	0.1	44.8	14,260.59	34.57
<u>All fish species</u>			total		<u>14,992.55</u>	<u>36.10</u>
<i>Abraliopsis felis</i>	12	0.041	0.03	18.2	39.50	0.13
<i>Belonella borealis</i>	1	0.899	0.1	1.7	1.00	0.89
<i>Boreoteuthis borealis</i>	1482	25.482	0.1	95.5	1,504.42	26.62
<i>Boreoteuthis borealis</i> , juv.	333	0.677	0.01	81.8	3,544.26	7.46
<i>Chroteuthis calyx</i>	12	0.056	0.1	22.7	22.54	0.07
<i>Gonatus onyx</i>	104	0.627	0.1	45.5	66.70	0.39
<i>Gonatus onyx</i> , juv.	5	0.015	0.01	9.1	52.22	0.16
<i>Gonatus</i> sp.	1	0.003	0.1	1.7	1.06	>0.005
<i>Japetella diaphana</i>	1	0.006	0.1	1.7	0.95	0.01
<i>Moroteuthis robusta</i>	1	1.07	0.1	1.7	0.22	0.24
<i>Onychoteuthis borealijaponica</i>	288	17.271	0.1	68.2	262.73	15.52
<u>All cephalopod species</u>			total		<u>5,495.60</u>	<u>51.49</u>
<i>Calycopsis</i> sp.	30	0.087	0.01	36.4	284.48	0.81
<i>Chrysaora melonaster</i>	5886	1451.85	0.1	51.7	5,021.54	1,233.49
<i>Hormiphora cucumis</i>	548	10.157	0.1	37.9	507.02	10.55
<i>Periphylla periphylla</i>	11	0.013	0.1	3.5	11.52	0.01
<i>Salpa</i> sp.	23151	79.162	0.1	15.5	15,988.21	52.61
<i>Sergestes similis</i>	39	0.01	0.1	3.5	303.33	0.08
<i>Siphonophora</i> gen. sp.	1	0.007	0.1	1.7	1.43	0.01

<i>Thysanoessa spinifera</i>	4779	0.477	0.1	5.2	44.88	0.01
All other macroplankton					22,162.41	1,297.57
All species			total		42,650.56	1,385.16

Remark: *Some species were caught during both day- and night-time trawls. However, because their abundance was several orders of magnitude higher at night than during the day, they are included in the night-time species list. Their numbers and biomass are calculated by night-time trawl sets only, while frequency of occurrence calculation based on the whole survey sets. The list of such species includes *Icichthys lockingtoni*, *Tarletonbeania crenularis*, *Belonella borealis*, *Gonatus* sp., *Japetella diaphana*, *Moroteuthis robusta*, *Periphylla periphylla*, *Calycopsis* sp., *Chrysaora melonaster*, *Salpa* sp., *Hormiphora cucumis*, *Siphonophora* gen. sp., *Sergestes similis*, and *Thysanoessa spinifera*

SUMMARY

This document provides preliminary findings of the GoA winter (February-March) 2019 expedition. This survey is first of its kind in this part of the North Pacific and established a baseline of environmental and ecosystem-level measurements for future comparisons. The success of the collaborative research initiative is clear and should serve as an example for future international expeditions. Catches of salmon showed large spatial variation across study area. Species differences may be the strongest signal. For example, pink salmon had limited distribution and low numbers, while coho salmon were encountered in higher numbers across the survey area. Those two species dominated salmon catches at the southern and westerly stations. By contrast, sockeye salmon was mainly caught in the coolest waters (northern parts) of the survey. Chum salmon were widely distributed but varied in their body condition both within a set and between sets with individuals of low weight (skinny) and more robust (normal condition) fish encountered. North-south differences in salmon species distributions appeared to correlate with the environmental characteristics of water masses as well as productivity, mesozooplankton composition and macroplankton/micronekton distributional patterns.

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