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Annual Survey of Juvenile Salmon, Ecologically-Related Species, and Biophysical Factors in the Marine Waters of Southeastern Alaska, May–August 2017

by

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ABSTRACT

Juvenile Pacific salmon (*Oncorhynchus* spp.), ecologically-related species, and associated biophysical data were collected from the marine waters of the northern region of southeastern Alaska (SEAK) in 2017. This annual survey, conducted by the Southeast Coastal Monitoring (SECM) project, marks 21 consecutive years of systematically monitoring how juvenile salmon utilize marine ecosystems during a period of climate change. The survey was implemented to identify the relationships between year-class strength of juvenile salmon and biophysical parameters that influence their habitat use, marine growth, prey fields, predation, and stock interactions. Nine stations were sampled monthly in epipelagic waters from May to August (total of 13 sampling days). Fish, zooplankton, surface water samples, and physical profile data were collected during daylight at each station using a surface rope trawl, bongo nets, a water sampler, and a conductivity-temperature-depth profiler. Surface (3-m) temperatures and salinities ranged from approximately 8 to 12 ºC and 18 to 31 PSU across inshore and strait habitats for the four months. Integrated (top 20-m) temperatures and salinities ranged from approximately 7 to 11 ºC and 26 to 31 PSU. A total of 10,277 fish and squid, representing 17 taxa, were captured in 32 rope trawl hauls fished from June to July. Juvenile salmon comprised 4 and 51% of the catch in June and July, respectively. Abundance of juvenile salmon, especially juvenile pink salmon was very low in 2017. Coded-wire tags were recovered from four juvenile coho and one immature Chinook salmon, that all originated from hatchery and wild stocks in SEAK. Of the juvenile salmon examined for otolith marks, Alaska enhanced stocks comprised 79% of the juvenile chum (93 of 118) and 30% of the juvenile sockeye salmon (12 of 40). Of the 153 potential predators of juvenile salmon, no predation on juvenile salmon was observed. The long term seasonal time series of SECM juvenile salmon stock assessment and biophysical data is used in conjunction with basin-scale ecosystem metrics to annually forecast pink salmon harvest in SEAK. Long term seasonal monitoring of key stocks of juvenile salmon and associated ecologically-related species, including fish predators and prey, permits researchers to understand how growth, abundance, and interactions affect year-class strength of salmon in marine ecosystems during a period of rapid climate change.

INTRODUCTION

The Southeast Coastal Monitoring (SECM) project, an ecosystem study in the northern region of southeastern Alaska (SEAK), was initiated in 1997 to study the early marine ecology of Pacific salmon (*Oncorhynchus* spp.) and associated epipelagic ichthyofauna and to better understand effects of climate change on salmon production. Salmon are a keystone species in SEAK whose role in marine ecosystems remains poorly understood. Fluctuations in the survival of this important living marine resource have broad ecological and socio-economic implications for coastal localities throughout the northern Pacific Rim.

Relationships between climate shifts and production have impacted year-class strength of Pacific salmon throughout their distribution (Beamish et al. 2010a, b). In particular, climate variables such as temperature have been associated with freshwater production (Bryant 2009; Taylor 2008) and ocean production and survival of both wild and hatchery salmon (Wertheimer et al. 2001; Beauchamp et al. 2007). Biophysical attributes of climate may influence trophic linkages and lead to variable growth and survival of salmon (Brodeur et al. 2007; Coyle et al. 2011). However, research is lacking on the links between salmon production and climate variability, intra- and interspecific competition and carrying capacity, and biological interactions among stock groups (Beamish et al. 2010a). In addition, past research has not provided adequate time series data to explain these links (Pearcy 1997; Beamish et al. 2008). Increases in salmon production throughout the northern Pacific Rim in recent decades has elevated the need to understand the consequences of population changes and potential interactions on the growth, distribution, migratory rates, timing, and survival of all salmon species and stock groups (Rand et al. 2012). Furthermore, region-scale spatial effects that are important to salmon production (Pyper et al. 2005) may be linked to local dynamics in complex marine ecosystems like SEAK (Weingartner et al. 2008).

A goal of the SECM project is to identify mechanisms linking salmon production to climate change using a time series of synoptic data related to ocean conditions and salmon, including stock-specific life history characteristics. The SECM project obtains stock information from coded-wire tags (CWT; Jefferts et al. 1963) or otolith thermal marks (Courtney et al. 2000) from all five Pacific salmon species: pink (*O. gorbuscha*), chum (*O. keta*), sockeye (*O. nerka*), coho (*O. kisutch*), and Chinook (*O. tshawytscha*). Portions of wild and hatchery salmon stocks are tagged or marked prior to ocean entry by enhancement facilities or state and federal agencies in SEAK, Canada, and the Pacific Northwest states. Catches of these marked fish by the SECM project in the northern, southern, and coastal regions of SEAK have provided information on habitat use, migration rates and timing (e.g., Orsi et al. 2004, 2007); in addition, interceptions in the regional common property fisheries have documented substantial contributions of enhanced fish to commercial harvests (White 2011). Therefore, examining trends in early marine ecology and potential interactions of these marked stock groups provides an opportunity to link increasing wild and hatchery salmon production to climate change (Ruggerone and Nielsen 2009; Rand et al. 2012).

Examining the extent of interactions between salmon stock groups and co-occurring species in marine ecosystems is also important with regard to carrying capacity, and should examine both "bottom-up" and "top-down" production controls (Miller et al. 2013). For example, increased hatchery production of juvenile chum salmon coincided with declines of some wild chum salmon stocks, suggesting the potential for negative stock interactions in the marine environment (Seeb et al. 2004; Reese et al. 2009). In SEAK, however, SECM and other studies have indicated that growth is not food limited and that stocks interact extensively with little negative impact (Orsi et al. 2004; Sturdevant et al. 2012a). Zooplankton prey fields are more likely to be cropped by the more abundant planktivorous forage fish, including walleye pollock (*Gadus chalcogrammus*) and Pacific herring (*Clupea pallasi*) (Orsi et al. 2004; Sigler and Csepp 2007), than by juvenile salmon. Seasonal and interannual changes in abundance of planktivorous jellyfish, another potential competitor with juvenile salmon, have been reported by SECM (Fergusson et al. 2018). Therefore, monitoring abundance of jellyfish may be an important indicator of potential "bottom-up" trophic interactions (Purcell and Sturdevant 2001), particularly during periods of environmental change (Brodeur et al. 2008; Cieciel et al. 2009). Monitoring the composition, abundance, energetic content, and timing of zooplankton taxa with different life history strategies may permit the detection of climate-related changes in the seasonality and interannual abundance of prey fields (Coyle and Paul 1990; Fergusson et al. 2017). In contrast, "top-down" predation events can also influence salmon year-class strength (Sturdevant et al. 2009, 2013). Highly abundant smaller juvenile salmon species, such as wild pink salmon, may be a predation buffer for less abundant, larger species, such as juvenile coho salmon (LaCroix et al. 2009; Weitkamp et al. 2011). These findings also stress the need to examine the entire epipelagic community in the context of trophic interactions (Cooney et al. 2001; Fergusson et al. 2013; Sturdevant et al. 2012b) and to compare ecological processes, community structure, and life history strategies among salmon production areas (Brodeur et al. 2007; Orsi et al. 2007, 2013).

In 2017, SECM sampling was conducted in the northern region of SEAK for the 21st consecutive year to continue annual ecosystem and climate monitoring, to document juvenile salmon abundance in relation to biophysical parameters, and to support models to forecast adult pink salmon returns. This document summarizes data collected by the SECM project in 2017 on juvenile salmon, ecologically-related species, and associated biophysical parameters.

METHODS

Sampling was conducted in the northern region of SEAK monthly from May to August 2017. Spatially, sampling stations extended from inshore waters of the Alexander Archipelago to Chatham and Icy Straits (Figure 1). At each station, the physical environment, zooplankton, and fish were sampled during daylight hours. Oceanographic sampling was conducted in May and August, while both oceanographic and trawl sampling were conducted in June and July. The 12 m NOAA vessel R/V *Sashin* was used for sampling in May and August. The chartered fishing vessel, FV *Northwest Explorer* (*NWE*), a 52 m stern trawler with twin engines producing 1,800 HP, was used for sampling in June and July.

Sampling stations (Table 1; Figure 1) were chosen to: 1) continue historical time series of biophysical data, 2) sample primary seaward migration corridors used by juvenile salmon, and 3) accommodate vessel logistics (Fergusson et al, 2018).

Oceanographic sampling

The oceanographic data collected at each station consisted of one conductivity-temperature-depth profiler (CTD) cast, one water sample, and one plankton tow. The CTD data were collected with a Sea-Bird[1] SBE 49 'Fastcat' profiler deployed, in tandem with the bongo

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[1]Reference to trade names does not imply endorsement by the Auke Bay Laboratories, National Marine Fisheries Service, NOAA Fisheries.

net, to 200 m or within 20 m of the bottom. The CTD profiles were used to determine the 3-m sea surface temperature (SST, °C) and salinity (PSU), the average 20-m integrated water column temperature and salinity. The 20-m water column depth bracketed typical seasonal pycnoclines and the stratum fished by the surface trawl. Water samples for chlorophyll (µg/L) concentrations were taken at the surface once at each station per month.

Zooplankton was collected monthly with a bongo net towed obliquely to 200 m or within 20 m of bottom. The bongo net had a 60-cm diameter tandem frame with 333- and 505-µm meshes. General Oceanics Model 2031 flow meters were placed inside the bongo nets for calculation of water volumes filtered.

Zooplankton samples were immediately preserved in a 5% formalin-seawater solution buffered with a 2.5% borax-seawater solution. In the laboratory, displacement volumes (DV, ml), standing stock (DV/m^3), and density (number/m^3) were determined. Standing stock was calculated using DV and filtered water volumes. Detailed zooplankton species composition from the 333-µm samples was determined microscopically from subsamples obtained using a Folsom splitter. Densities were then estimated using the subsample counts, split fractions, and water volumes filtered. Percent total composition was summarized across species by major taxa, including small calanoid copepods ($\leq$ 2.5 mm total length, TL), large calanoid copepods (> 2.5 mm TL), euphausiids (principally larval and juvenile stages), larvaceans, decapod larvae, hyperiid amphipods, chaetognaths, pteropods, and combined minor taxa.

Once each month, an additional bongo sample was collected and zooplankton were sorted live on the vessel then frozen for later lipid analysis.

Fish sampling

Fish sampling was accomplished with a Nordic 264 rope trawl modified to fish the surface water directly astern of the trawl vessel. The trawl was 184 m long and had a mouth opening of approximately 24 m wide by 30 m deep, with actual fishing dimensions of 18 m wide by 24 m deep (Sturdevant et al. 2012b). A pair of 3-m foam-filled Lite trawl doors, each weighing 544 kg (91 kg submerged), were used to spread the trawl open. Trawl mesh sizes from the jib lines aft to the cod end were 162.6 cm, 81.3 cm, 40.6 cm, 20.3 cm, 12.7 cm, and 10.1 cm over the 129.6-m meshed length of the rope trawl. A 6.1-m long, 0.8-cm knotless liner mesh was sewn into the cod end. The trawl also contained a small mesh panel of 10.2-cm mesh sewn along the jib lines on the top panel between the head rope and the 162.6-cm mesh to reduce loss of small fish. Two 50-kg chain-link weights were added to the corners of the foot rope as the trawl was deployed to maximize fishing depth. To keep the trawl head rope fishing at the surface, two clusters of three A-4 Polyform buoys (inflated to 0.75 m diameter and encased in knotted mesh bags) were clipped on the opposing corner wingtips of the head rope and one A-3 Polyform float (inflated to 0.5 m diameter) was clipped into a mesh kite pocket in the center of the head rope with a third-wire unit to monitor the net spread. Two acoustic pingers (10 kHz, 132 dB) were attached to the corners of the head rope to deter porpoise interactions. The trawl was fished with approximately 150 m of 1.6-cm wire main warp attached to each door, a 9.1 m length of 1.6-cm TS-II Dyneema line trailing off the top and bottom of each trawl door (back strap). Each back strap was connected with a “G” hook and flat link to an 80-m parallel rigging system constructed of 1.6-cm TS-II Dyneema bridles.

For each haul, the trawl was fished across a station for 20 min at approximately 1.5 m/sec (3 knots) to cover 1.9 km (1.0 nautical mile). Station coordinates were targeted as the midpoint of the trawl haul, and current, swell, and wind conditions usually dictated the setting direction. Thirty-two hauls were scheduled in the strait habitat to meet sampling requirements for the forecasting model and to ensure that sufficient samples of marked juvenile salmon were obtained for interannual comparisons.

After each trawl haul, the fish were separated from the jellyfish, identified, enumerated, measured, labeled, bagged, and frozen. Jellyfish were identified to species when possible, counted, and total wet biomass was measured to the nearest 0.1 kg. After the catch was sorted, all fish and squid were typically measured to the nearest mm fork length (FL) or mantle length, respectively. In instances of very large catches, all fish were counted, a subsample of each species (≤ 100) was processed, and excess fish were discarded. All Chinook and coho salmon were examined for missing adipose fins that could indicate the presence of implanted CWTs. Additionally, in the laboratory, all juvenile Chinook and coho salmon were screened with a magnetic detector and any CWTs detected were excised from the snouts. All tags were decoded and verified to determine the stock of origin.

Adult salmon captured in the trawl were identified, measured (FL, mm), weighed (g), and stomachs were frozen for diet analysis. In the laboratory, stomachs were weighed (0.1 g) and visually classified by percent fullness (0, 10, 25, 50, 75, 100, and distended). Stomach content weight was determined by subtracting the empty stomach weight from the full stomach weight. Feeding intensity was reported as percentage of fish with food in their guts. General prey composition was determined by visually estimating the contribution of major taxa to the nearest 10% of total volume, and the wet-weight contribution to the diets was calculated by multiplying the % by the total content weight (%W). Overall diets of each species were summarized by %W of major prey taxa. Whenever possible, fish prey was identified to species and FLs were measured.

In the laboratory, frozen individual juvenile salmon were weighed (0.001 g) and otoliths were removed from the chum and sockeye salmon. Mean lengths, weights, and residuals from a length-weight linear regression (condition residuals, CR) were computed for each species by locality or habitat and sampling month. Mean energy density (kJ/g dry weight) of monthly subsets of each species was determined through calorimetry (Fergusson et al. 2010). Diet composition (%wt) was also determined for this subset of fish. To determine stock of origin, sagittal otoliths were extracted from the crania and preserved in 95% ethyl alcohol, then later mounted on slides, ground down to the primordia, and examined for potential thermal marks (Secor et al. 1992). Stock composition and growth trajectories of thermally marked fish were determined for each month and habitat.

RESULTS AND DISCUSSION

In 2017, 9 stations were sampled from Auke Bay to Icy Strait monthly from May to August (Table 1; Figure 1). In total, data were collected from 32 rope trawl hauls, 52 CTD casts, 20 bongo net samples, and 27 surface water samples during 13 days at-sea (Table 2).

Oceanography

Sea surface (3-m) temperatures (SST) ranged from 7.6 to 12.3 ºC from May to August and averaged 10.2 ºC while the integrated (top 20-m) temperatures ranged from 7.3 to 10.5 °C from May to August and averaged 8.9 °C (Table 3; Figure 2). Seasonal SST and integrated 20-m temperature patterns were similar among habitats, with a peak in July. Monthly mean SSTs were higher in the inshore habitat except in August when SSTs were highest in the strait habitat. Monthly mean integrated temperatures were similar between the two habitats.

Sea surface (3-m) salinities ranged from 17.8 to 31.2 PSU from May to August and averaged 26.1 PSU while the integrated (top 20-m) salinities ranged from 25.5 to 31.3 PSU from May to August and averaged 28.8 (Table 3; Figure 2). Seasonal salinity patterns were similar in the inshore and strait habitats, with a decreasing trend from May to August. Salinities were higher in the strait habitat compared to the inshore habitat all season for both salinity measures and showed similar decreasing patterns from May to August.

Chlorophyll-a concentrations ranged from 1.15 to 6.85 µg/L from June to August and averaged 3.0 µg/L for all depths (Table 4; Figure 3). Chlorophyll concentrations were highest in June and declined seasonally to August.

Zooplankton standing stock from oblique bongo net tows (333-µm mesh) ranged from 0.04 to 1.4 ml/m^3 from May to August and averaged 0.6 ml/m^3 (Table 5; Figure 4). Mean standing stock was highest in the strait habitat and decreased seasonally from May to August. Seasonal total density of zooplankton prey fields from oblique bongo tows (333-µm mesh) at stations in Icy Strait ranged from 460 to 4,494 organisms/m^3 from May to August and averaged 1,640 organisms/m^3 (Table 5; Figure 5). Mean density was highest in May and declined over the season. The zooplankton community was dominated in all months by the small calanoid copepod *Pseudocalanus* spp.

Catch composition

Jellyfish catches included five species (*Aequorea* sp., *Aurelia* sp., *Chrysaora melanaster*, *Cyanea capillata*, and *Staurophora* sp.; Figure 6). Total biomass (weight, kg) of jellyfish ranged from 0 to 17 kg per haul, was composed mainly of *Aequorea* sp. and biomass increased from June to July.

In total, 10,277 fish, representing 17 taxa, were captured in 32 rope trawl hauls (Table 6). Juvenile salmon comprised approximately 4% of the total fish catch in June and 51% in July (Figure 7). Juvenile chum, sockeye, and coho salmon occurred in 47–84% of the trawls, while juvenile pink and Chinook salmon occurred in 13% of the hauls (Table 7). The catch of juvenile pink salmon was the 2nd lowest in the time-series. Catches of juvenile coho and Chinook salmon peaked in June while catches of juvenile pink, chum, and sockeye salmon peaked in July (Figure 8). Catches of non-salmonids were relatively minor except for three large catches of Pacific herring (*Clupea pallasii*) in June.

Length, weight, condition, and energy density of juvenile salmon differed among species and months (Table 8; Figures 9–11). All species increased in length and weight from June to July, with the exception of juvenile pink salmon which were only caught in July. From June to July, mean FLs of juvenile salmon increased from 97 to 143 mm for chum; 95 to 155 mm for sockeye; 163 to 188 mm for coho; and 202 to 249 mm for Chinook salmon. Mean weights of juvenile salmon increased monthly from 9 to 29 g for chum; 10 to 39 g for sockeye; 53 to 75 g for coho; and 111 to 182 for Chinook salmon. The CRs for chum and sockeye salmon were below average but increased from June to July while CRs for coho and Chinook salmon decreased from above average in June to below average in July. Energy density either stayed constant or decreased from June to July (Figure 12).

All juvenile coho (n = 413) and juvenile and immature Chinook (n = 21) salmon were scanned (either visually onboard the vessel or electronically in the laboratory) for the presence of CWTs. Stock-specific information was obtained from five CWT recoveries from four juvenile coho and one immature Chinook salmon lacking the adipose fin (Table 9). One additional juvenile coho salmon was missing the adipose fin but did not have a CWT. All of the tagged fish originated from hatchery and wild stocks in the northern region of SEAK.

Stock-specific information was also obtained from recoveries of otolith-marked hatchery juvenile chum and sockeye salmon, using the same individuals that were subsampled for weight and condition. Releases of these species from SEAK enhancement facilities are commonly mass-marked and not tagged. These facilities include: Douglas Island Pink and Chum Hatchery (DIPAC), Northern Southeast Regional Aquaculture Association (NSRAA), Southern Southeast Regional Aquaculture Association (SSRAA), and Armstrong Keta Incorporated (AKI). A total of 158 juvenile salmon were examined for thermal marks: 118 chum salmon and 40 sockeye salmon (Tables 10-11; Figures 13–14).

For juvenile chum salmon, stock-specific information was derived from a subsample of 118 from the 122 fish caught, representing 97% of the catch (Tables 6 and 10). Of all the chum salmon otoliths examined, 93 (79%) were marked by hatcheries in SEAK and 25 (21%) were not marked. Of the marked fish, 48 (52%) were from DIPAC, 33 (35%) were from NSRAA, 11 (12%) were from SSRAA, and 1 (1%) was from AKI. Hatchery chum salmon catch composition shifted monthly through Icy Strait, with northern stocks such as DIPAC peaking in June and central and southern stocks peaking in July (Figure 13).

For juvenile sockeye salmon, stock-specific information was derived from a subsample of 40 from the 42 fish caught, representing 95% of the catch (Tables 6 and 11). Of all the sockeye salmon otoliths examined, 12 (30%) were marked and 28 (70%) were not marked. Of the marked fish, 7 (58%) were from Speel Arm, SEAK and 5 (42%) were from Tahltan Lake/Stikine River, British Columbia (Table 11). Speel Arm sockeye salmon were caught in both June and July, but Tahltan Lake sockeye salmon were only caught in July (Figure 14).

Stomachs of 153 potential predators of juvenile salmon were examined onboard from a suite of five fish species. Of the fish examined, 51% were feeding and no juvenile salmon were found in any of the stomachs (Tables 12 and 14). Diet compositions differed by predator species (Figure 15). For feeding fish, the planktivorous adult pink and sockeye salmon had very diverse diets that included gelatinous zooplankton, euphausiids, decapod larvae, amphipods, and fish (including herring). Piscivorous immature and adult Chinook and adult coho salmon consumed primarily fish (herring and unknown digested fish) but some amphipods and pteropods was also consumed.

Stomachs of 76 juvenile salmon were examined in the laboratory, fish examined for diet composition were the same fish analyzed for energy density (Table 13). Of the fish examined, 92% were feeding (Table 15). Diet compositions differed by species (Figure 16). For feeding fish, the planktivorous juvenile pink, chum, and sockeye salmon consumed mostly invertebrates including hyperiid amphipods, gelatinous prey (oikopleurans), and gastropods. Piscivorous juvenile coho and Chinook salmon consumed mostly fish (pollock larvae, osmerid larvae, and sandlance) but amphipods and decapod larvae was also consumed.

Summary

This document summarizes SECM data collected on juvenile salmon, ecologically-related species, and associated biophysical parameters collected from May to August in 2017 in the northern region of SEAK. These data continue to be used in conjunction with basin-scale data to 1) develop forecast models and predictive tools for pink salmon production and in SEAK; 2) develop a Chinook salmon production index for SEAK; and 3) to explore year-class strength relationships for other commercially important species. Subsets of the 21-year long-term time series are also examined in recent ecosystem documents. Comparing annual effects of biophysical parameters to long term mean values permits climate-related changes in marine conditions to be detected. Long term monitoring of key stocks of juvenile salmon, on seasonal and interannual time scales, will permit researchers to understand how growth, abundance, and ecological interactions affect year-class strength of salmon in SEAK and to better understand their role in North Pacific marine ecosystems.

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Table 1. Localities and coordinates of thirteen stations sampled May–August 2017. Transect and station positions are shown in Figure 1.

Station[a]	Latitude N	Longitude W	Offshore (km)	Between adjacent station (km)	Bottom depth (m)
			Inshore habitat		
ABM	58°22.00'	134°40.00'	0.5	–	60
			Strait habitat		
UCA	58°04.57'	135°00.08'	3.2	3.2	400
UCB	58°06.22'	135°00.91'	6.4	3.2	100
UCC	58°07.95'	135°01.69'	6.4	3.2	100
UCD	58°09.64'	135°02.52'	3.2	3.2	200
ISA	58°13.25'	135°31.76'	3.2	3.2	128
ISB	58°14.22'	135°29.26'	6.4	3.2	200
ISC	58°15.28'	135°26.65'	6.4	3.2	200
ISD	58°16.38'	135°23.98'	3.2	3.2	234

[a] ABM = Auke Bay Monitor; UC* = Upper Chatham Strait; IS* = Icy Strait

Table 2. Numbers and types of samples collected by habitat and month, May–August 2017.

			Data Collection Type			
Dates (days)	Vessel	Habitat	Rope trawl[a]	CTD[b]	Bongo[c]	Chlorophyll[d]
05/26-05/30 (2)	R/V Sashin	Inshore	0	1	1	0
		Strait	0	8	4	0
06/29-07/03 (5)	F/V NW Explorer	Inshore	0	1	1	1
		Strait	16	16	4	8
07/28-07/31 (4)	F/V NW Explorer	Inshore	0	1	1	1
		Strait	16	16	4	8
09/05-09/06 (2)	R/V Sashin	Inshore	0	1	1	1
		Strait	0	8	4	8

[a] 20-min hauls with Nordic 264 surface trawl 18m wide by 24m deep

[b] To 200m or within 10m of the bottom

[c] 60-cm frame, 505- & 333-µm mesh, oblique tows down to & up from 200m or within 20m of bottom.

[d] chlorophyll are from surface seawater samples.

Table 3. Monthly mean surface (3m) and top 20-m integrated temperatures (°C) and salinities (PSU) collected May–August 2017. n = number of station visits.

	May			June			July			August		
Station[a]	n	Temp	Salinity	n	Temp	Salinity	n	Temp	Salinity	n	Temp	Salinity
Surface (3-m) measures												
ABM	1	8.5	26.9	1	11.7	21.5	1	12.3	18.2	1	10.2	17.8
ISA	1	7.6	31.2	3	8.1	30.5	3	9.0	30.0	1	10.6	26.9
ISB	1	8.3	30.5	3	9.3	28.7	3	10.3	29.0	1	10.5	26.5
ISC	1	8.2	30.3	3	10.7	26.1	3	11.6	26.1	1	11.4	21.2
ISD	1	8.7	29.7	3	11.2	25.8	3	11.7	25.9	1	11.6	20.3
UCA	1	8.4	29.6	1	9.9	26.9	1	10.5	29.1	1	10.7	25.2
UCB	1	9.1	29.0	1	9.5	27.8	1	11.6	27.6	1	11.3	20.1
UCC	1	8.6	29.3	1	10.3	25.9	1	11.5	25.6	1	11.3	21.1
UCD	1	8.7	29.5	1	10.7	24.9	1	11.4	26.3	1	11.6	19.2
Integrated (surface to 20-m) measures												
ABM	1	7.3	29.2	1	8.9	27.0	1	9.2	26.9	1	9.7	25.5
ISA	1	7.3	31.3	3	7.5	31.0	3	8.4	30.5	1	9.5	28.5
ISB	1	7.5	31.1	3	8.3	30.1	3	8.9	30.0	1	9.8	28.0
ISC	1	7.4	31.0	3	9.1	28.9	3	9.5	28.9	1	10.2	26.3
ISD	1	7.8	30.6	3	9.3	28.4	3	9.5	28.9	1	10.3	25.7
UCA	1	7.7	30.3	1	8.7	29.1	1	9.0	30.0	1	9.7	28.5
UCB	1	8.0	30.1	1	8.2	29.9	1	9.3	29.5	1	10.1	26.7
UCC	1	8.0	30.1	1	8.9	28.9	1	9.7	28.9	1	10.3	26.2
UCD	1	7.8	30.3	1	9.2	28.4	1	10.5	27.9	1	10.3	25.6

[a]ABM = Auke Bay Monitor; UC* = Upper Chatham Strait; IS* = Icy Strait

Table 4. Monthly surface chlorophyll (Chl-a) and phaeopigment (Phaeo) concentrations collected June–August 2017.

Station[a]	June		July		August	
	Chl-a	Phaeo	Chl-a	Phaeo	Chl-a	Phaeo
ISA	1.65	1.12	1.98	0.57	2.99	1.29
ISB	4.32	1.28	1.75	0.51	1.68	0.40
ISC	4.76	3.07	2.59	0.66	1.15	0.27
ISD	2.20	1.08	2.58	0.96	2.02	0.82
UCA	6.85	4.78	4.09	1.23	4.79	0.72
UCB	2.66	1.85	3.14	0.82	3.58	0.65
UCC	-	-	4.49	1.05	2.57	0.87
UCD	-	-	2.20	0.60	-	-

[a]UC* = Upper Chatham Strait; IS* = Icy Strait;

Table 5. Monthly zooplankton displacement volumes (DV, ml), standing stocks (DV/m^3), and total densities (number/m^3) from oblique bongo tows (333-µm mesh) collected May–August 2017. Standing stock (ml/m^3) is computed using flowmeter readings to determine water volume filtered. A 1 ml zooplankton volume approximates 1 g biomass. Dash indicates no data.

	May				June				July				August			
Month	Depth (m)	DV	DV/m^3	Total density	Depth (m)	DV	DV/m^3	Total density	Depth (m)	DV	DV/m^3	Total density	Depth (m)	DV	DV/m^3	Total density
ABM	30	25	0.4	-	49	5	0.1	-	41	10	0.1	-	39	2	0	-
ISA	91	140	1.4	4,493.9	95	90	0.6	1,986.0	87	70	0.5	1,140.5	70	30	0.3	576.8
ISB	148	160	0.9	1,554.0	172	205	0.9	3,235.3	178	235	0.9	1,643.8	144	105	0.7	1,231.7
ISC	215	195	0.9	1,806.6	201	195	0.9	1,312.9	200	190	0.6	1,002.1	196	175	0.8	1,229.1
ISD	217	185	0.9	1,609.6	200	170	0.7	1,301.4	199	220	0.8	1,662.6	214	95	0.4	459.7

[a]ABM = Auke Bay Monitor; UC* = Upper Chatham Strait; IS* = Icy Strait

Table 6. Salmonid and non-salmonid catches from rope trawl hauls June–July 2017. See Table 2 for sampling effort by month and habitat. Catches were not adjusted for vessel calibrations.

		Strait	
Species	*Scientific name*	June	July
Salmonids			
Coho (juvenile)	*Oncorhynchus kisutch*	337	76
Chum (juvenile)	*Oncorhynchus keta*	39	83
Pink (adult)	*Oncorhynchus gorbuscha*	31	73
Pink (juvenile)	*Oncorhynchus gorbuscha*	0	48
Sockeye (juvenile)	*Oncorhynchus nerka*	19	23
Chum (adult)	*Oncorhynchus keta*	16	6
Chinook (imm.)	*Oncorhynchus tshawytscha*	12	3
Chinook (juvenile)	*Oncorhynchus tshawytscha*	5	1
Chinook (adult)	*Oncorhynchus tshawytscha*	2	0
Sockeye (adult)	*Oncorhynchus nerka*	2	3
Coho (adult)	*Oncorhynchus kisutch*	1	5
Dolly Varden	*Salvelinus malma*	0	1
Salmonid subtotals		**464**	**322**
Non-salmonids			
Pacific herring	*Clupea pallasii*	9309	96
Walleye pollock larvae	*Gadus chalcogramma*	35	1
Crested sculpin	*Blepsias bilobus*	4	26
Prowfish	*Zaprora silenus*	5	1
Smooth lumpsucker	*Aptocyclus ventricosus*	3	2
Walleye pollock	*Gadus chalcogramma*	2	1
Pacific spiny lumpsucker	*Eumicrotremus orbis*	2	0
Big mouth sculpin	*Hemitripterus bolini*	1	0
Spineless sculpin	*Psychrolutes sp.*	1	0
Silver-spine sculpin	*Blepsias cirrhosus*	1	0
Soft sculpin	*Gilbertidia sigalutes*	1	0
Non-salmonid subtotals		**9364**	**127**

Table 7. Monthly frequency of occurrence of salmonid and non-salmonid catches from rope trawl hauls in strait (n = 32) habitat, June–August 2017.

		Strait	
Common name	Scientific name	June	July
Salmonids			
Coho (juvenile)	*Oncorhynchus kisutch*	13	14
Chum (juvenile)	*Oncorhynchus keta*	10	6
Pink (adult)	*Oncorhynchus gorbuscha*	9	15
Pink (juvenile)	*Oncorhynchus gorbuscha*	0	4
Sockeye (juvenile)	*Oncorhynchus nerka*	7	8
Chum (adult)	*Oncorhynchus keta*	6	3
Chinook (imm.)	*Oncorhynchus tshawytscha*	6	3
Chinook (juvenile)	*Oncorhynchus tshawytscha*	3	1
Chinook (adult)	*Oncorhynchus tshawytscha*	2	0
Sockeye (adult)	*Oncorhynchus nerka*	2	2
Coho (adult)	*Oncorhynchus kisutch*	1	3
Dolly Varden	*Salvelinus malma*	0	1
Non-salmonids			
Pacific herring	*Clupea pallasii*	9	4
Walleye pollock larvae	*Gadus chalcogramma*	7	1
Crested sculpin	*Blepsias bilobus*	4	12
Prowfish	*Zaprora silenus*	3	1
Smooth lumpsucker	*Aptocyclus ventricosus*	2	2
Walleye pollock	*Gadus chalcogramma*	2	1
Pacific spiny lumpsucker	*Eumicrotremus orbis*	2	0
Big mouth sculpin	*Hemitripterus bolini*	1	0
Spineless sculpin	*Psychrolutes sp.*	1	0
Silver-spine sculpin	*Blepsias cirrhosus*	1	0
Soft sculpin	*Gilbertidia sigalutes*	1	0

Table 8. Monthly length (mm, fork), weight (g), condition residuals (CR) from length-weight regression analysis, and energy density (kJ/g) of juvenile salmon captured during June-July 2017.

	June			July		
Factor	n	mean	se	n	mean	se
			Pink salmon			
Length	-	-	-	48	128	1.6
Weight	-	-	-	48	19.9	0.7
CR	-	-	-	48	0.02	0.01
Energy	-	-	-	10	21.4	0.1
			Chum salmon			
Length	37	96	1.5	83	140	1.5
Weight	37	7.7	0.4	83	27.4	0.9
CR	37	-0.09	0.03	83	-0.01	0.01
Energy	10	20.8	0.1	10	21.0	0.2
			Sockeye salmon			
Length	19	105	5.4	23	152	4.2
Weight	19	12.3	2.1	23	37.6	2.8
CR	19	-0.08	0.03	23	-0.01	0.01
Energy	10	21.5	0.3	10	21.7	0.1
			Coho salmon			
Length	253	165	1.5	76	188	2.9
Weight	253	54.5	1.5	76	74.8	4.6
CR	253	0.01	0.01	76	-0.08	0.01
Energy	10	21.0	0.1	10	20.6	0.0
			Chinook salmon			
Length	5	201	5.1	1	249	-
Weight	5	111.2	11.9	1	182.0	-
CR	5	0.06	0.03	1	-0.13	-
Energy	5	21.2	0.2	1	20.3	-

Table 9. Monthly coded-wire tag (CWT) data from coho and Chinook salmon lacking an adipose fin, captured during June–July 2017.

		Release Information						Recovery Information						
Species	CWT code	Brood year	Agency[a]	Locality (Alaska)	Date	FL[b]	Wt[c]	Station	2017 date	FL	Wt	Age	DSR[d]	Dist[e]
June														
Chinook	044299	2014	DIPAC	Lena Cove	6/5/16		39	UCA	7/1	359	620	1.1	391	60
Coho	044566	2015	DIPAC	Gastineau Channel	5/11/17	100	28	UCC	7/1	219	124	1.0	51	70
Coho	044166	2015	ADFG	Berners River	5/9/17	100		ISB	7/2	155	40	1.0	54	90
Coho	042096	2015	ADFG	Berners River	5/10/17	100		ISC	7/2	172	56	1.0	53	90
Coho	044780	2015	ADFG	Taku River	4/12/17	69	3	ISC	7/2	127	26	1.0	81	120
Coho	No tag							ISC	7/2	154	36			
July														
Coho	044164	2015	NMFS	Auke Creek	2017	113	14	ISA	7/29	201	80	1.0		65

[a]Agency: ADFG = Alaska Department of Fish and Game; DIPAC = Douglas Island Pink and Chum, Inc.; NMFS = National Marine Fisheries Service.
[b]FL: Fork length (mm)
[c]Wt: Weight (g)
[d]DSR: Days since release, may include freshwater residency, such as for salmon fry marked and released in fall that over-wintered in freshwater and smolted the subsequent year.
[e]Dist: Distance from release location (km)

Table 10. Information on 118 juvenile chum salmon released from regional enhancement sites and captured during June–July 2017. Factor includes length (mm, fork), weight (g), and condition residual (CR) from length-weight regression analysis and are reported for each Agency—Release site. LL in Agency—Release site denotes a late, large release strategy was used. See Table 9 for Agency acronyms. Dashes indicate no samples.

	June			July		
Factor	n	mean	se	n	mean	se
AKI – Port Armstrong						
Length	-	-	-	1	166	-
Weight	-	-	-	1	42.0	-
CR	-	-	-	1	-0.09	-
DIPAC – multiple sites						
Length	31	94	1	17	139	2
Weight	31	7.0	0.3	17	26.6	1.3
CR	31	-0.04	0.04	17	0.01	0.02
NSRAA – Kasnyku Bay						
Length	1	119	-	20	143	3
Weight	1	14.0	-	20	29.1	1.6
CR	1	-0.10	-	20	0.01	0.01
NSRAA – Kasnyku Bay LL						
Length	-	-	-	1	141	-
Weight	-	-	-	1	30.0	-
CR	-	-	-	1	0.1	-
NSRAA – Southeast Cove						
Length	-	-	-	8	138	4
Weight	-	-	-	8	25.2	2.4
CR	-	-	-	8	-0.03	0.02
NSRAA – Southeast Cove LL						
Length	-	-	-	3	140	5
Weight	-	-	-	3	27.3	2.9
CR	-	-	-	3	0.03	0.02
SSRAA – Anita Bay						
Length	-	-	-	3	149	7
Weight	-	-	-	3	33.3	3.5
CR	-	-	-	3	0.02	0.07
SSRAA – Burnett Inlet						
Length	-	-	-	1	143	-
Weight	-	-	-	1	28.0	-
CR	-	-	-	1	-0.01	-

Factor	June n	June mean	June se	July n	July mean	July se
SSRAA – Neets Bay (summer)						
Length	-	-	-	7	151	4
Weight	-	-	-	7	34.6	3.5
CR	-	-	-	7	0.00	0.03
Unmarked						
Length	4	103	3	21	131	4
Weight	4	11.5	1.3	21	23.0	2.0
CR	4	0.16	0.04	21	0.01	0.02

Table 11. Information on 40 juvenile sockeye salmon released from regional enhancement sites and captured during June–July 2017. Factor includes length (mm, fork), weight (g), and condition residual (CR) from length-weight regression analysis and are reported for each Agency—Release site. See Table 9 for Agency acronyms. Dashes indicate no samples.

	June			July		
Factor	n	mean	se	n	mean	se
			DIPAC – Speel Arm			
Length	5	122	6.4	2	154	13
Weight	5	18	2.6	2	42	12
CR	5	0	0.05	2	0.1	0.02
			DIPAC – Tahltan Lake			
Length	-	-	-	5	151	4.8
Weight	-	-	-	5	34.4	3.5
CR	-	-	-	5	-0.01	0.02
			Unmarked			
Length	13	100	6.5	15	152	6.2
Weight	13	10.8	2.6	15	37.7	4
CR	13	-0.02	0.05	15	0.01	0.02

Table 12. Information on stomachs from 153 potential predators of juvenile salmon captured during June–July 2017. Factors include fork length (mm), wet weight (g), stomach content as percent body weight (%BW) and feeding intensity (0–100% volume fullness). Dash indicates no samples. See Tables 6 and 7 for species information.

	June			July		
Factor	n	mean	Sd	n	mean	sd
Chinook salmon (Adult)						
Length	3	648	129	-	-	-
Weight	3	4,097	2,695	-	-	-
%BW	3	0	-	-	-	-
Fullness	3	37	64	-	-	-
Chinook salmon (Immature)						
Length	11	376	43	3	470	105
Weight	11	736	318	3	1,513	907
%BW	11	1	1	3	1	2
Fullness	11	32	41	3	40	61
Chum salmon (Adult)						
Length	18	661	40	-	-	-
Weight	18	3,551	486	-	-	-
%BW	18	0	-	-	-	-
Fullness	18	0	-	-	-	-
Coho salmon (Adult)						
Length	1	564	-	5	578	29
Weight	1	2,010	-	5	2,438	390
%BW	1	0	-	5	3	2
Fullness	1	0	-	5	108	4
Pink salmon (Adult)						
Length	31	557	47	70	502	42
Weight	31	2,313	644	70	1,480	420
%BW	31	0	-	70	0	-
Fullness	31	9	22	70	21	29
Sockeye salmon (Adult)						
Length	2	559	11	9	628	58
Weight	2	2,280	42	9	3,114	1,039
%BW	2	0	-	9	0	-
Fullness	2	0	-	9	11	25

Table 13. Information on stomachs from 76 juvenile salmon captured during June–July 2017. Factors include fork length (mm), wet weight (g), stomach content as percent body weight (%BW) and feeding intensity (0–100% volume fullness). Dash indicates no samples. See Tables 6 and 7 for species information.

	June			July		
Factor	n	mean	Sd	n	mean	sd
Pink salmon						
Length	-	-	-	10	131	5
Weight	-	-	-	10	25	2
%BW	-	-	-	10	2.7	1.5
Fullness	-	-	-	10	88	18
Chum salmon						
Length	10	88	4	10	134	8
Weight	10	6	1	10	26	5
%BW	10	0.7	0.6	10	1.9	1.1
Fullness	10	34	24	10	80	20
Sockeye salmon						
Length	10	119	15	10	138	3
Weight	10	18	8	10	30	2
%BW	10	1.5	1.0	10	1.7	1.2
Fullness	10	68	31	10	78	25
Coho salmon						
Length	10	166	12	10	166	4
Weight	10	59	15	10	48	4
%BW	10	0.8	1.4	10	2.3	1.5
Fullness	10	28	39	10	90	13
Chinook salmon						
Length	5	192	9	1	249	-
Weight	5	110	26	1	182	-
%BW	5	1.5	0.9	1	0.0	-
Fullness	5	85	22	1	0	-

Table 14. Feeding intensity of 153 potential predators of juvenile salmon captured during June-July 2017 (see Table 12). Dash indicates an undefined value where a zero was in the denominator.

Species	Number examined	Number empty	Percent feeding	Number w/ salmon	Percent w/salmon
Chinook salmon (Adult)	3	2	33.0	0	0.0
Chinook salmon (Immature)	16	5	69.0	0	0.0
Chum salmon (Adult)	18	18	0.0	0	-
Coho salmon (Adult)	8	1	88.0	0	0.0
Pink salmon (Adult)	127	56	56.0	0	0.0
Sockeye salmon (Adult)	12	9	25.0	0	0.0

Table 15. Feeding intensity of 76 juvenile salmon captured during June–July 2017 (see Table 13). Dash indicates an undefined value where a zero was in the denominator.

Species	Number examined	Number empty	Percent feeding
Pink salmon	10	0	100
Chum salmon	20	1	95
Sockeye salmon	20	0	100
Coho salmon	20	4	80
Chinook salmon	6	1	83

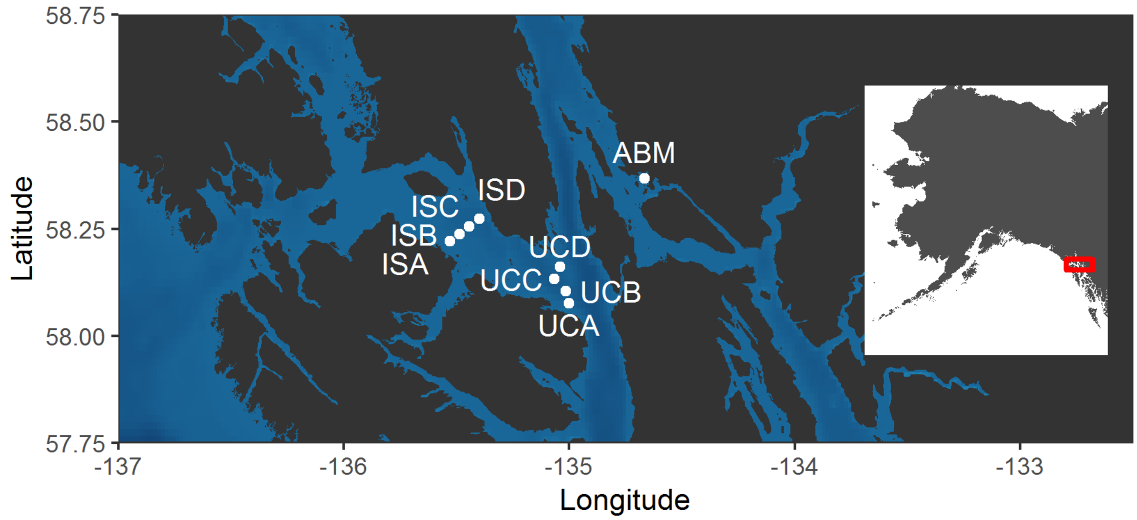

Figure 1. Stations sampled at during May–August 2017. See Table 1 for stations details.

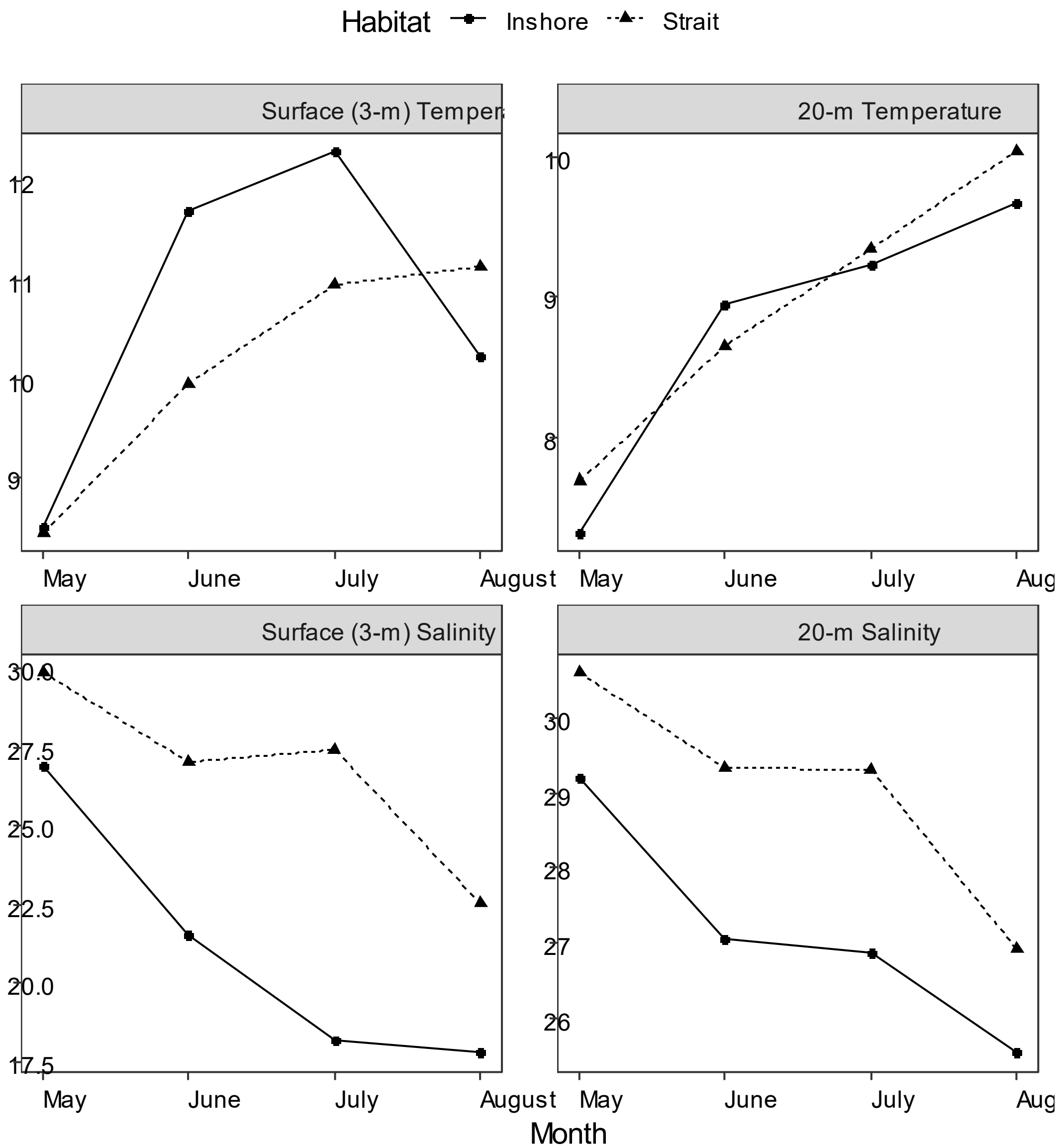

Figure 2. Mean surface (3-m) and 20-m integrated temperature (°C; average of top 20 m temperatures) (top) and salinity (PSU) (bottom). The surface measures represent the active segment of the water column, while the 20-m represent more stable waters sampled by trawl.

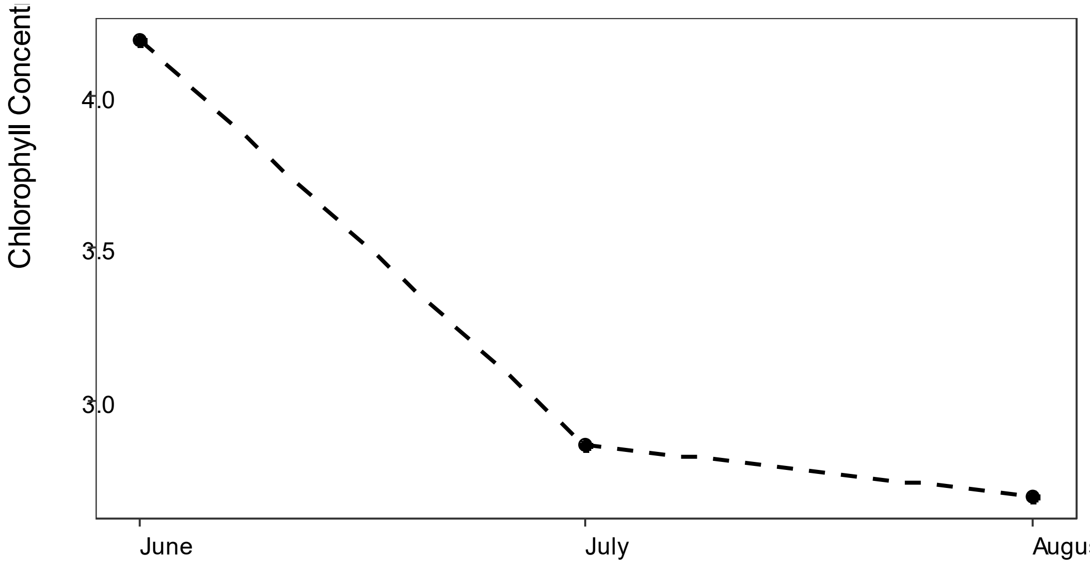

Figure 3. Mean chlorophyll-a concentration (µg/L) from surface water samples collected June-August 2017.

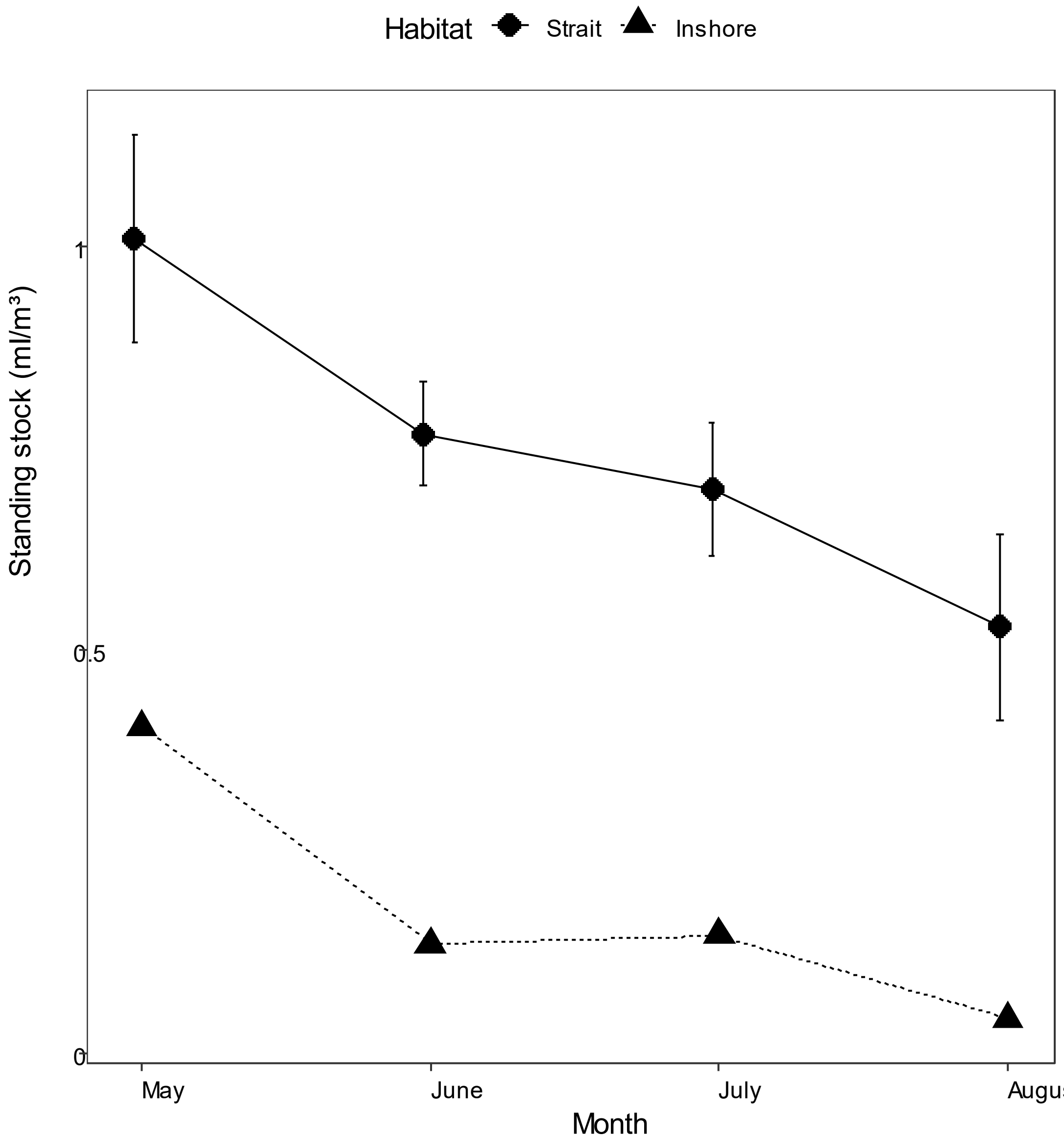

Figure 4. Monthly zooplankton standing stock (ml/m^3; +/- 1 standard error) from 333-µm mesh oblique bongo net samples towed from less than or equal to 200-m depths during daylight, May–August 2017.

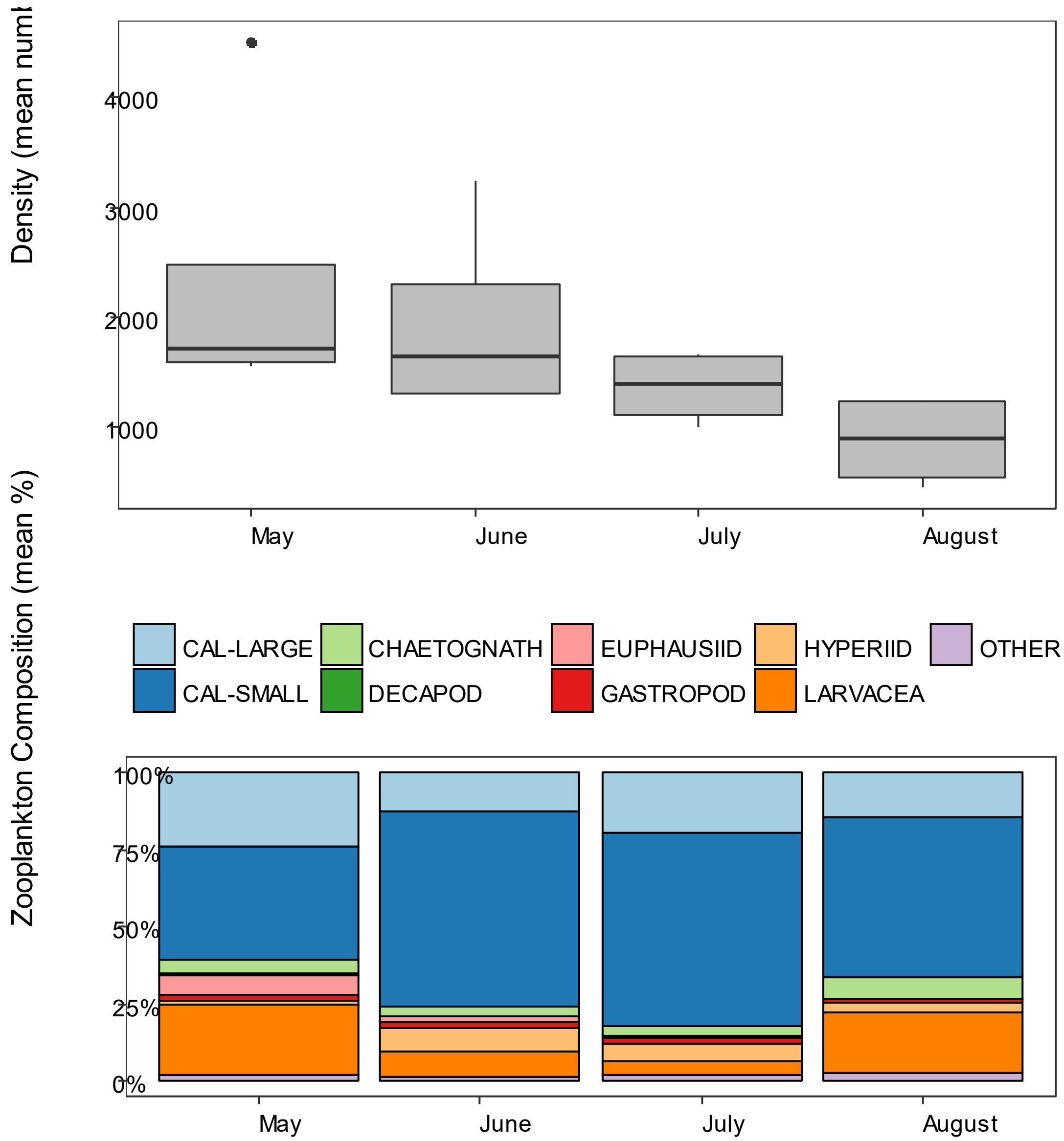

Figure 5. Monthly zooplankton density with standard error (top); and taxonomic composition (bottom) from 333-um mesh oblique bongo net samples towed from less than or equal to 200-m depths during daylight, May–August 2017. Cal-large and Cal-small are calanoid copepods.

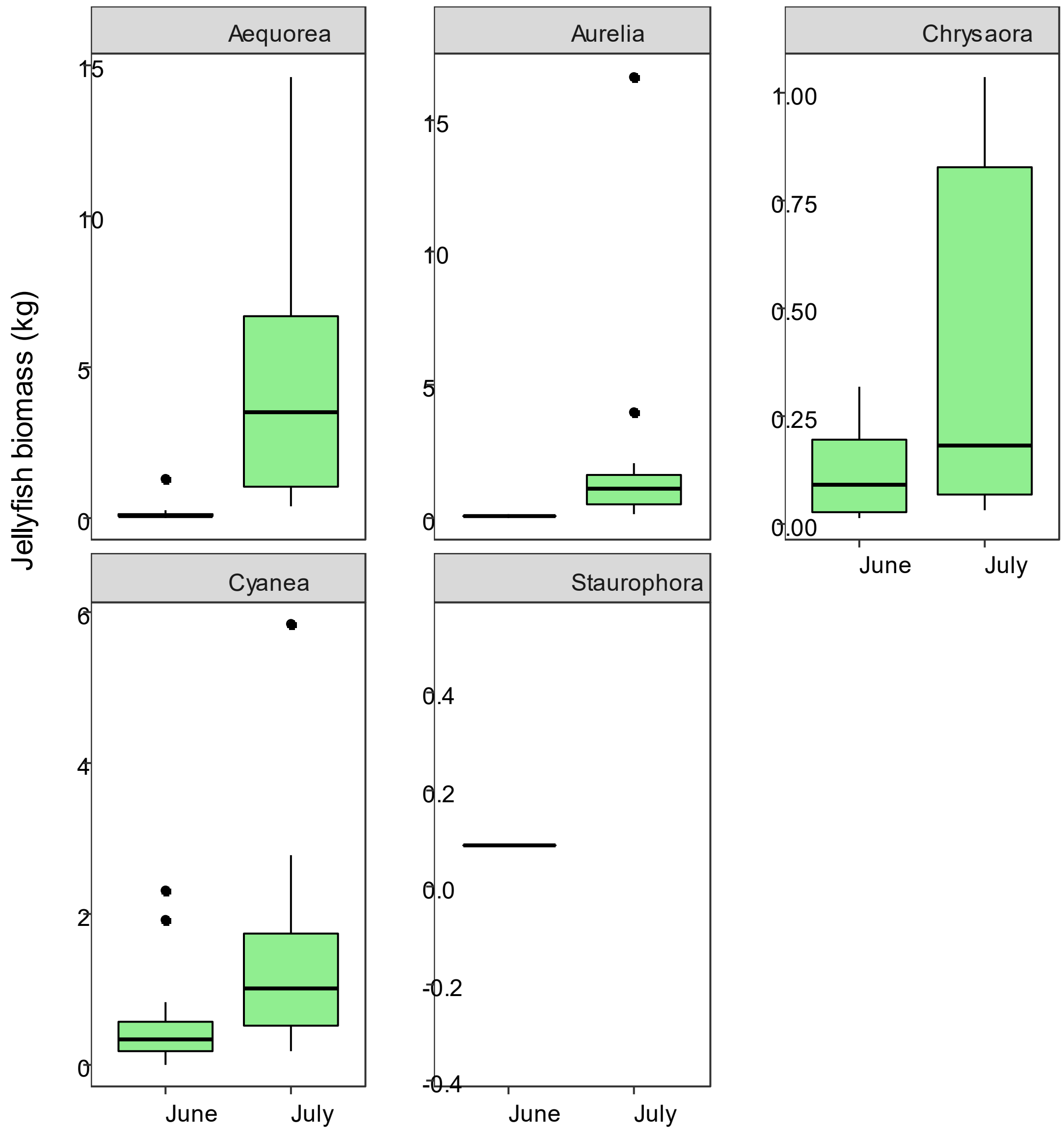

Figure 6. Monthly mean biomass (kg) of jellyfish captured during June–July 2017.

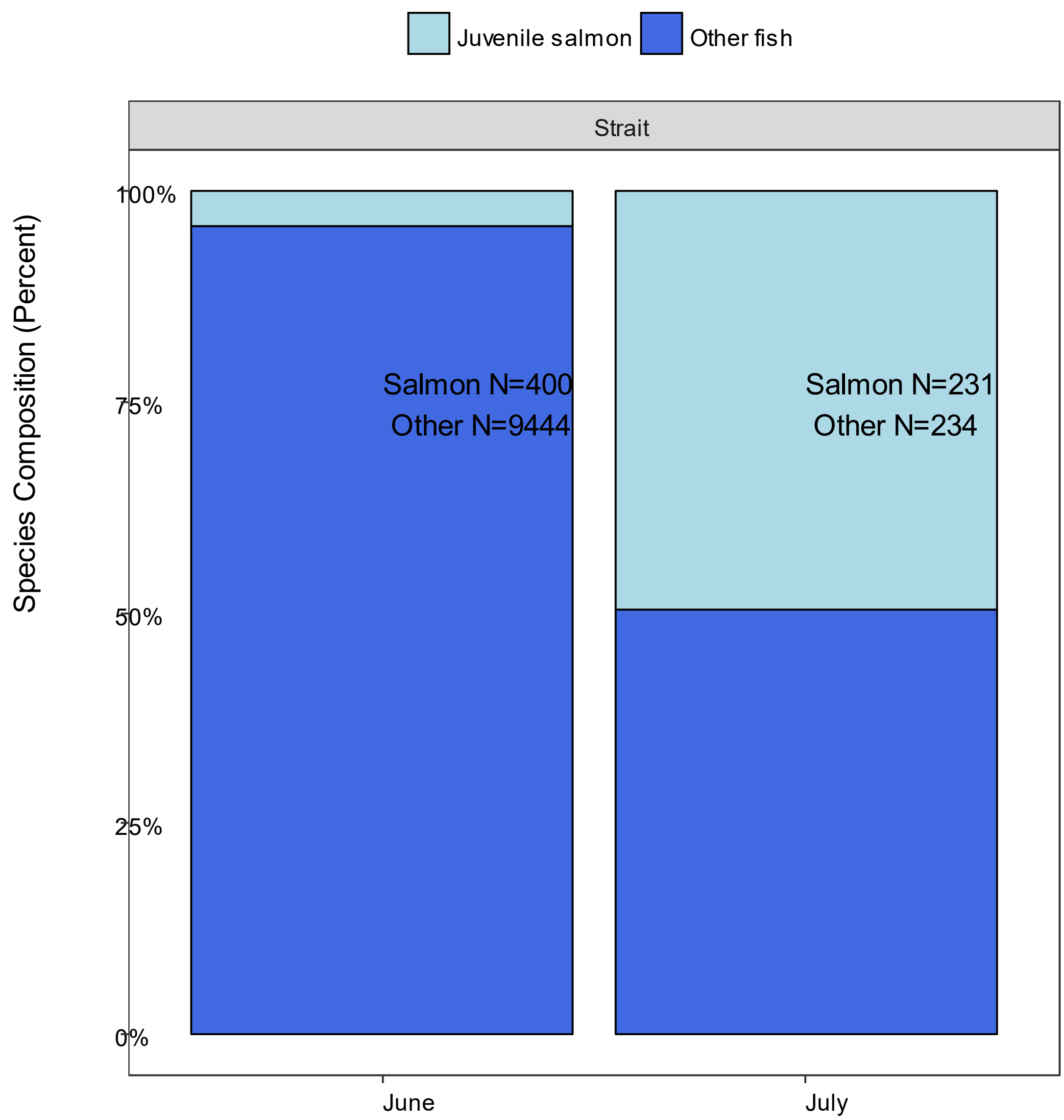

Figure 7. Monthly fish composition from rope trawl catches during June–July 2017. Total numbers of fish are indicated in bars.

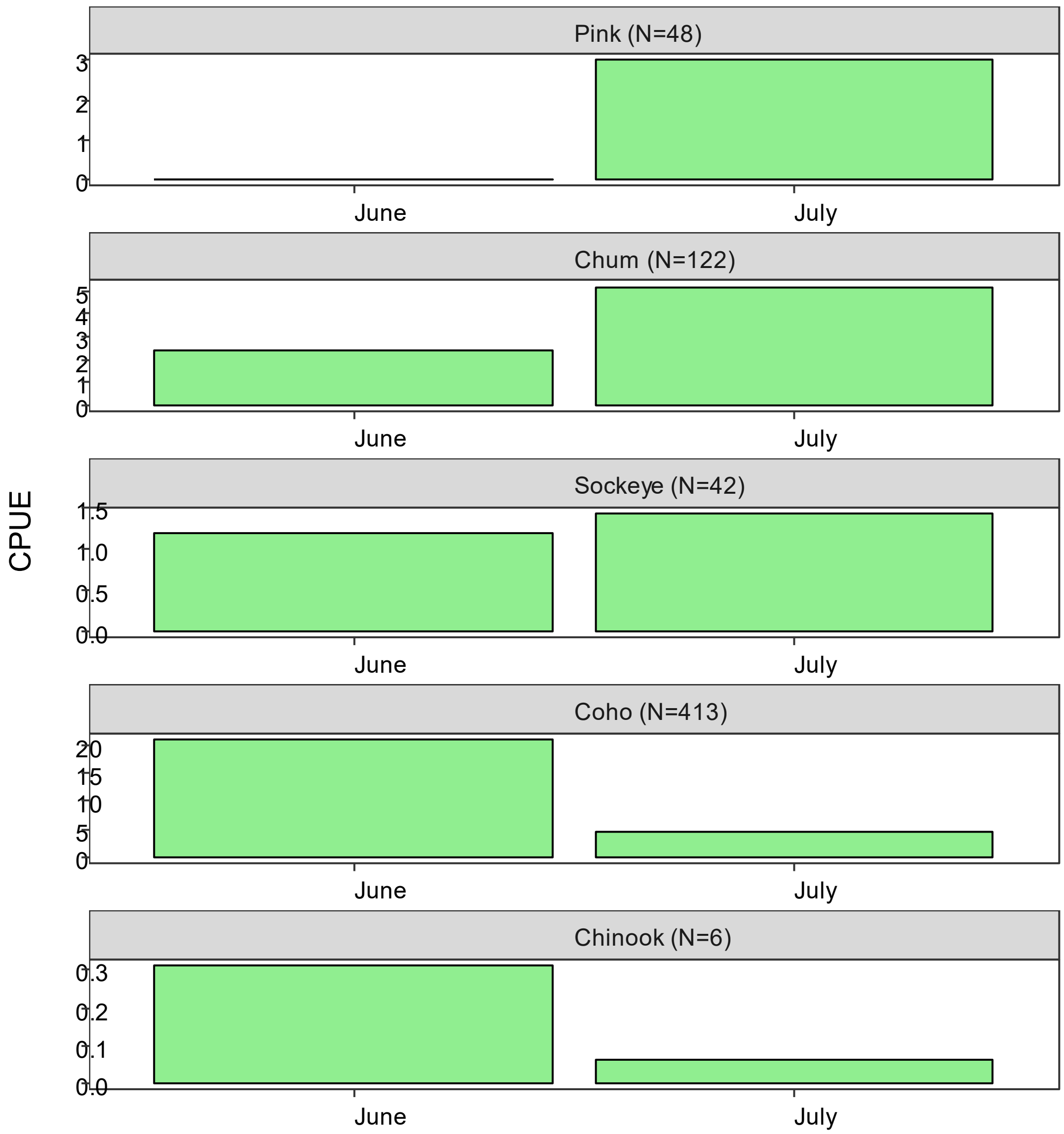

Figure 8. Monthly catch-per-unit-effort (CPUE) of juvenile salmon, June–July 2017. Total season catch (N) is indicated for each species.

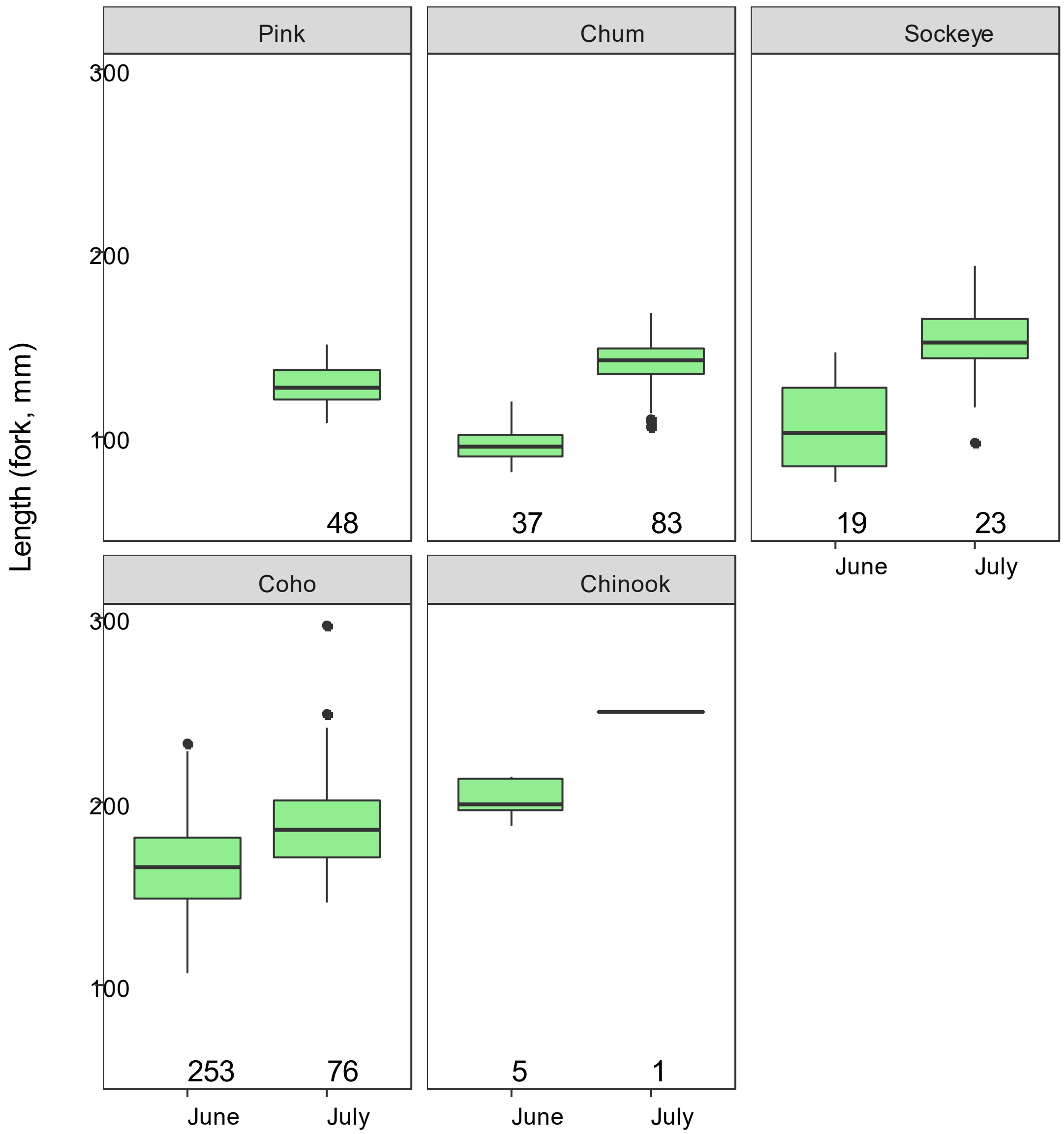

Figure 9. Monthly length (mm, fork) distributions of juvenile salmon caught during June–July 2017. Horizontal bars represent medians and box widths are the 25th and 75th percentiles. Whiskers extend 1.5 times the box span (interquartile range).

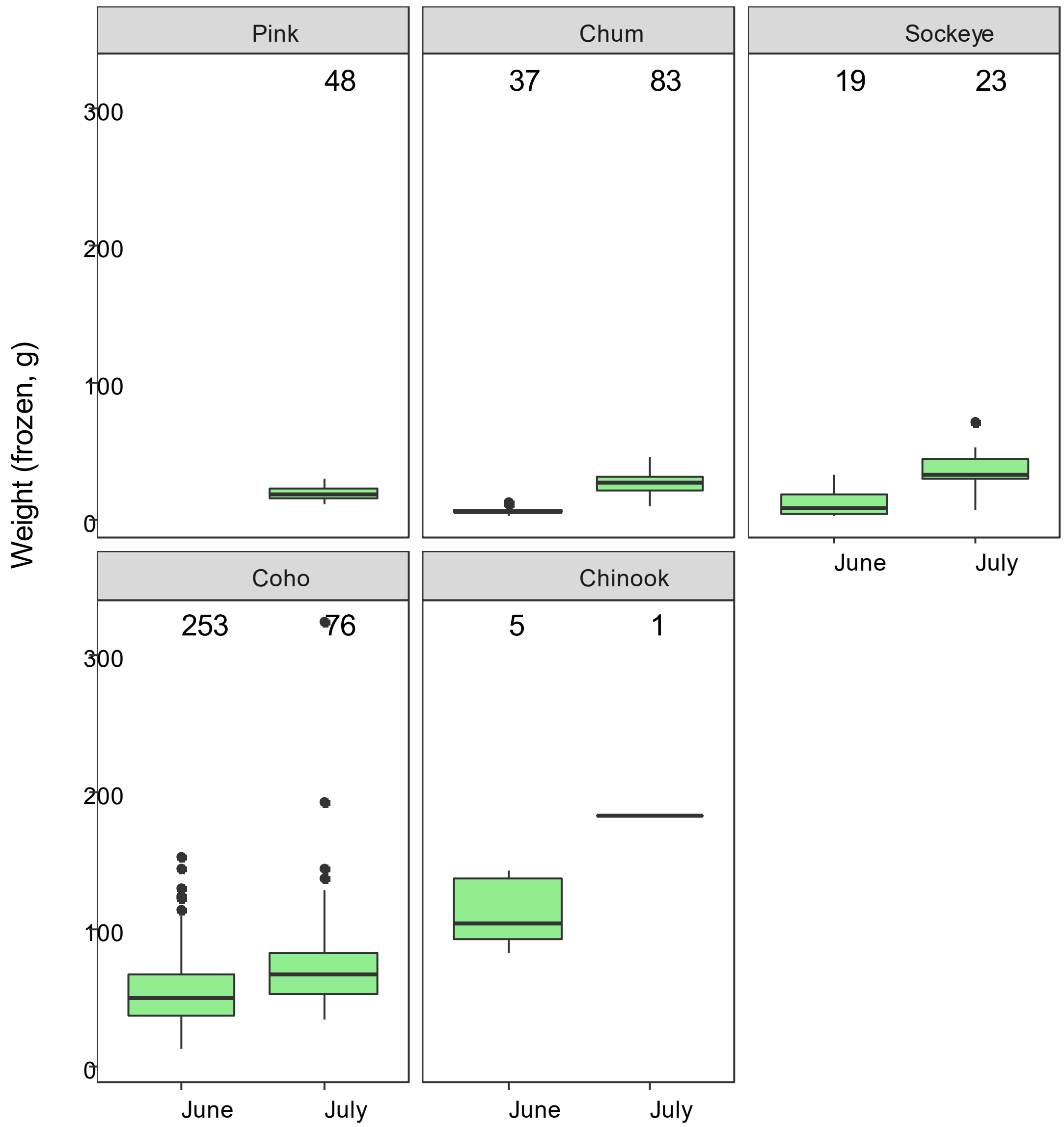

Figure 10. Monthly weight (g) distributions of juvenile salmon caught during June–July 2017. Horizontal bars represent medians and box widths are the 25th and 75th percentiles. Whiskers extend 1.5 times the box span (interquartile range).

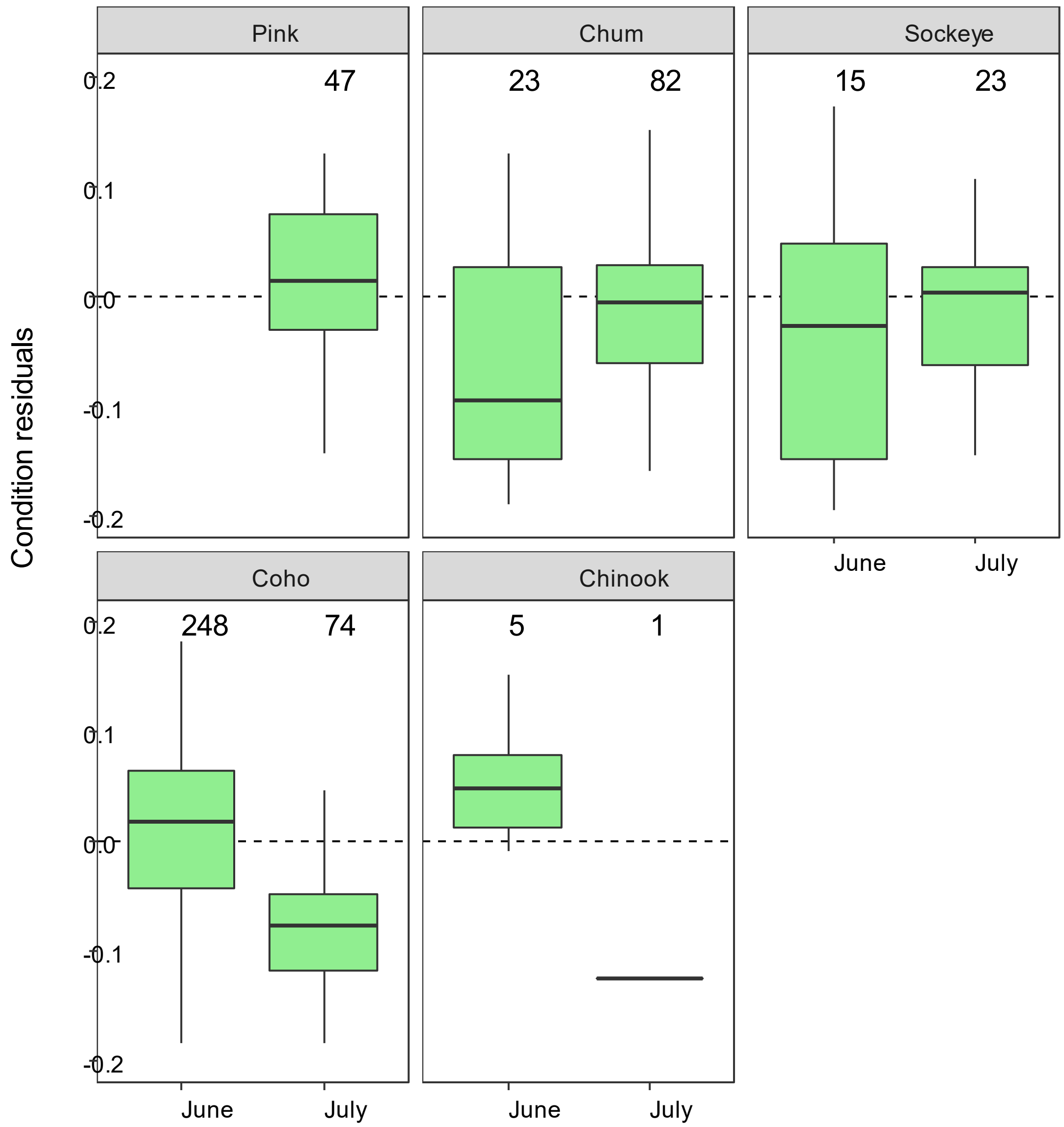

Figure 11. Condition residuals from length-weight regressions of juvenile salmon captured during June–July 2017. Sample sizes are given as numbers in above each box.

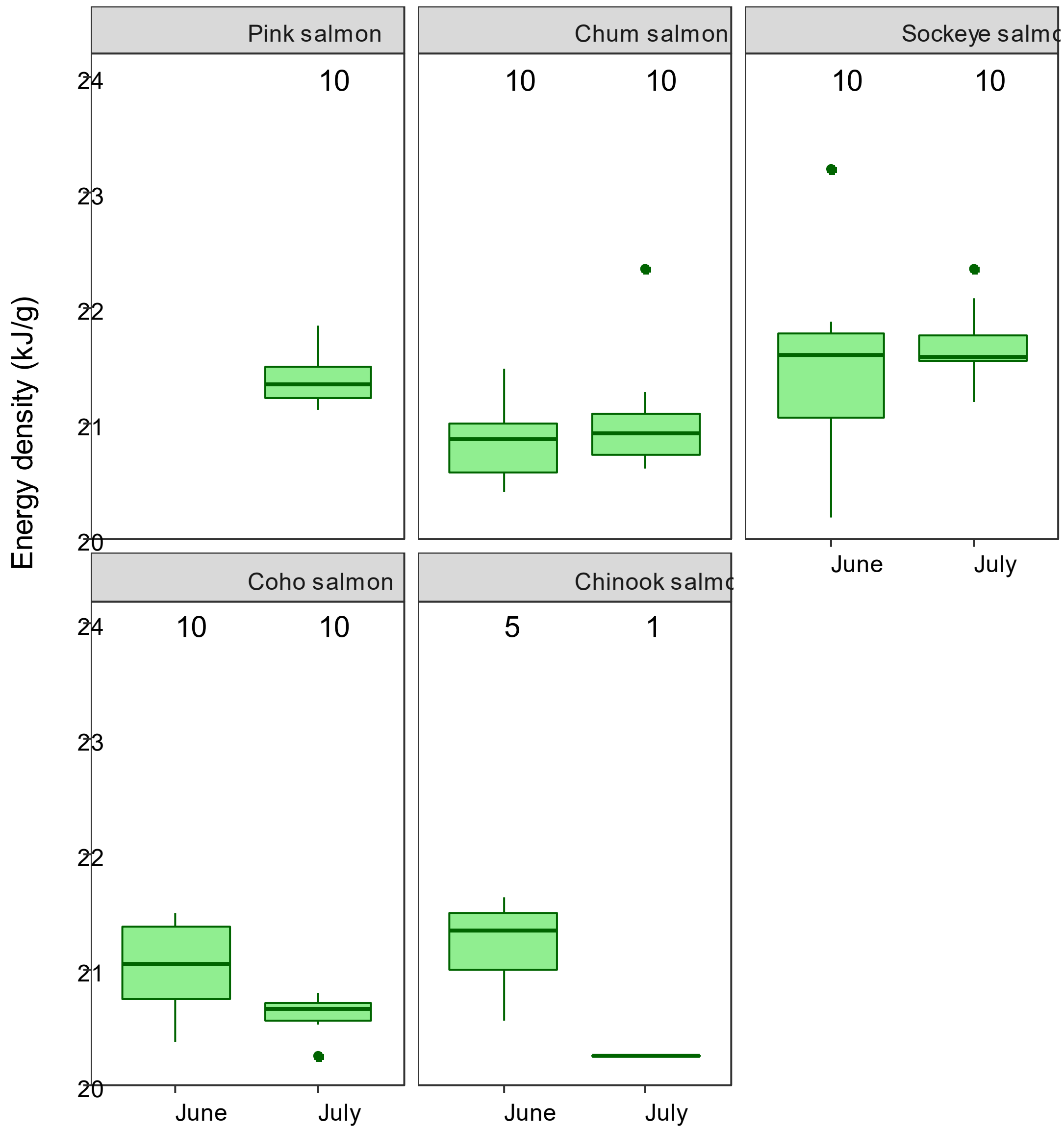

Figure 12. Energy density (kJ/g dry weight) of juvenile salmon captured during June–July 2017. Sample sizes are given as numbers in above each box.

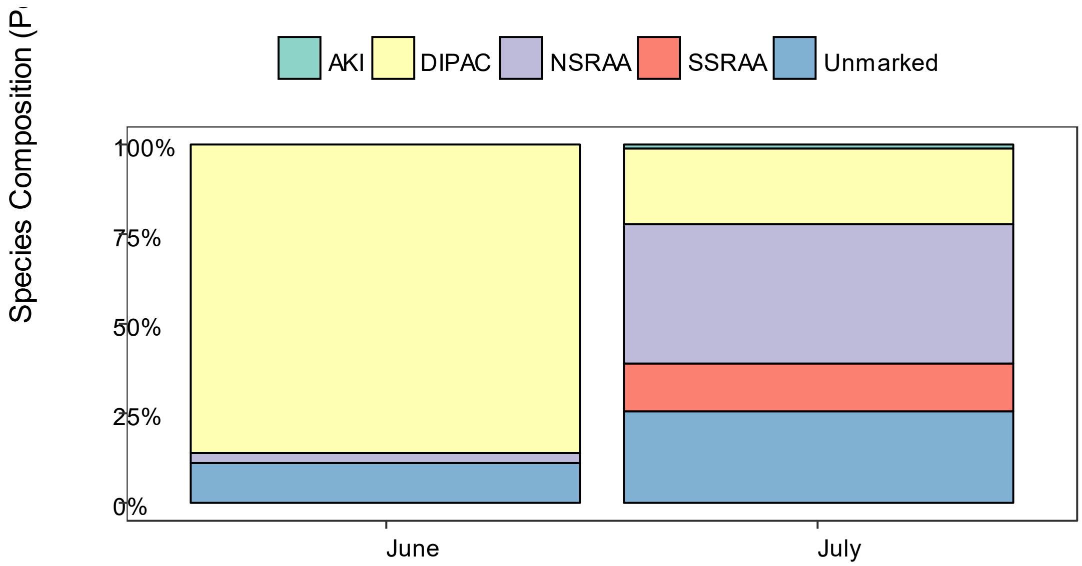

Figure 13. Monthly stock composition (based on otolith marks) of juvenile chum salmon captured during June–July 2017.

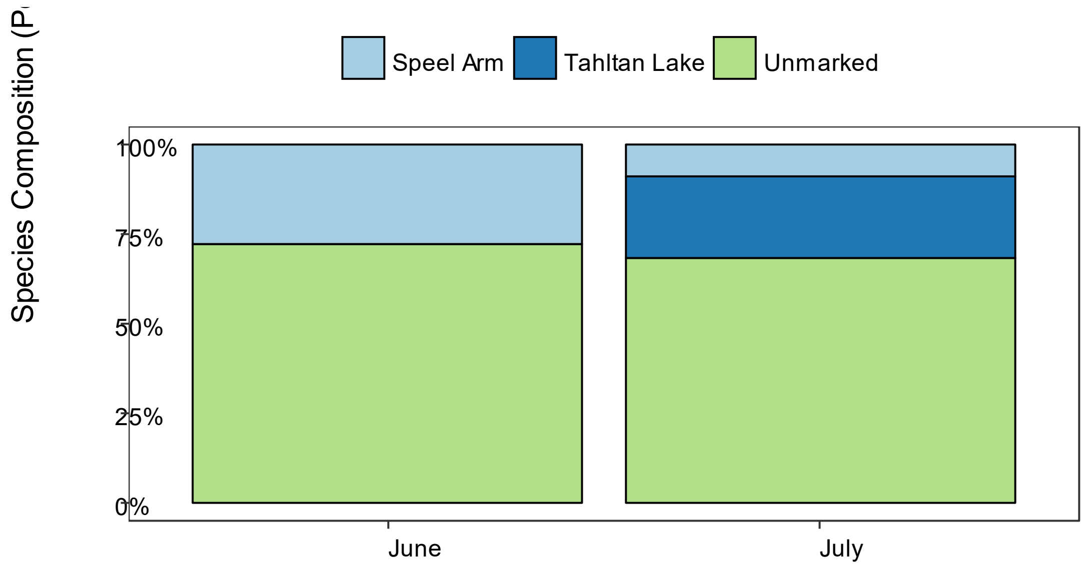

Figure 14. Monthly stock composition (based on otolith marks) of juvenile sockeye salmon captured during June–July 2017.

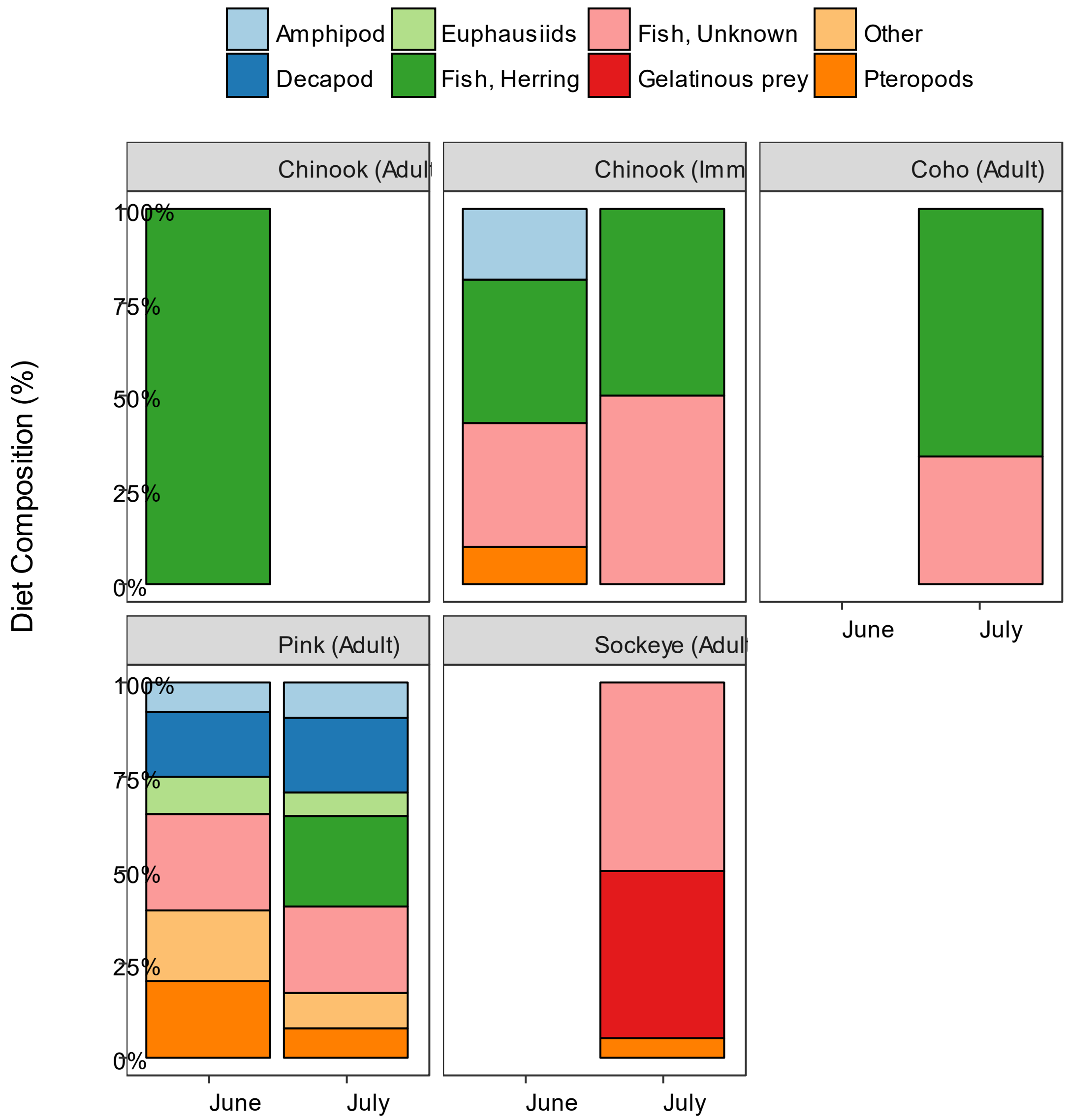

Figure 15. Diet composition (% by weight) of immature and adult salmon captured during June–July 2017. See Table 12 for sample counts.

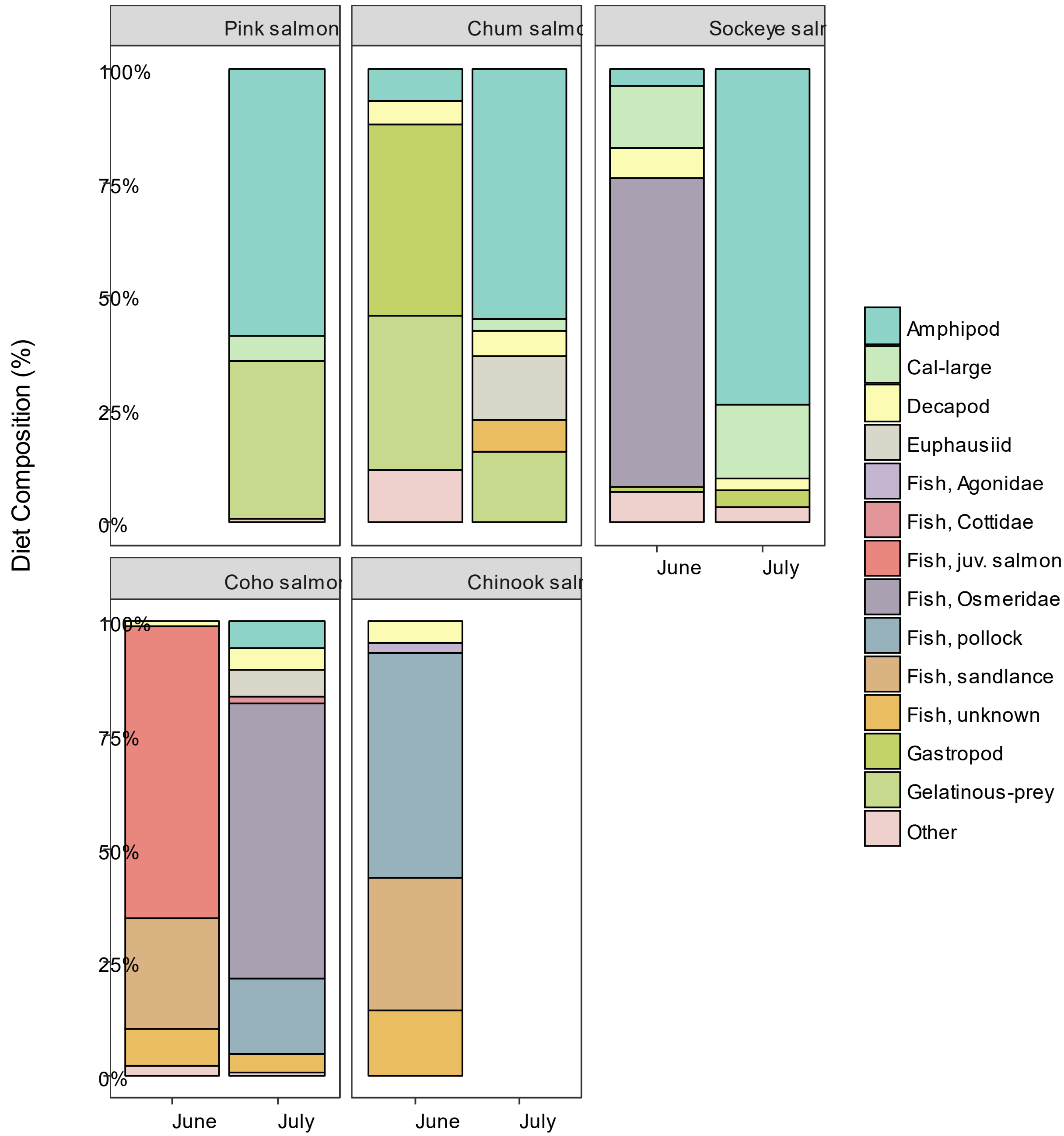

Figure 16. Diet composition (% by weight) of juvenile salmon captured during June–July 2017. See Table 13 for sample counts.