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Southeast Alaska Coastal Monitoring Survey: Salmon Trophic Ecology and Bioenergetics, 2018

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 2018. This annual survey, conducted by the Southeast Coastal Monitoring (SECM) project, marks 22 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. Up to 13 stations were sampled monthly in epipelagic waters from May to August. 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. Coded-wire tags were recovered from two juvenile coho and eight 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 68% of the juvenile chum and 24% of the juvenile sockeye salmon. Of the 14 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. 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 2018, SECM sampling was conducted in the northern region of SEAK for the 22nd 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 is Part 2 of the 2018 summary of data collected by the SECM project in 2018 and includes data from laboratory analyses of juvenile salmon, zooplankton, and phytoplankton collections.

METHODS

Sampling was conducted in the northern region of SEAK monthly from May to August 2018. 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, July, and August. The 12 m NOAA vessel R/V *Sashin* was used for sampling in May. The Alaska Department of Fish and Game research vessel, RV *Medeia*, a 33 m stern trawler with twin engines producing 1,250 HP, was used for sampling in June through August.

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). For full sampling methodology, see Murphy et al. 2019.

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 net, to 200 m or within 20 m of the bottom. The data from the CTD profiles is summarized in the 2018 Part 1 summary document (Murphy et al. 2019). Water samples for chlorophyll (µg/L) concentrations were taken at the surface once at each station per month.

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

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.

Fish sampling

Fish sampling was accomplished with a Nordic 264 rope trawl modified to fish the surface water directly astern of the trawl vessel. For detailed trawl methods see Murphy et al. 2019.

After each trawl haul, the fish were separated from the jellyfish, identified, enumerated, measured, labeled, bagged, and frozen for laboratory analyses. 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 compositions of thermally marked fish were determined for each month and habitat.

RESULTS AND DISCUSSION

In 2018, up to 13 stations were sampled from Stephens Passage to Icy Strait monthly from May to August (Table 1; Figure 1). In total, data were collected from 78 rope trawl hauls, 48 CTD casts, 16 bongo net samples, and 48 surface water samples during 16 days at-sea.

Oceanography

Chlorophyll-a concentrations ranged from 0.20 to 11.35 µg/L from May to August and averaged 2.46 µg/L for all habitats (Table 2; Figure 2). For inshore habitat, chlorophyll concentrations were similar in May through July then peaked in August. For strait habitat, chlorophyll concentrations were highest in May and declined seasonally to August.

Zooplankton standing stock from oblique bongo net tows (333-µm mesh) ranged from 0.4 to 0.9 ml/m^3 from May to August and averaged 0.7 ml/m^3 (Table 3; Figure 3). Mean standing stock was highest in May, decreased in June and July, then increased in August. Seasonal total density of zooplankton prey fields from oblique bongo tows (333-µm mesh) at stations in Icy Strait ranged from 861 to 4,171 organisms/m^3 from May to August and averaged 2,323 organisms/m^3 (Table 3; Figure 4). 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.

Juvenile salmon size and condition

Length, weight, condition, and energy density of juvenile salmon differed among species and months (Tables 4–5; Figures 5–8). For inshore habitat, juvenile chum and sockeye average length and weight did not change between July and August, but the juvenile coho and chinook did increase in size from June to August. The lack of increase in size may represent different age classes or stocks entering the marine environment throughout the summer season. For strait habitat, all species increased in length and weight from June to August, with the exception of juvenile Chinook salmon which were only caught in August. The CRs for all species were below average for all months. Energy density was generally constant from June to August.

Juvenile salmon origin

All juvenile coho and juvenile and immature Chinook salmon were scanned (either visually onboard the vessel or electronically in the laboratory) for the presence of CWTs. Stock-specific information was obtained from 10 CWT recoveries from two juvenile coho and eight juvenile Chinook salmon lacking the adipose fin (Table 6). Four additional juvenile Chinook salmon were 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. 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) and Northern Southeast Regional Aquaculture Association (NSRAA). A total of 317 juvenile salmon were examined for thermal marks: 181 chum salmon and 136 sockeye salmon (Tables 7–10; Figures 9–10).

For juvenile chum salmon, stock-specific information was derived from a subsample of 174 from the 322 chum salmon (54%) caught in the strait habitat and all chum salmon (n = 7, 100%) caught in the inshore habitat. For otoliths examined from strait habitat catches, 118 (68%) were marked by hatcheries in SEAK and 56 (32%) were not marked. Of the marked fish, 75

(64%) were from DIPAC and 43 (36%) were from NSRAA. For otoliths examined from inshore habitat catches, only 1 (14%) was marked and was from NSRAA, the remaining 6 (86%) were unmarked. 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 and August (Figure 9).

For juvenile sockeye salmon, stock-specific information was derived from a subsample of 82 from the 90 sockeye salmon (91%) caught in the strait habitat and 54 from the 125 sockeye salmon (43%) caught in the inshore habitat (Tables 9-10). For otoliths examined from strait habitat catches, 25 (30%) were marked by DIPAC and 57 (70%) were not marked. Of the marked fish, 23 (92%) were from Speel Arm, 1 (4%) was from Tatsamenie Lake, and 1 (4%) was from Sweetheart Lake. For otoliths examined from inshore habitat catches, 7 (13%) were marked by DIPAC and released from Sweetheart Lake; the remaining 47 (87%) sockeye salmon were unmarked (Figure 10).

Adult salmon diets

Stomachs of 14 potential predators of juvenile salmon were examined from a suite of four fish species. Of the fish examined, 43% were feeding and no juvenile salmon were found in any of the stomachs (Tables 11-13). Diet compositions differed by predator species and habitat (Figure 11). For feeding fish, the piscivorous immature Chinook and adult coho salmon consumed primarily fish, including walleye pollock, herring, and capelin.

Juvenile salmon diets

Stomachs of 265 juvenile salmon were examined in the laboratory, fish examined for diet composition were the same fish analyzed for energy density (Tables 14–15). Of the fish examined, 93% were feeding (Table 16). Diet compositions differed by species and habitat (Figure 12). For feeding fish in the inshore habitat, the planktivorous juvenile sockeye salmon surprisingly consumed mostly sandlance with minimal amounts of amphipods and euphausiids. Piscivorous juvenile coho consumed amphipods, euphausiids, and fish (digested) while juvenile Chinook consumed mainly sandlance and quillfish. For feeding fish in the strait habitat, the planktivorous juvenile pink, chum, and sockeye salmon consumed mostly invertebrates including hyperiid amphipods, gelatinous prey (oikopleurans), gastropods, and other invertebrates (chaetognaths). Piscivorous juvenile coho and Chinook salmon consumed mostly euphausiids except for June, when the coho exclusively ate pollock larvae.

Summary

This document summarizes the trophic ecology and bioenergetics data of salmon collected during the 2018 SECM survey 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 22-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 stations sampled May–August 2018. Transect and station positions are shown in Figure 1.

Station[a]	Latitude N	Longitude W	Bottom depth (m)
	Inshore habitat		
SPA	58° 10.76’	134° 16.70’	99
SPB	58° 12.09’	134° 23.98’	78
SPC	58° 12.52’	134° 31.62’	56
SPD	58° 14.06’	134° 38.55’	64
SPE*	58° 17.61’	134° 42.14’	107
SP1*	58° 11.55’	134° 21.60’	76
SP2*	58° 12.37’	134° 26.52’	68
TKI*	58° 11.19’	134° 11.71’	175
	Strait habitat		
UCA	58°04.57’	135°00.08’	400
UCB	58°06.22’	135°00.91’	100
UCC	58°07.95’	135°01.69’	100
UCD	58°09.64’	135°02.52’	200
ISA	58°13.25’	135°31.76’	128
ISB	58°14.22’	135°29.26’	200
ISC	58°15.28’	135°26.65’	200
ISD	58°16.38’	135°23.98’	234

[a] SP* = Stephens Passage; TKI = Taku Inlet; UC* = Upper Chatham Strait; IS* = Icy Strait

Table 2. Monthly surface chlorophyll (Chl-a) and phaeopigment (Phaeo) concentrations collected June–August 2018.

	June		July		August	
Station[a]	Chl-a	Phaeo	Chl-a	Phaeo	Chl-a	Phaeo
			Inshore habitat			
SPA	1.96	6.04	0.45	1.37	2.16	0.80
SPB	—	—	—	—	0.95	0.51
SPC	—	—	1.54	1.31	—	—
SPD	—	—	0.79	1.16	1.24	0.60
SPE	—	—	0.20	0.25	5.53	1.62
SP1	1.78	5.55	—	—	—	—
SP2	0.99	3.51	1.07	1.07	—	—
TKI	2.09	2.86	—	—	—	—
			Strait habitat			
ISA	2.23	0.97	1.54	1.63	1.70	0.59
ISB	2.77	1.12	1.47	1.70	1.43	0.51
ISC	2.37	1.77	4.28	2.75	1.27	0.44
ISD	2.85	1.10	7.03	4.46	0.92	0.42
UCA	3.67	2.11	0.62	0.43	1.63	0.58
UCB	2.78	1.80	0.88	0.94	2.11	1.12
UCC	2.55	1.78	3.61	3.09	1.02	0.34
UCD	1.62	1.09	2.30	1.69	0.89	0.35

[a] UC* = Upper Chatham Strait; IS* = Icy Strait; SP* = Stephens Passage; TKI = Taku Inlet

Table 3. 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 2018. Standing stock (ml/m^3) is computed using flowmeter readings to determine water volume filtered. A 1 ml zooplankton volume approximates 1 g biomass.

	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
ISA	59	75	0.7	3438.6	80	60	0.6	1771.8	94	55	0.5	2915.0	93	70	0.9	2754.0
ISB	140	155	0.9	2868.3	177	120	0.7	1622.2	180	105	0.9	4171.4	171	100	0.9	1729.7
ISC	201	155	0.8	2436.5	202	180	0.8	1736.4	205	120	0.5	1511.4	201	70	0.6	2109.6
ISD	215	170	0.8	2741.8	202	135	0.6	2964.8	188	80	0.4	860.7	201	95	0.6	1535.5

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

Table 4. Monthly length (mm, fork), weight (g), condition residuals (CR) from length-weight regression analysis, and energy density (kJ/g) of juvenile salmon captured in the strait habitat during June–August 2018.

	June			July			August		
Factor	n	mean	se	n	mean	se	n	mean	se
Pink salmon									
Length	—	—	—	41	112	2	41	152	3
Weight	—	—	—	41	12.1	0.6	41	34.5	2.3
CR	—	—	—	41	-0.26	0.01	41	-0.13	0.01
Energy	—	—	—	10	21.3	0.2	10	21.2	0.1
Chum salmon									
Length	54	100	1	120	131	2	45	175	3
Weight	54	9.0	0.2	120	22.7	0.8	45	55.9	2.9
CR	54	-0.21	0.01	120	-0.17	0.01	45	-0.15	0.01
Energy	10	21.0	0.1	10	21.4	0.2	10	20.7	0.2
Sockeye salmon									
Length	65	116	2	10	122	6	14	174	6
Weight	65	15.1	0.8	10	18.7	3.2	14	55.7	5.7
CR	65	-0.20	0.01	10	-0.09	0.01	14	-0.21	0.03
Energy	10	21.4	0.2	8	21.5	0.2	10	22.1	0.3
Coho salmon									
Length	49	159	4	24	186	7	16	230	8
Weight	49	47.1	3.2	24	72	7.6	16	142.6	12.6
CR	49	-0.15	0.01	24	-0.19	0.01	16	-0.19	0.02
Energy	10	21.7	0.3	10	20.7	0.2	11	21.2	0.2
Chinook salmon									
Length	—	—	—	—	—	—	1	187	—
Weight	—	—	—	—	—	—	1	77.0	—
CR	—	—	—	—	—	—	1	-0.03	—
Energy	—	—	—	—	—	—	1	21.4	—

Table 5. Monthly length (mm, fork), weight (g), condition residuals (CR) from length-weight regression analysis, and energy density (kJ/g) of juvenile salmon captured in the inshore habitat during June–August 2018.

	June			July			August		
Factor	n	mean	se	n	mean	se	n	mean	se
Pink salmon									
Length	—	—	—	—	—	—	7	146	5
Weight	—	—	—	—	—	—	7	29.9	3.1
CR	—	—	—	—	—	—	7	-0.08	0.02
Energy	—	—	—	—	—	—	—	—	—
Chum salmon									
Length	—	—	—	4	115	12	3	104	4
Weight	—	—	—	4	15.1	4.9	3	9.8	1.4
CR	—	—	—	4	-0.10	0.03	3	-0.12	0.01
Energy	—	—	—	—	—	—	—	—	—
Sockeye salmon									
Length	—	—	—	2	110	0	123	109	1
Weight	—	—	—	2	13.7	0.5	123	11.8	0.4
CR	—	—	—	2	0.04	0.02	123	-0.31	0.01
Energy	—	—	—	2	21.3	0.3	10	21.7	0.2
Coho salmon									
Length	56	137	2	24	201	7	3	195	3
Weight	56	25.2	1.4	24	89.2	9.3	3	82.9	3.5
CR	56	-0.30	0.01	24	-0.26	0.01	3	-0.08	0.03
Energy	10	21.3	0.4	13	20.6	0.2	3	21.6	0.3
Chinook salmon									
Length	40	127	3	32	151	3	58	178	1
Weight	40	22.7	1.9	32	38.9	2.3	58	64.5	1.5
CR	40	-0.18	0.01	32	-0.17	0.01	58	-0.38	0.01
Energy	40	21.4	0.2	32	20.7	0.1	58	21.3	0.1

Table 6. Monthly coded-wire tag (CWT) data from coho and Chinook salmon lacking an adipose fin, captured during June-August 2018.

		Release Information						Recovery Information						
Species	CWT code	Brood year	Agency[a]	Locality (Alaska)	Date	FL[b]	Wt[c]	Station	2018 date	FL	Wt	Age	DSR[d]	Dist[e]
							June							
Chinook	44966	2016	DIPAC	Fish Creek, AK	5/29/2018		29.6	SPC	6/19	146	32.2	1	21	40
Chinook	44964	2016	DIPAC	Gastineau Ch., AK	5/18/2018		27	SPC	6/19	151	39.2	1	32	50
Coho	45038	2016	DIPAC	Thane net pens, AK	5/22/2018		22	SPA	6/20	182	57.9	1	29	39
Chinook	30291	2016	NMFS	Little Port Walter, AK	5/15/2018	127	26.1	SPA	6/20	181	61.1	1	36	315
Coho	44965	2016	DIPAC	Gastineau Ch., AK	5/18/2018		27	UCB	6/22	198	91.6	1	35	73
							July							
Chinook	44967	2016	DIPAC	Gastineau Ch., AK	6/7/2018		31.8	SP2	7/26	156	39.1	1	49	40
Chinook	44866	2016	ADFG	Taku R., AK (Wild)	5/18/2018	82	6	SPC	7/26	141	28.3	1	69	46
Chinook	No tag							SPE	7/26	137	26.1			
Chinook	No tag							SPE	7/27	160	42.9			
Chinook	No tag							ISC	7/28	290	298			
							August							
Chinook	44964	2016	DIPAC	Gastineau Ch., AK	5/18/2018		27	SPA	8/20	180	78.5	1	94	20
Chinook	44866	2016	ADFG	Taku R., AK (Wild)	5/18/2018	82	6	SPB	8/21	188	77.4	1	95	35
Chinook	44865	2016	ADFG	Taku R., AK (Wild)	5/15/2018	80	5.7	SPE	8/21	174	62.9	1	98	72
Chinook	No tag							SPE	8/21	193	65.4			

[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 7. Information on 174 juvenile chum salmon released from regional enhancement sites and captured in the strait habitat during June–August 2018. 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 6 for Agency acronyms. Dashes indicate no samples.

	June			July			August		
Factor	n	mean	se	n	mean	se	n	mean	se
DIPAC – multiple sites									
Length	51	100	1	16	136	5	8	175	3
Weight	51	9.0	0.2	16	25.2	2.6	8	54.9	3.1
CR	51	-0.05	0.01	16	-0.01	0.01	8	0.01	0.02
NSRAA – Kasnyku Bay & Takatz Bay									
Length	—	—	—	25	140	3	4	187	9
Weight	—	—	—	25	27.4	1.8	4	66.3	8.3
CR	—	—	—	25	-0.01	0.01	4	-0.01	0.02
NSRAA - Kasnyku Bay LL & Takatz Bay LL									
Length	—	—	—	2	156	6	4	184	8
Weight	—	—	—	2	38.5	3.7	4	63.7	8.1
CR	—	—	—	2	0.03	0.02	4	0.01	0.03
NSRAA – Kasnyku Bay LL									
Length	—	—	—	3	156	7	1	194	—
Weight	—	—	—	3	35.1	4.0	1	79.3	—
CR	—	—	—	3	-0.07	0.05	1	0.07	—
NSRAA – Southeast Cove									
Length	—	—	—	—	—	—	1	150	—
Weight	—	—	—	—	—	—	1	33.0	—
CR	—	—	—	—	—	—	1	0.00	—
NSRAA – Southeast Cove LL									
Length	—	—	—	2	117	6	—	—	—
Weight	—	—	—	2	13.7	2.6	—	—	—
CR	—	—	—	2	-0.11	0.05	—	—	—
NSRAA – Gunnuk Creek									
Length	—	—	—	1	142	—	—	—	—
Weight	—	—	—	1	26.4	—	—	—	—
CR	—	—	—	1	-0.06	—	—	—	—
Unmarked									
Length	2	96	8	32	125	2	22	168	5
Weight	2	10.2	0.5	32	19.7	1.4	22	49.9	4.4
CR	2	0.22	0.30	32	0.00	0.01	22	-0.02	0.01

Table 8. Information on 7 juvenile chum salmon released from regional enhancement sites and captured in the inshore habitat during June–August 2018. 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 6 for Agency acronyms. Dashes indicate no samples.

	June			July			August		
Factor	n	mean	se	n	mean	se	n	mean	se
				NSRAA – Bear Cove					
Length	—	—	—	—	—	—	1	100	—
Weight	—	—	—	—	—	—	1	8.5	—
CR	—	—	—	—	—	—	1	-0.10	—
				Unmarked					
Length				4	115	12	2	107	7
Weight				4	15.1	4.9	2	10.5	2.2
CR				4	-0.06	0.03	2	-0.10	0.02

Table 9. Information on 82 juvenile sockeye salmon released from regional enhancement sites and captured in the strait habitat during June–August 2018. 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 6 for Agency acronyms. Dashes indicate no samples.

	June			July			August		
Factor	n	mean	se	n	mean	se	n	mean	se
DIPAC – Speel Arm									
Length	22	120	2	1	147	—	—	—	—
Weight	22	17.0	0.8	1	29.9	—	—	—	—
CR	22	-0.03	0.01	1	-0.08	—	—	—	—
DIPAC – Tatsamenie Lake									
Length	1	102	—	—	—	—	—	—	—
Weight	1	10.6	—	—	—	—	—	—	—
CR	1	0.03	—	—	—	—	—	—	—
DIPAC – Sweetheart Lake									
Length	—	—	—	—	—	—	1	197	—
Weight	—	—	—	—	—	—	1	85.1	—
CR	—	—	—	—	—	—	1	0.05	—
Unmarked									
Length	42	114	2	9	120	6	6	174	10
Weight	42	14.3	1.1	9	17.4	3.3	6	56.5	10.8
CR	42	-0.09	0.01	9	-0.05	0.01	6	-0.05	0.04

Table 10. Information on 54 juvenile sockeye salmon released from regional enhancement sites and captured in the inshore habitat during June–August 2018. 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 6 for Agency acronyms. Dashes indicate no samples.

	June			July			August		
Factor	n	mean	se	n	mean	se	n	mean	se
				DIPAC – Sweetheart Lake					
Length	—	—	—	—	—	—	7	109	3
Weight	—	—	—	—	—	—	7	11.6	1.2
CR	—	—	—	—	—	—	7	-0.11	0.02
				Unmarked					
Length	—	—	—	2	110	1	45	112	2
Weight	—	—	—	2	13.7	0.5	45	13.0	0.8
CR	—	—	—	2	0.06	0.02	45	-0.11	0.01

Table 11. Information on stomachs from 7 potential predators of juvenile salmon captured in the strait habitat during June–August 2018. 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.

	June			July			August		
Factor	n	mean	sd	n	mean	sd	n	mean	sd
Sockeye salmon (Adult)									
Length	1	666	—	—	—	—	—	—	—
Weight	1	3784	—	—	—	—	—	—	—
%BW	1	0	—	—	—	—	—	—	—
Fullness	1	0	—	—	—	—	—	—	—
Chinook salmon (Immature)									
Length	—	—	—	2	347	81	1	380	—
Weight	—	—	—	2	590	413	1	772	—
%BW	—	—	—	2	0	—	1	0	—
Fullness	—	—	—	2	0	—	1	0	—
Coho salmon (Adult)									
Length	—	—	—	1	761	—	2	672	23
Weight	—	—	—	1	6460	—	2	4065	92
%BW	—	—	—	1	4	—	2	0	1
Fullness	—	—	—	1	110	—	2	55	78

Table 12. Information on stomachs from 7 potential predators of juvenile salmon captured in the inshore habitat during June–August 2018. 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.

	June			July			August		
Factor	n	mean	sd	n	mean	sd	n	mean	sd
				Pink salmon (Adult)					
Length	—	—	—	1	515	—	—	—	—
Weight	—	—	—	1	1608	—	—	—	—
%BW	—	—	—	1	0	—	—	—	—
Fullness	—	—	—	1	0	—	—	—	—
				Chinook salmon (Immature)					
Length	5	338	36	1	376	—	—	—	—
Weight	5	486	149	1	568	—	—	—	—
%BW	5	1	2	1	0	—	—	—	—
Fullness	5	67	44	1	0	—	—	—	—

Table 13. Feeding intensity of 14 potential predators of juvenile salmon captured during June-August 2018 (see Tables 11–12).

Species	Number examined	Number empty	Percent feeding	Number w/ salmon	Percent w/salmon
		Strait habitat			
Chinook salmon (Immature)	3	3	0	—	—
Coho salmon (Adult)	3	1	67	0	0.0
Sockeye salmon (Adult)	1	1	0	—	—
		Inshore habitat			
Chinook salmon (Immature)	6	2	67	0	0.0
Pink salmon (Adult)	1	1	0	—	—

Table 14. Information on stomachs from 104 juvenile salmon captured in the strait habitat during June–August 2018. 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.

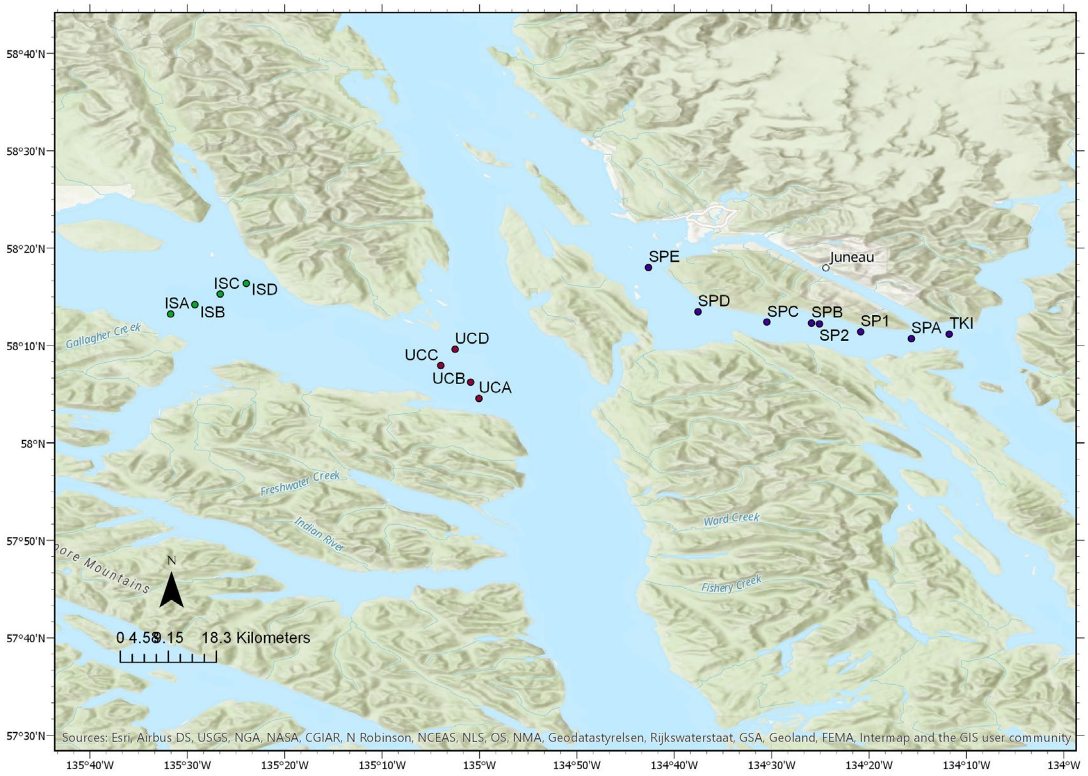
	June			July			August		
Factor	n	mean	sd	n	mean	sd	n	mean	sd
Pink salmon									
Length	—	—	—	10	114	0	10	144	1
Weight	—	—	—	10	13.7	0.3	10	29.0	0.9
%BW	—	—	—	10	1.4	0.3	10	0.5	0.1
Fullness	—	—	—	10	63	1	10	30	1
Chum salmon									
Length	10	96	0	10	126	0	10	165	2
Weight	10	9.1	0.2	10	20.2	0.5	10	50.1	2.3
%BW	10	3.1	0.5	10	1.6	0.3	10	1.5	0.2
Fullness	10	73	0	10	55	1	10	58	2
Sockeye salmon									
Length	10	110	0	8	108	2	5	174	10
Weight	10	14.7	0.3	8	14.4	1.5	5	62.6	9.6
%BW	10	1.6	0.2	8	1.4	0.3	5	1.5	0.5
Fullness	10	68	1	8	66	4	5	72	9
Coho salmon									
Length	10	147	2	10	172	5	10	227	12
Weight	10	39.6	1.7	10	59.8	5.1	10	152.2	11.6
%BW	10	2.8	0.5	10	1.3	0.3	10	2.6	0.3
Fullness	10	99	2	10	66	5	10	100	6
Chinook salmon									
Length	—	—	—	—	—	—	1	144	—
Weight	—	—	—	—	—	—	1	29.0	—
%BW	—	—	—	—	—	—	1	0.5	—
Fullness	—	—	—	—	—	—	1	30	—

Table 15. Information on stomachs from 161 juvenile salmon captured in the inshore habitat during June–August 2018. 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.

	June			July			August		
Factor	n	mean	sd	n	mean	sd	n	mean	sd
				Pink salmon					
Length	—	—	—	—	—	—	—	—	—
Weight	—	—	—	—	—	—	—	—	—
%BW	—	—	—	—	—	—	—	—	—
Fullness	—	—	—	—	—	—	—	—	—
				Chum salmon					
Length	—	—	—	—	—	—	—	—	—
Weight	—	—	—	—	—	—	—	—	—
%BW	—	—	—	—	—	—	—	—	—
Fullness	—	—	—	—	—	—	—	—	—
				Sockeye salmon					
Length	—	—	—	2	108	0	10	104	0
Weight	—	—	—	2	13.7	0.5	10	11.1	0.2
%BW	—	—	—	2	7.2	0.1	10	1.2	0.3
Fullness	—	—	—	2	100	2	10	68	0
				Coho salmon					
Length	10	132	1	13	183	10	—	—	—
Weight	10	24.4	0.7	13	73.0	9.8	—	—	—
%BW	10	1.5	0.4	13	1.1	0.3	—	—	—
Fullness	10	73	1	13	60	7	—	—	—
				Chinook salmon					
Length	40	121	2	28	147	3	58	171	1
Weight	40	22.7	1.9	28	39.6	2.6	58	64.5	1.5
%BW	40	1.9	0.3	28	1.0	0.3	58	0.9	0.1
Fullness	40	69	3	28	47	3	58	55	1

Table 16. Feeding intensity of 265 juvenile salmon captured during June–August 2018 (see Table 14–15).

Species	Number examined	Number empty	Percent feeding
Strait habitat			
Pink salmon	20	0	100
Chum salmon	30	0	100
Sockeye salmon	23	1	96
Coho salmon	30	1	97
Chinook salmon	1	0	100
Inshore habitat			
Pink salmon	0		
Chum salmon	0		
Sockeye salmon	12	0	100
Coho salmon	23	1	96
Chinook salmon	126	16	87



Sources: Esri, Airbus DS, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap and the GIS user community

Figure 1. Stations sampled during May–August 2018. See Table 1 for stations details.

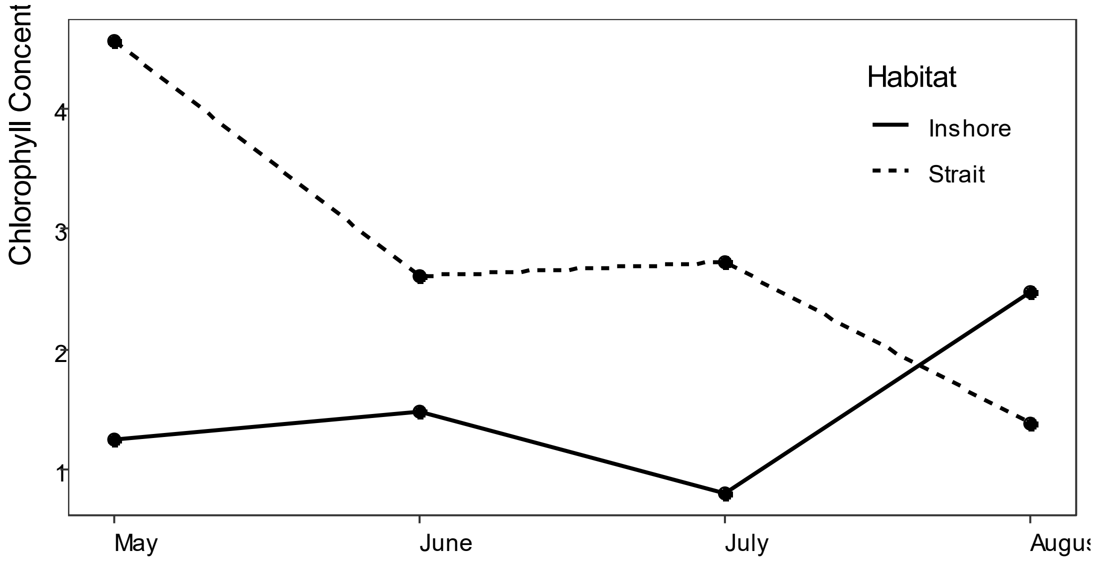


Figure 2. Mean chlorophyll-a concentration (µg/L) from surface water samples collected May–August 2018.

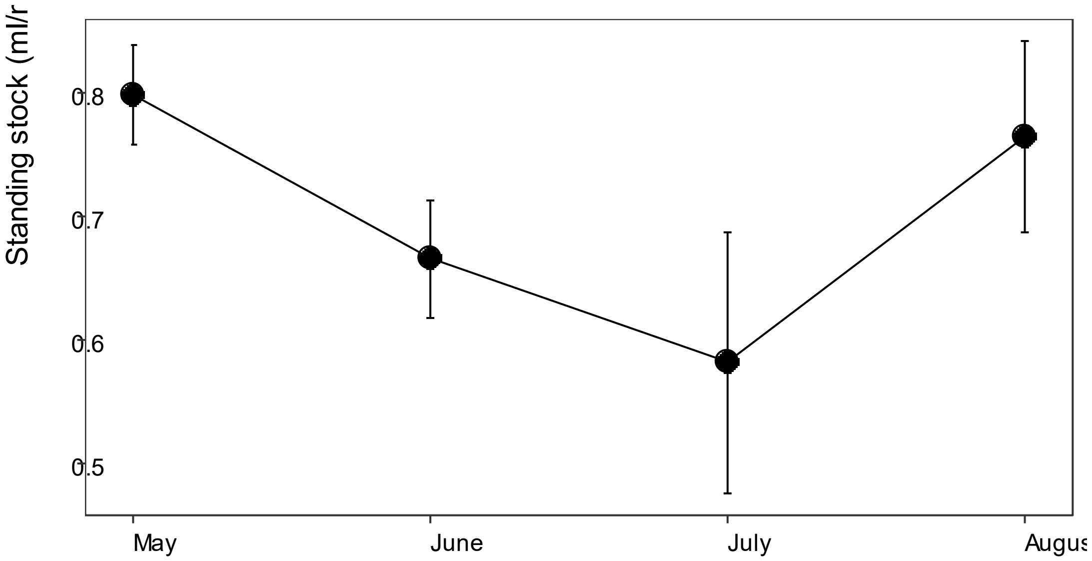


Figure 3. Monthly zooplankton standing stock (ml/m^3; +/- 1 standard error) from 333-µm mesh oblique bongo net samples towed from ≤ 200-m depths during daylight in Icy Strait, May–August 2018.

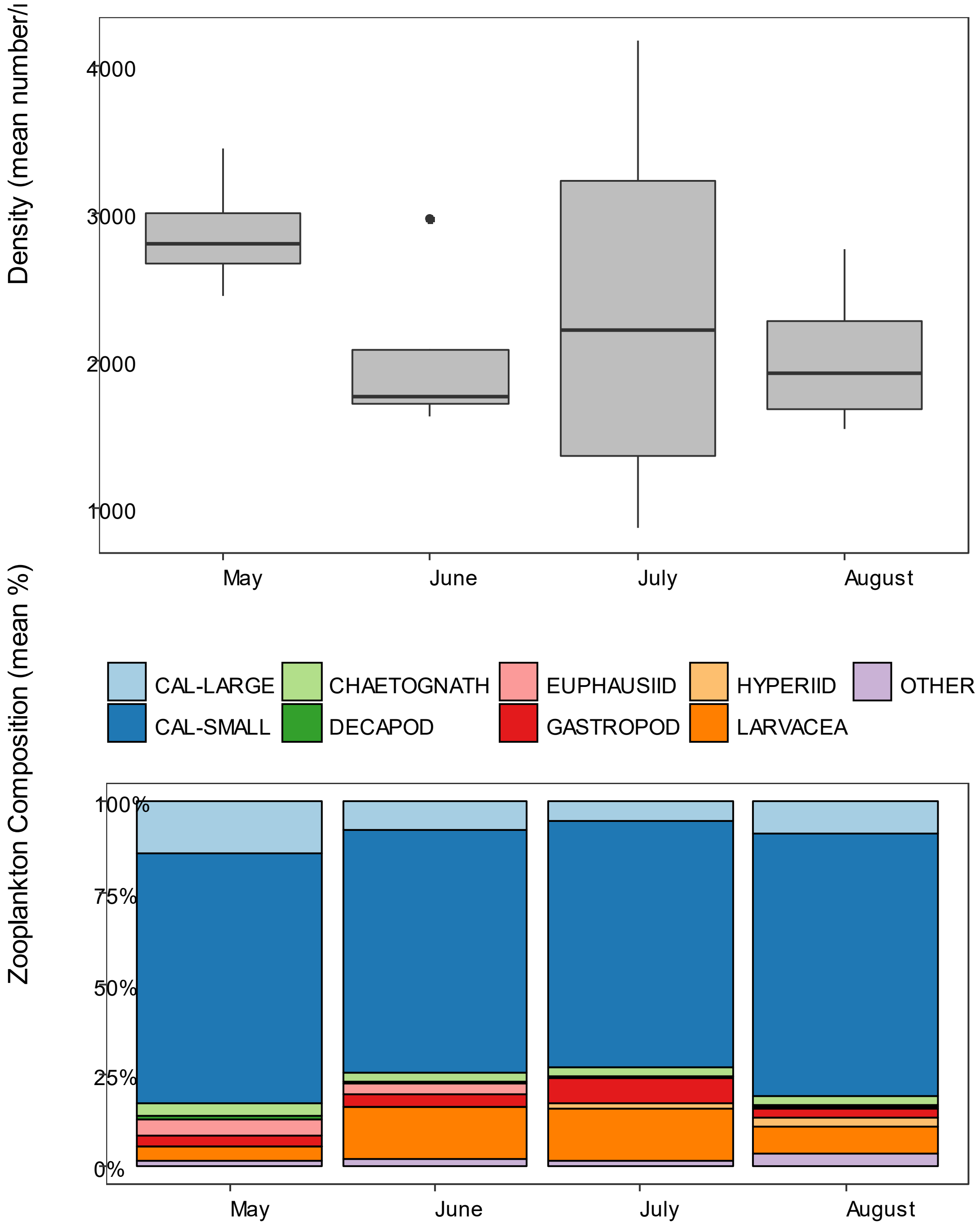


Figure 4. Monthly zooplankton density with standard error (top); and taxonomic composition (bottom) from 333-um mesh oblique bongo net samples towed from ≤ 200-m depths during daylight in Icy Strait, May–August 2018. Cal-large and Cal-small are calanoid copepods.

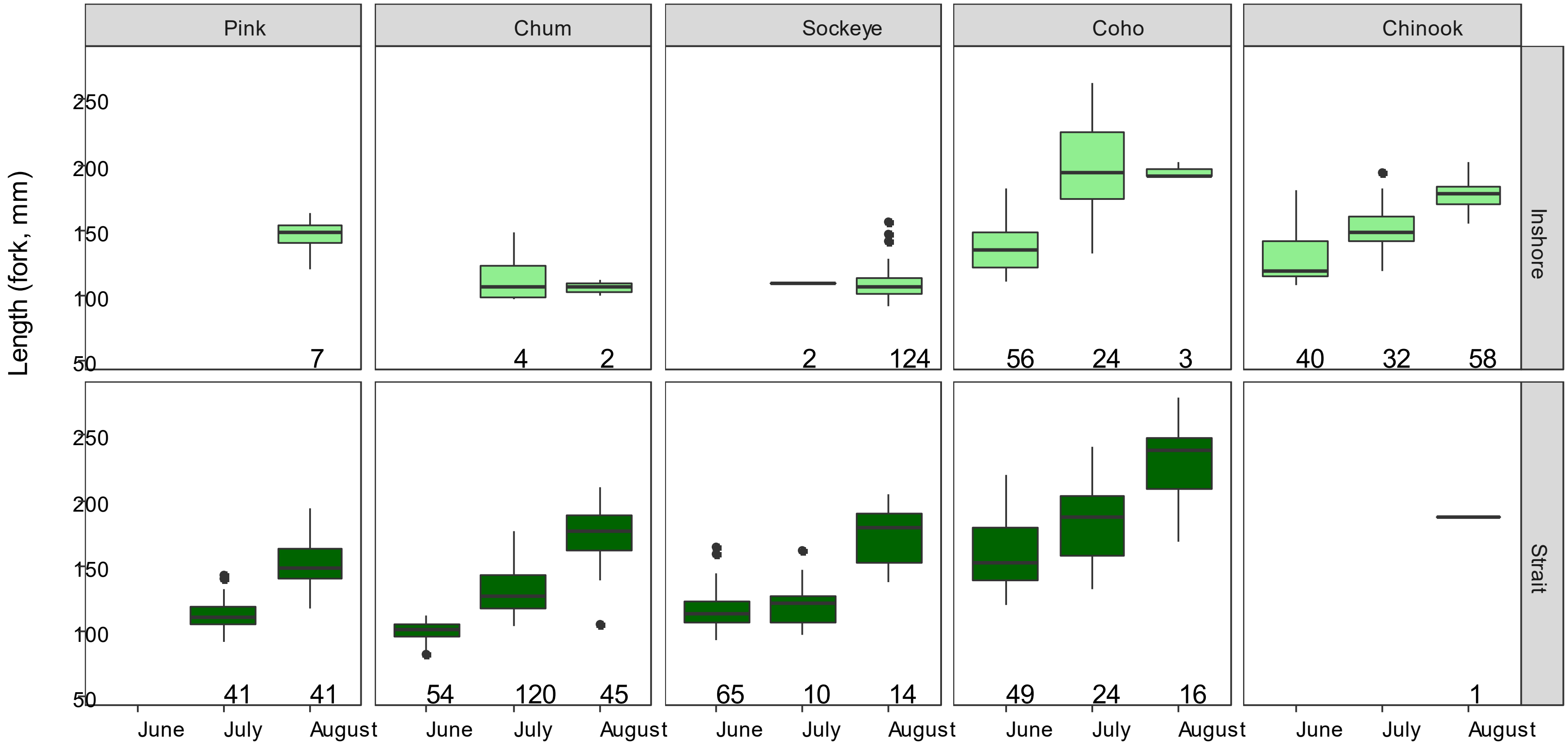


Figure 5. Monthly length (mm, fork) distributions of juvenile salmon caught in inshore and strait habitats during June–August 2018. Horizontal bars represent medians and box widths are the 25th and 75th percentiles. Whiskers extend 1.5 times the box span (interquartile range).

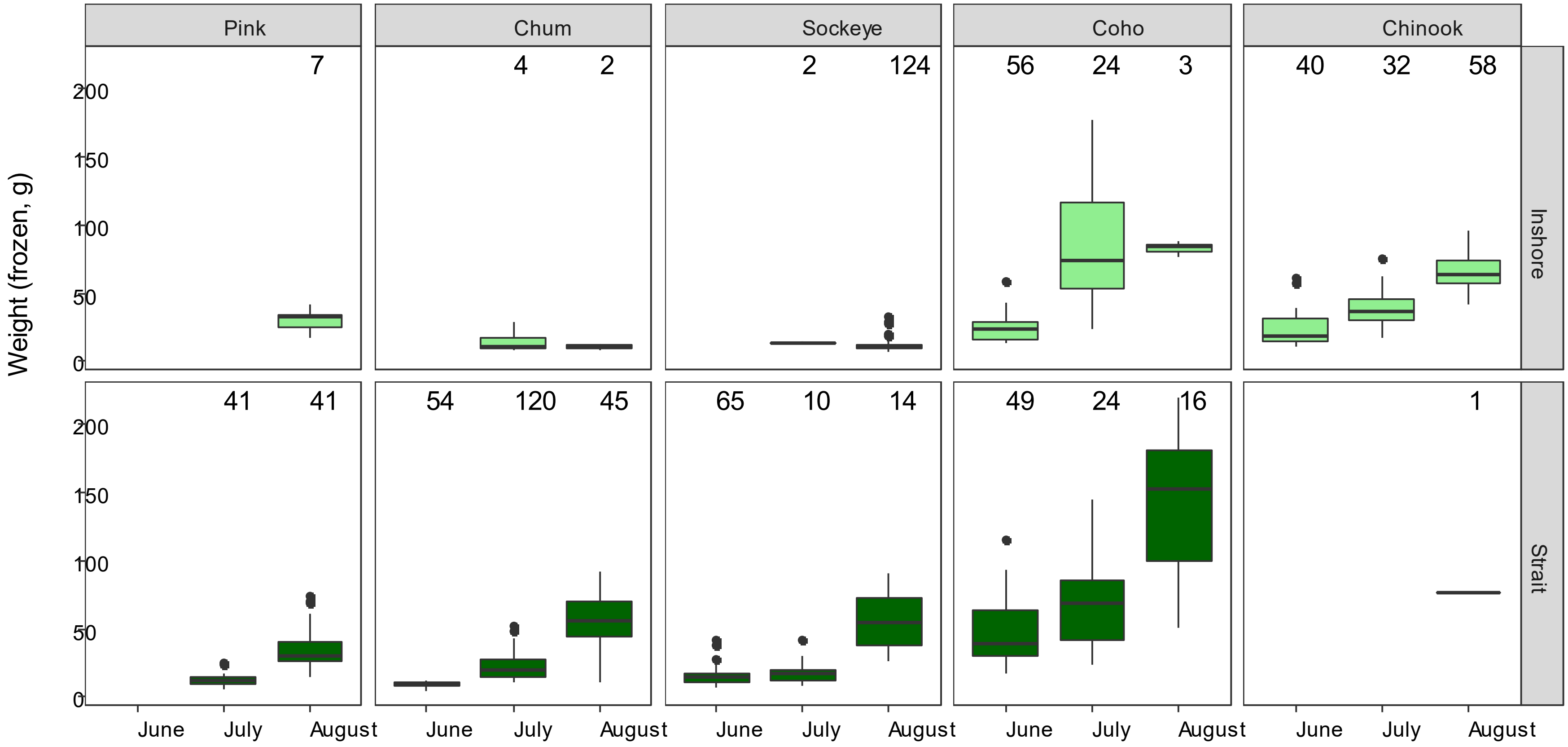


Figure 6. Monthly weight (g) distributions of juvenile salmon caught in inshore and strait habitats during June–August 2018. Horizontal bars represent medians and box widths are the 25th and 75th percentiles. Whiskers extend 1.5 times the box span (interquartile range).

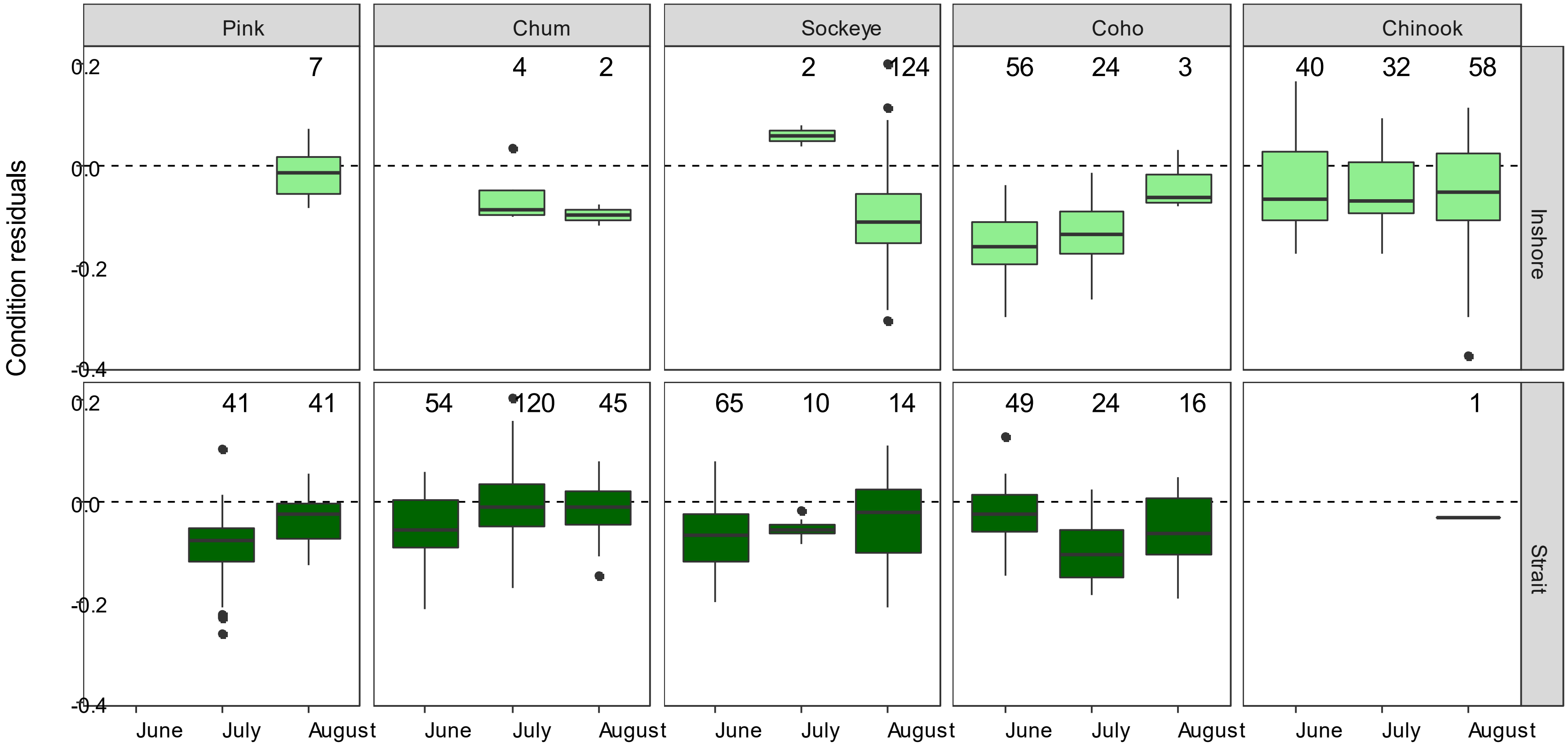


Figure 7. Condition residuals from length-weight regressions of juvenile salmon caught in inshore and strait habitats during June–August 2018. Sample sizes are given as numbers in above each box.

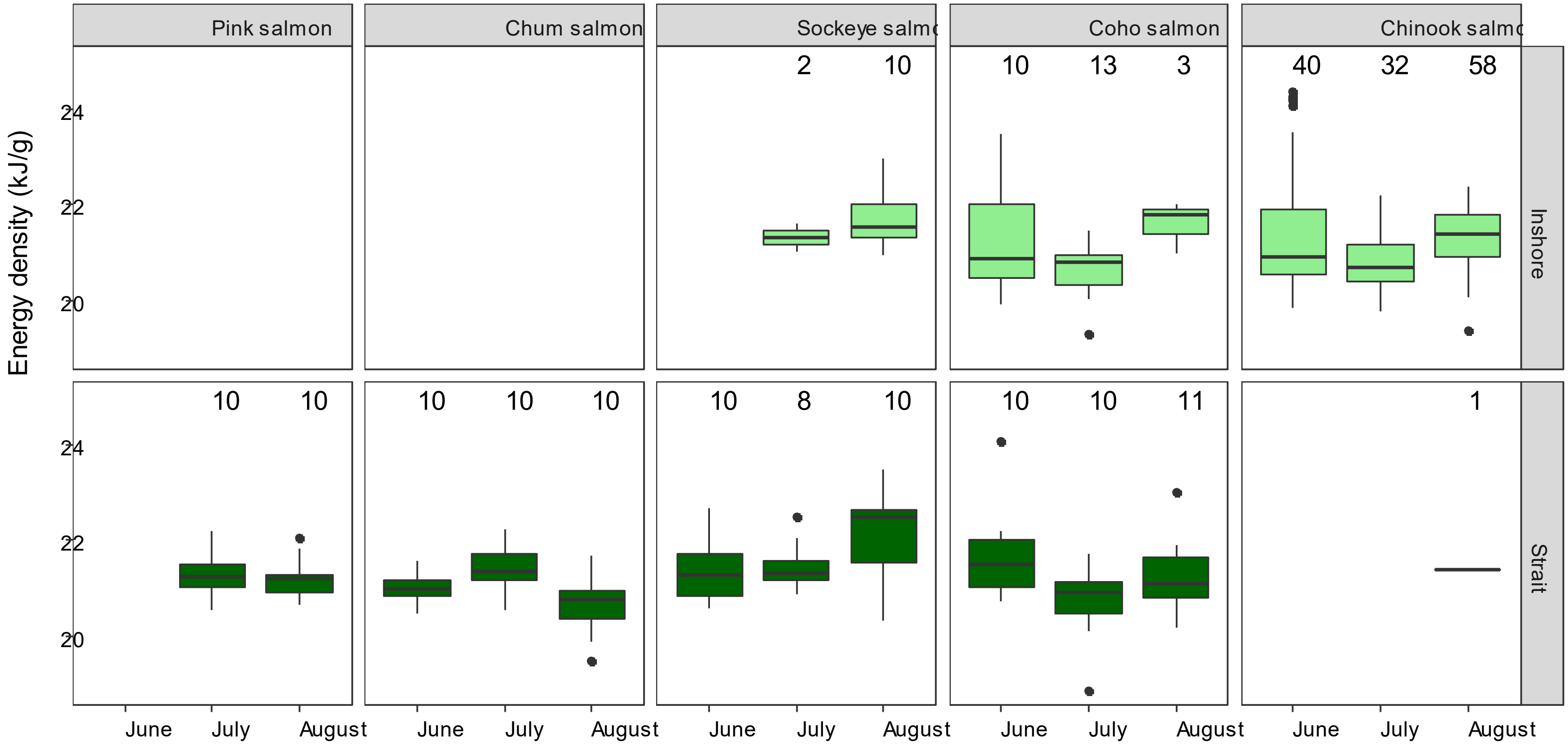


Figure 8. Energy density (kJ/g dry weight) of juvenile salmon caught in inshore and strait habitats during June–August 2018. Sample sizes are given as numbers in above each box.

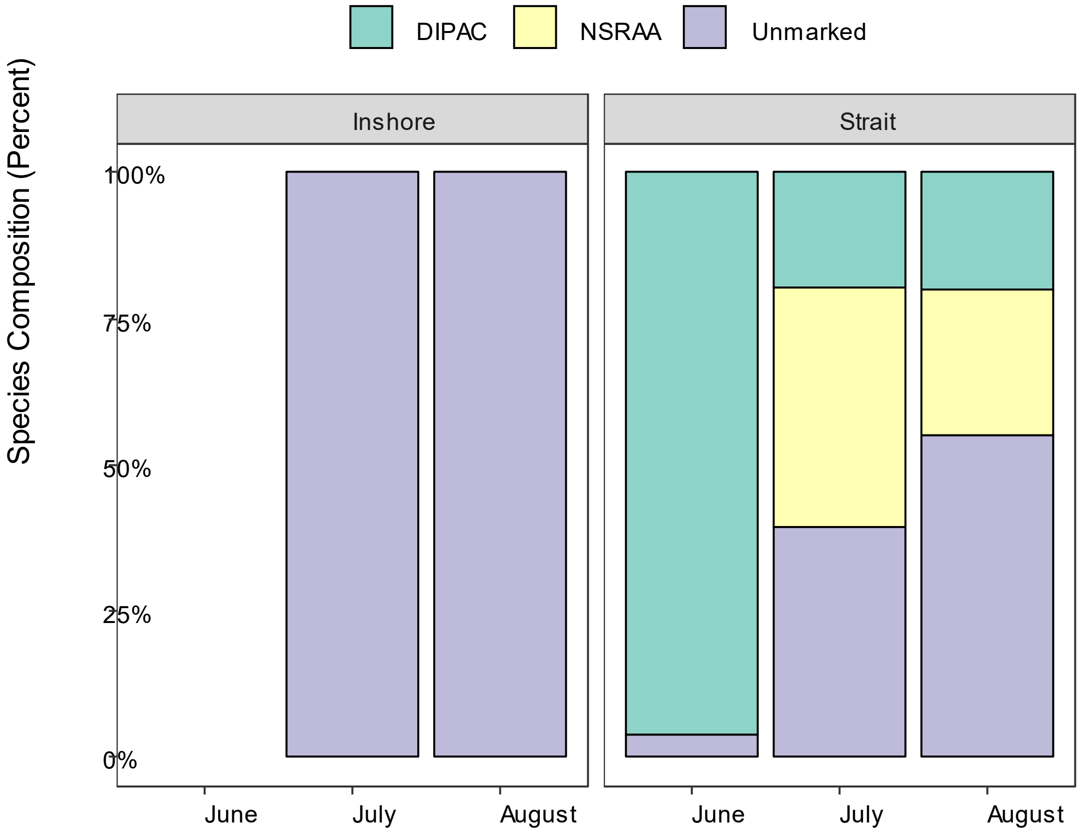


Figure 9. Monthly stock composition (based on otolith marks) of juvenile chum salmon caught in inshore and strait habitats during June–August 2018.

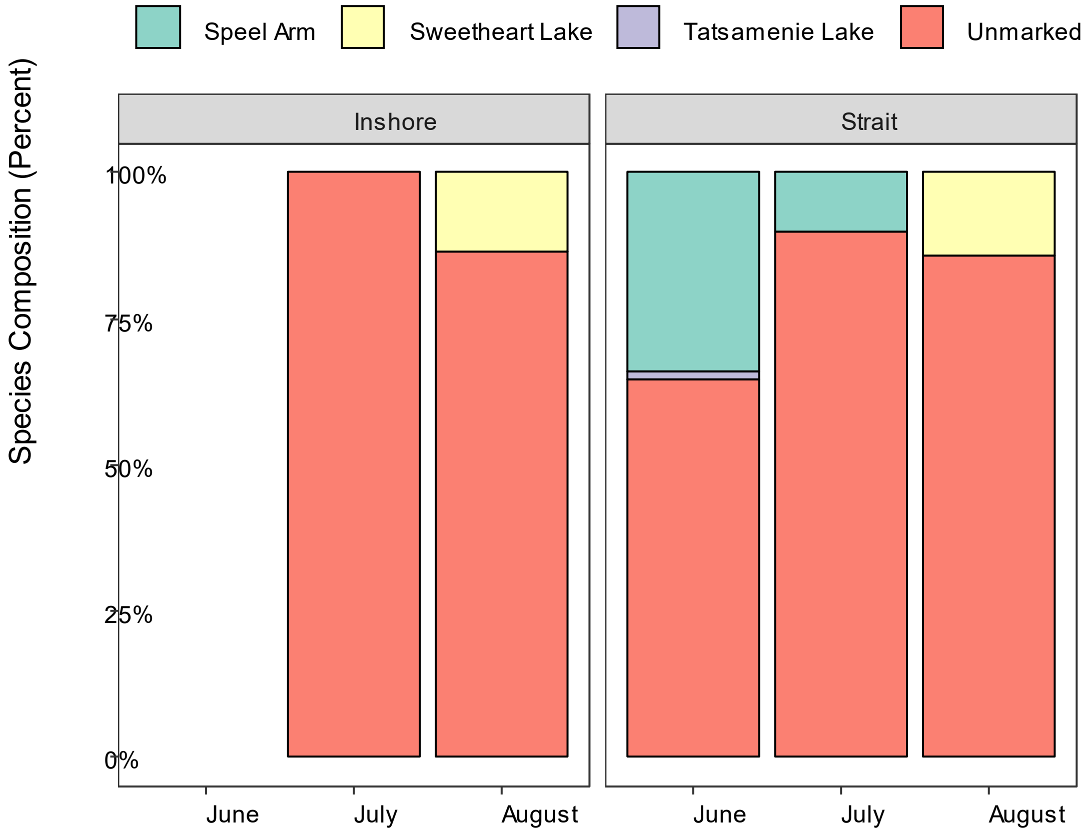


Figure 10. Monthly stock composition (based on otolith marks) of juvenile sockeye salmon captured in inshore and strait habitats during June–August 2018.

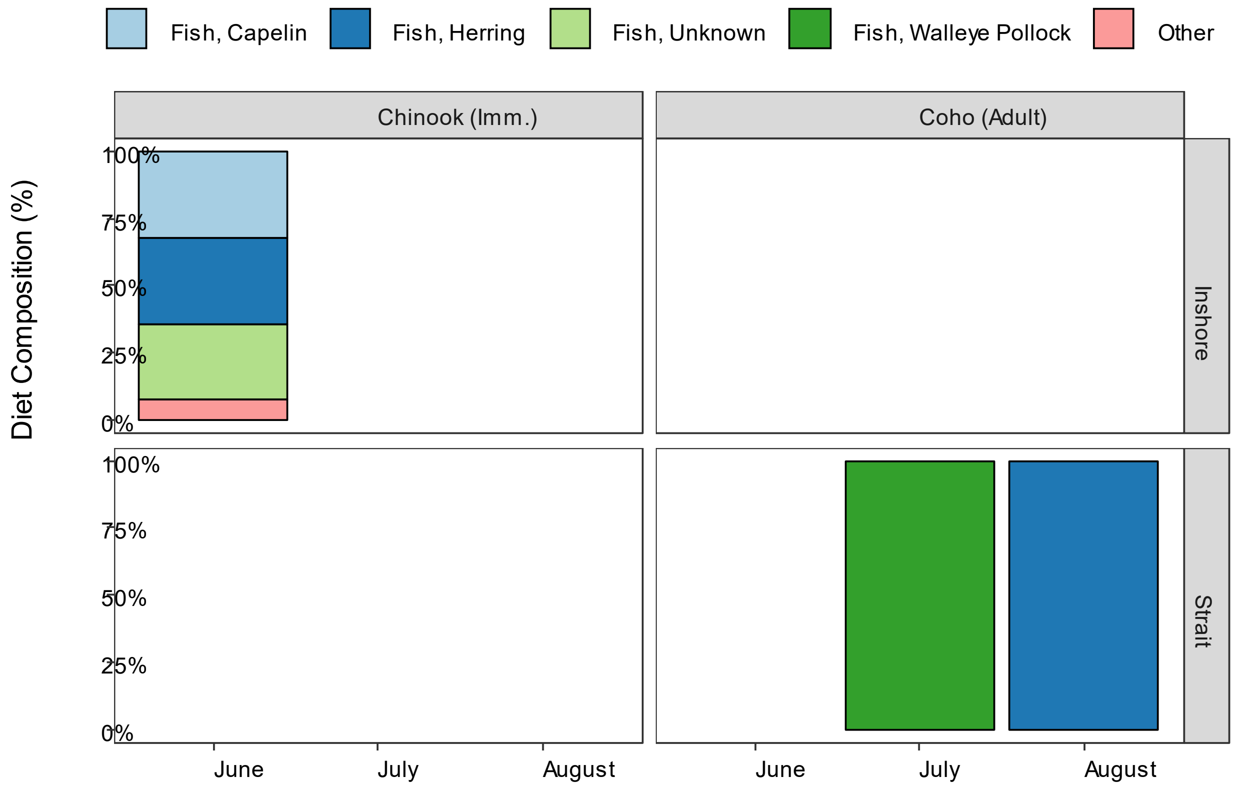


Figure 11. Diet composition (% by weight) of immature and adult salmon captured in inshore and strait habitats during June–August 2018. See Tables 11–12 for sample counts.

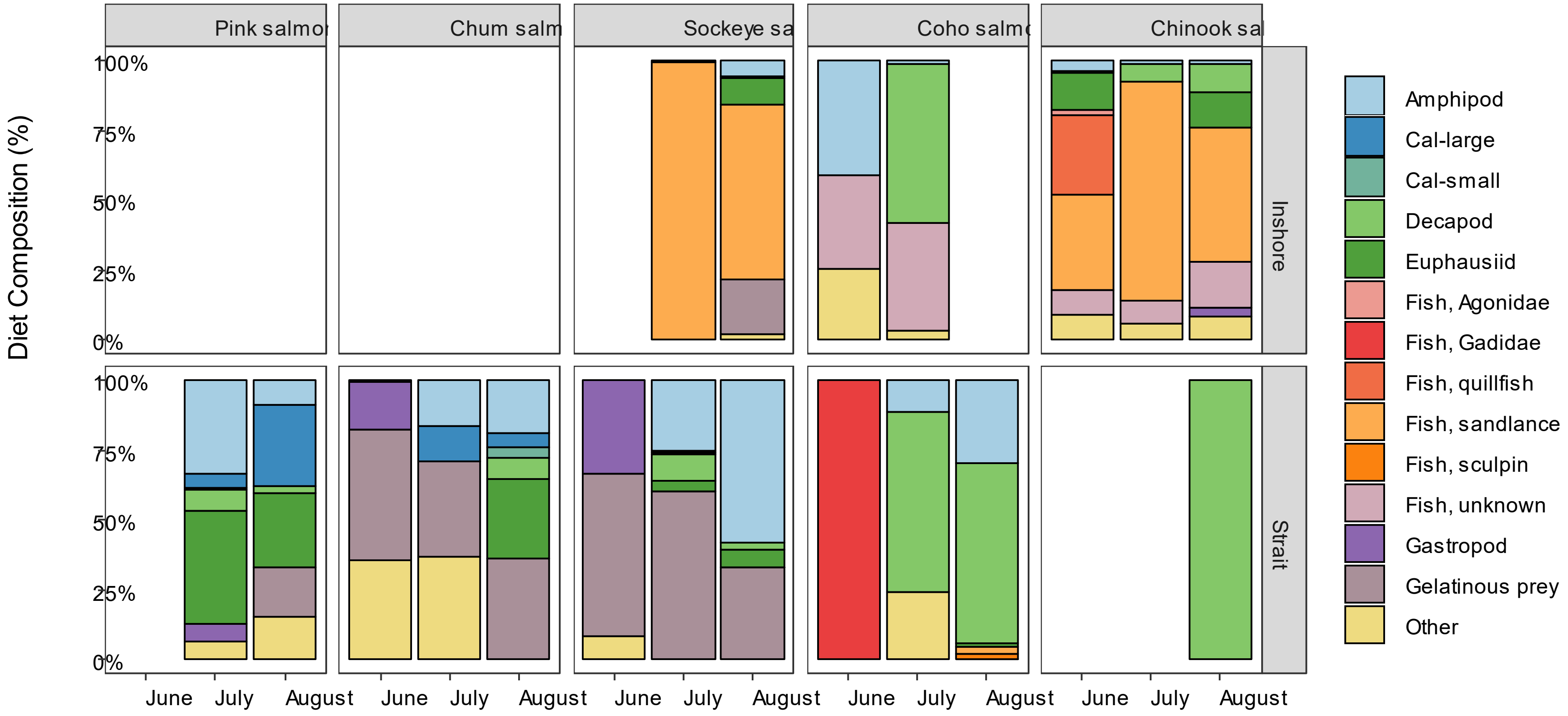


Figure 12. Diet composition (% by weight) of juvenile salmon captured in inshore and strait habitats during June–August 2018. See Tables 13–14 for sample counts.