Strait of Georgia Juvenile Herring Survey, September 2018

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STRAIT OF GEORGIA JUVENILE HERRING SURVEY, SEPTEMBER 2018

by

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A fall juvenile herring survey of the Strait of Georgia took place September 10th to 24th, 2018. This survey serves to address several questions of early herring survival, abundance, recruitment and trophodynamics. Forty-four core stations were sampled throughout the Strait of Georgia following the ten core transects that have been sampled since 1990. The survey area extends from Trincomali Channel in the south to Smelt Bay in the north. Zooplankton and physical environmental data were also collected in the study area.

RÉSUMÉ

Thompson, M., Boldt, J.L., Dennis-Bohm, H., and Grinnell, M. H. 2020. Strait of Georgia juvenile herring survey, September 2018. Can. Manuscr. Rep. Fish. Aquat. Sci. 3201: vi + 53 p.

Un relevé automnal du hareng juvénile dans le détroit de Georgie a été réalisé entre le 10 et le 24 septembre 2018. Ce relevé visait à répondre à plusieurs questions sur la survie, l'abondance, le recrutement et la trophodynamique du hareng durant les premiers stades de son développement. Les 44 stations situées dans le détroit de Georgie ont été échantillonnées en suivant les 10 transects principaux qui font l'objet d'un échantillonnage depuis 1990. La zone du relevé s'étend du chenal Trincomali au sud jusqu'à Smelt Bay au nord. Des données sur le zooplancton et l'environnement physique ont également été recueillies dans la zone d'étude.

INTRODUCTION

Pacific Herring (*Clupea pallasi*) are an important commercial fish and a vital forage species for many marine mammals, birds, and fish in British Columbia's coastal waters. Pacific Herring (hereafter referred to as herring) spawn principally on marine vegetation in the subtidal and upper intertidal zone between February and June, with peak spawning between March and April (Humphreys and Hourston 1978). Larvae hatch after two to three weeks, and disperse with surface currents, metamorphosing into juvenile or young-of-the-year herring at a length of ~25mm (Hourston and Haegele 1980). Herring are considered juveniles or immature until they are about three years of age and have joined the sexually mature spawning population (Hay and McCarter 1999). During daylight hours, juvenile herring congregate in schools, occasionally forming mixed aggregates with other pelagic species, close to shore near the bottom (Haegele 1997). At dusk, these fish migrate into surface waters to feed on plankton. During this time they are vulnerable to purse seine gear.

To determine the distribution and abundance of juvenile herring in the Strait of Georgia (SOG) purse seine surveys have been conducted annually since 1990, except for 1995 (Figure 1). The main objective of the survey was to estimate the relative abundance of juvenile herring in the SOG. Also, a goal of this report was to update the time series index (and associated variance) of the relative biomass and abundance, as well as mean lengths and weights of age-0 herring in the SOG using methods identified in Boldt et al. (2015; see Appendix 1). Survey data provide a potential leading indicator of recruitment to the adult herring population and may provide an indicator of prey availability and quality to predators in the SOG, such as Coho and Chinook Salmon.

METHODS

The annual survey of juvenile herring in the Strait of Georgia (Figure 2) followed ten core sampling transects (1 – 6, 8 – 11; no transect 7); with 3 to 5 stations per transect, for a total of 48 sampling stations. These stations have been sampled consistently since 1990 (except 1995). Data from these ten core transects have been used to predict juvenile herring recruitment (Hay et al. 2003, Schweigert et al. 2009, Boldt et al. 2018). Originally, the sampling transects were chosen based on known historical herring spawning sites and were roughly placed equal distances apart around the Strait of Georgia. Placement also represents both nearshore and open water habitats (Haegele et al. 2005). In 2018, sampling was conducted from September 10^{th} to 24^{th} (Table 1). Forty-four of the forty eight core stations were sampled. Henry Bay (transect 4, stations 1-3) was not sampled due to bad weather and Clarke Rock (transect 1, station 1) could not be sampled due to the roller chain breaking resulting in the inability to set the net.

Fish Sampling

In 2018, the 12 m, aluminum-hulled Fisheries Research Vessel *Walker Rock* was used for all fishing events. A 183 m long and 27 m deep purse seine net of knotless web, resulting in an area fished of ~2665 m^2, was used for all fishing events. The body of the net had 46 m of 22.2 mm mesh at the tow end followed by 91 m of 19.0 mm mesh, and the bunt end was 46 m of 9.5 mm mesh. The net fished to a depth of 10 m, and was able to retain fish greater than 20 mm in length. All sets were made after dusk when herring were near the surface. All sets were made at the pre-determined sampling stations. Five sets were completed per night, depending on location, and length of travel between transects and the marine weather forecast. For most sets, it was possible to land the entire catch for biological sampling. On occasion, it was not practical to land a large set in its entirety, so sub-sampling was necessary. When sub-sampling was required, a 40 kg capacity tote was filled with randomly selected fish and retained for biological sampling. Several dipnet samples were taken from various parts of the net (catch) to make up the random sub-sample. The remainder of the set was released over the corkline, its size (volume) estimated as the number of totes released. All fish retained for sampling were bagged and frozen, with the exception of large predator species (e.g. adult salmon and flatfish). These fish were individually measured in the field. All retained fish were later sampled in the laboratory at the Pacific Biological Station. From each set, up to 100 herring were individually weighed and measured. Up to 25 individuals for all other species caught were identified, weighed and measured. If the set contained fewer than 100 herring, then all herring were weighed and measured. Consistent with standard practices, herring were measured to standard length, salmon to fork length, groundfish to total length and all to the nearest millimetre. All other fish species were measured to standard length. The number of herring caught in each set was determined by dividing the total catch weight by the mean individual fish weights of the subsampled herring. The number of other species caught was determined in the same manner (Tables 2 and 3). Where they existed, as a pilot study, a subsample of scales was collected from the preferred region under the pectoral fin for aging.

Zooplankton Sampling

Twenty stepped oblique zooplankton tows were performed (Figure 3). The tows were always completed after dusk and immediately before the fishing events. A nearshore and offshore tow location was sampled on all transects. Dual 19 cm diameter bongo nets with 350 µm mesh were used for sampling, resulting in 'left' and 'right' bongo zooplankton samples (only 'left' samples were processed). The bongos were lowered to 20 m depth (10 m in shallow areas) and raised by an electric winch at a rate of 1 m every 15 sec (or 1 m every 30 sec for shallow areas). The zooplankton tow was performed with the vessel doing a small circle at ~2 knots speed. Each tow took approximately 5 minutes to complete. An additional twenty vertical zooplankton tows were also performed again this year for comparative sampling between the two methods. A General Oceanics® 2030R model flowmeter was attached to the left bongo net to determine the volume of seawater filtered. Volume filtered was calculated for oblique tows using the following equation (McCarter and Hay 2002):

$$\mathbf{V = (A \cdot F \cdot K) / 999{,}999}$$

where:

> **V** = volume of water filtered through the plankton net (m^3)
> **A** = area of net opening (0.02835 m^2)
> **F** = number of revolutions recorded by the flow meter (m)
> **K** = standard speed rotor constant for 7cm rotor (26,873)
> **999,999 =** maximum rotor digit count

For vertically-towed zooplankton samples, the winch speed was too low for accurate flowmeter readings. Volume filtered was therefore calculated as V = (π * net radius^2 * depth of tow), where the depth was either 10 m (transect 1, station 1; transect 3, station 1; transect 4, station 5; and transect 5, station 1) or 20 m (all other stations).

Upon retrieval, the bongo nets were washed with a high pressure deck hose to rinse zooplankton into the codends, and the samples were preserved in 3.7% seawater formalin.

In the laboratory, a volumetric splitter was used to reduce the sample size to where organisms could be conveniently counted and identified in a counting tray using a stereo microscope under 30X magnification. Sample splitting continued until a target size of roughly 300 organisms was reached (Thompson et al. 2003).

Zooplankton was identified to the lowest possible taxonomic level. Copepods were identified to species, where possible. Densities for all zooplankton species were determined and expressed as number of animals/m^3.

CTD Sampling

A Conductivity Temperature Depth recorder (CTD) was used to characterize oceanographic conditions in the surveyed area. Twenty casts were conducted using a RBR XR-60 CTD at stations where zooplankton samples were also collected (Figure 3). One CTD cast was performed at each location before zooplankton sampling. The CTD unit was weighted and lowered over the side of the vessel to within ~2 meters of the bottom to give the largest water profile possible. Descent rate of the CTD was approximately 1 m/sec. Data from the CTD casts were subsequently downloaded to a laptop at the end of the each evening.

RESULTS

Herring

Forty-four stations were sampled from transects 1 – 6, 8 - 11. A total of 3,346 herring were weighed and measured resulting in a multimodal length frequency distribution (Figure 4). Length designations for juvenile herring age-classes were determined by general spacing of the length frequency histogram. A total of 492 scales were taken for aging to try and clarify age-class length categories. Scale ages fell within the designated aging based on the length frequency plot. The following age class designations were used:

0+ = herring less than or equal to 109 mm standard length
1+ = herring between 110 mm and 155 mm standard length
2+ and older = herring greater than or equal to 156 mm standard length

Thirty-nine sampled stations (88.6%) contained age-0+ herring (Tables 2 and 3). The mean length and weight of age-0+ herring was 91 mm and 10.28 g respectively (n = 2,051). A total weight of 68.22 kg and estimated 6,735 individual age-0+ herring were caught (Table 4).

Catches at thirty-one of the forty-four stations (70.5%) sampled contained age-1+ herring (Tables 2 and 3). The mean length and weight of age-1+ herring was 130 mm and 32.47 g, respectively (n = 1,258). A total weight of 131.63 kg and estimated 3,868 individual age-1+ herring were caught (Table 4).

Catches at eleven of the forty-four stations (25%) sampled contained age-2+ herring (Tables 2 and 3). The mean length and weight of age-2+ herring was 165 mm and 66.36 g, respectively (n = 37). A total weight of 8.93 kg and estimated 126 individual age-2+ herring were caught (Table 4).

Length frequency histograms by transect location for all sampled herring are shown in Figure 5. All transects were dominated by age-0+ herring, except French Creek (transect 5) and Secret Cove (transect 11). Age-1+ herring were sampled on most transects, and dominated catches on two transects: French Creek (transect 5) and Secret Cove (transect 11). A length-weight relationship for all sampled herring from the survey showed a significant, positive correlation (R^2=0.976; Figure 6).

Zooplankton

In obliquely-towed zooplankton samples, there were 28 categories of organisms identified in 20 zooplankton samples (Tables 5, 6 and 7). An average of 14.93 m^3 (± 6.02 m^3) of water was filtered per zooplankton tow. Larvaceans (*Oikopleura sp.* and *Fritillaria sp.*), barnacles, gastropods and calanoid copepods (*Calanus sp.* and *Pseudocalanus sp.*) occurred in all 20 samples. More than 80% of all zooplankton abundance comprised gastropods, larvaceans (*Oikopleura sp.* and *Fritillaria sp.*), siphonophores, barnacles and *Calanus sp.* copepods.

In vertical-towed zooplankton samples, there were 22 categories of organisms identified in 20 zooplankton samples (Tables 5, 6 and 8). An average of 0.51 m^3 of water was filtered per zooplankton tow. Barnacles and larvaceans (*Oikopleura sp.* and *Fritillaria sp.*) were the most common occurring in all 20 samples. More than 75% of sampled abundance comprised barnacles, larvaceans (*Oikopleura sp.* and *Fritillaria sp.*), gastropods and calanus copepods (*Calanus sp.*).

There were some station by station differences in zooplankton densities between oblique and vertical tows (not shown), but on average (across all tows) the proportion of zooplankton densities were generally similar between the two methods (Figure 7).

CTD

Two CTD casts were performed at each transect location before zooplankton sampling. The CTD typically records temperature (^{o}C), salinity (ppt), dissolved oxygen (%) and depth (m). A major failure with the CTD depth sensor during the survey; however, resulted in no usable data.

CONCLUSIONS

Forty-four stations were sampled resulting in 18 different fish species recorded from purse seine sets. A total of 3,346 herring were measured and weighed creating a multimodal histogram clearly representing age-0+ and age-1+ juvenile herring. Oblique and vertical plankton tows were performed with Larvaceans (*Oikopleura sp.* and *Fritillaria sp.*), barnacles, gastropods and calanoid copepods (*Calanus sp.* and *Pseudocalanus sp.*) being the predominant organisms in both tow types.

ACKNOWLEDGMENTS

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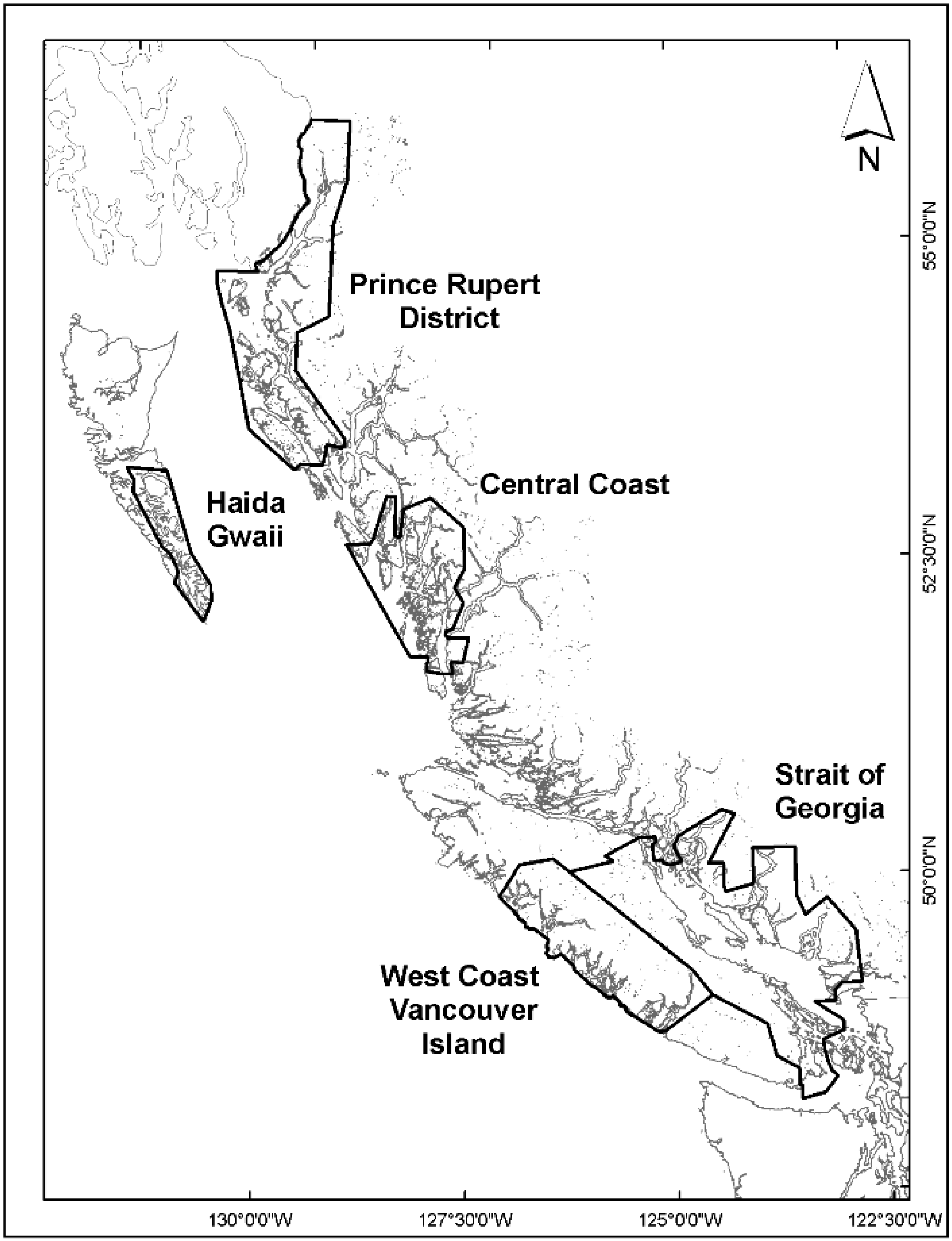


Figure 1. The five major British Columbia herring stock assessment areas.

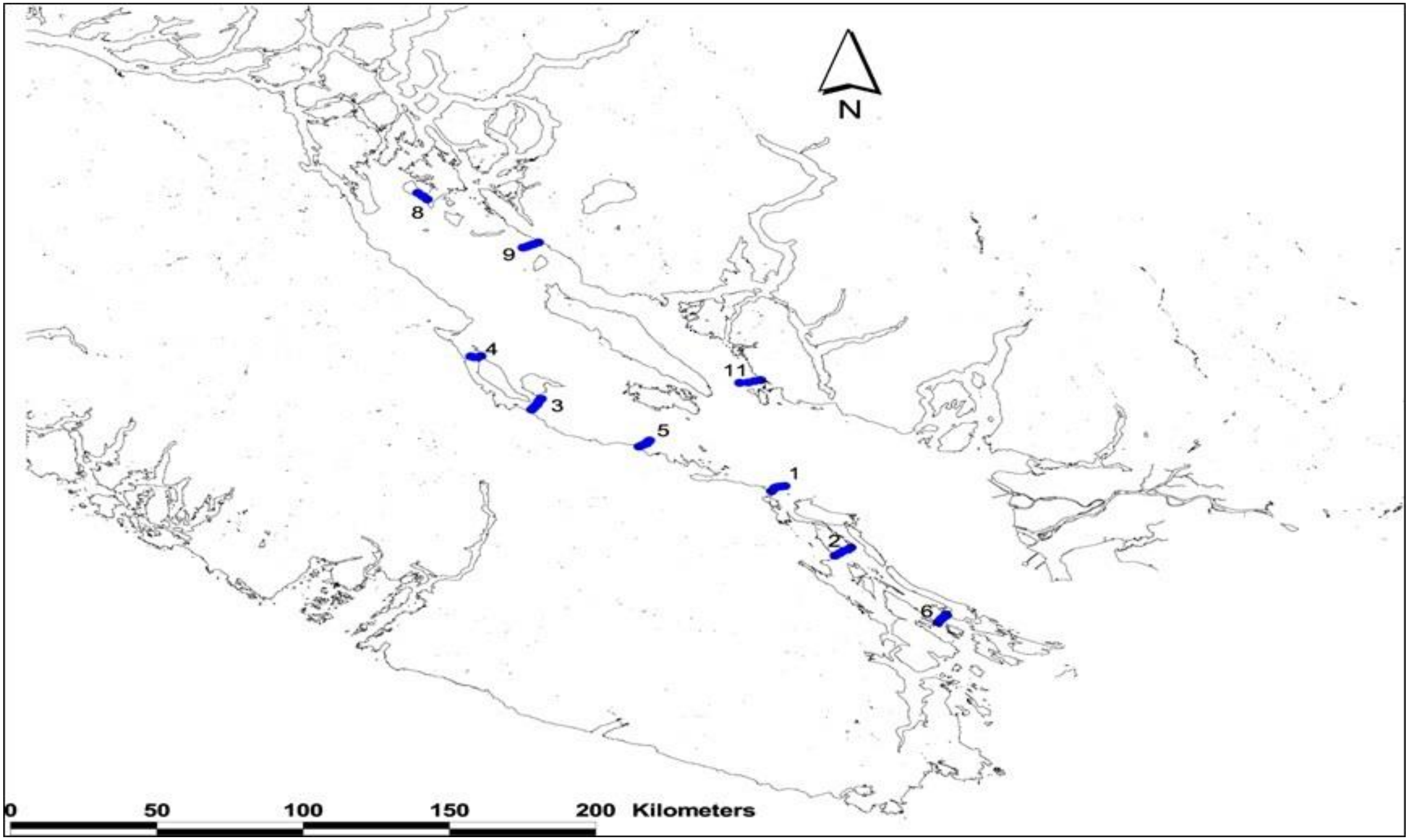


Figure 2. Purse seine set locations for the 2018 Strait of Georgia juvenile herring survey.

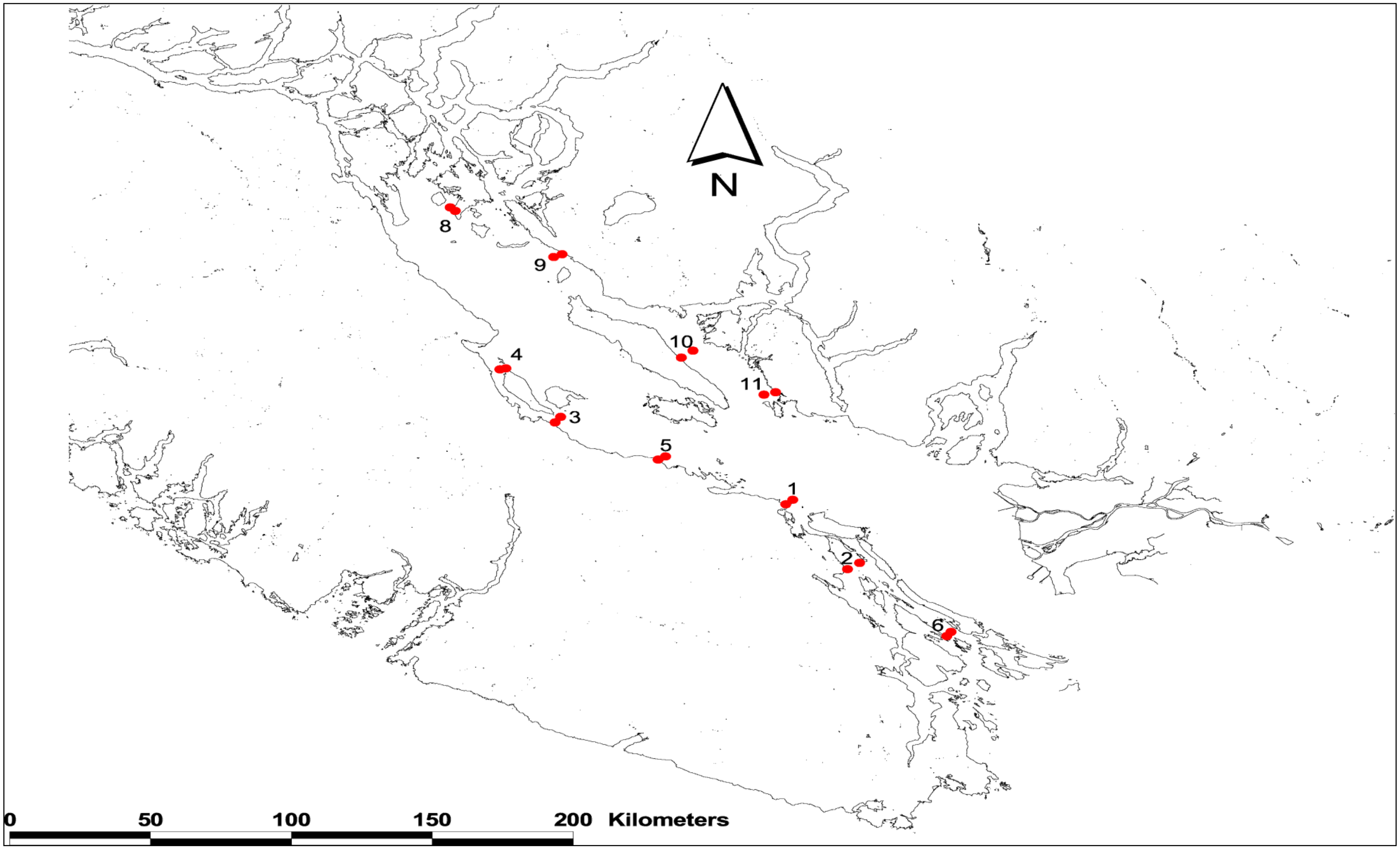


Figure 3. Zooplankton and CTD stations for 2018 Strait of Georgia juvenile herring survey.

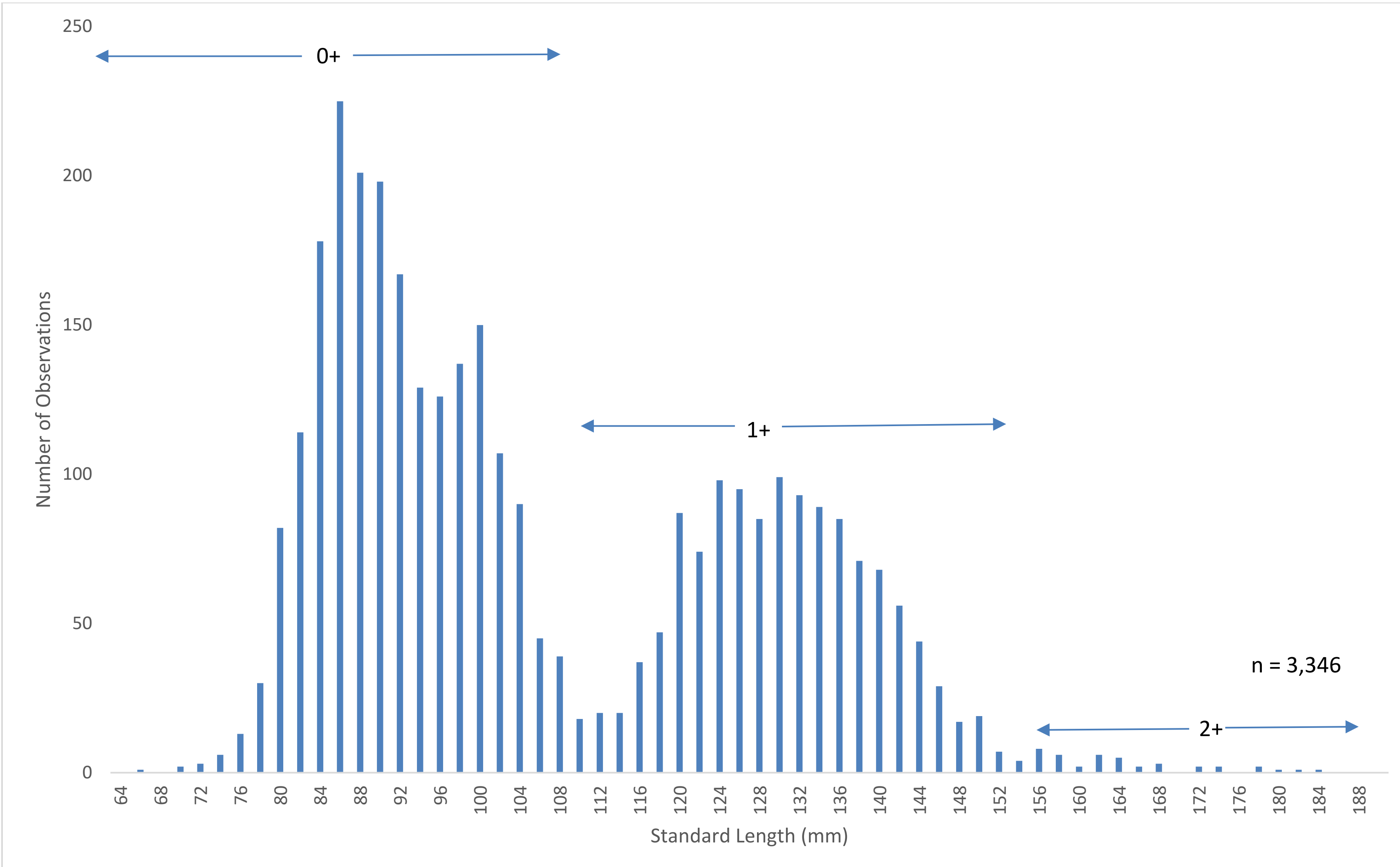
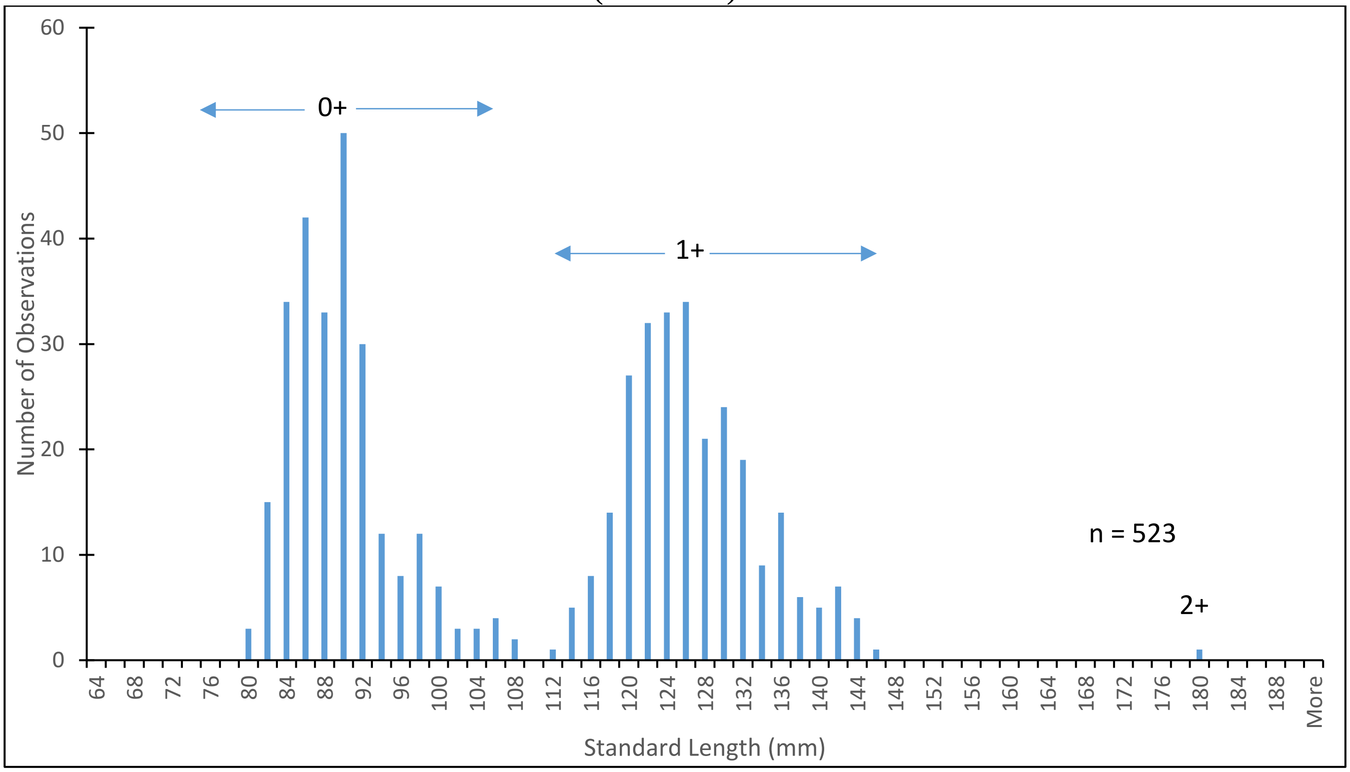


Figure 4. Length-frequency distribution for all herring sampled during the 2018 Strait of Georgia juvenile herring survey.

Clarke Rock (transect 1)



Yellow Point (transect 2)

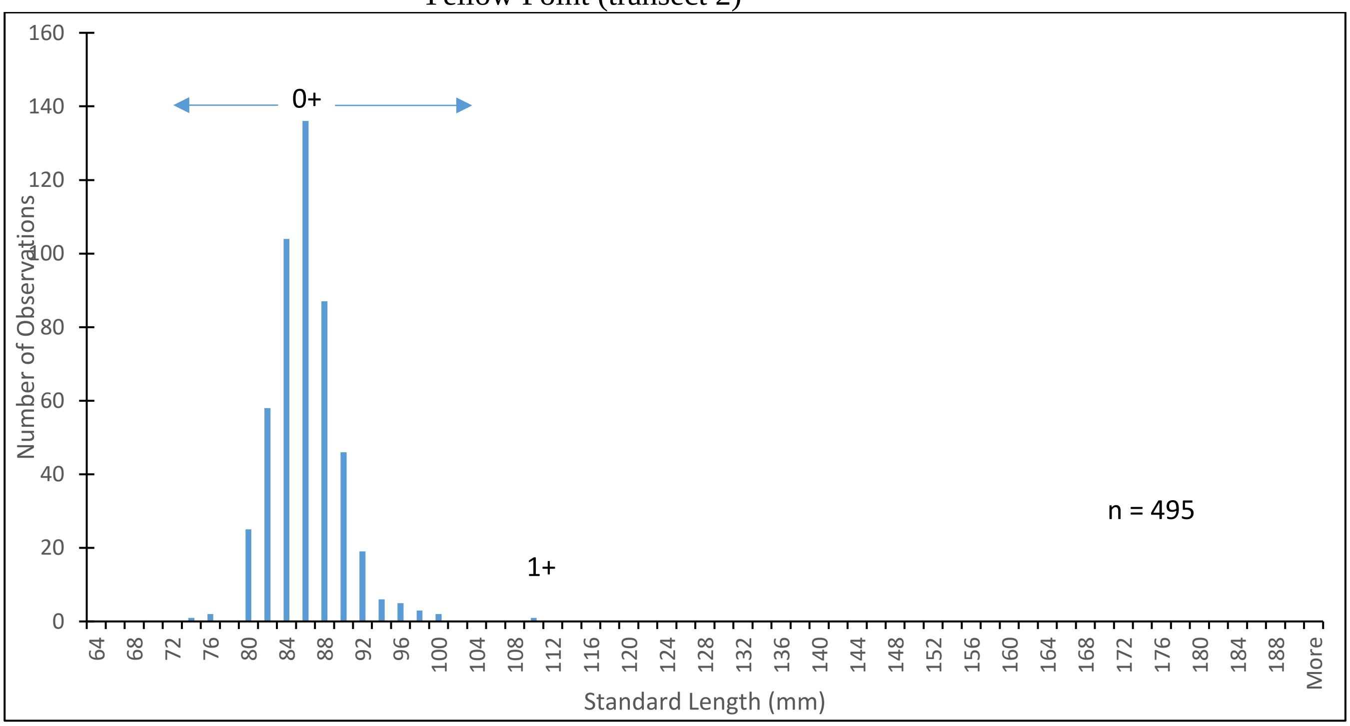
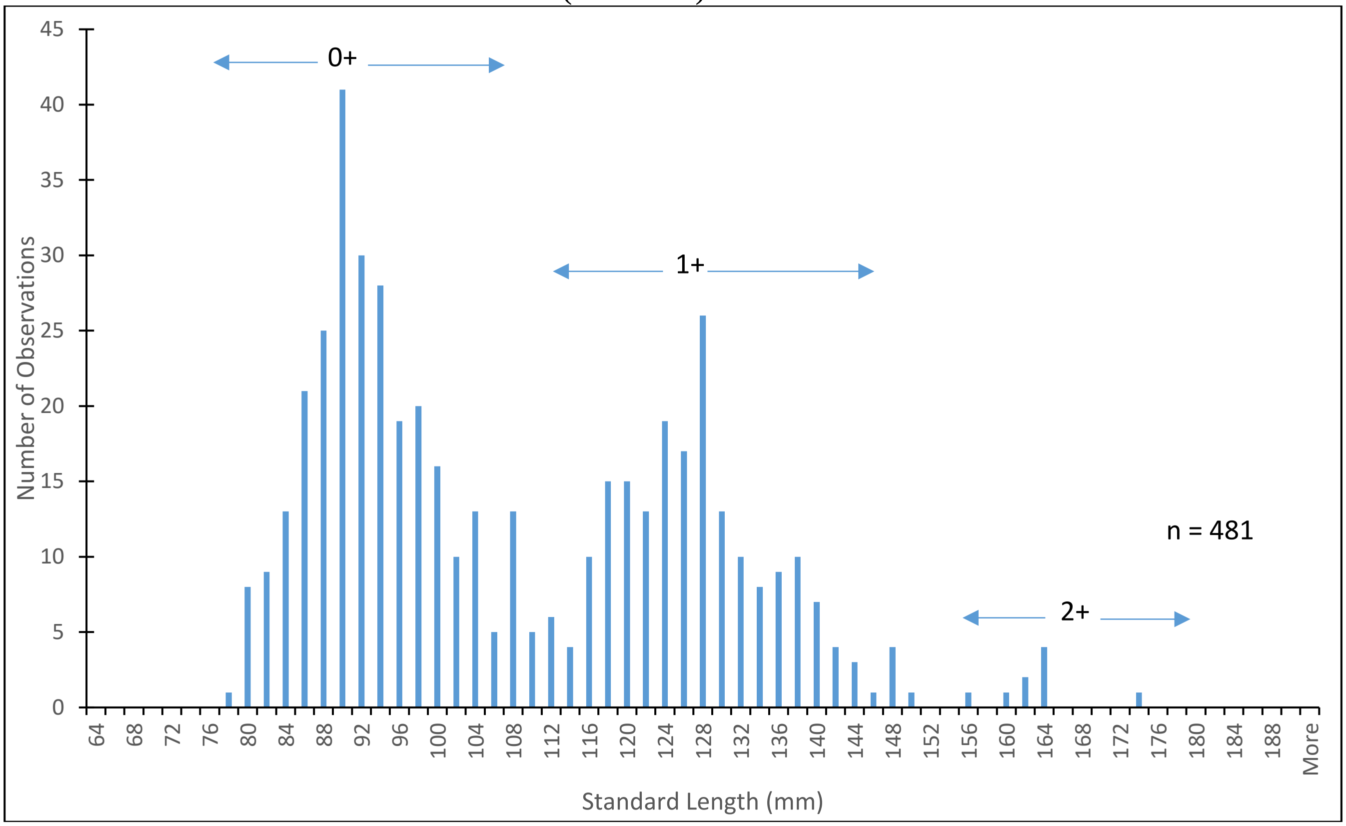


Figure 5. Length-frequency histograms of juvenile herring by transect location for the 2018 Strait of Georgia juvenile herring survey.

Bowser (transect 3)



Henry Bay (transect 4)

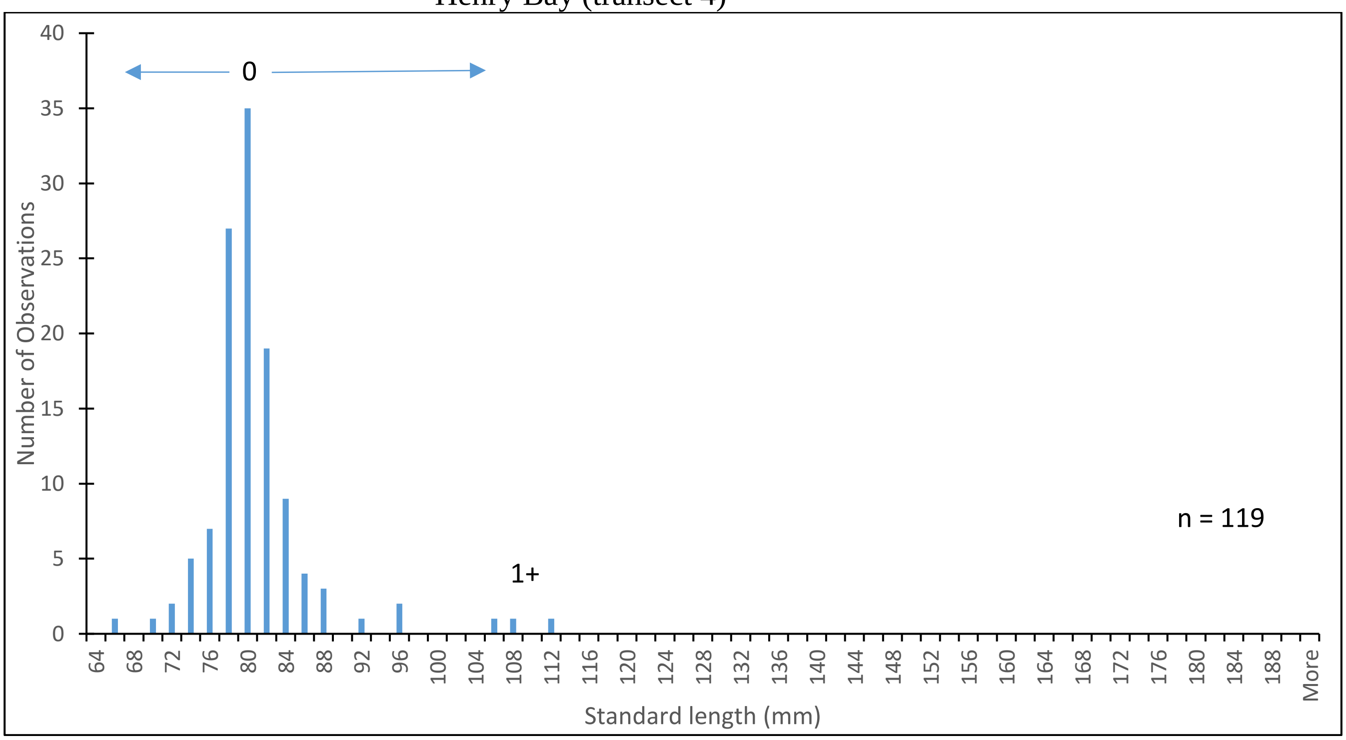
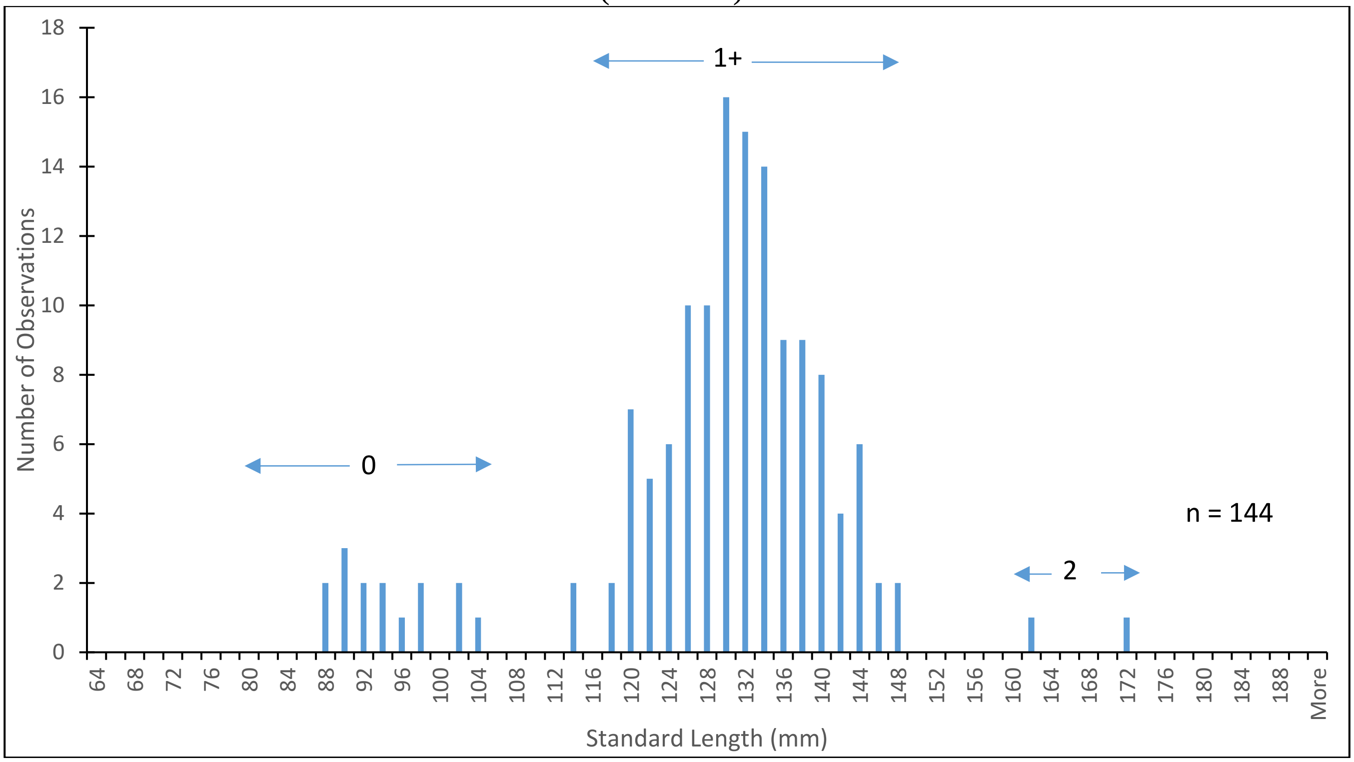


Figure 5 continued.

French Creek (transect 5)



Trincomali Channel (transect 6)

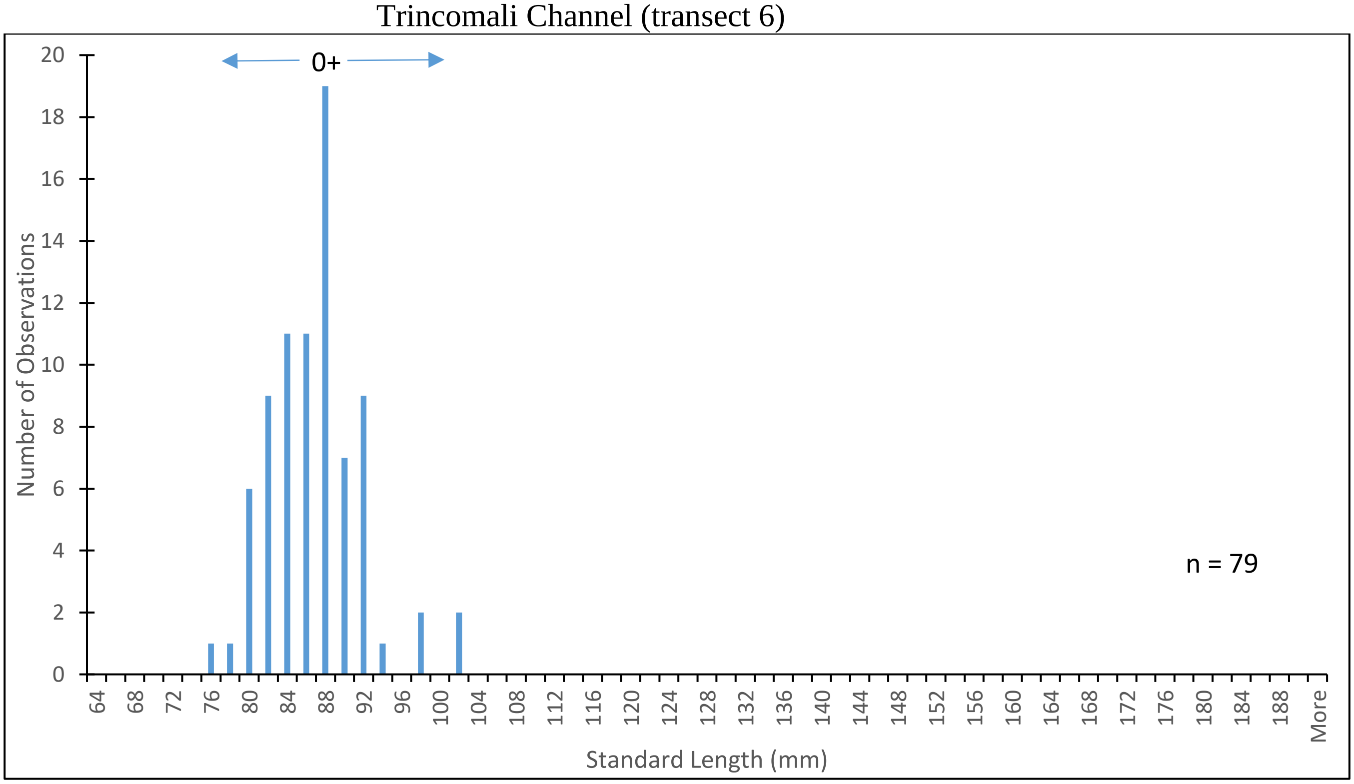
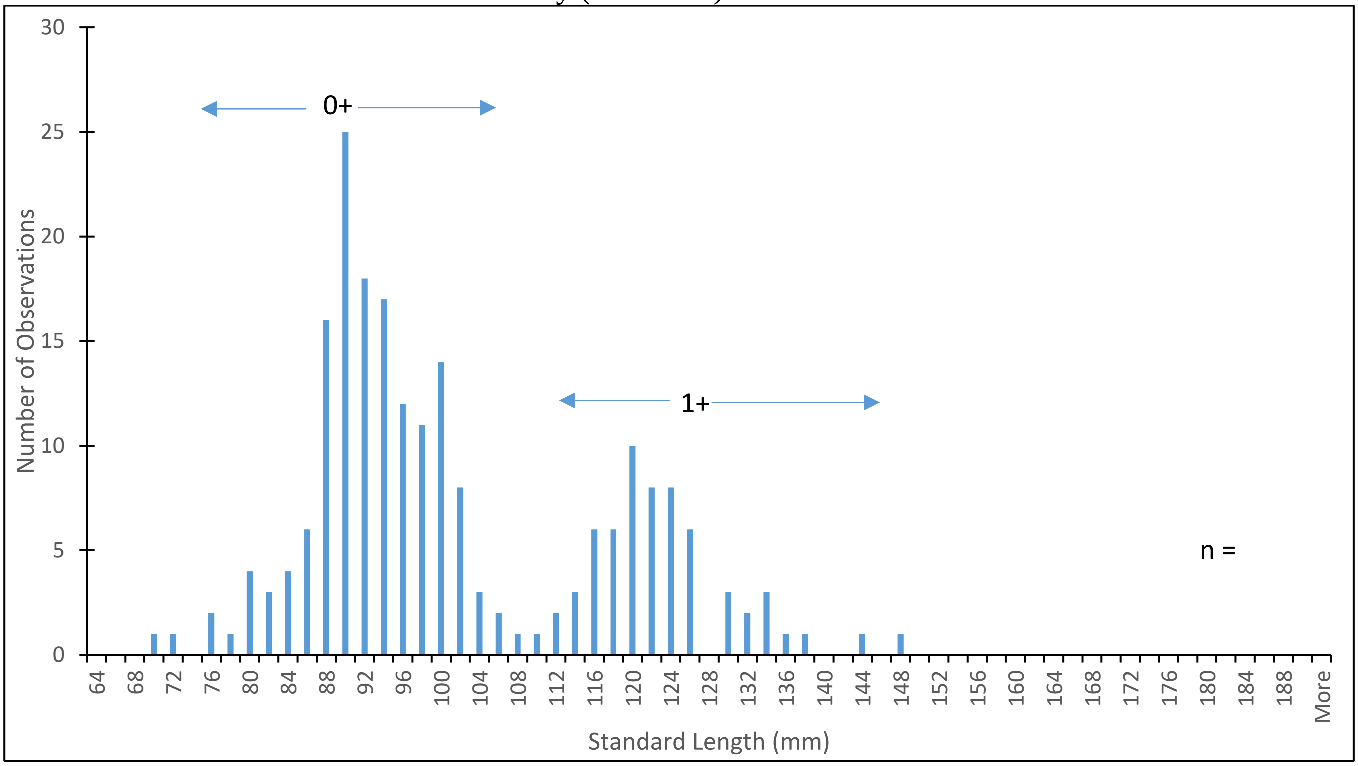


Figure 5 continued.

Smelt Bay (transect 8)



Atrevida Reef (transect 9)

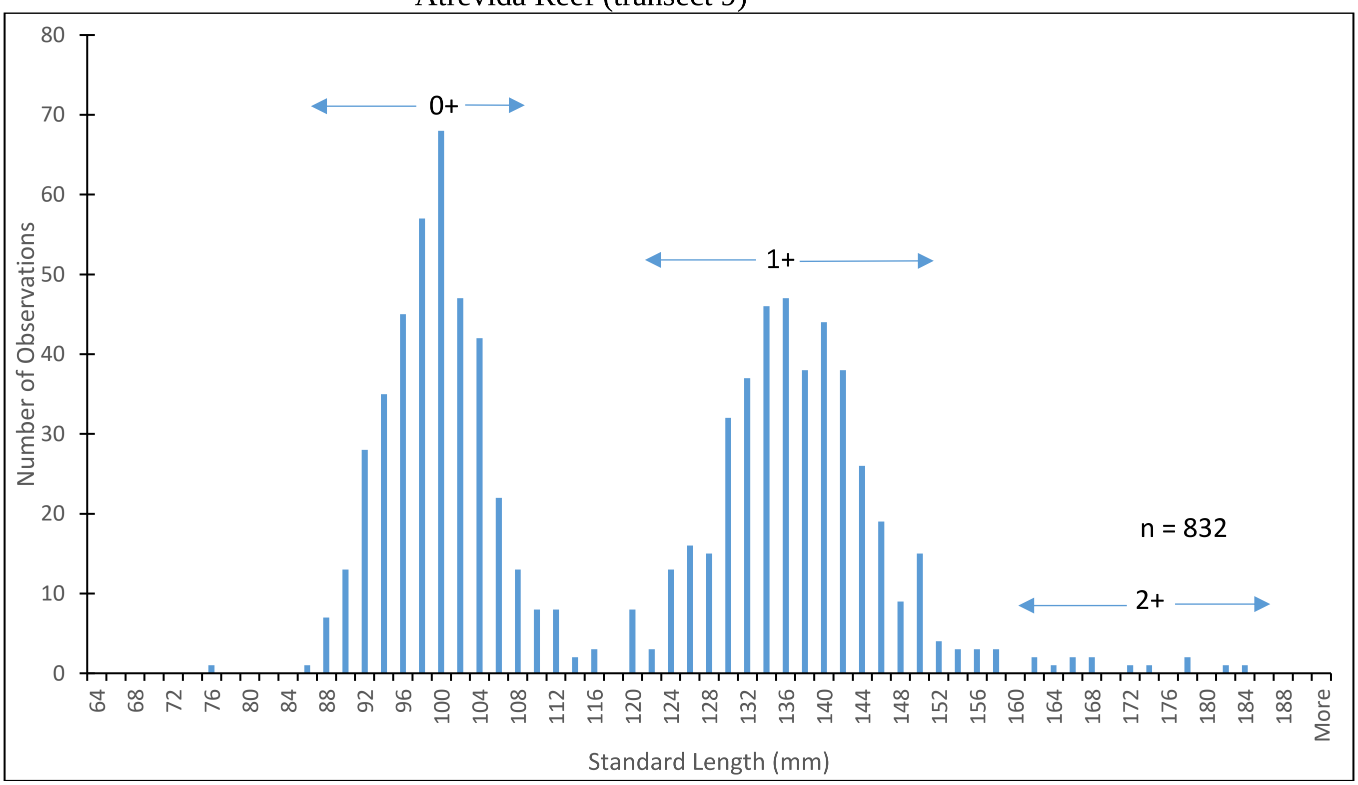
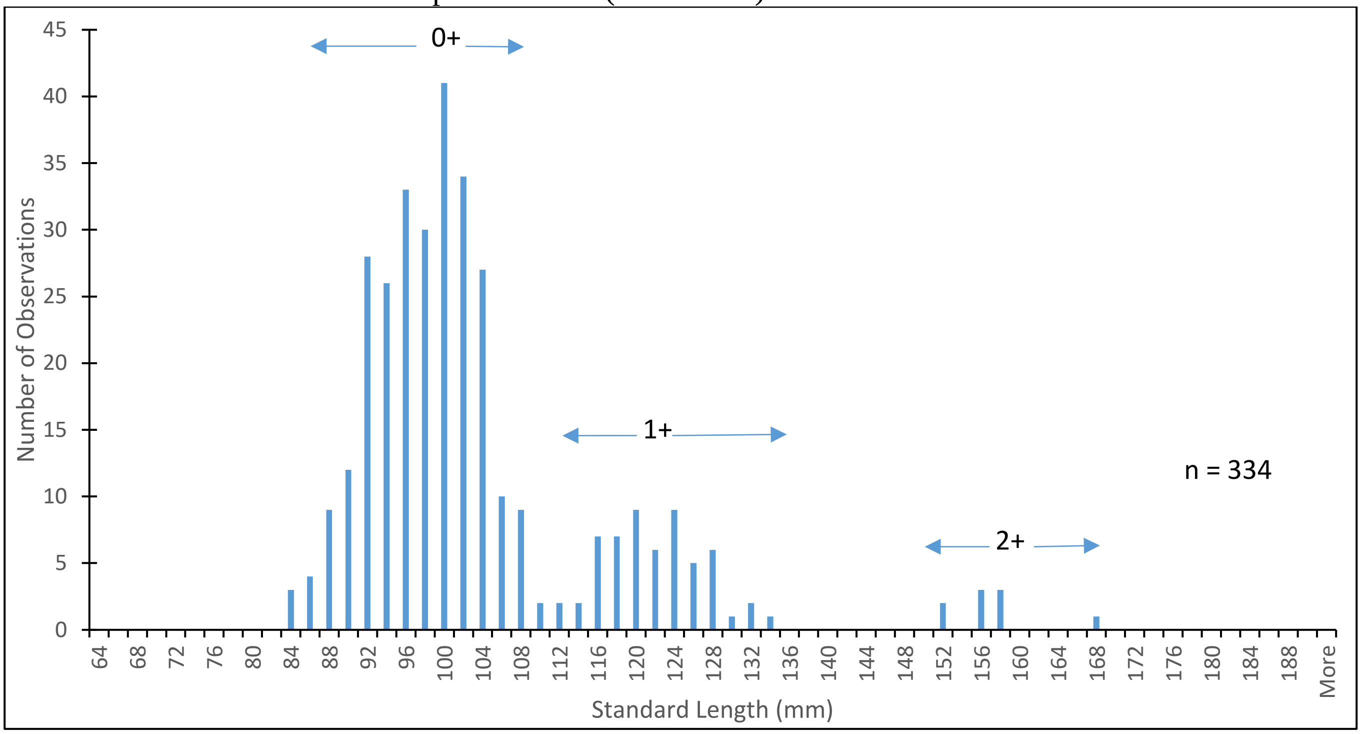


Figure 5 continued.

Cape Cockburn (transect 10)



Secret Cove (transect 11)

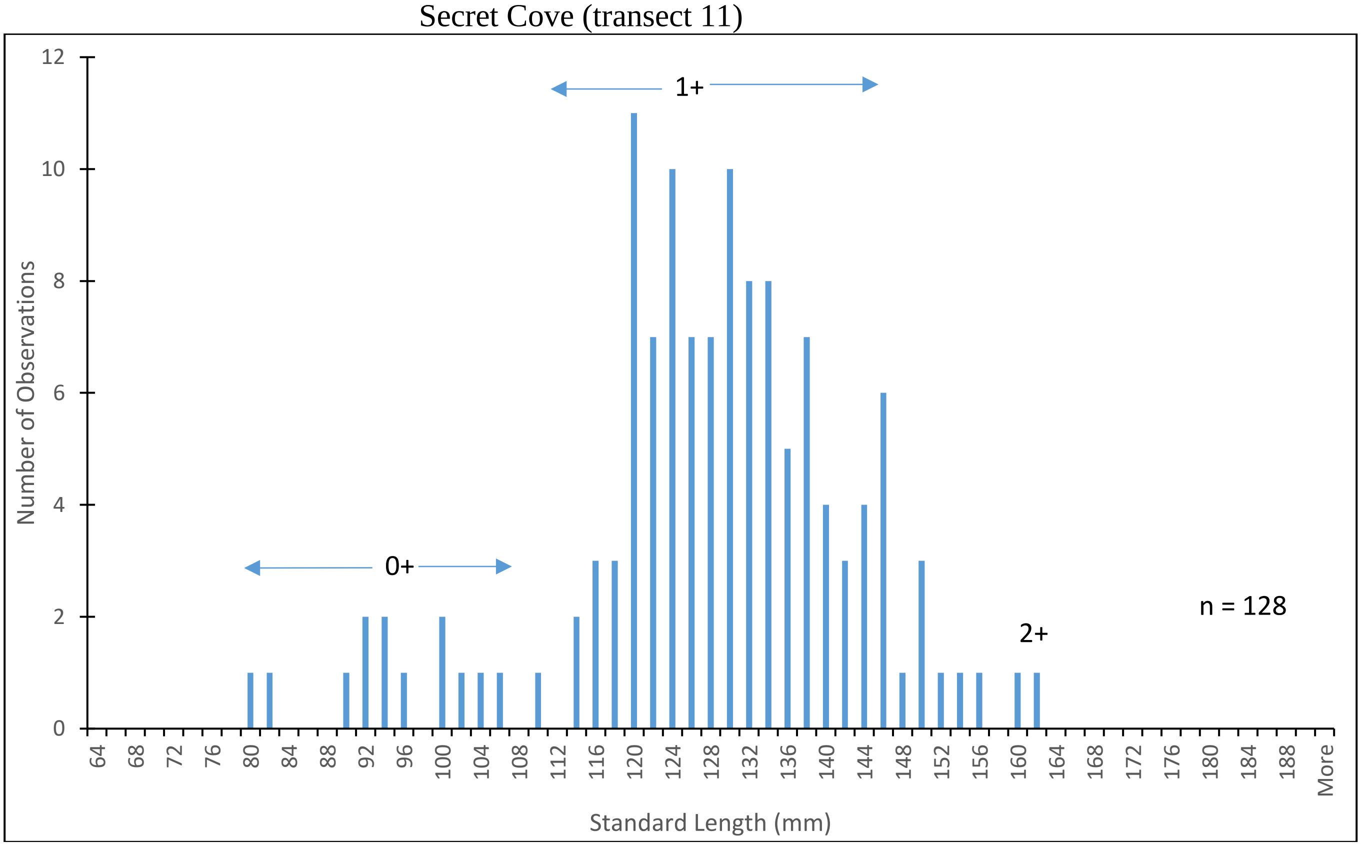


Figure 5 continued.

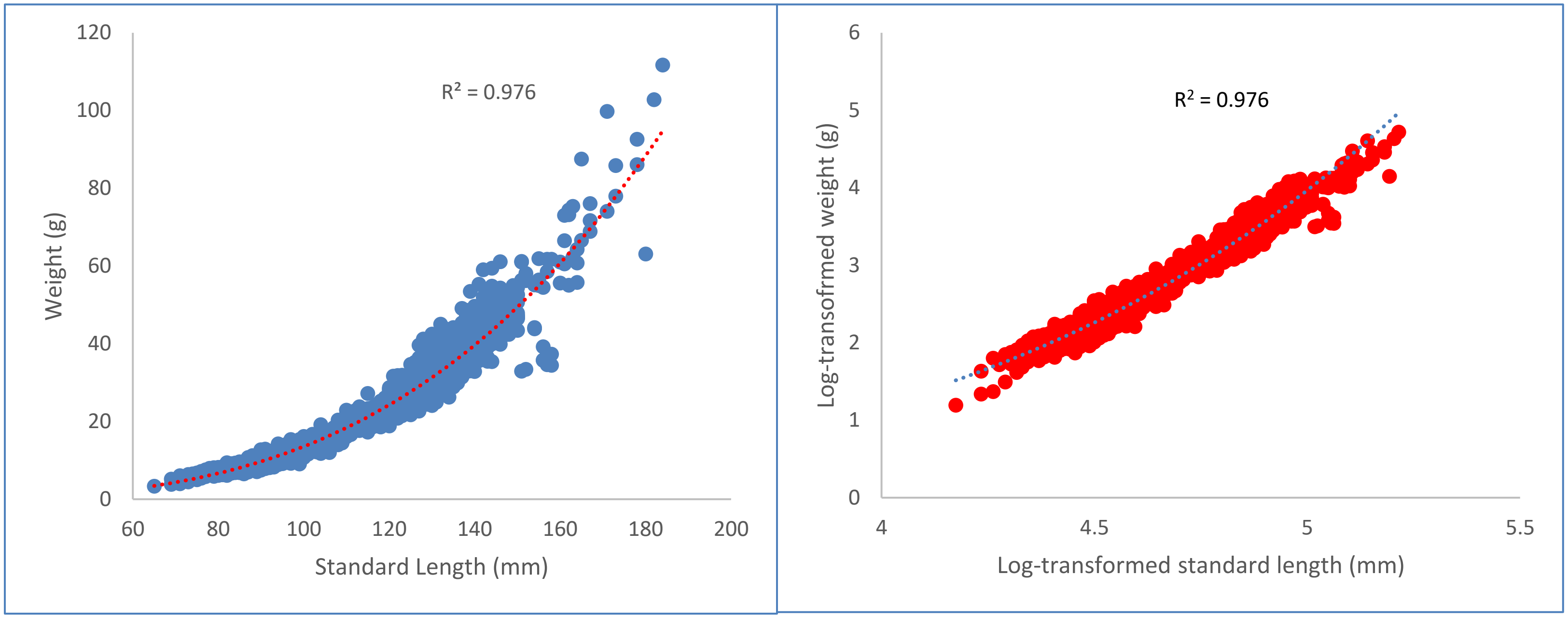


Figure 6. Non-transformed (left) and double log-transformed (right) length-weight relationships for all herring sampled during the 2018 Strait of Georgia juvenile herring survey.

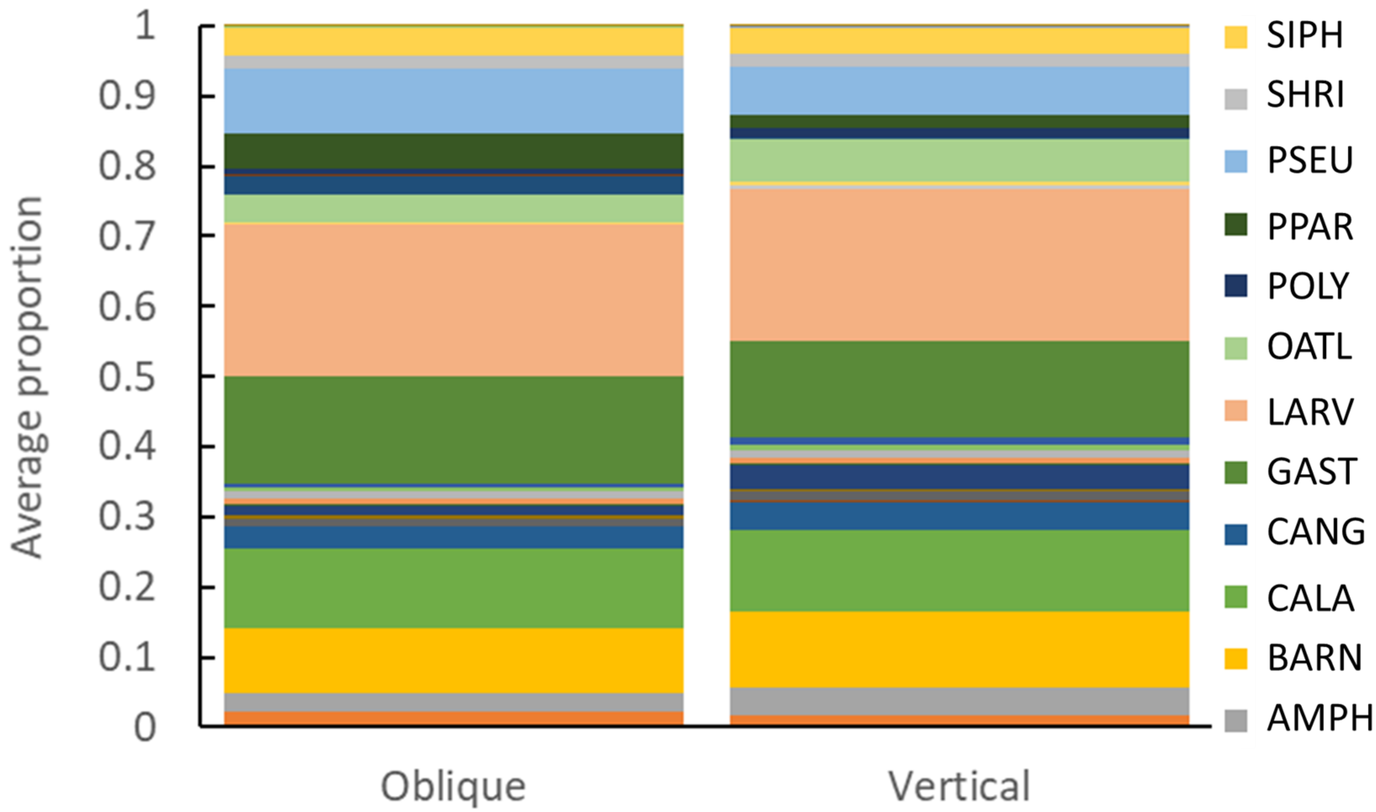


Figure 7. Average proportion zooplankton densities in oblique and vertical bongo tows from the 2018 Strait of Georgia juvenile herring survey (only major zooplankton taxonomic groups are shown in the legend; see Tables 5 and 6 for acronym definitions).

Table 1. Summary of the purse seine set locations from the 2018 Strait of Georgia juvenile herring survey. DD = decimal degrees.

Year	Month	Day	Transect	Station	Seine Set Time	Location Name	DD Lat (N)	DD Long (W)
2018	9	10	6	1	21:45	Trincomali Channel	48.855	-123.430
2018	9	10	6	2	22:15	Trincomali Channel	48.862	-123.423
2018	9	10	6	3	22:40	Trincomali Channel	48.867	-123.417
2018	9	10	6	4	23:05	Trincomali Channel	48.873	-123.407
2018	9	10	6	5	23:30	Trincomali Channel	48.877	-123.407
2018	9	11	2	5	20:35	Yellow Point	49.066	-123.698
2018	9	11	2	4	21:00	Yellow Point	49.060	-123.708
2018	9	11	2	3	21:30	Yellow Point	49.056	-123.722
2018	9	11	2	2	22:00	Yellow Point	49.050	-123.733
2018	9	11	2	1	22:30	Yellow Point	49.042	-123.747
2018	9	12	1	5	20:40	Clarke Rock	49.238	-123.902
2018	9	12	1	4	21:15	Clarke Rock	49.237	-123.912
2018	9	12	1	3	21:45	Clarke Rock	49.237	-123.922
2018	9	12	1	2	22:05	Clarke Rock	49.233	-123.932
2018	9	13	5	5	20:40	French Creek	49.366	-124.317
2018	9	13	5	4	21:05	French Creek	49.362	-124.323
2018	9	13	5	3	21:35	French Creek	49.358	-124.327
2018	9	13	5	2	21:55	French Creek	49.353	-124.338
2018	9	13	5	1	22:25	French Creek	49.348	-124.350
2018	9	17	11	1	20:40	Secret Cove	49.535	-123.977
2018	9	17	11	2	21:10	Secret Cove	49.532	-123.995
2018	9	17	11	3	21:40	Secret Cove	49.528	-124.014
2018	9	17	11	4	22:15	Secret Cove	49.527	-124.040
2018	9	17	11	5	22:45	Secret Cove	49.523	-124.060
2018	9	18	10	1	20:40	Cape Cockburn	49.670	-124.198
2018	9	18	10	2	21:05	Cape Cockburn	49.662	-124.218
2018	9	18	10	3	21:55	Cape Cockburn	49.651	-124.242
2018	9	18	10	4	22:25	Cape Cockburn	49.642	-124.255
2018	9	18	10	5	23:00	Cape Cockburn	49.632	-124.278
2018	9	19	8	3	21:30	Smelt Bay	50.054	-125.000
2018	9	19	8	2	22:00	Smelt Bay	50.046	-125.016
2018	9	19	8	1	22:20	Smelt Bay	50.036	-125.030

Table 1 continued.

Year	Month	Day	Transect	Station	Seine Set Time	Location Name	DD Lat (N)	DD Long (W)
2018	9	19	9	5	01:05	Atrevida Reef	49.902	-124.707
2018	9	19	9	4	01:30	Atrevida Reef	49.906	-124.694
2018	9	19	9	3	01:55	Atrevida Reef	49.909	-124.684
2018	9	19	9	2	02:15	Atrevida Reef	49.911	-124.673
2018	9	19	9	1	02:40	Atrevida Reef	49.916	-124.659
2018	9	20	4	5	20:05	Henry Bay	49.602	-124.836
2018	9	20	4	4	20:30	Henry Bay	49.598	-124.846
2018	9	24	3	5	20:20	Bowser	49.482	-124.651
2018	9	24	3	4	20:45	Bowser	49.476	-124.657
2018	9	24	3	3	21:10	Bowser	49.467	-124.663
2018	9	24	3	2	21:35	Bowser	49.459	-124.672
2018	9	24	3	1	22:00	Bowser	49.452	-124.680

Table 2. Summary of the number and weight by species, transect, and station for the 2018 Strait of Georgia juvenile herring survey.

Transect	Station	Location Name	SPECIES	Number	Weight (Kg)*
1	2	Clarke Rock	**Pacific herring age-0+**	22	0.24
			Pacific herring age-1+	272	7.04
			Pacific herring age-2+	2	0.13
			Walleye pollock, juvenile	10	0.06
			Pink salmon	4	0.23
			Squid	4	trace
			Northern anchovy	2	trace
			Chinook salmon	2	0.14
1	3	Clarke Rock	**Pacific herring age-0+**	104	0.95
			Pacific herring age-1+	93	2.61
			Chinook salmon	5	0.40
			Squid	3	trace
			Walleye pollock, juvenile	2	0.01
			Chum salmon	1	0.06
			Bay pipefish	1	0.00
1	4	Clarke Rock	**Pacific herring age-0+**	498	4.06
			Pacific herring age-1+	189	5.44
			Squid	9	0.45
			Pink salmon	6	0.33
			Chinook salmon	3	0.52
			Chum salmon	3	0.22
			Three-spine stickleback	3	trace
			Coho salmon	1	2.27
1	5	Clarke Rock	**Pacific herring age-0+**	41	0.36
			Pacific herring age-1+	9	0.26
			Squid	8	0.02
			Chum salmon	4	0.27
			Northern anchovy	2	0.04
			Pink salmon	2	0.11
			Plainfin midshipman	1	trace
2	1	Yellow Point	**Pacific herring age-0+**	726	6.01
			Squid	18	0.03
			Shiner perch	3	0.03

* weights <0.01 Kg referred to as trace

Transect	Station	Location Name	SPECIES	Number	Weight (Kg)*
2	2	Yellow Point	**Pacific herring age-0+**	196	1.65
			Squid	12	0.02
			Three-spine stickleback	10	0.01
			Chum salmon	2	0.09
2	3	Yellow Point	**Pacific herring age-0+**	410	3.31
			Squid	20	0.04
			Chinook salmon	2	0.09
			Plainfin midshipman	2	trace
			Three-spine stickleback	2	trace
2	4	Yellow Point	**Pacific herring age-0+**	456	4.00
			Squid	10	0.02
			Chum salmon	2	0.08
			Three-spine stickleback	2	trace
2	5	Yellow Point	**Pacific herring age-0+**	381	3.26
			Squid	237	0.54
			Three-spine stickleback	6	trace
			Northern anchovy	3	0.06
			Bay pipefish	3	trace
3	1	Bowser	Flatfish	42	6.34
			Sculpin	39	2.02
			Squid	39	0.86
			Shiner perch	27	0.30
			Plainfin midshipman	9	0.01
			Chinook salmon	3	0.16
			Walleye pollock, juvenile	3	0.06
3	2	Bowser	Chinook salmon	8	0.62
			Chum salmon	5	0.27
			Three-spine stickleback	3	trace
			Squid	1	trace
3	3	Bowser	**Pacific herring age-0+**	120	1.35
			Pacific herring age-1+	172	4.42
			Squid	40	0.14
			Chinook salmon	22	1.75
			Chum salmon	20	1.52
			Northern anchovy	2	0.04
			Three-spine stickleback	2	trace

Transect	Station	Location Name	SPECIES	Number	Weight (Kg)*
3	4	Bowser	**Pacific herring age-0+**	620	6.88
			Pacific herring age-1+	490	14.86
			Pacific herring age-2+	40	2.53
			Squid	95	0.32
			Chum salmon	5	0.40
3	5	Bowser	**Pacific herring age-0+**	524	5.14
			Pacific herring age-1+	28	0.75
			Squid	408	1.05
			Chinook salmon	6	0.62
			Chum salmon	2	0.15
4	4	Henry Bay	**Pacific herring age-0+**	47	0.38
			Northern anchovy	355	2.30
			Three-spine stickleback	28	0.02
			Squid	13	0.03
			Snake prickleback	5	0.03
			Plainfin midshipman	4	trace
4	5	Henry Bay	**Pacific herring age-0+**	179	1.10
			Pacific herring age-1+	1	0.02
			Northern anchovy	92	0.26
			Three-spine stickleback	75	0.04
			Shiner perch	3	0.02
			Squid	3	0.03
			Chinook salmon	2	0.15
			Plainfin midshipman	1	trace
			Sculpin	1	0.02
5	1	French Creek	**Pacific herring age-0+**	27	0.30
			Pacific herring age-1+	480	15.96
			Pacific herring age-2+	3	0.18
			Plainfin midshipman	27	0.02
			Bay pipefish	27	0.01
			Chum salmon	6	0.23
			Shiner perch	3	0.05
			Squid	3	0.12

Transect	Station	Location Name	SPECIES	Number	Weight (Kg)*
5	2	French Creek	**Pacific herring age-0+**	5	0.06
			Pacific herring age-1+	5	0.14
			Pacific herring age-2+	1	0.07
			Squid	4	0.01
			Chinook salmon	3	0.32
			Bay pipefish	2	trace
			Chum salmon	1	0.04
			Three-spine stickleback	1	trace
5	3	French Creek	**Pacific herring age-1+**	12	0.45
			Squid	7	0.01
			Chinook salmon	1	0.16
5	4	French Creek	**Pacific herring age-0+**	1	0.01
			Pacific herring age-1+	8	0.28
			Squid	24	0.13
5	5	French Creek	**Pacific herring age-1+**	2	0.08
			Squid	6	0.19
6	1	Trincomali Channel	**Pacific herring age-0+**	7	0.06
			Squid	1	trace
6	2	Trincomali Channel	**Pacific herring age-0+**	44	0.35
			Squid	1	trace
6	3	Trincomali Channel	**Pacific herring age-0+**	3	0.02
6	4	Trincomali Channel	**Pacific herring age-0+**	3	0.02
6	5	Trincomali Channel	**Pacific herring age-0+**	22	0.19
8	1	Smelt Bay	**Pacific herring age-0+**	375	3.64
			Pacific herring age-1+	3	0.09
			Squid	19	0.01
			Plainfin midshipman	13	0.01
			Chinook salmon	10	0.65
			Chum salmon	9	0.83
			Three-spine stickleback	8	0.01
			Bay pipefish	1	trace

Transect	Station	Location Name	SPECIES	Number	Weight (Kg)*
8	2	Smelt Bay	**Pacific herring age-0+**	19	0.21
			Pacific herring age-1+	50	1.30
			Squid	4	0.03
			Plainfin midshipman	3	trace
			Chum salmon	2	0.18
			Hake, juvenile	2	0.07
			Three-spine stickleback	2	trace
			Northern anchovy	1	trace
			Chinook salmon	1	0.06
8	3	Smelt Bay	**Pacific herring age-0+**	30	0.34
			Pacific herring age-1+	9	0.22
			Squid	334	0.29
			Plainfin midshipman	83	0.06
			Northern anchovy	9	0.11
			Chinook salmon	5	0.33
			Bay pipefish	2	trace
			Pacific sand lance	1	0.01
9	1	Atrevida Reef	**Pacific herring age-0+**	465	5.75
			Pacific herring age-1+	310	11.60
			Pacific herring age-2+	5	0.50
			Chum salmon	55	4.26
			Squid	45	0.07
			Chinook salmon	5	0.67
9	2	Atrevida Reef	**Pacific herring age-0+**	231	3.06
			Pacific herring age-1+	153	6.49
			Pacific herring age-2+	18	1.27
			Chum salmon	3	0.21
			Coho salmon	3	0.21
9	3	Atrevida Reef	**Pacific herring age-0+**	364	4.97
			Pacific herring age-1+	484	19.08
			Pacific herring age-2+	16	1.34
			Chinook salmon	4	0.89
			Chum salmon	4	0.31
			Bay pipefish	4	trace

Transect	Station	Location Name	SPECIES	Number	Weight (Kg)*
9	4	Atrevida Reef	**Pacific herring age-0+**	430	5.74
			Pacific herring age-1+	720	28.13
			Pacific herring age-2+	30	2.36
			Chum salmon	10	1.51
9	5	Atrevida Reef	**Pacific herring age-0+**	64	0.83
			Pacific herring age-1+	94	3.46
			Chinook salmon	4	0.82
			Squid	3	trace
			Plainfin midshipman	2	trace
			Pink salmon	2	0.13
			Bay pipefish	1	trace
10	1	Cape Cockburn	**Pacific herring age-0+**	56	0.66
			Pacific herring age-1+	52	1.30
			Squid	21	0.06
			Walleye pollock, juvenile	16	0.09
			Chinook salmon	13	0.40
			Chum salmon	7	0.45
			Hake, juvenile	1	trace
10	2	Cape Cockburn	**Pacific herring age-0+**	17	0.23
			Pacific herring age-1+	1	0.03
			Pacific herring age-2+	1	0.07
			Hake, juvenile	221	2.04
			Chinook salmon	2	0.05
			Chum salmon	2	0.13
			Northern anchovy	1	trace
			Pacific lamprey	1	0.03
10	3	Cape Cockburn	**Pacific herring age-0+**	82	1.07
			Pacific herring age-1+	1	0.02
			Hake, juvenile	525	4.41
			Chum salmon	4	0.29
			Chinook salmon	3	0.24
10	4	Cape Cockburn	**Pacific herring age-0+**	76	0.93
			Pacific herring age-1+	1	0.03
			Hake, juvenile	166	0.37
			Chum salmon	1	0.07
			Three-spine stickleback	1	trace

Transect	Station	Location Name	SPECIES	Number	Weight (Kg)*
10	5	Cape Cockburn	**Pacific herring age-0+**	67	0.83
			Pacific herring age-1+	4	0.12
			Pacific herring age-2+	6	0.22
			Plainfin midshipman	8	trace
			Chinook salmon	6	0.47
			Northern anchovy	1	0.02
			Chum salmon	1	0.09
11	1	Secret Cove	**Pacific herring age-1+**	2	0.05
			Chum salmon	24	1.89
			Plainfin midshipman	10	0.01
			Squid	10	0.01
			Chinook salmon	8	0.51
			Northern anchovy	2	0.01
			Hake, juvenile	2	0.03
			Bay pipefish	2	trace
11	2	Secret Cove	**Pacific herring age-0+**	2	0.03
			Pacific herring age-1+	128	4.14
			Pacific herring age-2+	4	0.27
			Hake, juvenile	22	0.19
			Northern anchovy	14	0.35
			Plainfin midshipman	12	0.01
			Chum salmon	8	0.85
			Bay pipefish	2	trace
			Three-spine stickleback	2	trace
11	3	Secret Cove	**Pacific herring age-0+**	14	0.14
			Pacific herring age-1+	72	2.43
			Northern anchovy	174	4.77
			Chinook salmon	4	0.34
			Chum salmon	2	0.14
			Plainfin midshipman	2	trace
			Bay pipefish	2	trace
11	4	Secret Cove	**Pacific herring age-0+**	4	0.05
			Pacific herring age-1+	22	0.80
			Northern anchovy	270	8.14

Transect	Station	Location Name	SPECIES	Number	Weight (Kg)*
11	5	Secret Cove	**Pacific herring age-0+**	3	0.03
			Pacific herring age-1+	1	0.05
			Northern anchovy	3	0.08
			Chum salmon	1	0.10
			Hake, juvenile	1	trace

Table 3. Percent occurrence by species in purse seine sets for the Strait of Georgia juvenile herring survey in 2018.

Common Name	Scientific Name	Number of sets	Percent Occurrence
Pacific herring age-0+	*Clupea pallasi* in year of birth	39	88.6
Pacific herring age-1+	*Clupea pallasi* in first year	31	70.5
Pacific herring age-2+	*Clupea pallasi* in second or more years	11	25.0
Bay pipefish	*Syngnathus griseolineatus*	11	25.0
Chinook salmon	*Oncorhyncus tshawytscha*	23	52.3
Chum salmon	*Oncorhyncus keta*	26	59.1
Coho salmon	*Oncorhyncus kisutch*	2	4.5
Flatfish	*Parophyrus vetulus, Lepidopsetta bilineata, Platichthys stellatus,*or *Citharichthys stigmaens*	1	2.3
Hake, juvenile	*Merluccius productus*	8	18.2
Northern anchovy	*Engraulis mordax mordax*	15	34.1
Pacific lamprey	*Lampetra tridentatus*	1	2.3
Pacific sand lance	*Ammodytes hexapterus*	1	2.3
Pink salmon	*Oncorhyncus gorbuscha*		
Plainfin midshipman	*Porichthys notatus*	14	31.8
Sculpin	*Hemilepidotus hemilepidotus*	2	4.5
Snake prickleback	*Lumpenus sagitta*	1	2.3
Squid	*Loligo opalescens,* or *Gonatus fabricii*	30	68.2
Shiner perch	*Cymatogaster aggregata*	4	9.1
Three-spine stickleback	*Gasterosteus aculeatus*	14	31.8
Walleye pollock, juvenile	*Gadus chalcogrammus*	4	9.1

* Jellyfish occurrence is not included due to the large quantities usually encountered and the inability to correctly quantify.

Table 4. Summary of the number of herring sampled, range of standard lengths (mm), mean lengths, range of weights (g), mean weights, and standard deviations for three age classes sampled during the 2018 Strait of Georgia juvenile herring survey. Total catch in numbers (N) and weight (Wt) of all herring are shown for each transect.

Age-0+ Herring

			Length (mm)			Weight (g)				
Location Name	**Transect**	**Number Sampled**	**Range**	**Mean**	**SD**	**Range**	**Mean**	**SD**	**N**	**Wt (Kg)**
Clarke Rock	1	258	79-108	89	5.60	6.11-17.78	8.76	1.64	665	5.60
Yellow Point	2	495	73-109	86	3.57	4.45-14.42	8.42	0.92	2169	18.23
Bowser	3	275	78-109	93	7.15	6.37-18.29	10.74	2.45	1264	13.37
Henry Bay	4	118	65-108	80	5.51	3.29-17.29	7.47	1.65	226	1.48
French Creek	5	15	87-104	94	5.51	8.53-16.01	11.43	2.38	33	0.37
Trincomali	6	79	75-102	86	4.92	5.48-14.23	8.17	1.55	79	0.65
Smelt Bay	8	149	69-107	92	6.70	3.81-18.34	10.35	2.25	424	4.18
Atrevida Reef	9	381	76-109	98	4.87	6.09-20.34	13.10	1.93	1554	20.36
Cape Cockburn	10	268	83-109	97	5.46	7.36-19.13	12.45	2.24	298	3.72
Secret Cove	11	13	80-105	94	7.85	7.15-14.69	11.16	2.40	23	0.26
All Locations		2051	65-109	91	6.09	3.29-20.34	10.28	2.69	6735	68.22

Age-1+ Herring

			Length (mm)			Weight (g)				
Location Name	**Transect**	**Number Sampled**	**Range**	**Mean**	**SD**	**Range**	**Mean**	**SD**	**N**	**Wt (Kg)**
Clarke Rock	1	264	111-145	126	6.87	17.23-45.28	27.34	5.59	563	15.35
Yellow Point	2	-	-	-	-	-	-	-	-	-
Bowser	3	198	110-155	127	8.76	16.63-55.57	28.05	6.41	690	20.02
Henry Bay	4	1	111	111	-	19.47	19.47	-	1	0.02
French Creek	5	127	114-147	131	7.33	20.02-53.08	34.29	6.69	507	16.90
Trincomali	6	-	-	-	-	-	-	-	-	-
Smelt Bay	8	62	110-147	123	7.44	17.21-45.40	26.09	5.62	62	1.62
Atrevida Reef	9	434	110-155	135	8.65	16.07-61.88	38.81	8.16	1761	68.76
Cape Cockburn	10	59	111-152	122	7.47	18.55-38.23	25.26	4.33	59	1.49
Secret Cove	11	113	110-155	131	9.92	20.72-58.07	33.22	8.22	225	7.46
All Locations		1258	110-155	130	9.32	16.07-61.88	32.47	8.73	3868	131.63

Table 4 continued.

Age-2+ Herring

			Length (mm)			Weight (g)				
Location Name	**Transect**	**Number Sampled**	**Range**	**Mean**	**SD**	**Range**	**Mean**	**SD**	**N**	**Wt (Kg)**
Clarke Rock	1	1	180	180	-	63.07	63.07	-	2	0.13
Yellow Point	2	-	-	-	-	-	-	-	-	-
Bowser	3	8	160-173	164	3.89	55.02-77.98	63.25	8.71	40	2.53
Henry Bay	4	-	-	-	-	-	-	-	-	-
French Creek	5	2	161-171	166	7.07	60.52-74.02	67.27	9.55	4	0.26
Trincomali	6	-	-	-	-	-	-	-	-	-
Smelt Bay	8	-	-	-	-	-	-	-	-	-
Atrevida Reef	9	17	156-184	167	9.03	54.44-111.66	78.18	16.76	69	5.47
Cape Cockburn	10	7	156-167	158	3.95	34.41-71.68	41.23	13.53	7	0.29
Secret Cove	11	2	160-162	161	1.41	60.97-73.15	67.06	8.61	4	0.27
All Locations		37	156-184	165	7.86	34.41-111.66	66.36	19.13	126	8.93

Table 5. Organisms by phylum, and with abbreviations, observed in zooplankton samples collected during the 2018 Strait of Georgia juvenile herring survey.

Coelenterata	
COEL	Medusae - *Aequorea victoria*
SIPH	Siphonophores
Ctenophora	
CTEN	Ctenophores
Annelida	
POLY	Polychaetes
Mollusca	
GAST	Prosobranch gastropods
PELE	Pelecypods
Arthropoda	
AMPH	Amphipods
BARN	Barnacle, unknown stage
CLAD	Cladocerans; *Podon sp.* and *Evadne sp.*
CNAU	Unidentified copepod nauplii
COPE	Copepods (see Table 6 for list of species)
CRAM	Crab megalopea, including porcillinadea
CRAZ	Crab zoea, including porcillinadea
CUMA	*Cumacea sp.*
EUPA	Adult euphausiids; mainly *Euphausia pacifica*
EUPL	Larval euphausiids; mainly *Euphausia pacifica*
ISOP	Isopods
MYSI	Mysids
OSTR	Ostracods
SEAL	*Caligus sp.*
SHRI	Shrimp zoea
Chaetognatha	
CHAE	Chaetognaths; mainly *Sagitta sp.*
Chordata	
LARV	Larvaceans; mainly *Oikopleura sp.* and some *Fritillaria sp.*
TELA	Teleosts (fish larvae)
Echinoderm	
ECHI	Echinoderms
Ectoproct	
ECTO	Ectoprocts
Miscellaneous	
EGGS	Unidentified eggs; either euphausiid or teleost

Table 6. Abbreviations for calanoid and cyclopoid copepods identified in the 2018 zooplankton samples from the Strait of Georgia juvenile herring survey.

Calanoid copepods	
ADIV	*Aetidius divergens*
ALON	*Acartia longiremis*
CABD	*Centropages abdominates*
CALA	*Calanus sp.*
CPAC	*Calanus pacificus*
EBUN	*Eucalanus bungii*
ELON	*Epilabidocera longipedata*
METR	*Metridia sp.*
MPAC	*Metridia pacifica*
PARA	*Paracalanus sp.*
PPAR	*Paracalanus parvus*
PSEU	*Pseudocalanus sp.*
SMIN	*Scolecithricella minor*
TDIS	*Tortanus discaudatus*
UCAL	Unidentified calanoid copepod
Cyclopoid copepods	
CANG	*Corycaeus anglicus*
OATL	*Oithona atlantica*
OSIM	*Oithona similis*
Harpacticoid copepods	
UHAR	Unidentified harpacticoid copepod

Table 7. Volume of water filtered and number of zooplankton per m^3 of water in oblique tow samples collected during the 2018 Strait of Georgia juvenile herring survey. Species codes as shown in Tables 5 and 6.

Location	Tran	Stn	Volume (m^3)	ALON	AMPH	BARN	CALA	CANG	CHAE	CLAD	CNAU	COEL
Clarke Rock	1	1	17.015	0.9	33.9	7.5	1.9	2.8	-	-	-	11.0
		3	24.928	10.3	14.8	20.5	56.8	28.2	-	-	2.6	10.3
Yellow Point	2	1	10.201	-	0.4	63.1	145.8	70.2	-	-	-	34.5
		4	9.742	-	0.4	65.7	49.9	62.4	-	-	3.3	9.2
Bowser	3	1	10.562	-	-	78.8	33.3	3.0	-	30.3	3.0	-
		3	13.142	9.7	5.2	21.9	66.2	9.7	0.1	56.0	-	-
Henry Bay	4	3	8.031	-		454.2	26.0	8.0	0.1	15.9	-	0.5
		5	3.879	8.2	-	1715.8	33.0	-	-	33.0	8.2	1.3
French Creek	5	1	16.164	9.9	2.0	3.0	4.0	4.0	-	1.0	-	0.1
		3	20.326	3.1	3.0	3.3	56.7	-	0.1	-	-	0.1
Trincomali Channel	6	1	17.731	46.9	3.9	375.7	32.0	86.6	0.7	-	-	3.9
		3	21.328	45.0	10.0	255.1	42.0	105.0	3.3	-	-	12.2
Smelt Bay	8	1	9.049	-	15.2	91.9	162.9	14.1	-	-	7.1	9.8
		2	3.371	-	64.1	151.9	1423.8	19.0	-	-	38.0	47.5
Atrevida Reef	9	1	18.744	2.1	3.2	0.4	3.4	2.1	-	-	-	1.9
		3	17.909	10.7	11.6	0.4	98.4	3.6	-	0.4	14.3	0.4
Cape Cockburn	10	1	18.950	1.7	4.5	1.7	21.5	1.7	0.1	1.3	-	1.3
		3	19.511	26.2	13.3	0.8	250.8	39.4	1.0	0.6	-	33.2
Secret Cove	11	1	18.609		14.0	12.0	56.7	13.8	0.1	24.1	-	17.5
		3	19.449	19.7	10.0	5.3	19.8	6.6	0.5	1.2	3.3	1.0

Table 7 continued.

Location	Tran	Stn	CPAC	CRAM	CRAZ	CTEN	CUMA	EBUN	ECHI	ECTO	EGGS	ELON	EUPA
Clarke Rock	1	1	-	-	5.6	29.6	-	-	-	2.8	-	0.2	-
		3	-	-	4.4	4.3	-	0.1	-	-	1.3	-	-
Yellow Point	2	1	-	-	6.3	0.8	-	-	-	-	-	-	-
		4	-	0.2	13.5	-	-	-	6.6	-	6.6	-	-
Bowser	3	1	-	-	-	0.6	-	-	6.1	-	-	0.7	-
		3	-	-	2.4	0.2	-	-	-	-	-	-	-
Henry Bay	4	3	0.2	-	16.1	-	-	-	8.0	-	0.1	-	-
		5	-	-	1.5	-	-	-	49.5	-	-	8.2	-
French Creek	5	1	-	-	7.3	-	-	0.1	-	-	1.0	-	-
		3	-	0.0	2.2	-	-	0.2	-	-	-	-	-
Trincomal Channel	6	1	-	0.1	11.7	0.8	-	-	-	-	-	-	-
		3	-	-	3.3	3.3	-	-	-	-	0.1	0.1	-
Smelt Bay	8	1	0.3	0.1	7.3	5.4	-	0.1	35.4	-	-	-	-
		2	227.8	-	61.7	16.6	-	-	-	-	-	-	-
Atrevida Reef	9	1	-	-	0.9	0.1	-	-	0.6	-	-	-	-
		3	0.1	-	0.4	-	-	-	5.4	-	-	-	-
Cape Cockburn	10	1	0.2	0.1	0.4	0.9	0.2	-	-	-	-	-	0.1
		3	-	-	0.4	5.1	-	-	1.6	-	-	0.4	-
Secret Cove	11	1	0.1	0.1	7.6	-	-	-	-	-	-	0.7	-
		3	-	0.1	-	0.6	-	-	-	-	-	-	-

Table 7 continued.

Location	Tran	Stn	EUPL	GAST	ISOP	LARV	MPAC	MYSI	OATL	OSIM	OSTR	PELE	POLY
Clarke Rock	1	1	-	71.5	-	4.7	-	-	1.9	-	-	-	2.8
		3	-	118.1	-	25.7	7.7	-	-	2.6	-	-	6.4
Yellow Point	2	1	12.5	56.5	-	819.5	-	-	-	18.8	-	-	6.3
		4	6.6	118.3	-	814.6	-	-	-	6.6	-	-	6.6
Bowser	3	1	-	194.0	3.0	360.6	13.4	-	-	109.1	3.0	-	-
		3	-	51.1	-	255.7	0.2	-	4.9	39.0	-	-	2.5
Henry Bay	4	3	-	263.0	-	709.6	-	-	-	67.7	-	-	79.7
		5	-	280.5	-	1996.2	8.2	-	-	41.2	-	-	198.0
French Creek	5	1	-	83.1	-	13.9	2.0	-	102.9	2.0	-	-	3.0
		3	-	9.6	-	6.3	3.2	-	116.5	-	-	-	-
Trincomal Channel	6	1	3.7	95.2	-	176.9	-	-	3.6	-	3.6	-	14.4
		3	3.0	45.0	-	117.0	3.0	-	-	15.0	-	-	12.0
Smelt Bay	8	1	-	742.6	-	658.1	0.1	0.2	-	7.1	0.8	-	7.1
		2	2.4	1670.6	-	284.8	-	-	-	-	-	-	19.0
Atrevida Reef	9	1	1.7	17.3	-	5.0	-	-	-	3.4	-	-	-
		3	6.0	13.8	-	38.8	3.6	-	-	14.3	0.9	-	-
Cape Cockburn	10	1	0.2	5.9	-	7.6	0.1	-	-	10.1	0.1	-	-
		3	0.2	10.0	-	1.2	-	-	-	13.1	-	0.4	-
Secret Cove	11	1	3.4	72.2	-	144.4	-	-	-	10.3	-	-	5.2
		3	1.6	4.9	-	31.3	-	-	-	9.9	-	-	-

Table 7 continued.

Location	Tran	Stn	PPAR	PSEU	SEAL	SHRI	SIPH	SMIN	TDIS	TELA	UCAL	UHAR
Clarke Rock	1	1	0.9	1.9	-	-	1.9	-	-	-	-	1.9
		3	14.4	18.7	-	0.2	9.0	-	-	-	-	-
Yellow Point	2	1	18.8	1.5	-	20.4	300.7	-	-	0.4	-	-
		4	51.9	6.6	-	8.6	296.5	-	-	-	-	-
Bowser	3	1	6.3	50.0	0.1	9.5	20.1	-	-	-	-	-
		3	13.3	86.4	-	2.8	39.0	-	-	-	-	-
Henry Bay	4	3	36.9	32.9	-	25.3	19.2	-	4.0	-	-	-
		5	41.2	74.2	-	19.6	33.3	-	8.2	0.3	-	-
French Creek	5	1	2.0	9.9	-	47.8	3.0	2.0	-	-	-	4.0
		3	-	78.0	-	1.4	0.05	-	-	-	-	-
Trincomal Channel	6	1	-	76.5	-	9.5	11.2	-	-	-	-	-
		3	12.0	39.0	-	0.1	6.0	-	3.0	-	-	-
Smelt Bay	8	1	21.2	14.1	-	53.3	257.0	-	-	-	-	-
		2	-	38.0	-	92.5	655.0	-	-	2.4	-	-
Atrevida Reef	9	1	11.5	9.0	-	1.7	0.8	-	-	-	-	-
		3	91.0	75.0	-	0.8	0.9	-	-	0.1	-	-
Cape Cockburn	10	1	10.4	18.0	-	2.6	0.4	-	-	-	-	-
		3	52.5	275.5	-	0.4	-	-	-	-	-	-
Secret Cove	11	1	14.3	21.2	-	10.9	3.5	-	-	-	0.1	-
		3	26.3	29.6	-	0.6	-	-	-	-	-	-

Table 8. Volume of water filtered and number of zooplankton per m^3 of water in vertical tow samples collected during the 2018 Strait of Georgia juvenile herring survey. Species codes as shown in Tables 5 and 6.

Location	Tran	Stn	Volume (m^3)	ADIV	ALON	AMPH	BARN	CABD	CALA	CANG	CHAE	CLAD
Clarke Rock	1	1	0.284	-	3.53	112.86	17.63	3.53	-	7.05	-	-
		3	0.567	-	14.11	-	7.05	-	15.87	28.22	-	-
Yellow Point	2	1	0.567	-	-	19.40	51.14	-	176.35	70.54	-	-
		4	0.567	-	-	-	169.30	-	215.15	126.97	-	-
Bowser	3	1	0.284	-	21.16	7.05	112.86	-	14.11	7.05	-	63.49
		3	0.567	-	-	3.53	31.74	-	84.65	7.05	-	28.22
Henry Bay	4	3	0.567	-	-	-	680.71	3.53	-	-	-	10.58
		5	0.284	-	-	-	19412.51	-	338.59	-	-	451.45
French Creek	5	1	0.284	-	14.11	-	28.22	-	7.05	14.11	-	3.53
		3	0.567	-	28.22	10.58	14.11	-	79.36	-	-	-
Trincomali Channel	6	1	0.567	28.22	253.94	1.76	775.94	-	359.75	507.89	1.76	-
		3	0.567	-	169.30	47.61	938.18	-	677.18	902.91	21.16	-
Smelt Bay	8	1	0.567	-	-	3.53	225.73	-	47.61	28.22	-	-
		2	0.567	-	-	63.49	56.43	-	1632.99	56.43	-	56.43
Atrevida Reef	9	1	0.567	-	1.76	14.11	7.05	-	1.76	3.53	-	1.76
		3	0.567	-	-	24.69	1.76	-	70.54	-	-	-
Cape Cockburn	10	1	0.567	-	5.29	42.32	1.76	-	45.85	12.34	1.76	3.53
		3	0.567	-	-	402.08	3.53	-	1661.21	225.73	121.68	7.05
Secret Cove	11	1	0.567	-	7.05	8.82	19.40	-	59.96	7.05	-	15.87
		3	0.567	-	14.11	89.94	3.53	-	301.56	112.86	7.05	3.53

Table 8 continued.

Location	Tran	Stn	CNAU	COEL	CPAC	CRAM	CRAZ	CTEN	EBUN	ECHI	ECTO	ELON	EUPA
Clarke Rock	1	1	7.05	67.01	-	-	14.11	24.69	-	3.53	10.58	-	-
		3	3.53	1.76	-	-	1.76	3.53	-	-	-	-	-
Yellow Point	2	1	-	45.85	-	-	-	61.72	-	-	-	-	-
		4	-	19.40	31.74	-	29.98	52.90	-	-	14.11	-	-
Bowser	3	1	-	3.53	-	-	24.69	-	-	-	-	7.05	-
		3	-	-	-	-	-	-	-	-	-	-	-
Henry Bay	4	3	3.53	-	-	3.53	7.05	-	-	-	-	-	-
		5	-	-	-	-	112.86	-	-	112.86	-	-	-
French Creek	5	1	-	-	-	-	10.58	-	-	-	-	-	-
		3	-	-	-	-	-	-	-	-	-	-	-
Trincomali Channel	6	1	-	15.87	28.22	-	22.93	58.20	-	-	-	-	-
		3	-	125.21	-	1.76	29.98	-	-	-	-	-	-
Smelt Bay	8	1	-	116.39	-	-	5.29	98.76	28.22	197.51	-	-	-
		2	-	126.97	176.35	-	-	148.13	-	451.45	-	-	42.32
Atrevida Reef	9	1	-	7.05	-	-	1.76	1.76	-	-	-	-	-
		3	-	-	-	-	-	-	-	5.29	-	-	-
Cape Cockburn	10	1	1.76	82.88	-	-	-	3.53	-	3.53	-	-	-
		3	-	564.32	-	-	7.05	5.29	-	7.05	-	-	-
Secret Cove	11	1	-	12.34	-	-	8.82	21.16	-	-	-	1.76	-
		3	7.05	5.29	3.53	-	-	3.53	-	-	-	-	-

Table 8 continued.

Location	Tran	Stn	EUPL	GAST	LARV	METR	MPAC	OATL	OSIM	OSTR	PARA	PELE	POLY
Clarke Rock	1	1	7.05	310.37	7.05	-	3.53	14.11	-	-	-	-	14.11
		3	-	49.38	8.82	-	29.98	59.96	-	-	-	-	12.34
Yellow Point	2	1	14.11	42.32	1015.77	-	-	7.05	-	-	-	-	-
		4	42.32	112.86	3851.46	-	-	28.22	-	-	-	-	112.86
Bowser	3	1	14.11	7.05	225.73	-	-	7.05	-	-	-	-	28.22
		3	-	56.43	342.12	21.16	-	49.38	-	-	-	-	3.53
Henry Bay	4	3	-	-	246.89	-	-	-	-	-	-	3.53	38.80
		5	-	1805.81	12189.25	-	-	-	-	-	-	-	451.45
French Creek	5	1	-	112.86	52.90	-	-	155.19	-	-	-	-	-
		3	-	56.43	49.38	22.93	-	282.16	-	-	-	-	-
Trincomali Channel	6	1	7.05	91.70	253.94	28.22	-	-	-	14.11	-	-	14.11
		3	-	155.19	261.00	-	-	-	-	-	-	-	42.32
Smelt Bay	8	1	84.65	2934.45	1777.60	-	-	28.22	-	-	-	-	174.59
		2	56.43	2652.29	733.61	79.36	-	-	-	-	-	-	282.16
Atrevida Reef	9	1	7.05	82.88	28.22	-	-	-	5.29	-	-	-	-
		3	8.82	10.58	70.54	-	-	-	-	-	-	-	-
Cape Cockburn	10	1	1.76	8.82	10.58	3.53	-	22.93	-	-	3.53	-	-
		3	7.05	31.74	3.53	-	-	169.30	-	-	-	-	-
Secret Cove	11	1	7.05	98.76	130.50	-	-	7.05	-	-	-	-	1.76
		3	10.58	38.80	186.93	-	-	21.16	-	3.53	-	-	-

Table 8 continued.

Location	Tran	Stn	PPAR	PSEU	SHRI	SIPH	SMIN	TELA	UHAR
Clarke Rock	1	1	-	-	7.05	3.53	-	-	10.58
		3	-	24.69	10.58	5.29	-	-	-
Yellow Point	2	1	21.16	7.05	7.05	315.66	-	-	-
		4	28.22	14.11	105.81	648.96	-	-	-
Bowser	3	1	21.16	35.27	7.05	7.05	-	-	-
		3	3.53	59.96	-	3.53	-	-	-
Henry Bay	4	3	7.05	7.05	14.11	45.85	-	-	-
		5	225.73	338.59	225.73	338.59	-	-	-
French Creek	5	1	-	14.11	31.74	-	-	3.53	-
		3	-	151.66	31.74	3.53	14.11	-	-
Trincomali Channel	6	1	74.07	603.11	28.22	29.98	-	-	-
		3	56.43	1128.63	28.22	35.27	-	-	-
Smelt Bay	8	1	58.20	84.65	174.59	715.98	-	-	-
		2	192.22	135.79	126.97	1587.14	-	-	-
Atrevida Reef	9	1	1.76	10.58	1.76	3.53	-	-	-
		3	12.34	15.87	3.53	3.53	-	-	-
Cape Cockburn	10	1	8.82	21.16	3.53	-	-	-	-
		3	56.43	169.30	21.16	-	-	3.53	-
Secret Cove	11	1	10.58	17.63	26.45	3.53	-	-	-
		3	89.94	174.59	10.58	3.53	-	-	-

APPENDIX 1

An index of relative biomass and abundance of juvenile Pacific Herring in the Strait of Georgia

The Strait of Georgia (SOG) juvenile herring and nearshore pelagic ecosystem survey collects time-series information that can be used to estimate the relative abundance of age-0 herring and perhaps provide a forecast of low recruitment to the adult spawning population. This information may also represent trends in prey availability to Coho and Chinook Salmon and other predators in the SOG. The index (and associated variance) of the relative biomass or abundance of age-0 herring in the SOG was updated with the 2018 survey data using methods identified in Boldt et al. (2015). In addition, annual variation in herring lengths and weights were examined.

Estimates of mean catch weights (g), abundance, and CPUE (weight and abundance) of age-0 herring varied interannually with no significant overall trend during 1992-2018 (Figures A1 and Table A1). In 2018, age-0 herring estimates continued to be low and were the 4th lowest in the time series. The interannual variability in mean estimates has been low compared to observations prior to 2012, when there was a pattern of alternating high (with high associated variance estimates) and low indices every two or three years. (Figure A1 and Table A1). Estimates of CVs ranged from 23% to 81% with an average of 46% (Figure A1 and Table A1). In 2018, age-0 herring lengths and weights were higher than those measured in 2017 (Figure A2), and their condition (residuals from a double-log-transformed length weight regression) was above average (not shown). During the time series, there was no significant linear trend in mean lengths or weights of age-0 herring (Figure A2).

Literature cited:

Boldt, J.L., Thompson, M., Fort, C., Rooper, C.N., Schweigert, J., Quinn II, T.J., Hay, D., and Therriault, T.W. An index of relative biomass, abundance, and condition of juvenile Pacific Herring (*Clupea pallasi*) in the Strait of Georgia, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 3081: x + 80 p.

Thompson, S.K. 1992. Sampling. John Wiley and Sons, Inc. New York. 343 p.

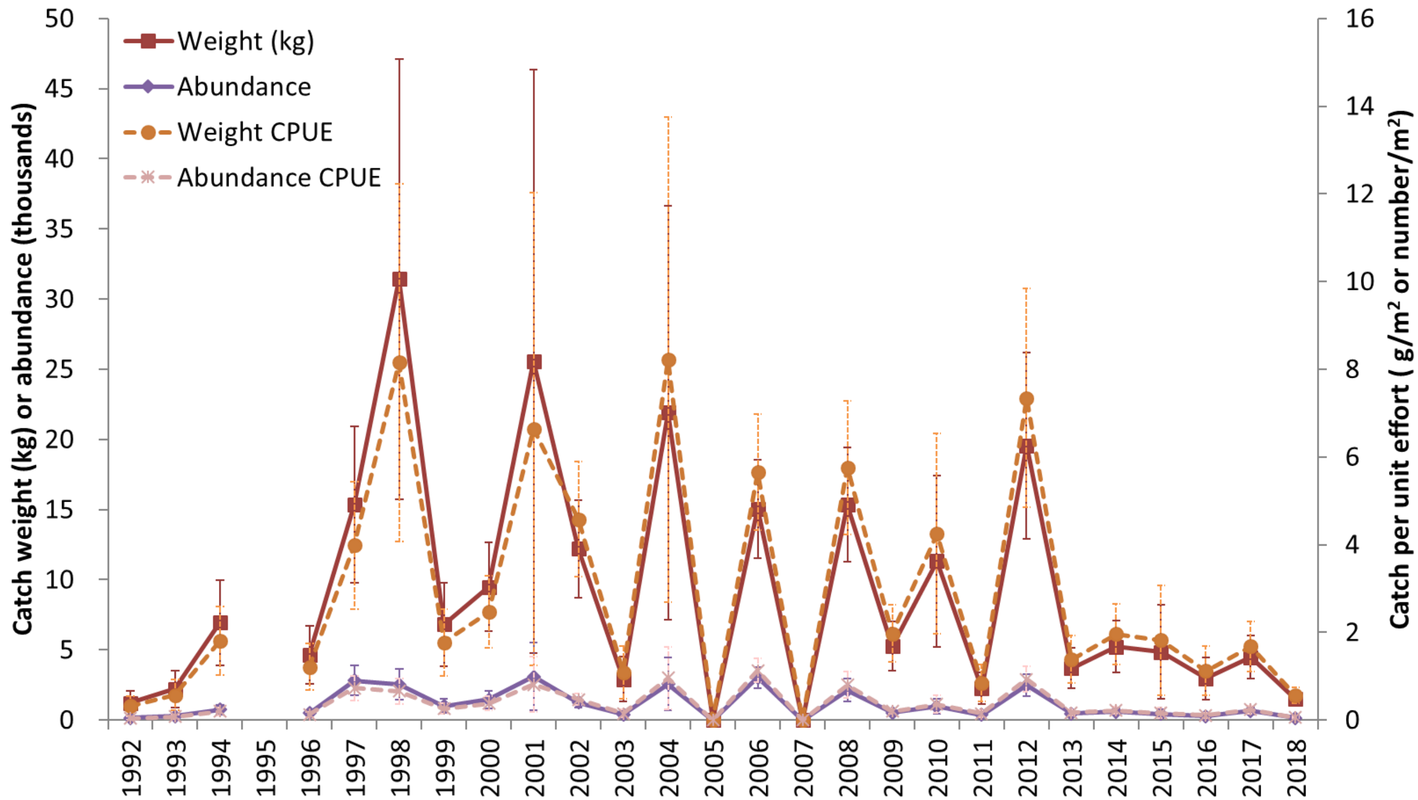


Figure A1. Estimates of catch weight (kg), catch weight-per-unit-effort (weight CPUE; g/m^2), abundance, and abundance CPUE (number/m^2) of age-0 herring caught in the Strait of Georgia juvenile herring survey at core transects and stations during 1992-2018 (no survey in 1995). Estimates were calculated using a two-stage method (see Boldt et al. 2015). Estimates of CPUE were calculated by dividing catch weight (or abundance) by the area fished by the net (assuming the net length changed in 2002 from 220 m to 183 m; see Boldt et al. 2015 for details). Standard error bars (using the Thompson 1992 variance estimator) are shown.

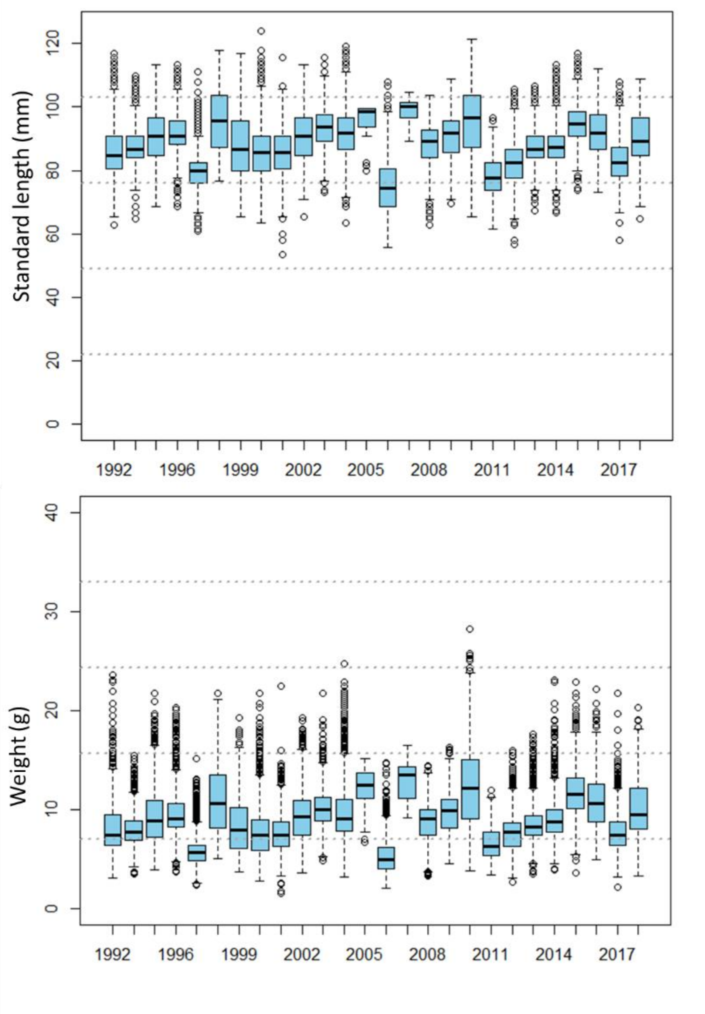


Figure A2. Boxplots of age-0 herring standard lengths (mm; top panel) and weights (g; bottom panel) measured in the laboratory during 1992-2018 (no survey in 1995). Standard error bars are shown.

Table A1. Mean catch weight (g), catch weight per unit effort (CPUE; g/m^2), abundance, abundance CPUE (number/m^2), standard error (SE), and coefficient of variation (CV) of age-0 herring caught in the Strait of Georgia juvenile herring survey at core transects and stations during 1992-2018 (no survey in 1995). Two-stage sampling formulae (Thompson 1992) were used to calculate the mean and variance.

Year	Weight (g)	SE	CV	Weight CPUE (g/m^2)	SE	CV	Abundance	SE	CV	Abundance CPUE (number/m^2)	SE	CV
1992	1226.333	852.076	0.695	0.318	0.221	0.695	163.358	122.426	0.749	0.042	0.032	0.749
1993	2206.211	1337.446	0.606	0.573	0.347	0.606	285.847	178.452	0.624	0.074	0.046	0.624
1994	6930.616	3010.497	0.434	1.799	0.782	0.434	748.304	334.987	0.448	0.194	0.087	0.448
1995												
1996	4669.740	2065.650	0.442	1.212	0.536	0.442	499.247	228.320	0.457	0.130	0.059	0.457
1997	15341.900	5569.885	0.363	3.983	1.446	0.363	2813.467	1072.734	0.381	0.730	0.278	0.381
1998	31418.933	15708.446	0.500	8.157	4.078	0.500	2529.717	1111.968	0.440	0.657	0.289	0.440
1999	6809.267	2963.350	0.435	1.768	0.769	0.435	1001.333	485.487	0.485	0.260	0.126	0.485
2000	9490.827	3175.900	0.335	2.464	0.824	0.335	1472.513	626.178	0.425	0.382	0.163	0.425
2001	25568.172	20777.096	0.813	6.638	5.394	0.813	3100.970	2429.038	0.783	0.805	0.631	0.783
2002	12197.863	3497.051	0.287	4.577	1.312	0.287	1249.845	345.835	0.277	0.469	0.130	0.277
2003	2900.546	1597.512	0.551	1.088	0.599	0.551	399.895	247.569	0.619	0.150	0.093	0.619
2004	21901.546	14754.345	0.674	8.218	5.536	0.674	2556.415	1889.527	0.739	0.959	0.709	0.739
2005	10.596	5.108	0.482	0.004	0.002	0.482	0.840	0.396	0.472	0.000	0.000	0.472
2006	15045.055	3526.160	0.234	5.645	1.323	0.234	3020.660	738.642	0.245	1.133	0.277	0.245
2007	6.804	4.281	0.629	0.003	0.002	0.629	0.528	0.315	0.596	0.000	0.000	0.596
2008	15334.313	4082.787	0.266	5.754	1.532	0.266	2132.927	806.846	0.378	0.800	0.303	0.378
2009	5261.335	1737.286	0.330	1.974	0.652	0.330	533.687	175.386	0.329	0.200	0.066	0.329
2010	11322.919	6089.296	0.538	4.249	2.285	0.538	957.535	534.899	0.559	0.359	0.201	0.559
2011	2233.234	1128.388	0.505	0.838	0.423	0.505	381.820	206.055	0.540	0.143	0.077	0.540
2012	19564.914	6640.157	0.339	7.341	2.492	0.339	2480.540	791.017	0.319	0.931	0.297	0.319
2013	3688.389	1443.124	0.391	1.384	0.542	0.391	460.198	191.919	0.417	0.173	0.072	0.417

2014	5215.187	1856.540	0.356	1.957	0.697	0.356	581.953	224.927	0.387	0.218	0.084	0.387
2015	4855.123	3343.553	0.689	1.822	1.255	0.689	428.560	301.774	0.704	0.161	0.113	0.704
2016	2976.148	1499.108	0.504	1.117	0.563	0.504	289.093	157.325	0.544	0.108	0.059	0.544
2017	4472.289	1536.429	0.344	1.678	0.577	0.344	640.950	237.764	0.371	0.241	0.089	0.371
2018	1492.813	468.729	0.314	0.560	0.176	0.314	150.458	45.529	0.303	0.056	0.017	0.303

APPENDIX 2

INTRODUCTION

In British Columbia a key forage fish species is Pacific Herring (*Clupea pallasii*) (hereafter called herring). Juveniles need to store enough energy before the fall to survive their first winter when food is scarce (Haegele 1997, Paul et al 1998, Foy and Paul 1999). Energy density is an indicator of fish physiological status, nutritional status, and overall condition (Johnson et al. 2017). Calorimetry is a method of measuring the heat energy of a reaction from combusting a tissue sample to determine caloric content (Hartman and Brant 1985, Paul 1997). The objectives of this study were to measure whole body energy density of age-0 herring, where sufficient samples were collected, in an effort to improve the understanding of herring survival by examining the size and condition of juveniles prior to their first winter. These measures can then be related to estimates of future recruitment. Age-0 herring for energy density analysis were collected as part of the annual Strait of Georgia (SOG) juvenile herring survey.

METHODS

Where sufficient samples existed, twenty juvenile herring (not exceeding three samples per transect) were frozen and brought back to the laboratory. Individual lengths (standard to the nearest mm) and weights (nearest 0.01 g) were measured, otoliths and stomach contents were removed, then fish were oven-dried at 60°C until reaching a consistent weight (+/- 5%). Of the twenty juvenile herring samples collected at each station, morphometrics were collected for all samples but only 10 were randomly selected to be processed using the calorimeter. A Parr Instrument 6765 Combination Calorimeter was used to determine caloric content (interchangeable with the term energy density) of the sample. Individual dried fish were homogenized thoroughly with an electric grinder. A subsample of each ground fish was pressed into a pellet of about 0.150 g using a pellet press (Parr 2817). Pellets were weighed immediately after being pressed and stored in a desiccator to maintain sample integrity. Methods used for calorimetry process were as stated in the Parr manual (Parr Instrument Co. 1994). Sulfuric and nitric acid formations were disregarded in energy calculations because they are considered minimal (Parr Instrument Co. 1994, Boldt and Haldorson 2004). The number of calorimetry samples processed ranged from 50-80 individual fish per year from 2012 to 2018 (Table 1).

Linear regression was used to model the relationship of energy density as a function of various parameters including standard length (mm), wet weight (g), dry weight (g), percent dry weight, and condition. Condition values were obtained from calculating the residuals from a double log-transformed length-weight regression (Boldt et al. 2020). One-way analysis of variance (ANOVA) was used to compare energy density, wet weights, and lengths among years. If a difference was found then a Tukeys or Games-Howell post-hoc test was conducted to determine which years were different.

RESULTS

Fish weight and energy density values varied among years with 2015, 2016, and 2018 having the heaviest and highest energy density values (Figure 1 and 2). Energy density values averaged at the transect level ranged from 4,854 cal/g in 2012 to 5,317 cal/g in 2015. Energy density estimates were also weighted by catch per unit effort (CPUE) estimates, which had a minimal effect on values (see Figure 2). Average fish standard lengths ranged from 81.7mm to 96.7mm and average fish wet weights varied between 7.1g and 11.3g in 2012 and 2015, respectively (Figure 1). Average fish dry weight varied between 1.6g (2012) and 2.7g (2015) (Figure 1).There was evidence of an effect of year on energy density, wet weight and standard length ($p<0.0001$). Energy density values differed among three groups: 1) 2013 differed from 2012 ($p<0.007$), 2) 2012, 2014 and 2017 were similar to each other but differed from all other years ($p<0.01$), and 3) 2015, 2016, and 2018 were similar to each other but differed from all other years ($p<0.01$). For standard length, 2012 differed from all years ($p<0.0001$) except 2013 ($p=0.02$) and 2017 ($p=0.92$); 2015 differed from all years ($p<0.0001$) except 2016 ($p=0.44$); and 2018 differed from all years ($p<0.0001$) except 2016 ($p=0.76$). For wet weight there were two distinct groups: 1) 2012, 2013, 2014, and 2017 were similar to each other but different from all other years ($p<0.0001$), and 2) 2015, 2016, and 2018 were similar to each other but differed from all other years ($p<0.0001$).

There was evidence of a positive, linear relationship between energy density and length ($R^2= 0.20$, $p<0.001$), dry weight (g) ($R^2= 0.40$, $p<0.001$), wet weight (g) ($R^2= 0.28$, $p<0.001$), percent dry weight ($R^2= 0.24$, $p<0.001$), and length-weight residuals ($R^2= 0.10$, $p<0.001$) (Figure 3). Preliminary results indicate there may be a positive relationship between age-0 herring energy density and age-2 recruit abundance (DFO 2020), lagged by two years; however, the relationship is not significant ($R^2= 0.002$, $p=0.94$) (Figure 4). Samples from 2012 were stored in the freezer for several years and appeared to be freezer-burned which may have contributed to the low energy density values. If values from 2012 are not included, there is a positive relationship between age-2 recruit abundance and age-0 energy density, but only four years of data. This relationship has the potential to improve estimates of age-2 recruit abundance, which can be highly variable and comprise over 50% of the adult spawning biomass. Continued monitoring of age-0 herring could therefore improve stock assessment model projections of spawning stock biomass. Future data collection is needed to confirm this relationship.

Table 1. Number of Strait of Georgia age-0 Pacific Herring energy density samples processed per year, 2012-2018. Generally, where possible, 10 fish per transect were sampled.

Year	Total calorimetry samples processed	Transects from which samples were collected
2012	80	1-6, 8, 9
2013	60	1-4, 6, 8
2014	75	1-4, 8, 9, 11
2015	50	1-4, 10
2016	50	1, 2, 4-6
2017	80	1-6, 8 9
2018	60	2-4, 8-10

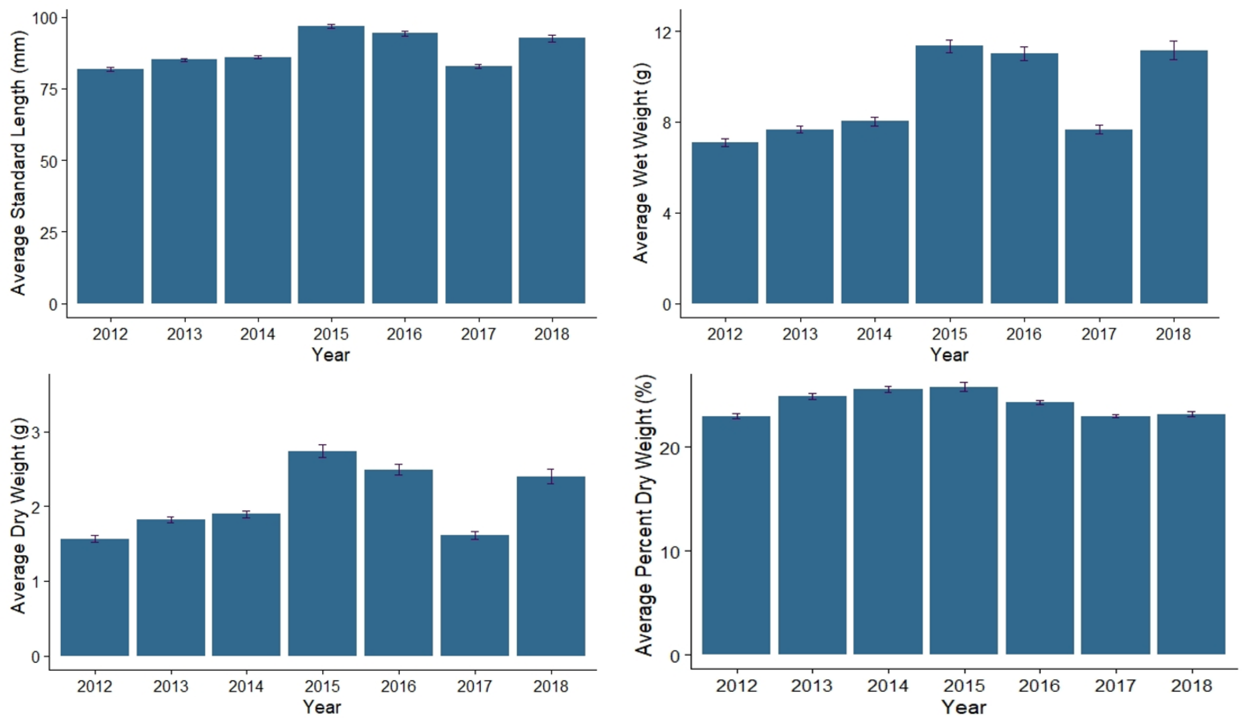


Figure 1. Average standard length (mm), wet weight (g), dry weight (g), and percent dry weight of age-0 Pacific Herring from the Straight of Georgia collected for energy density analysis, 2012-2018.

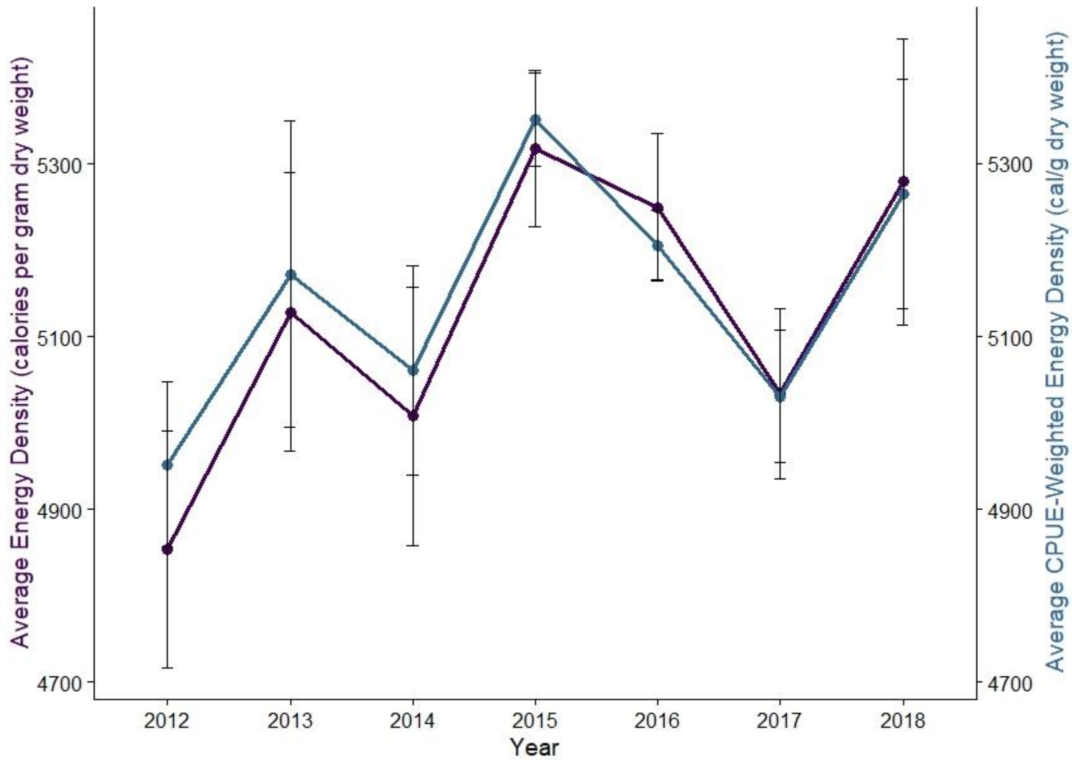


Figure 2. Average energy density and average energy density weighted by catch per unit effort (CPUE) for age-0 Pacific Herring in Strait of Georgia, 2012-2018.

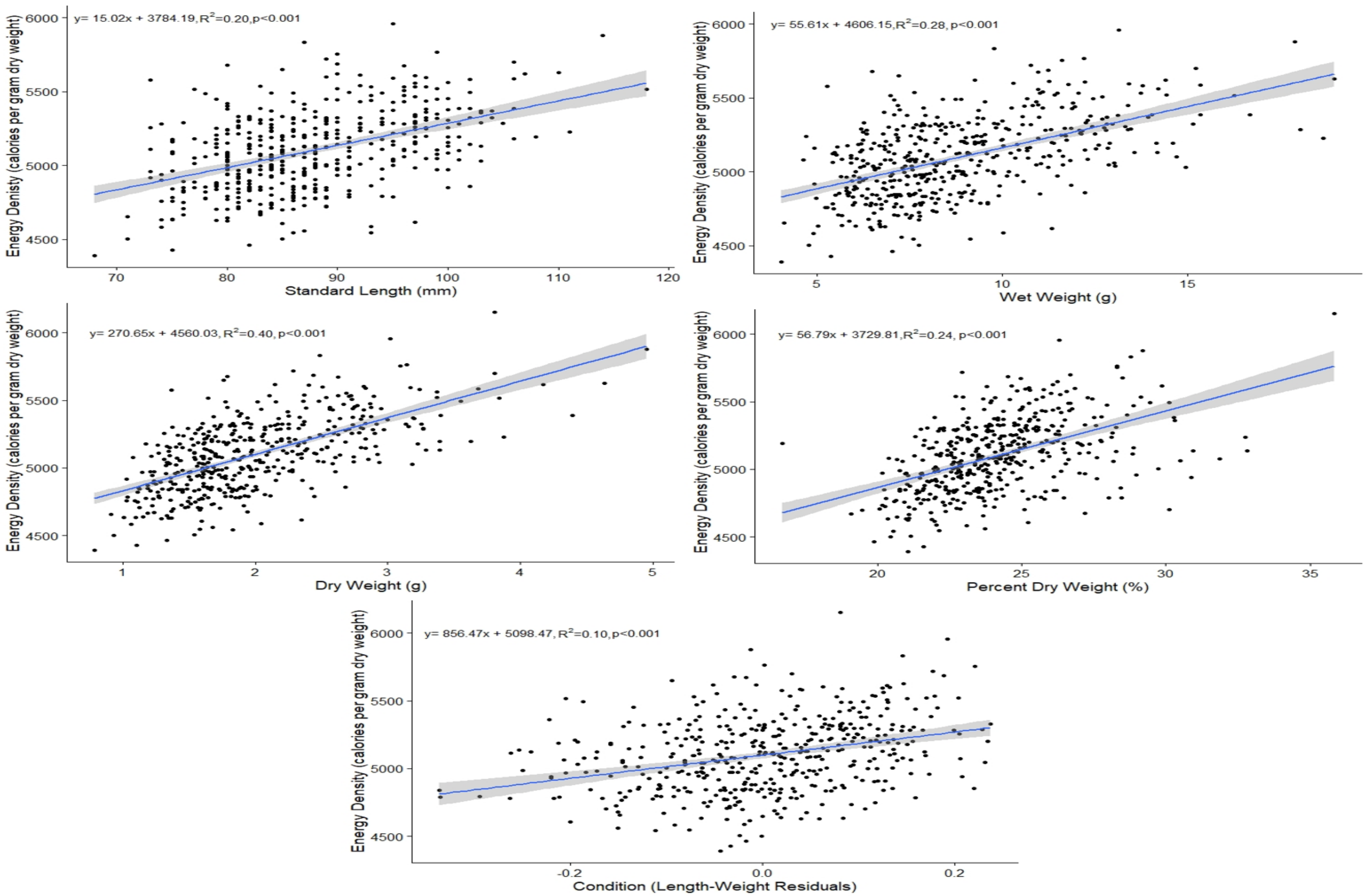


Figure 3. Standard length (mm), wet weight (g), dry weight (g), percent dry weight, and condition as a function of energy density of age-0 Pacific Herring samples collected in the Strait of Georgia for calorimetry analysis.

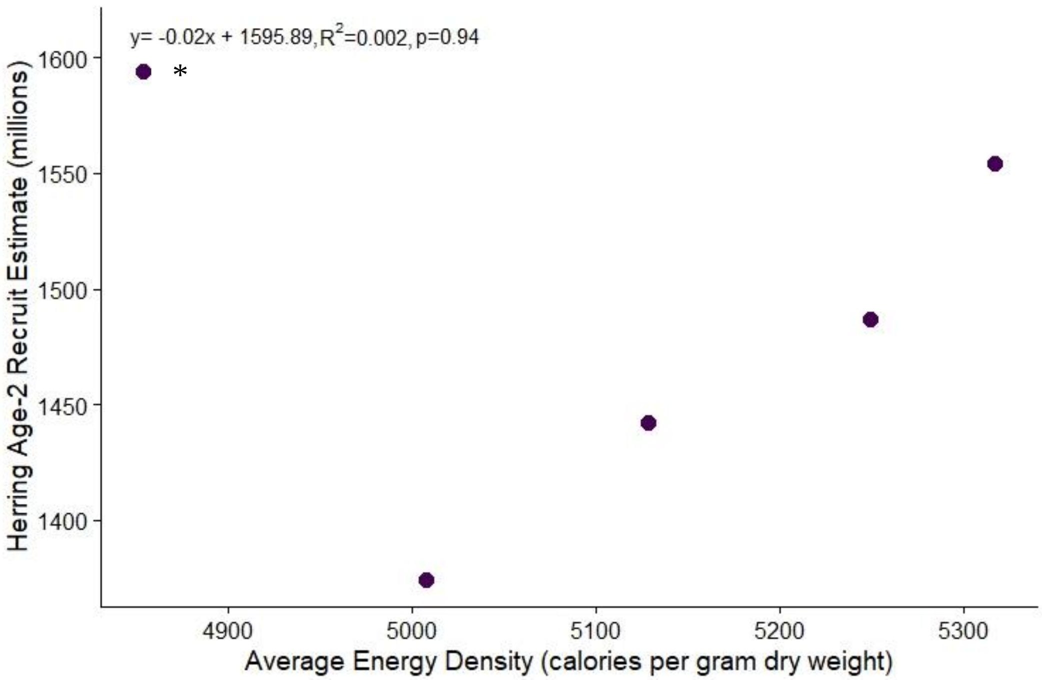


Figure 4. Estimate of age-2 herring recruitment (2014-2018; as estimated from a stock assessment model and lagged two years to align with the age-0 herring; DFO 2020) as a function of age-0 average energy density (2012-2016; cal/g dry weight), in the Strait of Georgia. *- Note that freezer burn was present on the age-0 herring samples from 2012.

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