

Strait of Georgia Juvenile Pacific Herring Survey, September 2024

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STRAIT OF GEORGIA JUVENILE PACIFIC HERRING SURVEY,
SEPTEMBER 2024

by

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ABSTRACT

Thompson, M., Boldt, J.L., Dennis-Bohm, H., Grinnell, M. H., and Rooper, C.N. 2026. Strait of Georgia Juvenile Pacific Herring Survey, September 2024. Can. Manusc. Rep. Fish. Aquat. Sci. 3302: vii + 49 p. <https://doi.org/10.60825/eh42-pp15>

A fall juvenile herring survey of the Strait of Georgia took place September 9th to 18th, 2024. This survey addresses several questions on early herring survival, abundance, recruitment and trophodynamics. Thirty-seven stations were sampled throughout the Strait of Georgia following the ten core transects that have been sampled since 1990. The survey area extends from Saanich Inlet 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., Grinnell, M. H., and Rooper, C.N. 2026. Strait of Georgia Juvenile Pacific Herring Survey, September 2024. Can. Manusc. Rep. Fish. Aquat. Sci. 3302: vii + 49 p. <https://doi.org/10.60825/eh42-pp15>

Un relevé automnal du hareng juvénile dans le détroit de Georgie a été réalisé entre le 9 et le 18 septembre 2024. 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 37 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 Saanich 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 pallasii*) are an important species for First Nations and commercial fishers 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 ~25 mm (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 and 2020 (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, weights, condition, and energy density of age-0 herring in the SOG using methods identified in Boldt et al. (2015; see Appendices 1 and 2). 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 three to five stations per transect, for a total of 48 sampling stations. These stations have been sampled consistently since 1990 (except 1995 and 2020). 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 2024, sampling was conducted from September 9th to 18th (Table 1). Thirty-seven of the forty-eight stations were sampled. Cape Cockburn (transect 10) and Henry Bay (transect 4) were not sampled due to bad weather. Trincomali (transect 6, station 1) was not sampled due to equipment malfunction.

Fish Sampling

In 2024, 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 m², was used for all fishing events. The body of the net had 46 m of 48 mm mesh at the tow end (note: this was misreported as 22.2 mm in previous reports on surveys conducted prior to 2019) 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, 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 portion of 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).

Zooplankton Sampling

Sixteen 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 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. No samples were collected at Cape Cockburn (transect 10) and Henry Bay (transect 4) due to bad weather. An RBRsolo³ D was attached to the bongo net frame to confirm tow depth. 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):

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

where:

V = volume of water filtered through the plankton net (m³)

A = area of net opening (0.02835 m²)

F = number of revolutions recorded by the flow meter (m)

K = standard speed rotor constant for 7 cm rotor (26,873)

999,999 = maximum rotor digit count

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 were 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/m³.

CTD Sampling

A Conductivity Temperature Depth recorder (CTD) was used to record temperature (°C), salinity (ppt), conductivity (S/m), and depth (m). Vertical casts were conducted using a Seabird SBE 19plus V2 at stations where zooplankton samples were also collected (Figure 3). No casts were conducted at Cape Cockburn (transect 10) and Henry Bay (transect 4) due to weather. 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. 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. After the survey the CTD data were sent to DFO's Institute of Ocean Science (IOS) for processing. The approximate depth of the thermocline was identified using the RLakeAnalyzer package and `thermos.depth()` function within the statistical program R (R Core Team, 2025). This function analyzes the temperature profile in relation to water depth data collected at each location to identify the depth where a significant temperature gradient occurs, thermally separating the upper and lower sections of the water column.

RESULTS

Herring

Herring were sampled from thirty-seven stations on transects 1, 2, 3, 5, 6, 8, 9, and 11. A total of 3484 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. The following age class designations were used:

0+ = herring less than or equal to 98 mm standard length,
1+ = herring between 99 mm and 148 mm standard length,
2+ and older = herring greater than or equal to 149 mm standard length.

Catches at thirty-six of the thirty-seven sampled stations (97.3%) contained age-0+ herring (Tables 2 and 3). The mean length and weight of age-0+ herring was 76 mm and 6.03 g, respectively (n = 2283). A total weight of 223.21 kg and an estimated 36638 individual age-0+ herring were caught (Table 4).

Catches at twenty-seven of the thirty-seven stations (73.0%) sampled contained age-1+ herring (Tables 2 and 3). The mean length and weight of age-1+ herring was 124 mm and 28.09 g, respectively (n = 1173). A total weight of 193.69 kg and an estimated 6537 individual age-1+ herring were caught (Table 4).

Catches at nine of the thirty-seven stations (24.3%) sampled contained age-2+ herring (Tables 2 and 3). The mean length and weight of age-2+ herring was 158 mm and 57.36 g, respectively (n = 28). A total weight of 8.56 kg and 144 individual age-2+ herring were caught (Table 4).

Length frequency histograms by transect location for all sampled herring are shown in Figure 5. The majority of age-0+ catch was along the Vancouver Island transects from Bowser (transect 3) down to Trincomali Channel (transect 6). The majority of age-1+ herring were caught on the mainland transects, Smelt Bay (transect 8), Atrevida Reef (transect 9) and Secret Cove (transect 11). A length-weight relationship for all sampled herring from the survey showed a significant, positive correlation ($R^2=0.9862$; Figure 6).

Zooplankton

As recorded by the RBR attached to the bongo net, the depth of the stepped oblique tows ranged from 16.04 m to 19.47 m (Figure 8 and Table 7). The shallowest cast occurred at Trincomali Channel (transect 6, station 3) and the deepest cast at Yellow Point (transect 2, station 1) (Table 7).

In obliquely-towed zooplankton samples, there were 34 categories of organisms identified in 16 zooplankton samples (Tables 5, 6 and 7). An average of 8.25 m³ (± 1.66 m³ SD) of water was filtered per zooplankton tow. The main taxonomic categories

included larvaceans (*Oikopleura sp.* and *Fritillaria sp.*), siphonophores, barnacles (early life history stages), and a cyclopoid copepod species (*Oithona similis*) (Figure 7).

CTD

Sixteen CTD casts were completed: two casts at each transect sampled, however the flow through the instrument during the first cast at Secret Cove (transect 11, station 1) was impeded, therefore the data were not useable. The depths of the CTD casts ranged from 20.5 m to 120.7 m, with the shallowest cast at Bowser (transect 3, station 1) and the deepest cast at Clarke Rock (transect 1, station 3; Figure 9).

Surface temperatures varied between 13.2 °C and 16.9 °C, with the coolest surface temperature recorded at Trincomali Channel (transect 6, station 5) (Table 9) and the warmest sea surface temperature recorded at Secret Cove. The coldest temperatures at depth were recorded at Atrevida Reef (transect 9, station 3) with a temperature of 9.4 °C at 118.5 m and at Smelt Bay (transect 8, station 2) with a temperature of 9.5 °C at 93.8 m. The warmest temperatures at depth were both recorded at Yellow Point (transect 2) with a temperature of 11.7 °C at 58.4 m (station 4) and 11.5 °C at a depth of 60.3 m (station 1). Surface salinities ranged from 27.0 to 29.2 PSS-78 with the lowest recordings at Atrevida Reef (station 1), followed closely by Smelt Bay (station 1), and the highest recorded at Trincomali Channel (station 5). The salinities at depth ranged from 29.7 to 31.2 PSS-78 at French Creek (transect 5, station 1) and Trincomali Channel (station 5) (Table 9). Thermocline depths ranged from approximately 1.5 m to 33.3 m, with the shallowest thermocline at Secret Cove (station 1; CTD max depth of 40.7 m) and the deepest at Trincomali Channel (station 3, CTD max depth of 35.8 m) (Table 9).

CONCLUSIONS

Thirty-seven stations were sampled resulting in 16 different fish species recorded from purse seine sets. A total of 3484 herring were measured and weighed creating a multimodal histogram clearly representing age-0+ and age-1+ juvenile herring. Oblique plankton tows were performed with Larvaceans (*Oikopleura sp.* and *Fritillaria sp.*), siphonophores, and barnacles being the predominant organisms.

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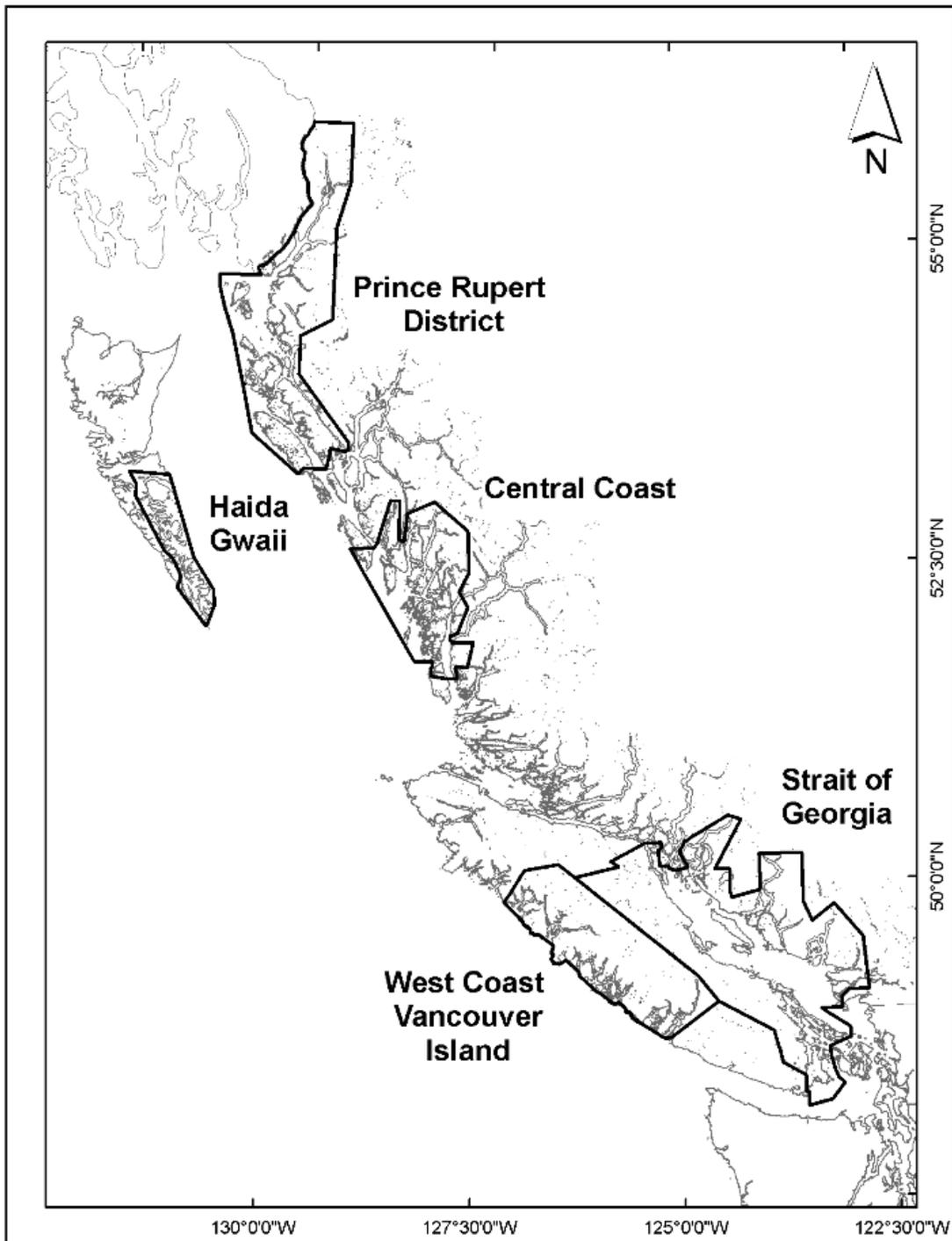


Figure 1. The five major British Columbia herring stock assessment areas.

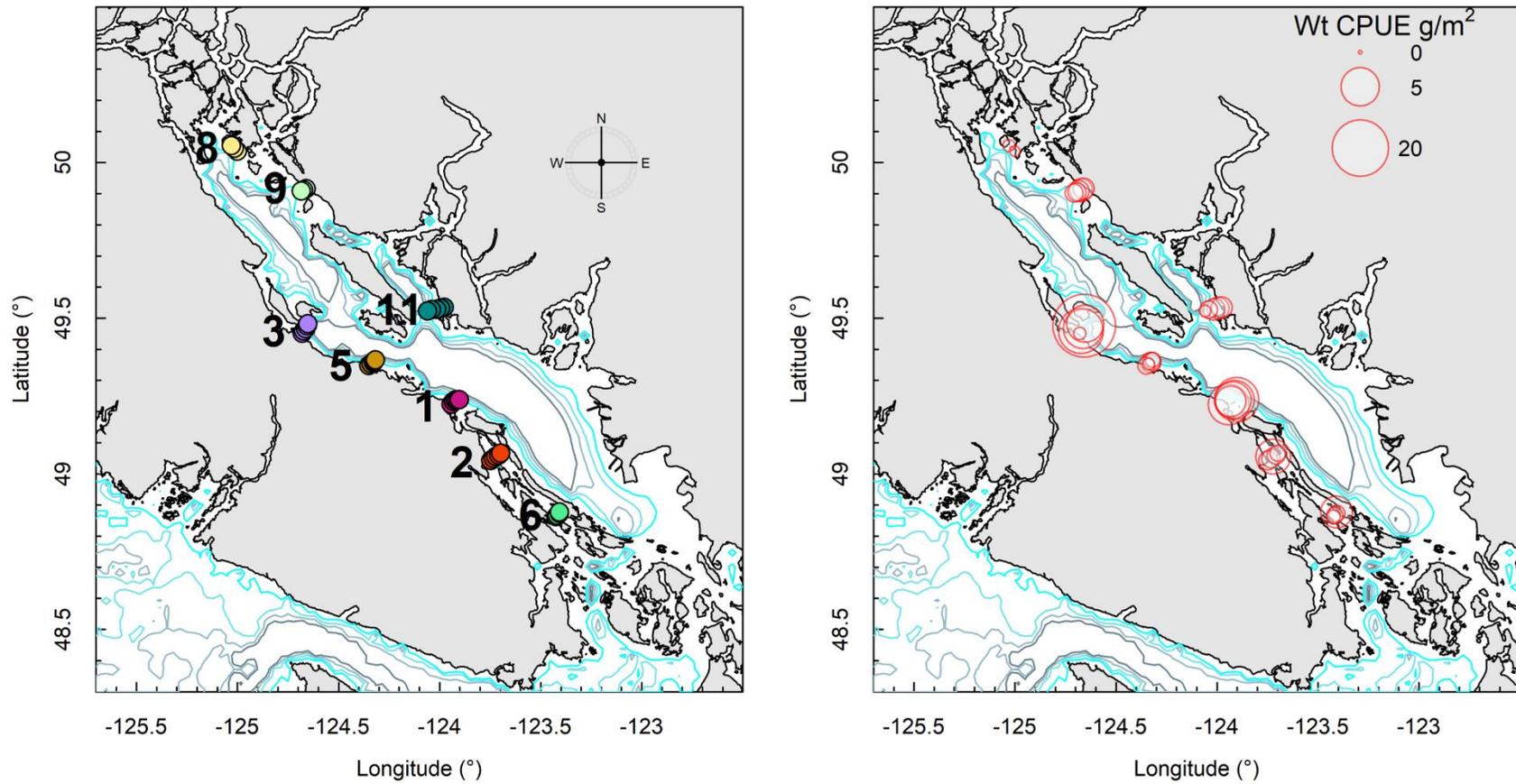


Figure 2. 2024 Strait of Georgia juvenile herring survey purse seine set locations (left panel) and herring catch weight per unit effort (right panel).

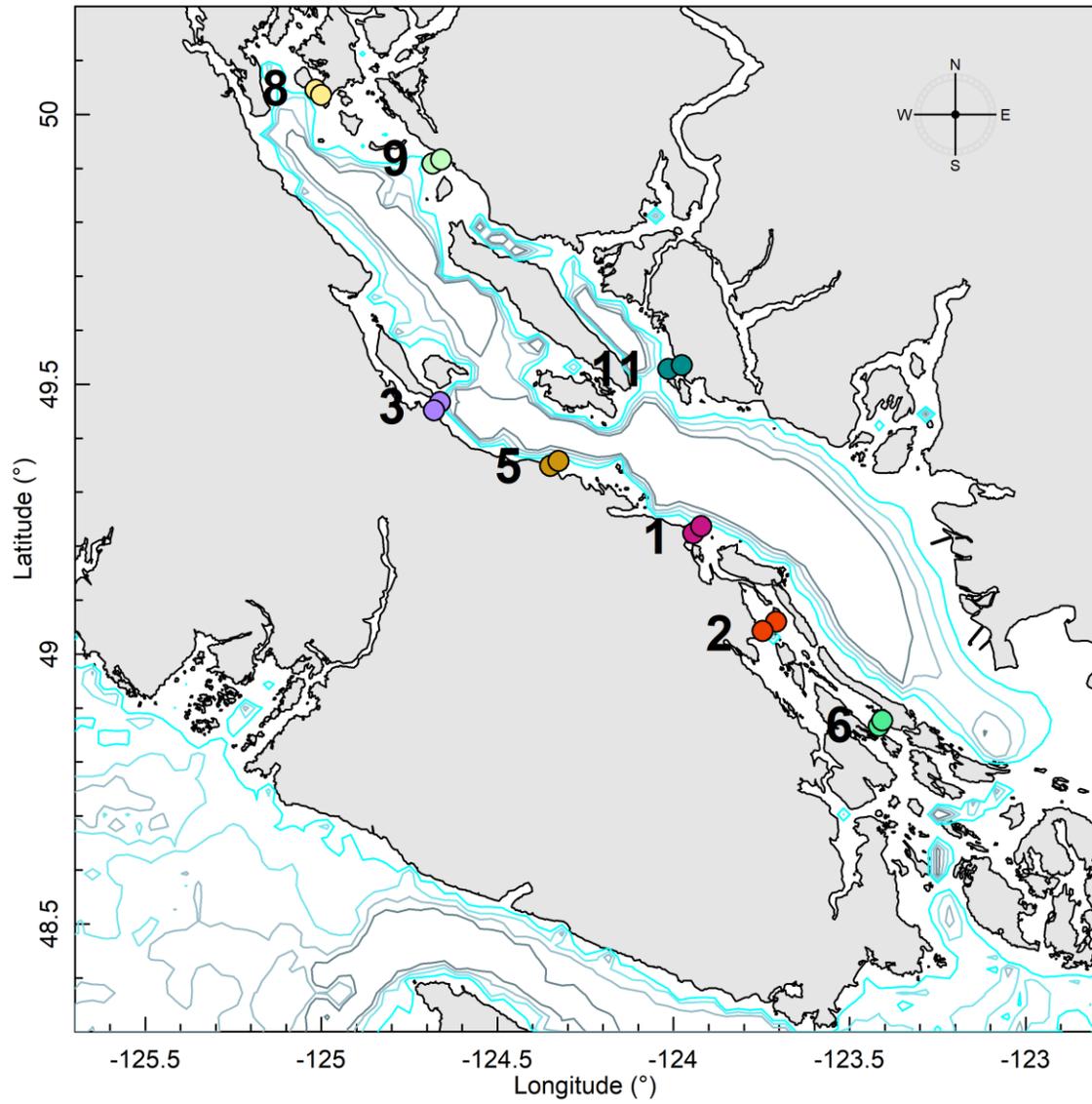


Figure 3. Zooplankton and CTD stations for 2024 Strait of Georgia juvenile herring survey.

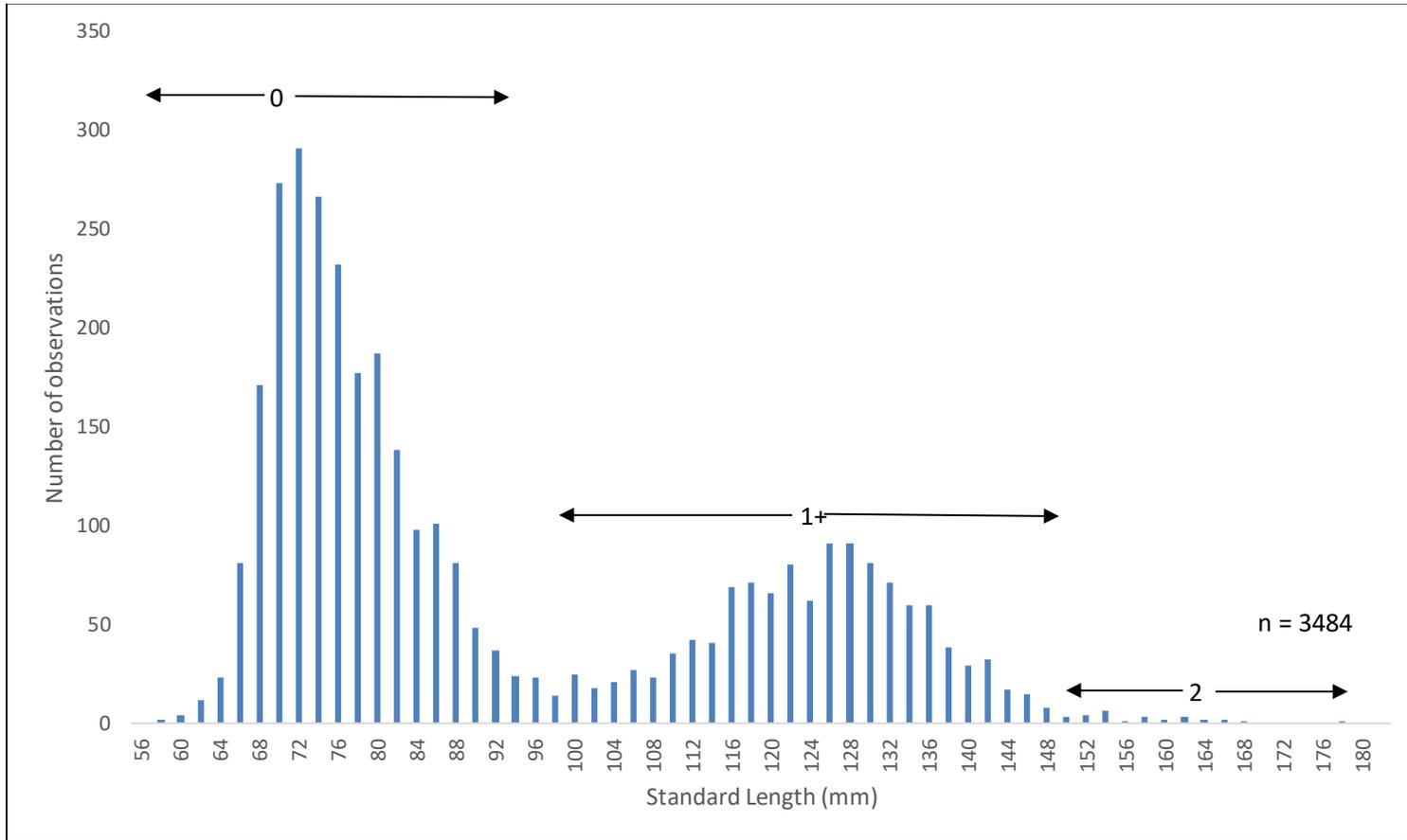


Figure 4. Length-frequency distribution for all herring sampled during the 2024 Strait of Georgia juvenile herring survey.

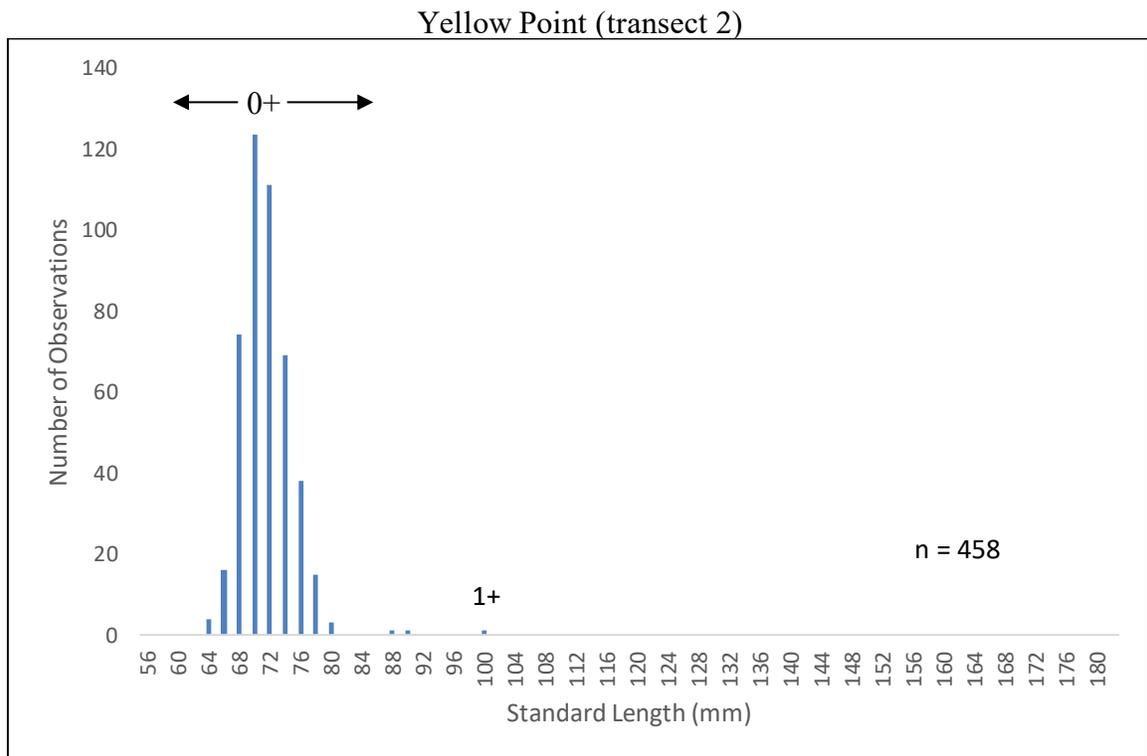
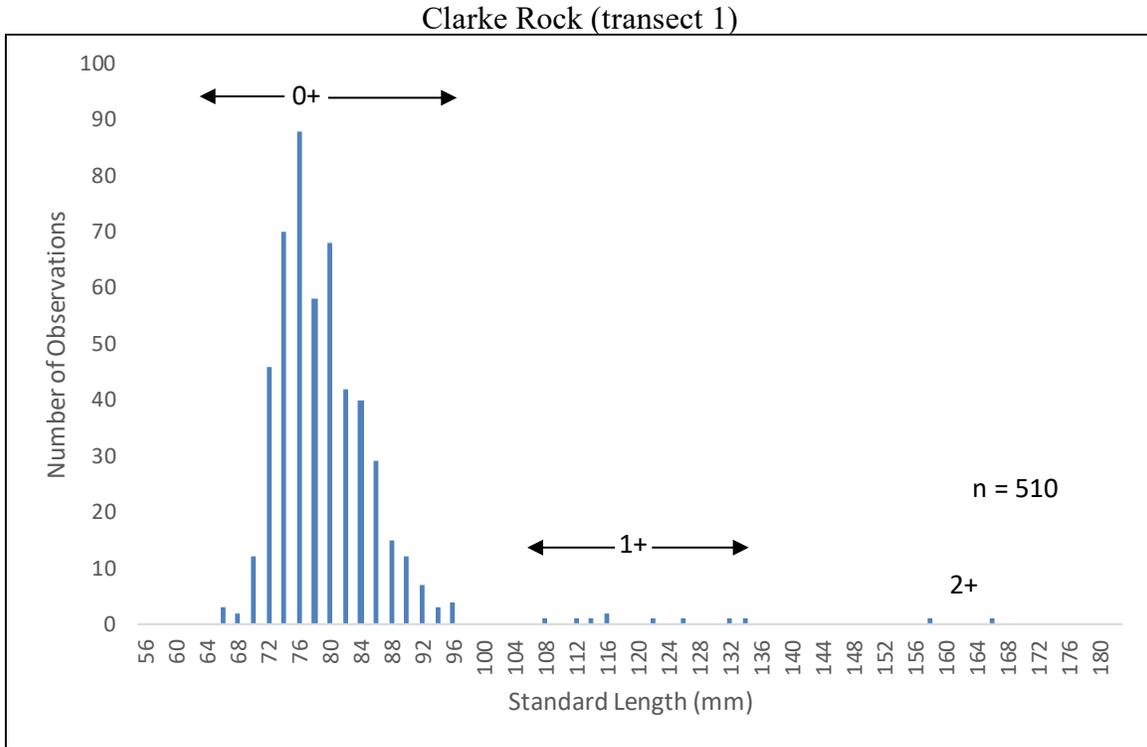
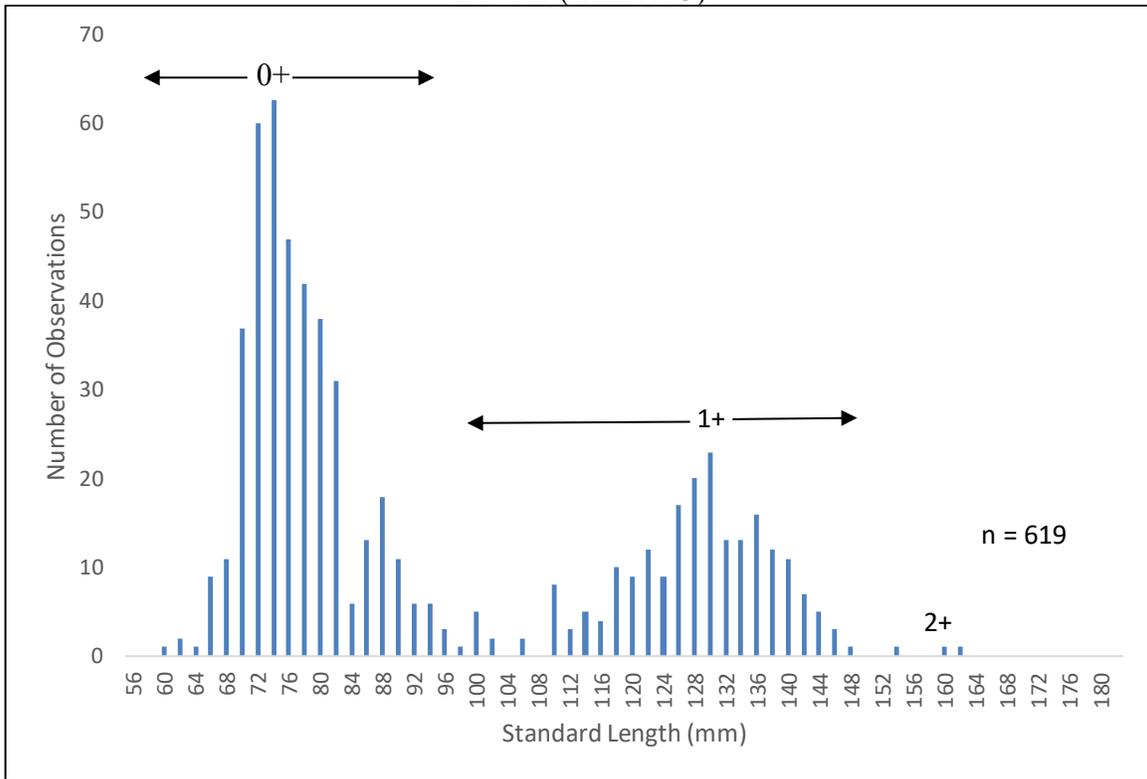


Figure 5. Length-frequency histograms of juvenile herring by transect location for the 2024 Strait of Georgia juvenile herring survey.

Bowser (transect 3)



French Creek (transect 5)

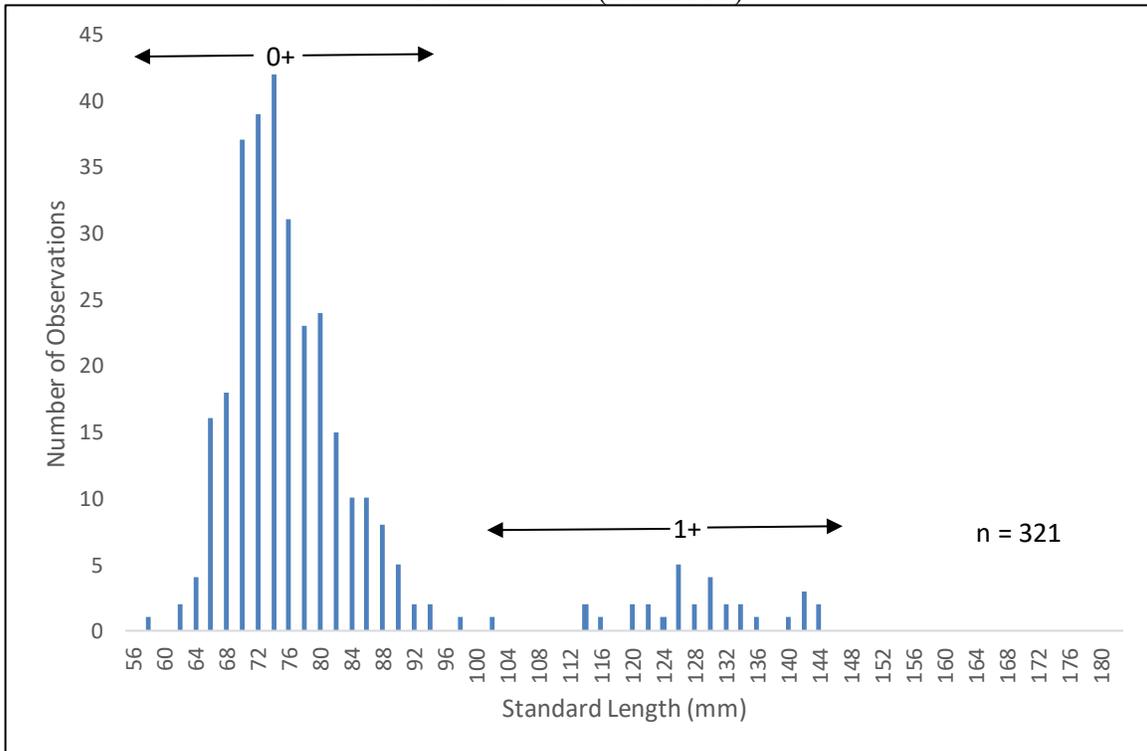
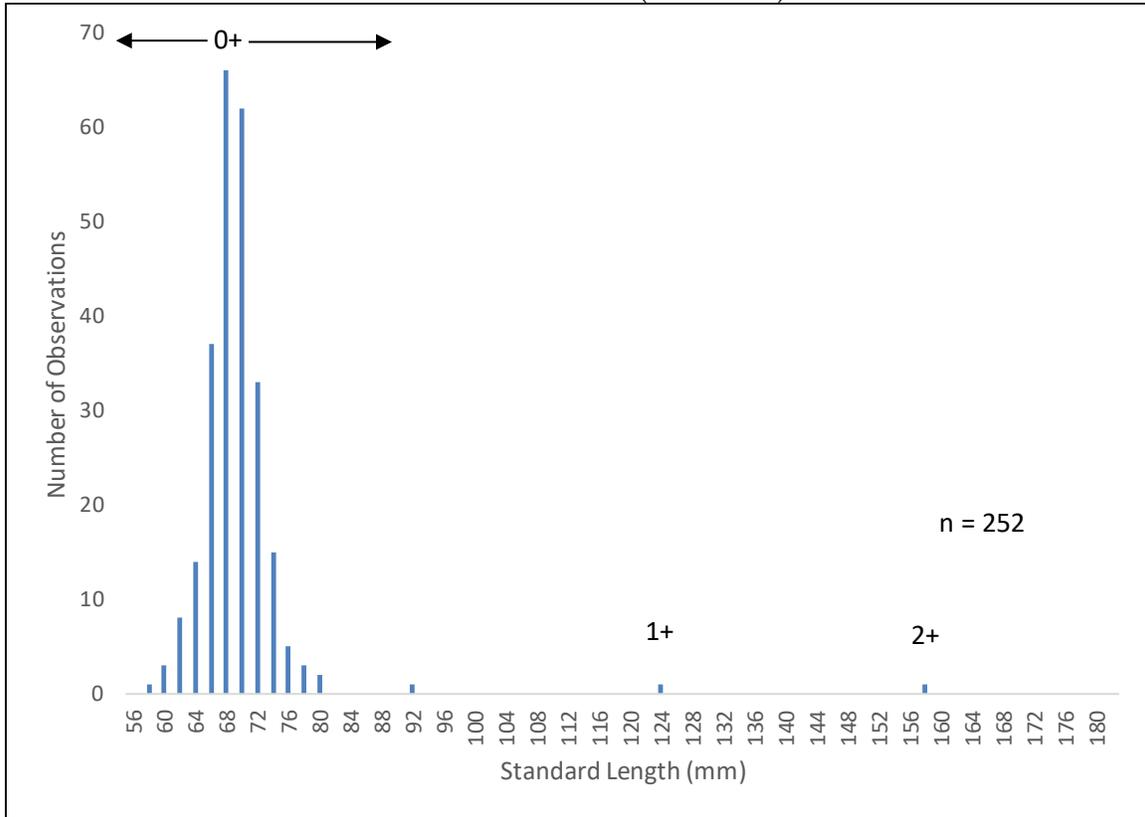


Figure 5 continued.

Trincomali Channel (transect 6)



Smelt Bay (transect 8)

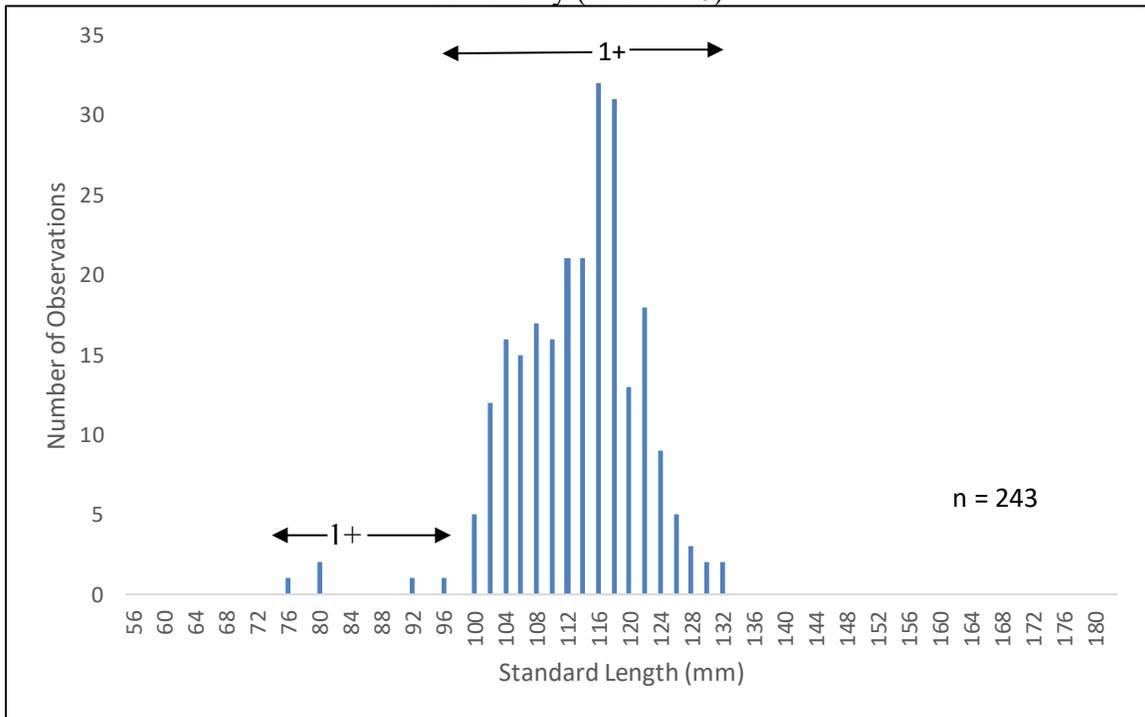
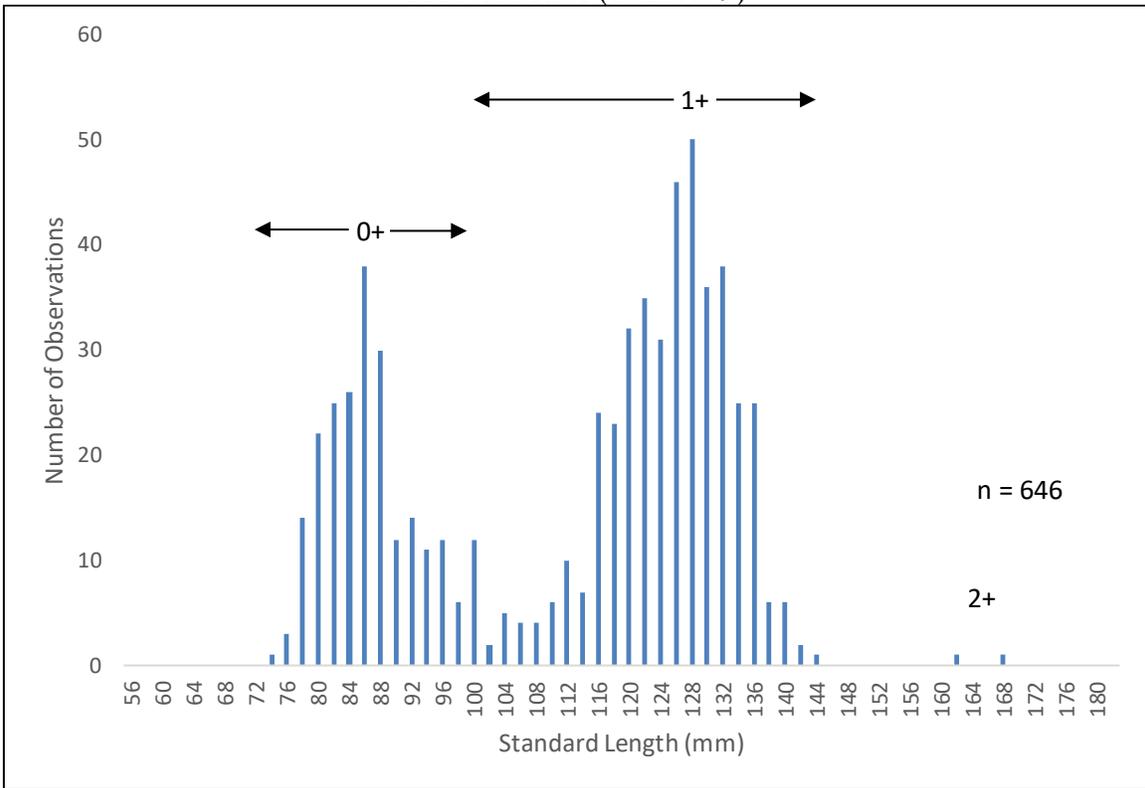


Figure 5 continued.

Atrevida Reef (transect 9)



Secret Cove (transect 11)

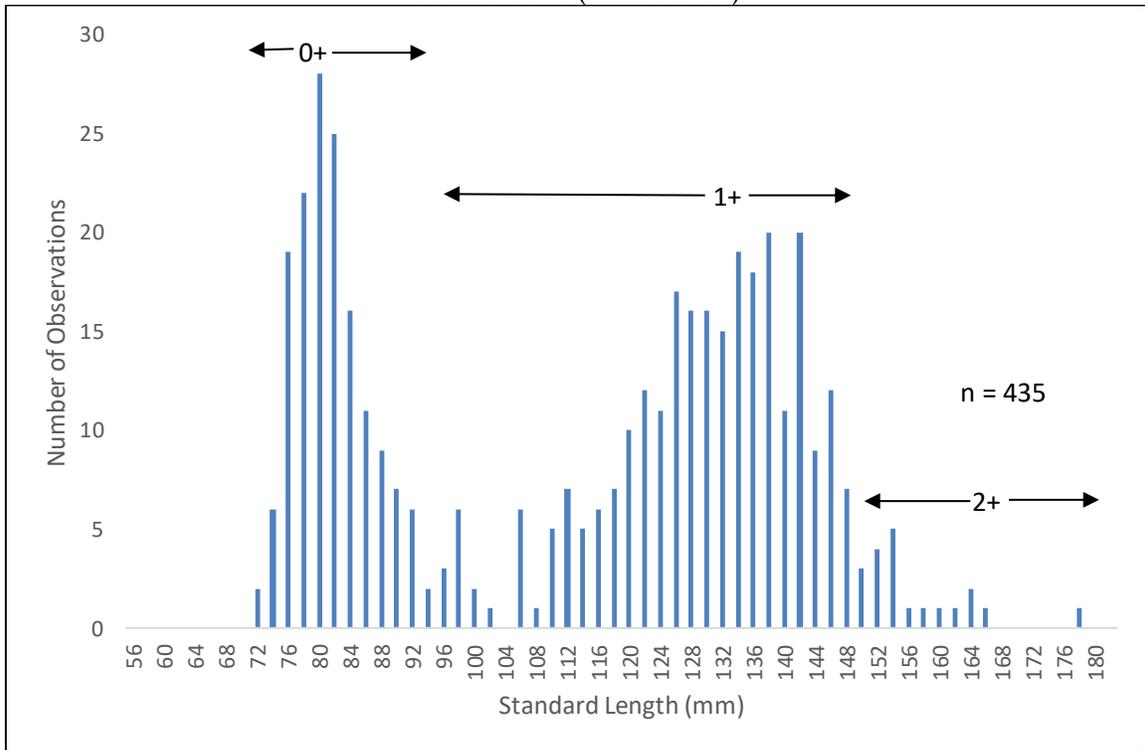


Figure 5 continued.

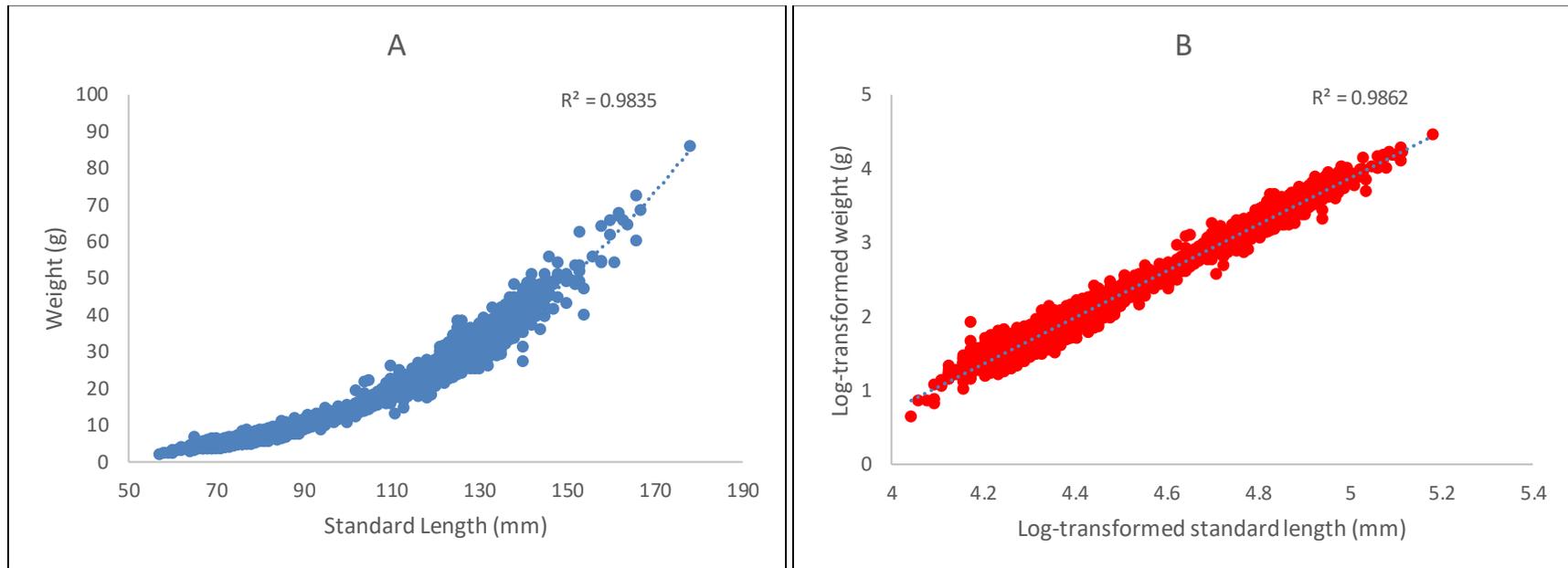


Figure 6. Non-transformed (A) and double log-transformed (B) length-weight relationships for all herring sampled during the 2024 Strait of Georgia juvenile herring survey.

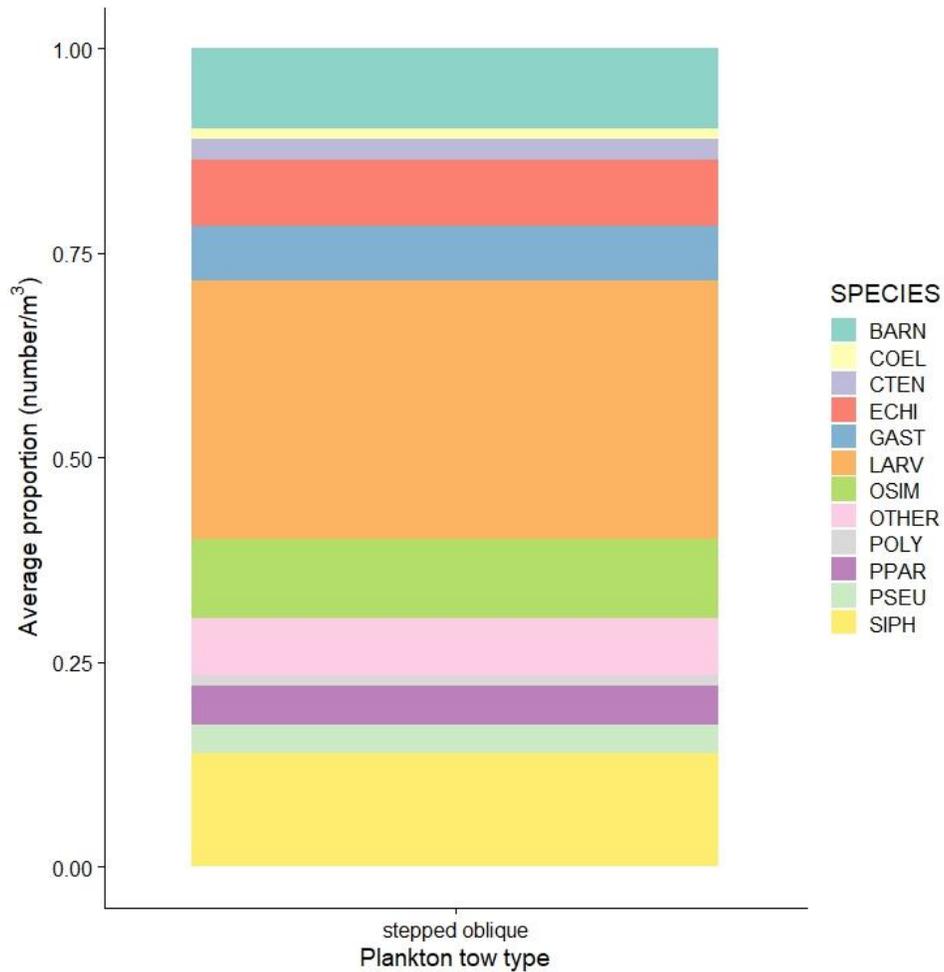


Figure 7. Average proportion zooplankton densities in oblique bongo tows from the 2024 Strait of Georgia juvenile herring survey. Major zooplankton taxonomic groups (11) are shown in the legend; remaining taxa are grouped into “other” and comprise 23 taxa (see Tables 5 and 6 for acronym definitions).

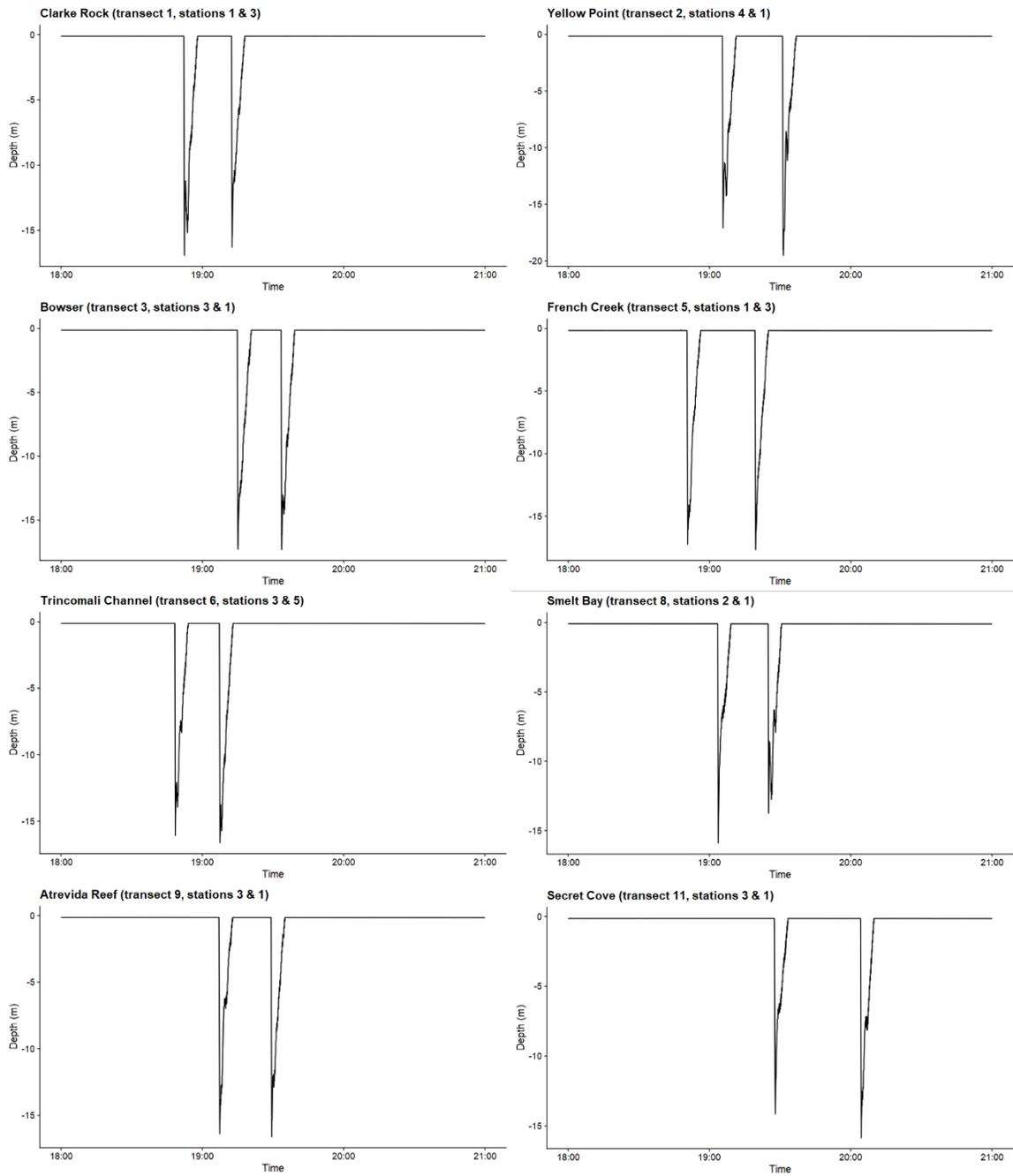


Figure 8. RBR depth recordings from stepped oblique bongo tows conducted on the 2024 Strait of Georgia juvenile herring survey.

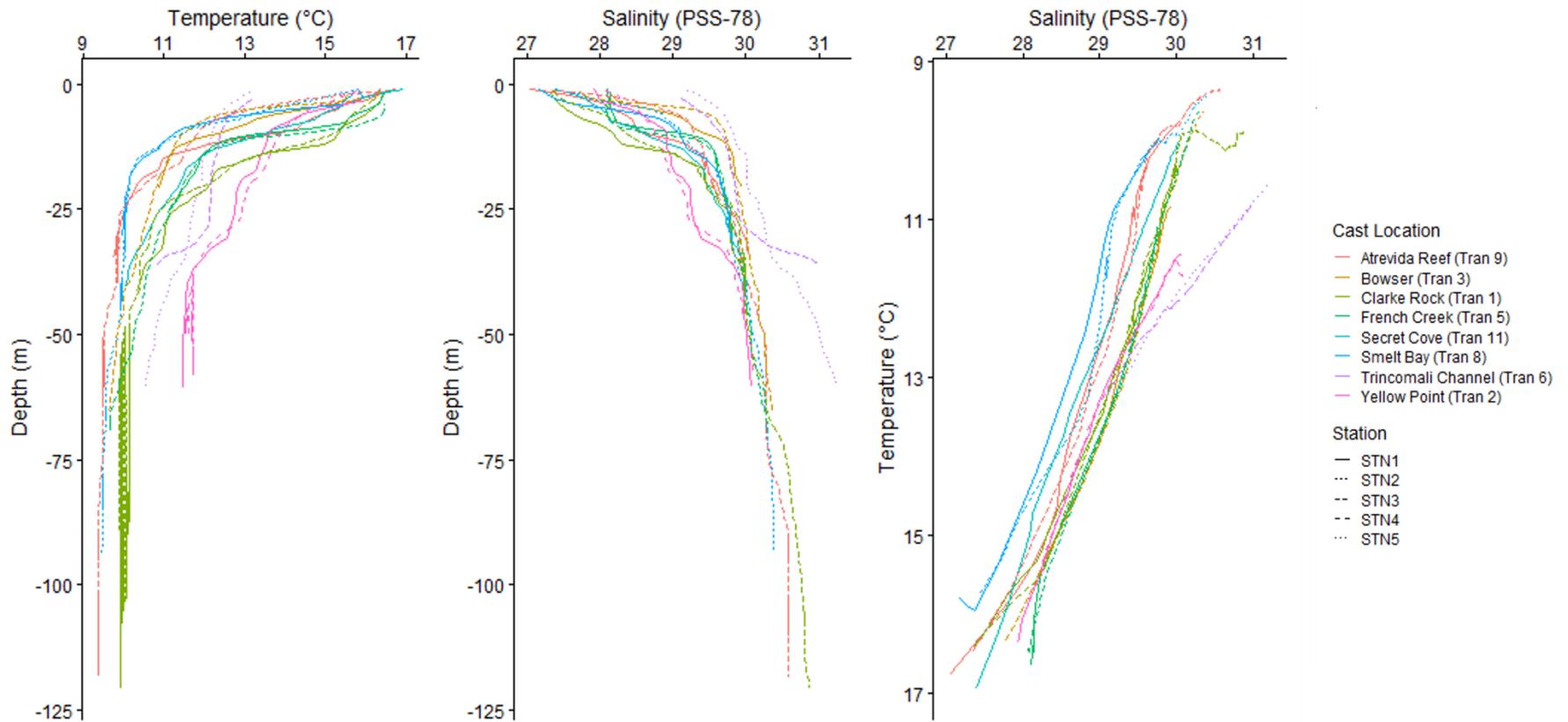


Figure 9. CTD casts (by transect and station) from the 2024 Strait of Georgia juvenile herring survey. The left panel shows the relationship between temperature (°C) and depth (m). The middle panel shows the relationship between salinity (PSS-78) and depth (m). The right panel shows the relationship between salinity (PSS-78) and temperature.

Table 1. Summary of the purse seine set locations from the 2024 Strait of Georgia juvenile herring survey. DD = decimal degrees

Year	Mont h	Day	Transec t	Statio n	Seine Set Time	Location Name	DD Lat (N)	DD Long (W)
2024	9	9	11	1	2040	Secret Cove	49.535	-123.977
2024	9	9	11	2	2120	Secret Cove	49.532	-123.995
2024	9	9	11	3	2150	Secret Cove	49.528	-124.014
2024	9	9	11	4	2235	Secret Cove	49.527	-124.040
2024	9	9	11	5	2300	Secret Cove	49.523	-124.060
2024	9	11	8	1	2000	Smelt Bay	50.036	-125.000
2024	9	11	8	2	2035	Smelt Bay	50.046	-125.016
2024	9	11	8	3	2155	Smelt Bay	50.054	-125.030
2024	9	12	9	1	2020	Atrevida Reef	49.916	-124.659
2024	9	12	9	2	2050	Atrevida Reef	49.912	-124.673
2024	9	12	9	3	2115	Atrevida Reef	49.909	-124.684
2024	9	12	9	4	2150	Atrevida Reef	49.906	-124.694
2024	9	12	9	5	2220	Atrevida Reef	49.902	-124.707
2024	9	14	3	1	2015	Bowser	49.452	-124.680
2024	9	14	3	3	2045	Bowser	49.467	-124.663
2024	9	14	3	2	2115	Bowser	49.459	-124.672
2024	9	14	3	4	2155	Bowser	49.476	-124.657
2024	9	14	3	5	2240	Bowser	49.482	-124.651
2024	9	15	5	1	2010	French Creek	49.348	-124.350
2024	9	15	5	2	2030	French Creek	49.353	-124.338
2024	9	15	5	3	2100	French Creek	49.358	-124.327
2024	9	15	5	4	2125	French Creek	49.362	-124.323
2024	9	15	5	5	2150	French Creek	49.366	-124.317
2024	9	16	1	5	2005	Clarke Rock	49.238	-123.902
2024	9	16	1	4	2035	Clarke Rock	49.237	-123.912
2024	9	16	1	3	2100	Clarke Rock	49.237	-123.922
2024	9	16	1	2	2125	Clarke Rock	49.233	-123.932
2024	9	16	1	1	2200	Clarke Rock	49.224	-123.943
2024	9	17	6	5	2000	Trincomali Channel	48.877	-123.407
2024	9	17	6	4	2020	Trincomali Channel	48.873	-123.407
2024	9	17	6	3	2105	Trincomali Channel	48.867	-123.417
2024	9	17	6	2	2130	Trincomali Channel	48.862	-123.423
2024	9	18	2	1	2005	Yellow Point	49.042	-123.747
2024	9	18	2	2	2030	Yellow Point	49.050	-123.733
2024	9	18	2	3	2100	Yellow Point	49.056	-123.722
2024	9	18	2	4	2135	Yellow Point	49.060	-123.708
2024	9	18	2	5	2200	Yellow Point	49.066	-123.698

Table 2. Summary of the number and weight by species, transect, and station for the 2023 Strait of Georgia juvenile herring survey. * trace weight <0.09g

Transect	Station	Location Name	Species	Number	Weight (kg)*
1	1	Clarke Rock	Pacific herring age-0+	2150	16.12
			Pacific herring age-1+	30	0.77
			Pacific herring age-2+	10	0.57
			Squid	115	0.92
			Chinook salmon	20	1.38
1	2	Clarke Rock	Pacific herring age-0+	928	5.43
			Pacific herring age-1+	2	0.03
			Squid	446	2.44
			Northern anchovy	226	0.49
			Chum salmon	20	1.70
			Chinook salmon	15	4.34
			Coho salmon	14	1.93
			Plainfin midshipman	4	0.03
1	3	Clarke Rock	Pacific herring age-0+	1756	11.03
			Pacific herring age-1+	4	0.09
			Northern anchovy	672	1.42
			Squid	88	0.76
			Chum salmon	16	1.51
			Plainfin midshipman	4	0.01
			Coho salmon	3	3.46
1	4	Clarke Rock	Pacific herring age-0+	2252	13.99
			Pacific herring age-1+	4	0.07
			Squid	24	0.18
			Chinook salmon	4	0.33
			Northern anchovy	4	0.01
			Plainfin midshipman	4	0.02
1	5	Clarke Rock	Pacific herring age-0+	3535	22.24
			Coho salmon	15	3.14
2	1	Yellow Point	Chinook salmon	7	0.47
			Coho salmon	6	0.72
			Northern anchovy	5	0.00
			Pacific herring age-0+	119	0.56
			Squid	24	0.17

Table 2 continued.

Transect	Station	Location Name	Species	Number	Weight (kg)*
2	2	Yellow Point	Pacific herring age-0+	119	0.53
			Pacific herring age-1+	1	0.01
			Squid	43	0.15
			Chinook salmon	2	0.15
			Northern anchovy	1	trace
			Three-spine stickleback	1	trace
2	3	Yellow Point	Pacific herring age-0+	1900	9.00
			Squid	100	0.14
			Chinook salmon	5	0.28
			Northern anchovy	5	0.07
2	4	Yellow Point	Pacific herring age-0+	83	0.46
			Squid	32	0.13
			Chinook salmon	5	0.53
			Northern anchovy	1	trace
			Pacific sand lance	1	trace
2	5	Yellow Point	Pacific herring age-0+	56	0.26
			Squid	148	0.21
			Chinook salmon	1	0.08
			Northern anchovy	1	trace
3	1	Bowser	Pacific herring age-0+	10	0.05
			Pacific herring age-1+	84	2.56
			Pacific herring age-2+	1	0.07
			Squid	205	0.93
			Chinook salmon	13	1.33
			Bay pipefish	1	trace
3	2	Bowser	Pacific herring age-0+	3861	23.52
			Pacific herring age-1+	520	15.85
			Northern anchovy	10010	21.42
			Squid	91	0.57
			Plainfin midshipman	13	0.01
			Pacific cod	2	1.05

Table 2 continued.

Transect	Station	Location Name	Species	Number	Weight (kg)*
3	3	Bowser	Pacific herring age-0+	2520	14.43
			Pacific herring age-1+	294	10.20
			Pacific herring age-2+	21	1.40
			Northern anchovy	4095	10.63
3	4	Bowser	Pacific herring age-0+	12354	76.49
			Pacific herring age-1+	1740	54.58
			Pacific herring age-2+	29	1.81
			Northern anchovy	5365	15.04
			Squid	232	1.88
			Coho salmon	1	1.59
3	5	Bowser	Pacific herring age-0+	2037	11.54
			Pacific herring age-1+	252	5.83
			Squid	441	2.71
			Northern anchovy	63	0.14
			Rockfish, juvenile	21	0.03
5	1	French Creek	Pacific herring age-0+	73	0.37
			Pacific herring age-1+	25	0.79
			Squid	118	2.98
			Northern anchovy	32	0.07
			Plainfin midshipman	2	0.01
			Chum salmon	1	0.21
			Bay pipefish	1	trace
5	2	French Creek	Pacific herring age-0+	4	0.03
			Pacific herring age-1+	1	0.02
			Squid	24	0.25
			Northern anchovy	12	0.02
			Coho salmon	1	0.22
5	3	French Creek	Pacific herring age-0+	119	0.80
			Pacific herring age-1+	5	0.11
			Squid	119	0.40
			Northern anchovy	75	0.10
			Chum salmon	1	0.06
			Plainfin midshipman	1	trace

Table 2 continued.

Transect	Station	Location Name	Species	Number	Weight (kg)*
5	4	French Creek	Pacific herring age-0+	83	0.43
			Northern anchovy	25	0.05
			Squid	9	0.01
			Chum salmon	1	0.08
5	5	French Creek	Pacific herring age-0+	31	0.15
			Coho salmon	2	1.30
			Northern anchovy	2	trace
6	2	Trincomali Channel	Pacific herring age-0+	21	0.10
			Pacific herring age-2+	1	0.05
			Squid	17	0.04
			Northern anchovy	1	trace
6	3	Trincomali Channel	Pacific herring age-0+	56	0.28
			Pacific herring age-1+	1	0.03
			Squid	84	0.19
6	4	Trincomali Channel	Pacific herring age-0+	73	0.29
			Squid	17	0.09
6	5	Trincomali Channel	Pacific herring age-0+	1455	6.45
			Squid	6	0.02
8	1	Smelt Bay	Pacific herring age-0+	1	0.01
			Pacific herring age-1+	116	2.55
			Squid	21	0.13
8	2	Smelt Bay	Pacific herring age-1+	422	7.41
			Squid	182	1.08
			Three-spine stickleback	4	trace
			Chinook salmon	2	0.32
			Chum salmon	2	0.18
8	3	Smelt Bay	Pacific herring age-0+	4	0.04
			Pacific herring age-1+	22	0.39
			Squid	17	0.10
			Chum salmon	2	0.13

Table 2 continued.

Transect	Station	Location Name	Species	Number	Weight (kg)*
9	1	Atrevida Reef	Pacific herring age-0+	128	1.01
			Pacific herring age-1+	2	0.04
			Squid	183	0.41
			Northern anchovy	93	0.11
			Chinook salmon	11	0.76
			Chum salmon	2	0.12
			Bay pipefish	2	trace
9	2	Atrevida Reef	Pacific herring age-0+	183	1.61
			Pacific herring age-1+	576	14.61
			Northern anchovy	363	0.46
			Squid	36	0.13
			Bay pipefish	3	trace
			Walleye pollock, juvenile	3	0.33
			9	3	Atrevida Reef
Pacific herring age-1+	445	12.51			
Northern anchovy	2265	3.35			
Squid	5	0.03			
9	4	Atrevida Reef	Pacific herring age-0+	57	0.56
			Pacific herring age-1+	375	10.97
			Pacific herring age-2+	3	0.20
			Northern anchovy	147	0.73
			Hake, juvenile	3	trace
9	5	Atrevida Reef	Pacific herring age-0+	48	0.47
			Pacific herring age-1+	405	12.45
			Pacific herring age-2+	3	0.20
			Northern anchovy	189	0.36
			Squid	15	0.02

Table 2 continued.

Transect	Station	Location Name	Species	Number	Weight (kg)*
11	1	Secret Cove	Pacific herring age-0+	176	1.07
			Pacific herring age-1+	40	0.66
			Three-spine stickleback	3656	3.07
			Northern anchovy	1608	2.30
			Squid	48	0.05
			Walleye pollock, juvenile	8	0.03
			Pink salmon	4	0.26
11	2	Secret Cove	Pacific herring age-0+	160	1.26
			Pacific herring age-1+	110	3.69
			Northern anchovy	50	0.26
			Three-spine stickleback	36	0.04
			Hake, juvenile	18	0.25
11	3	Secret Cove	Pacific herring age-0+	132	1.20
			Pacific herring age-1+	279	9.88
			Pacific herring age-2+	36	1.92
			Chinook salmon	9	2.01
11	4	Secret Cove	Pacific herring age-0+	50	0.42
			Pacific herring age-1+	780	27.53
			Pacific herring age-2+	40	2.33
11	5	Secret Cove	Pacific herring age-0+	4	0.03
			Pacific herring age-1+	2	0.06
			Chinook salmon	17	8.67
			Coho salmon	4	4.88
			Hake, juvenile	1	trace
			Northern anchovy	1	0.01
			Pacific lamprey	1	0.03

Table 3. Percent occurrence by species in purse seine sets for the Strait of Georgia juvenile herring survey in 2024.

Common Name	Scientific Name	Number of sets	Percent Occurrence
Pacific herring age-0+	<i>Clupea pallasii</i> in year of birth	36	97.3
Pacific herring age-1+	<i>Clupea pallasii</i> in first year	27	73.0
Pacific herring age-2+	<i>Clupea pallasii</i> in second or more years	9	24.3
Bay pipefish	<i>Syngnathus griseolineatus</i>	4	10.8
Chinook salmon	<i>Oncorhynchus tshawytscha</i>	13	35.1
Chum salmon	<i>Oncorhynchus keta</i>	8	21.6
Coho salmon	<i>Oncorhynchus kisutch</i>	8	21.6
Hake, juvenile	<i>Merluccius productus</i>	3	8.1
Northern anchovy	<i>Engraulis mordax</i>	26	70.3
Pacific cod	<i>Gadus macrocephalus</i>	1	2.7
Pacific lamprey	<i>Lampetra tridentatus</i>	1	2.7
Pacific sand lance	<i>Ammodytes hexapterus</i>	1	2.7
Pink salmon	<i>Oncorhynchus gorbuscha</i>	1	2.7
Pipefish	<i>Syngnathus griseolineatus</i>	5	11.6
Plainfin midshipman	<i>Porichthys notatus</i>	6	16.2
Rockfish, juvenile	<i>Sebastes sp.</i>	1	2.7
Squid	<i>Loligo opalescens</i> , or <i>Gonatus fabricii</i>	29	78.4
Three-spine stickleback	<i>Gasterosteus aculeatus</i>	4	10.8
Walleye pollock, juvenile	<i>Gadus chalcogrammus</i>	2	5.4

* Jellyfish occurrence is not included because it's difficult to quantify the amount.

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 2024 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

Location Name	Transect	Number Sampled	Length (mm)			Weight (g)			N	Wt (Kg)
			Range	Mean	SD	Range	Mean	SD		
Clarke Rock	1	499	66-95	78	5.47	3.55-11.89	6.48	1.56	10621	68.82
Yellow Point	2	457	64-90	71	3.10	3.55-10.05	4.82	0.64	2277	10.82
Henry Bay	3	406	59-98	77	6.63	2.33-14.98	5.97	1.73	20782	126.02
French Creek	5	290	57-97	75	6.57	1.88-13.17	5.70	1.75	310	1.79
Trincomali Ch	6	250	58-92	69	3.64	2.27-11.41	4.32	0.83	1605	7.11
Smelt Bay	8	5	75-96	85	8.93	5.90-12.73	8.90	2.77	5	0.04
Atrevida Reef	9	214	74-98	86	5.38	5.79-14.51	8.64	1.71	516	4.64
Secret Cove	11	162	72-98	82	5.93	4.47-13.18	7.94	1.75	522	3.97
All Locations		2283	57-98	76	7.24	1.88-14.98	6.03	1.92	36638	223.21

Age-1+ Herring

Location Name	Transect	Number Sampled	Length (mm)			Weight (g)			N	Wt (Kg)
			Range	Mean	SD	Range	Mean	SD		
Clarke Rock	1	9	107-133	119	8.99	16.27-31.82	23.14	5.92	40	0.95
Yellow Point	2	1	100	-	-	11.18	-	-	1	0.01
Henry Bay	3	210	99-148	127	10.24	10.99-50.94	30.61	7.66	2890	89.02
French Creek	5	31	101-144	128	9.81	13.93-43.08	29.69	6.62	31	0.92
Trincomali Ch	6	1	123	-	-	28.13	-	-	1	0.03
Smelt Bay	8	238	99-131	113	7.06	12.61-28.98	19.95	3.66	560	10.35
Atrevida Reef	9	430	99-143	124	8.74	10.69-48.01	28.18	6.26	1803	50.58
Secret Cove	11	253	99-148	130	10.93	12.70-55.77	33.56	8.93	1211	41.82
All Locations		1173	99-148	124	10.90	10.69-55.77	28.09	8.22	6537	193.68

Table 4 continued.

Age-2+ Herring

Location Name	Transect	Number Sampled	Length (mm)			Weight (g)			N	Wt (Kg)
			Range	Mean	SD	Range	Mean	SD		
Clarke Rock	1	2	158-166	162	5.66	54.51-60.14	57.33	3.98	10	0.57
Yellow Point	2	-	-	-	-	-	-	-	-	-
Henry Bay	3	3	153-162	158	4.73	62.49-66.60	64.92	2.15	51	3.28
French Creek	5	-	-	-	-	-	-	-	-	-
Trincomali Ch	6	1	158	-	-	-	-	-	1	0.05
Smelt Bay	8	-	-	-	-	-	-	-	-	-
Atrevida Reef	9	2	162-167	165	3.54	67.61-68.22	67.92	0.43	6	0.41
Secret Cove	11	20	150-178	157	7.08	39.92-85.88	55.33	10.87	76	4.25
All Locations		28	150-178	158	6.67	39.92-85.88	57.36	10.10	144	8.56

Table 5. Organisms by phylum, and with abbreviations, observed in zooplankton samples collected during the 2024 Strait of Georgia juvenile herring survey.

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

Table 6. Abbreviations for calanoid, cyclopoid and monstilloid copepods identified in the 2024 zooplankton samples from the Strait of Georgia juvenile herring survey.

Calanoid copepods

ALON	<i>Acartia longiremis</i>
CALA	<i>Calanus sp.</i>
CMAR	<i>Calanus marshallae</i>
CPAC	<i>Calanus pacificus</i>
EBUN	<i>Eucalanus bungii</i>
MPAC	<i>Metridia pacifica</i>
PPAR	<i>Paracalanus parvus</i>
PSEU	<i>Pseudocalanus sp.</i>
SMIN	<i>Scolecithricella minor</i>
TDIS	<i>Tortanus discaudatus</i>

Cyclopoid copepods

CANG	<i>Corycaeus anglicus</i>
OATL	<i>Oithona atlantica</i>
OSIM	<i>Oithona similis</i>

Table 7. Volume of water filtered (from flow meter), maximum tow depth (from RBR), and number of zooplankton per m³ of water in oblique tow samples collected during the 2024 Strait of Georgia juvenile herring survey. Species codes as shown in Tables 5 and 6.

Location	Tran	Stn	Vol (m³)	Max depth (m)	ALON	AMPH	BARN	CALA	CANG	CHAE	CLAD	CMAR	COEL
Clarke Rock	1	1	9.414	16.89	-	6.37	6.80	-	-	-	1.27	-	-
	1	3	10.387	16.27	15.40	10.01	0.19	6.16	-	0.19	-	-	0.58
Yellow Point	2	1	7.215	17.05	-	18.30	97.58	18.85	23.29	-	-	-	51.56
	2	4	6.780	19.47	-	0.29	646.56	10.62	11.80	-	-	-	47.19
Bowser	3	1	7.034	17.24	-	4.55	22.75	-	-	-	22.75	-	10.95
	3	3	8.157	17.27	-	3.92	-	17.53	-	-	11.77	-	8.09
French Creek	5	1	9.517	17.20	1.68	1.26	12.19	0.84	-	-	8.83	-	0.84
	5	3	9.005	17.63	1.33	2.22	16.77	1.78	0.11	0.44	0.11	-	0.78
Trincomali Ch	6	3	9.285	16.04	1.72	34.90	136.14	13.79	51.70	-	-	-	28.33
	6	5	8.392	16.59	3.81	15.49	356.66	22.88	95.33	2.03	-	-	16.92
Smelt Bay	8	1	5.968	13.72	-	-	26.81	5.36	-	-	16.08	-	2.68
	8	2	6.448	15.87	-	9.93	39.70	7.44	-	-	-	-	15.82
Atrevida Reef	9	1	9.227	16.58	-	8.67	2.60	9.54	-	-	-	-	-
	9	3	10.578	16.35	-	42.35	3.03	24.96	-	-	-	-	-
Secret Cove	11	1	5.008	15.81	-	3.19	63.89	-	-	-	-	-	3.19
	11	3	9.651	14.10	11.60	7.05	-	1.66	-	-	-	0.10	1.76

Table 7 continued.

Location	Tran	Stn	CPAC	CRAM	CRAZ	CTEN	EBUN	ECHI	ECTO	EGGS	EUPL	GAST	INLA
Clarke Rock	1	1	-	-	0.85	0.42	-	2.12	-	-	0.42	27.62	-
	1	3	-	-	0.19	-	-	-	-	-	-	8.28	-
Yellow Point	2	1	-	-	8.87	67.09	-	53.22	8.87	-	26.61	88.71	-
	2	4	-	-	5.01	46.90	-	28.32	14.16	-	14.16	80.23	-
Bowser	3	1	-	-	14.22	-	-	90.98	-	-	-	63.69	-
	3	3	0.86	0.49	9.32	3.92	-	70.61	3.92	-	-	43.15	-
French Creek	5	1	-	-	2.10	-	-	0.84	-	2.52	-	38.67	0.42
	5	3	-	0.11	0.11	-	-	-	-	0.11	0.11	5.11	-
Trincomali Ch	6	3	-	-	1.72	0.22	-	10.34	-	1.72	-	25.85	-
	6	5	-	0.48	0.24	0.24	-	17.16	-	-	3.81	22.88	-
Smelt Bay	8	1	-	-	6.03	5.86	0.34	29.49	-	-	2.68	93.83	-
	8	2	-	0.93	1.24	46.52	-	14.89	-	-	4.96	377.15	-
Atrevida Reef	9	1	-	-	1.73	0.43	0.11	156.07	-	-	-	19.07	-
	9	3	0.66	-	3.03	0.47	0.85	683.66	-	-	-	42.35	-
Secret Cove	11	1	-	-	-	146.15	-	9.58	-	-	-	25.56	-
	11	3	-	-	1.66	54.92	-	-	-	-	-	0.31	-

Table 7 continued.

Location	Tran	Stn	LARV	MPAC	OATL	OSIM	OSTR	PELE	POLY	PPAR	PSEU	SHRI
Clarke Rock	1	1	83.28	-	0.42	5.95	-	-	0.42	10.62	1.70	0.85
	1	3	18.10	-	-	20.02	-	-	-	36.97	24.45	0.39
Yellow Point	2	1	35.48	-	-	3.33	-	8.87	35.48	17.74	4.44	-
	2	4	198.22	-	-	3.54	-	4.72	61.35	24.78	-	4.72
Bowser	3	1	700.58	-	-	354.84	-	-	4.55	81.89	45.49	32.41
	3	3	796.36	8.46	-	674.75	-	-	7.85	54.92	47.08	21.21
French Creek	5	1	80.28	-	2.10	13.03	-	-	4.62	3.78	4.62	5.04
	5	3	10.22	3.55	1.67	0.33	0.11	0.11	0.89	2.67	12.88	0.78
Trincomali Ch	6	3	39.64	-	-	3.45	3.45	-	20.68	12.06	3.45	6.89
	6	5	49.57	-	-	3.81	-	-	20.97	34.32	15.25	15.25
Smelt Bay	8	1	600.50	-	-	69.70	-	-	8.04	99.19	13.40	35.19
	8	2	868.45	-	-	24.81	-	4.96	24.97	96.77	12.41	31.64
Atrevida Reef	9	1	56.36	-	5.20	24.28	-	-	-	13.01	31.21	4.34
	9	3	57.48	-	-	96.80	-	6.05	-	29.49	308.56	0.19
Secret Cove	11	1	718.79	-	-	67.09	-	-	-	79.87	-	13.98
	11	3	293.44	-	-	53.05	-	-	1.66	91.18	-	11.71

Table 7 continued.

Location	Tran	Stn	SIPH	SMIN	TDIS	TELA
Clarke Rock	1	1	2.66	-	-	-
	1	3	0.39	-	-	-
Yellow Point	2	1	894.28	-	-	-
	2	4	780.18	-	-	-
Bowser	3	1	73.64	9.10	-	-
	3	3	25.50	-	-	-
French Creek	5	1	-	-	-	-
	5	3	0.67	-	0.44	-
Trincomali Ch	6	3	7.00	-	8.62	-
	6	5	52.07	3.81	15.25	-
Smelt Bay	8	1	40.88	-	-	-
	8	2	124.68	-	-	-
Atrevida Reef	9	1	3.58	-	-	0.87
	9	3	6.14	-	-	0.09
Secret Cove	11	1	3.99	-	-	-
	11	3	0.21	-	-	-

Table 8. Summary of the CTD data collected during the 2024 Strait of Georgia juvenile herring survey. Data were not recorded at one station (station 3 on transect 11).

Location	Tran	Stn	Date sampled	Cast depth (m)	Temp at surface (°C)	Temp at depth (°C)	Salinity at surface (PSS-78)	Salinity at depth (PSS-78)	Thermocline (m)
Clarke Rock	1	1	09/16	41.4	16.4	10.3	27.3	30.0	12.9
		3		120.7	16.3	9.9	27.4	30.9	12.2
Yellow Point	2	1	09/18	60.3	16.4	11.5	27.9	30.1	3.8
		4		58.4	15.8	11.7	28.1	30.1	4.3
Bowser	3	1	09/14	20.5	15.6	10.9	28.2	29.9	4.9
		3		65.4	16.3	9.6	27.8	30.4	4.0
French Creek	5	1	09/15	25.5	16.6	11.1	28.1	29.8	9.4
		3		69.2	16.5	9.7	28.1	30.3	9.9
Trincomali Ch	6	3	09/17	35.8	13.2	10.8	29.1	31.0	33.3
		5		60.3	13.2	10.5	29.2	31.2	1.6
Smelt Bay	8	1	09/011	30.5	15.8	10.0	27.2	29.8	5.0
		2		93.8	15.7	9.5	27.5	30.4	1.6
Atrevida Reef	9	1	09/12	34.6	16.8	9.4	27.0	30.1	10.5
		3		118.5	16.4	9.4	27.4	30.6	1.6
Secret Cove	11	1	09/09	40.4	16.9	10.0	27.4	30.0	1.5
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APPENDIX A

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

The Strait of Georgia (SOG) juvenile herring 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. Survey information may also represent trends in prey availability and quality to Coho and Chinook Salmon and other predators in the SOG. The indices (and associated variance) of the relative biomass or abundance of age-0 herring in the SOG were updated with the 2024 survey data using a two-stage method identified in Boldt et al. (2015). Catch per unit effort (CPUE) was calculated by dividing catch weight (or abundance) by the area fished (assuming the net length changed in 2002 from 220 m to 183 m; see Boldt et al. 2015 for details). Estimates of variability were calculated using methods from Thompson (1992). In addition to standard transects (transect numbers <12), extra transects were sampled in 2021 (1 extra), 2022 (2 extra), and 2023 (1 extra). Indices of relative age-0 herring abundance, lengths, weights, and condition were calculated and compared using all transects (only standard transects were sampled in 2024).

Estimates of mean catch weights (g), abundance, and CPUE (weight and abundance) of age-0 herring varied interannually with no significant linear trend during 1992-2024 (Figures A1 and Table A1). These indices tended to peak every two or three years, with the peaks occurring in even years during 2004-2012 and in 2023. During 2013-2022, the indices were intermediate-low compared to the peaks in the time series, peaked again in 2023, and were near average in 2024 (Figure A1 and Table A1). High estimates of variability are associated with peak index values (Figure A1 and Table A1); the survey coefficient of variation (CV) was 0.49.

During the time series, there were no significant linear trends in mean lengths or weights of age-0 herring (Figure A2). Age-0 herring condition (length-weight residuals) increased during 1997-2012, and were positive in 2005 and 2007-2024 (Figure A2). In 2024, herring condition was above average; however, the average length and weight of age-0 herring was low compared to time series average (1992-2024; 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 pallasii*) 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.

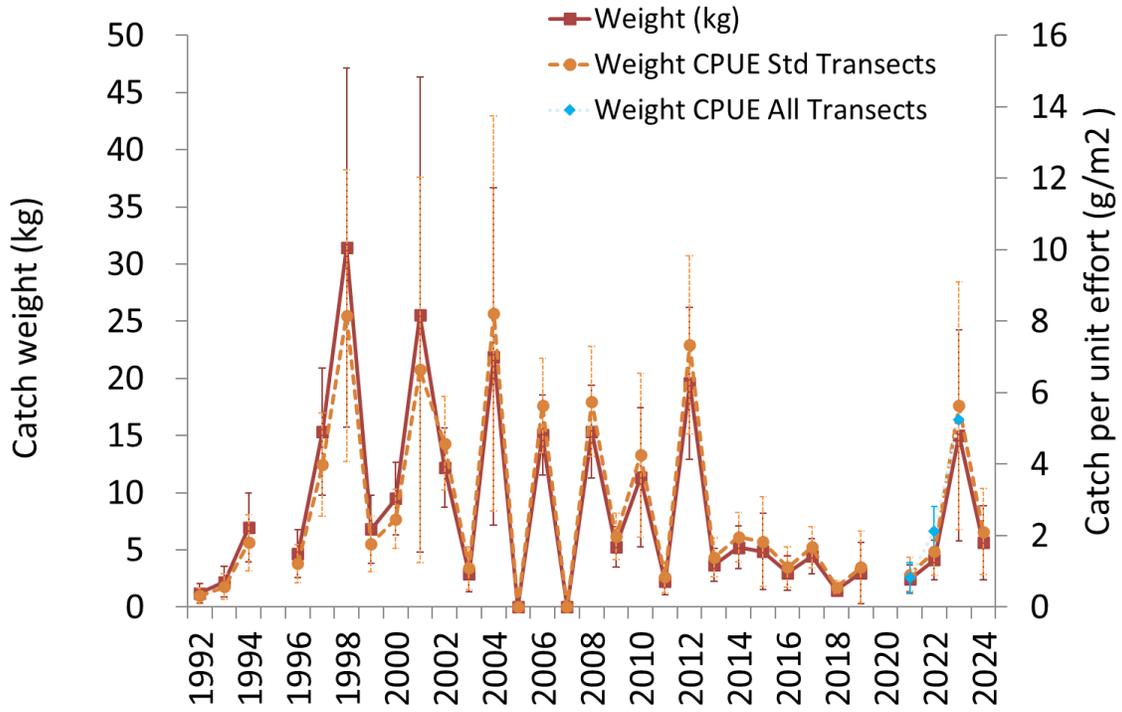


Figure A1. Estimates of catch weight (kg), catch weight-per-unit-effort (weight CPUE; g/m^2), abundance, and abundance CPUE (number/ m^2) of age-0 herring caught in the Strait of Georgia juvenile herring survey, at standard transects (orange and red) and at all transects (blue) sampled, during 1992-2024 (no survey in 1995 or 2020). Standard error bars (using the Thompson 1992 variance estimator) are shown.

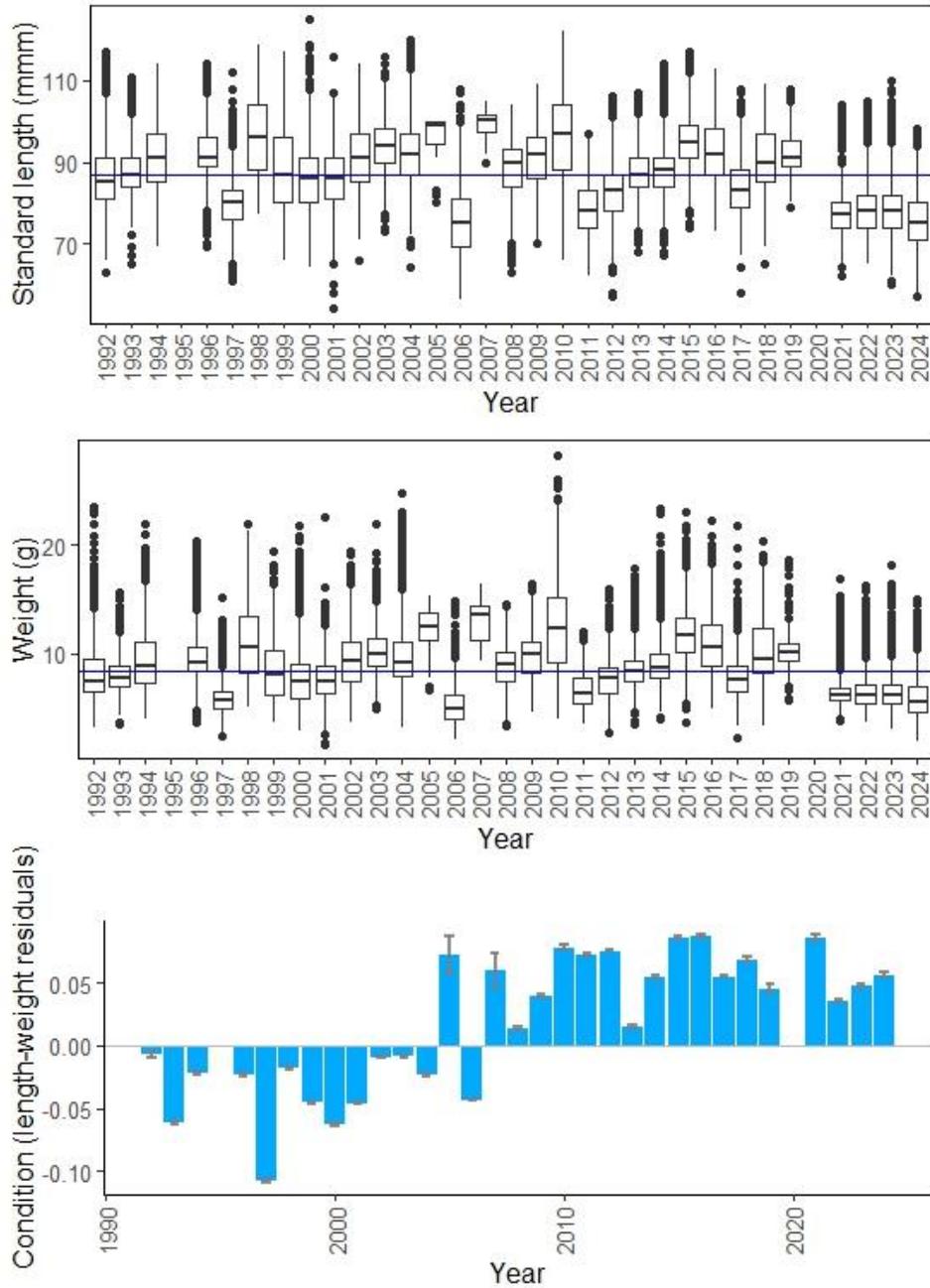


Figure A2. Boxplots of age-0 herring standard lengths (mm; top panel) and weights (g; middle panel), and bar plot of condition (residuals from a double-log-transformed length weight regression; bottom panel) from standard transects, as measured in the laboratory during 1992-2024 (no survey in 1995 or 2020). Horizontal lines are the time-series mean standard length and weight (top and middle panels). Standard error bars are shown on the bottom panel.

Table A1. Mean catch weight (g), catch weight per unit effort (CPUE; g/m²), abundance, abundance CPUE (number/m²), standard error (SE), and coefficient of variation (CV) of age-0 herring caught in the Strait of Georgia juvenile herring survey at standard transects and stations, during 1992-2024 (no survey in 1995 or 2020). 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

Table A1 continued

Year	Weight (g)	SE	CV	Weight CPUE (g/m ²)	SE	CV	Abundance	SE	CV	Abundance CPUE (number/m ²)	SE	CV
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
2019	2978.465	2681.382	0.900	1.118	1.006	0.900	285.200	254.358	0.892	0.107	0.095	0.892
2020												
2021	2430.830	1248.220	0.513	0.912	0.468	0.513	387.281	199.353	0.515	0.145	0.075	0.515
2022	4127.236	1740.483	0.422	1.549	0.653	0.422	649.289	268.625	0.414	0.244	0.101	0.414
2023	15019.404	9247.830	0.616	5.636	3.470	0.616	2812.846	1917.806	0.682	1.055	0.720	0.682
2024	5625.461	3221.071	0.573	2.111	1.209	0.573	926.065	523.056	0.565	0.347	0.196	0.565

Table A2. Mean catch weight (g), catch weight per unit effort (CPUE; g/m²), abundance, abundance CPUE (number/m²), standard error (SE), and coefficient of variation (CV) of age-0 herring caught in the Strait of Georgia juvenile herring survey at all transects and stations sampled during, 2021-2023 (when additional, non-standard transects were sampled). 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
2021	2198.615	1140.336	0.519	0.825	0.428	0.519	350.413	182.079	0.520	0.131	0.068	0.520
2022	5672.220	1833.869	0.323	2.128	0.688	0.323	997.903	339.813	0.341	0.374	0.128	0.341
2023	13945.373	8226.235	0.590	5.233	3.087	0.590	2592.307	1705.663	0.658	0.973	0.640	0.658

APPENDIX B

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 and 10 were randomly selected to be processed using the calorimeter. A Parr Instrument 6765 Semi-Micro Oxygen Calorimeter was used to determine caloric content (interchangeable with the term energy density). 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 (+/- 0.05) 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 30-80 individual fish per year from 2012 to 2024 (Table B1).

Linear regression was used to model the relationship of energy density as a function of standard length (mm), wet weight (g), dry weight (g), percent dry weight, and condition. Condition values were calculated as 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, weights (wet, dry, and percent dry), and lengths among years. If a difference was found then a Tukey's post-hoc test was conducted to determine which years were different. Using the Tukey's adjusted comparisons, a compact letter display was determined from the package 'emmeans' and cld() function within the statistical program R (R Core Team, 2025), which assigns a letter to groups so that groups sharing a

letter are not significantly different, while groups with no letters in common are not significantly different.

RESULTS

Fish weight and energy density values varied among years with 2015, 2018, and 2016 having the highest energy density values and 2012, 2024, and 2022 having the lowest energy density (Figure B1 and B2). Energy density values from 2024 samples were the second lowest in the time series, 4909.6 cal/g (Figure B1). 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 B2). Average fish standard lengths ranged from 78.4 mm to 96.8 mm and average fish wet weights varied between 7.0 g and 11.3 g in 2022 and 2015, respectively (Figure B1). Average fish dry weight varied between 1.42 g (2022) and 2.74 g (2015) (Figure B1). In 2024, the average length was the lowest of the time series at 79.1 mm, average wet weight was 7.13 g and the average dry weight was 1.46 g, which were the second lowest of the time series (Figure B1).

Average energy density of Pacific herring varied significantly among years showing that interannual differences were substantial with some years forming statistically different ($p < 0.0001$) groups while recent years (2022-2024) were similar to one another (Figure B1). Overall, there appears to be a mid-decade peak in energy density (2015-2019) followed by a decline and stabilization at moderate levels in 2021-2024 (Figure B1). Standard length, wet weight, and dry weight show pronounced interannual variability in herring body size over the time period, indicating that fish were largest during 2015-2019 (except 2017) and smallest in 2022. Percent dry weight followed a similar pattern however values in 2016 and 2018 remained elevated but lower than peak years (Figure B1). Condition showed a shift from lower condition early in the time series, 2012-2014, to a generally higher condition later in the time series with the peak occurring in 2018 (Figure B1). Condition was moderately high and relatively stable during 2021-2024, indicating fish were heavier for a given unit length than in the earlier years (Figure B1).

There was evidence of a positive, linear relationship between energy density and length ($R^2 = 0.24$, $p < 0.001$), dry weight (g) ($R^2 = 0.44$, $p < 0.001$), wet weight (g) ($R^2 = 0.31$, $p < 0.001$), percent dry weight ($R^2 = 0.41$, $p < 0.001$), and length-weight residuals ($R^2 = 0.11$, $p < 0.001$) (Figure B3).

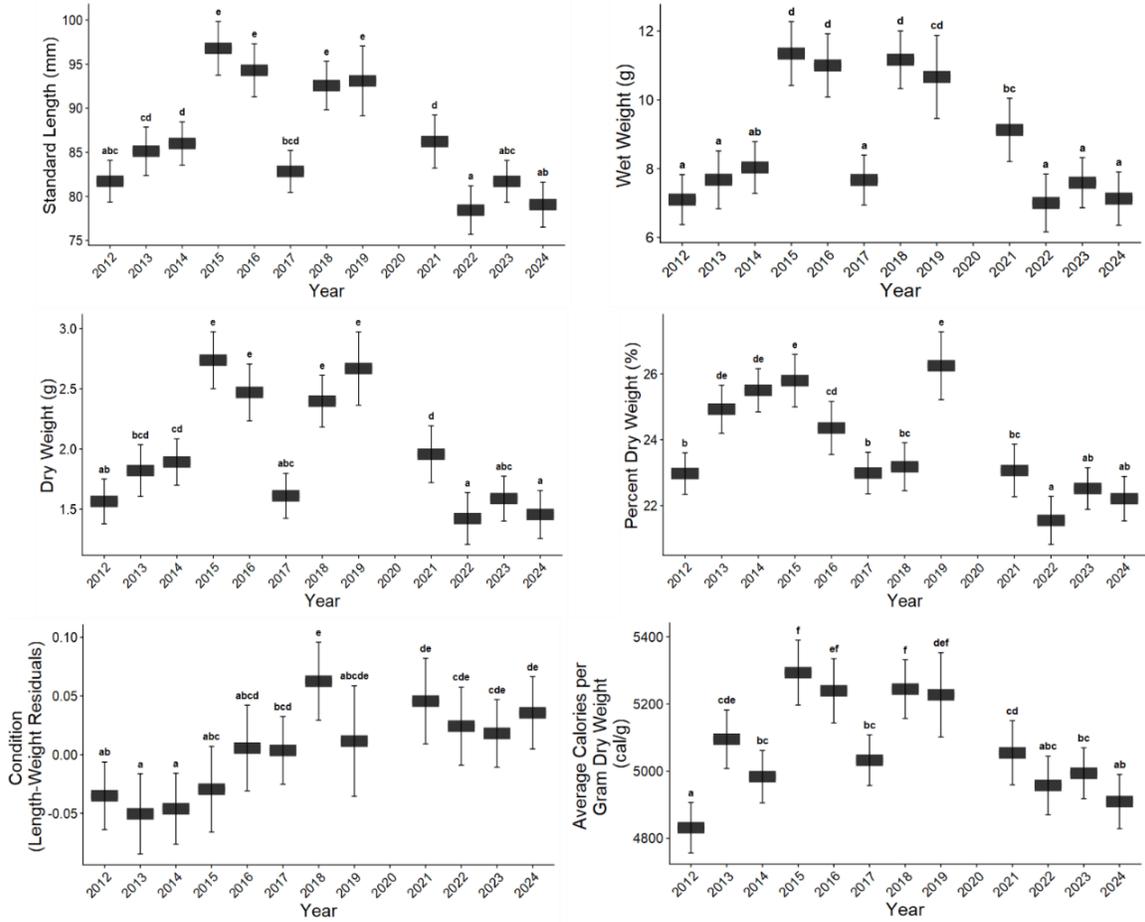


Figure B1. Boxplot comparing standard length (mm), wet weight (g), dry weight (g), percent dry weight (%), and energy density of age-0 Pacific Herring samples between years collected in the Strait of Georgia for calorimetry analysis from 2012-2024. Groups illustrate which years are similar across the study period for each variable, based on ANOVA, Tukey’s post-hoc comparisons and compact letter display. Letters summarize which group means are statistically different or similar.

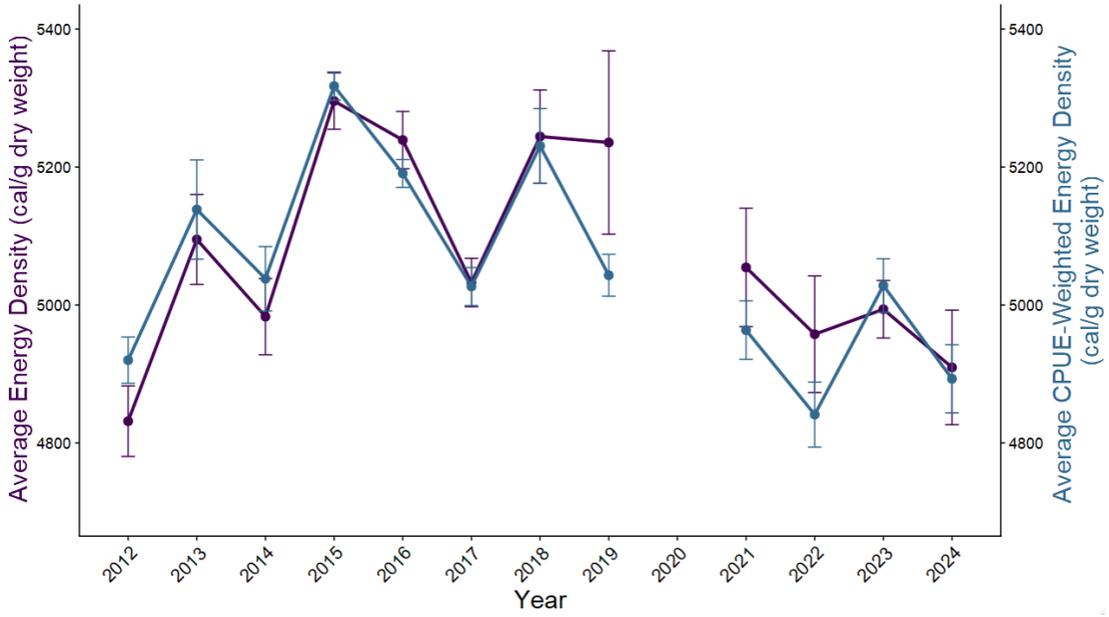


Figure B2. Average energy density and average energy density weighted by catch per unit effort (CPUE) for age-0 Pacific Herring in Strait of Georgia, 2012-2024. Standard error bars are shown.

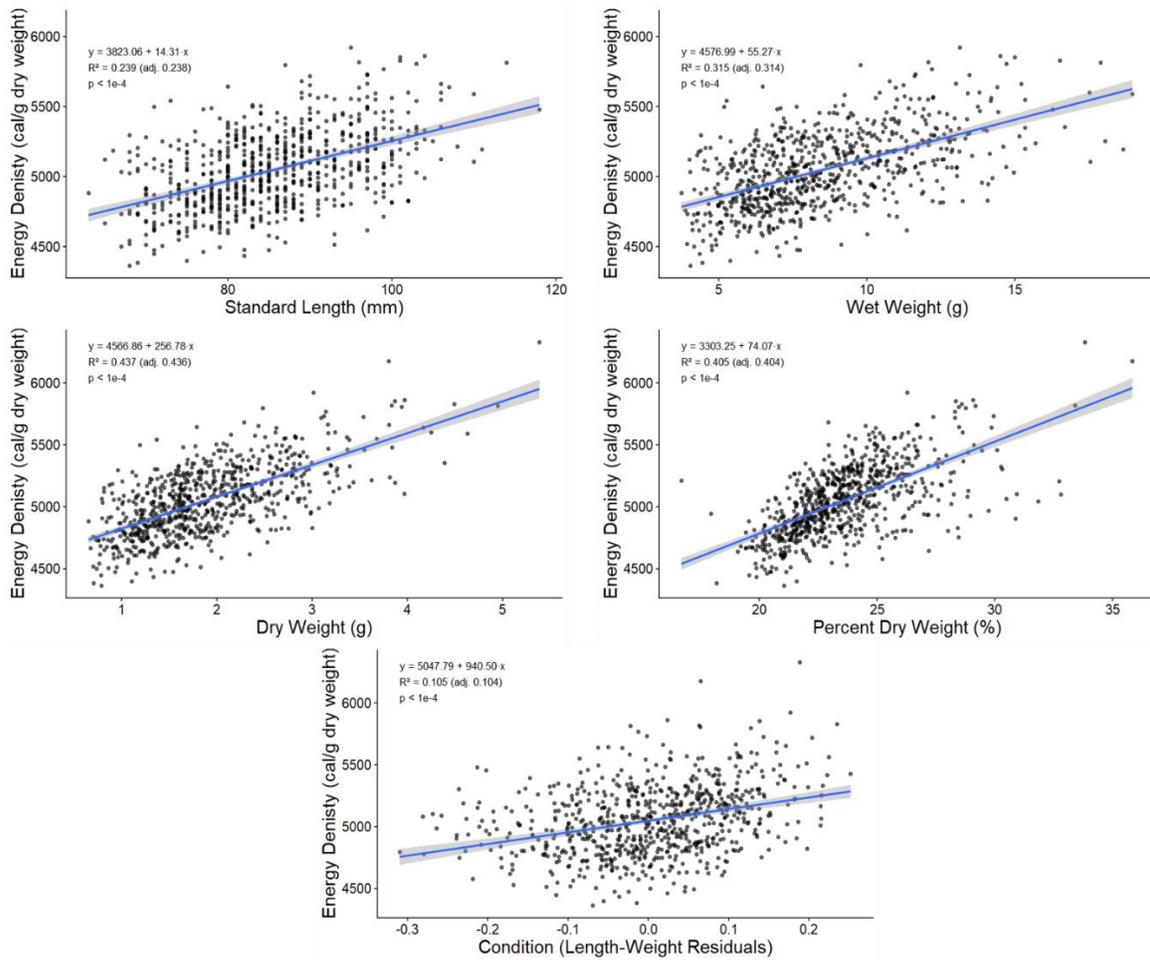


Figure B3. Standard length (mm), wet weight (g), dry weight (g), percent dry weight (%), and condition as a function of energy density of age-0 Pacific Herring samples collected in the Strait of Georgia for calorimetry analysis from 2012-2024. Linear regression lines (solid lines) are shown and grey shaded areas represent the standard errors.

Table B1. Number of Strait of Georgia age-0 Pacific Herring energy density samples processed per year, 2012-2024. 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
2019	30	2, 6, 11
2021	50	2, 4, 6, 8, 10
2022	60	1, 2, 5, 6, 12, 39
2023	80	1, 2, 4, 5, 8, 9, 10, 39
2024	70	1, 2, 3, 5, 6, 9, 11

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