Strait of Georgia Juvenile Herring Survey, September 2015

Matthew Thompson and Jennifer Boldt

Fisheries and Oceans Canada
Science Branch, Pacific Region
Pacific Biological Station
Nanaimo, British Columbia
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STRAIT OF GEORGIA JUVENILE HERRING SURVEY, SEPTEMBER 2015

by

Matthew Thompson and Jennifer Boldt

Fisheries and Oceans Canada
Science Branch, Pacific Region
Pacific Biological Station
Nanaimo, British Columbia
V9T 6N7

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

APPENDIX 1

ABSTRACT

Thompson, M. and Boldt, J. 2019. Strait of Georgia juvenile herring survey, September 2015. Can. Manuscr. Rep. Fish. Aquat. Sci. 3130: v + 48 p.

A fall juvenile herring survey of the Strait of Georgia took place September 17th to 30th, 2015. This survey serves to address several questions of early herring survival, abundance, recruitment and trophodynamics. Forty-five 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. and Boldt, J. 2019. Strait of Georgia juvenile herring survey, September 2015. Can. Manuscr. Rep. Fish. Aquat. Sci. 3130: v + 48 p.

Un relevé automnal du hareng juvénile dans le détroit de Georgie a été réalisé entre le 17 et le 30 septembre 2015. 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 45 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 and a vital forage species for many marine mammals, birds, and fish in British Columbia's coastal waters. 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 the ten core sampling transects (1 – 6, 8 – 11); which are made up of 48 sampling stations and 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). Originally, the sampling transects were chosen based on known historical herring spawning sites and were roughly placed equal distance apart around the Strait of Georgia. Placement also represents both nearshore and open water habitats (Haegele et. al. 2005). In 2015, sampling was conducted from September 17th to 30th (Table 1). Forty-five of the forty-eight core stations were sampled. Henry Bay (transect 4) stations 1, 4, and 5 were skipped due to weather.

Fish Sampling

In 2015, 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 feeding 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 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 are 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 3).

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. A General Oceanics® 2030R model flowmeter was attached to the left bongo net to determine the volume of seawater filtered. Volume filtered was calculated 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)

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

We used Conductivity Temperature Depth recorder (CTD) casts to characterize oceanographic conditions in the surveyed area. We did twenty casts using a RBR XR-60 CTD at stations where zooplankton was sampled (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 close to 1 m/sec. Data from the CTD casts were subsequently downloaded to a laptop at the end of the each evening.

RESULTS

Herring

Forty-five stations were sampled from transects 1 – 6, 8 – 11. A total of 2209 herring were weighed and measured resulting in a length frequency distribution that was distinctly unimodal for age-0+ herring (Figure 4). Length designations for the juvenile herring age-classes were:

0+ = herring less than or equal to 117 mm standard length
1+ = herring between 118 mm and 149 mm standard length
2+ and older = herring greater than or equal to 150 mm standard length

Catches at thirty-nine of the forty-five stations (86.6%) contained age-0+ herring (Tables 2 and 3). The mean length and weight of age-0+ herring was 95 mm and 11.77 g respectively. A total weight of 138.54 kg and estimated 12045 individual age-0+ herring were caught (Table 4).

Catches at fourteen of the forty-five stations (31.1%) sampled contained age-1+ herring (Tables 2 and 3). The mean length and weight of age-1+ herring was 136 mm and 36.24 g, respectively. A total weight of 6.6 kg and estimated 187 individual age-1+ herring were caught (Table 4).

Catches at nine of the forty-five stations (20.0%) sampled contained age-2+ herring (Tables 2 and 3). The mean length and weight of age-2+ herring was 162 mm and 64.15 g, respectively. A total weight of 8.63 kg and estimated 135 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 all transects on the survey were dominated by age-0+ except French Creek (transect 5) which had a mix of all three herring age groups. A length-weight relationship for all sampled herring from the survey showed a significant, positive correlation (R^2=0.98; Figure 6).

Zooplankton

There were 25 categories of organisms identified in 20 zooplankton samples (Tables 5, 6 and 7). An average of 10.658 m^3 of water was filtered per zooplankton tow. Larvaceans (*Oikopleura sp.*and *Fritillaria sp.*) and gastropods occurred most frequently in 19 of the 20 samples. More than 90% of all zooplankton biomass comprised larvaceans (*Oikopleura sp.* and *Fritillaria sp.*), barnacles and unidentified copepod nauplii.

CTD

Two CTD casts were performed at each transect location before plankton sampling. The CTD provided a range of data for temperature (^oC), salinity (ppt), dissolved oxygen (%) and depth (m). Generally, oxygen and salinity show similar patterns as temperature with depth (Figure 7). CTD data collection has been variable throughout the survey time period; therefore, longer term data collection is required to make broader annual oceanographic observations.

CONCLUSION

Forty-five stations were sampled resulting in 22 different fish species recorded from purse seine sets. A total of 2209 herring were measured and weighed creating a unimodal histogram clearly representing age-0+ juvenile herring. Twenty zooplankton tows were performed with larvaceans (*Oikopleura sp.*and *Fritillaria sp.*) being the predominant organisms in numbers and biomass.

ACKNOWLEDGMENTS

The 2015 Strait of Georgia juvenile herring survey was funded by the Pacific Salmon Foundation along with the Department of Fisheries and Oceans. This survey could not have been possible without the hard work and good cheer of skipper Doug Henderson.

Thanks to Vanessa Hodes for filling in for a couple evenings of sampling. Zooplankton samples were processed by Zotec services.

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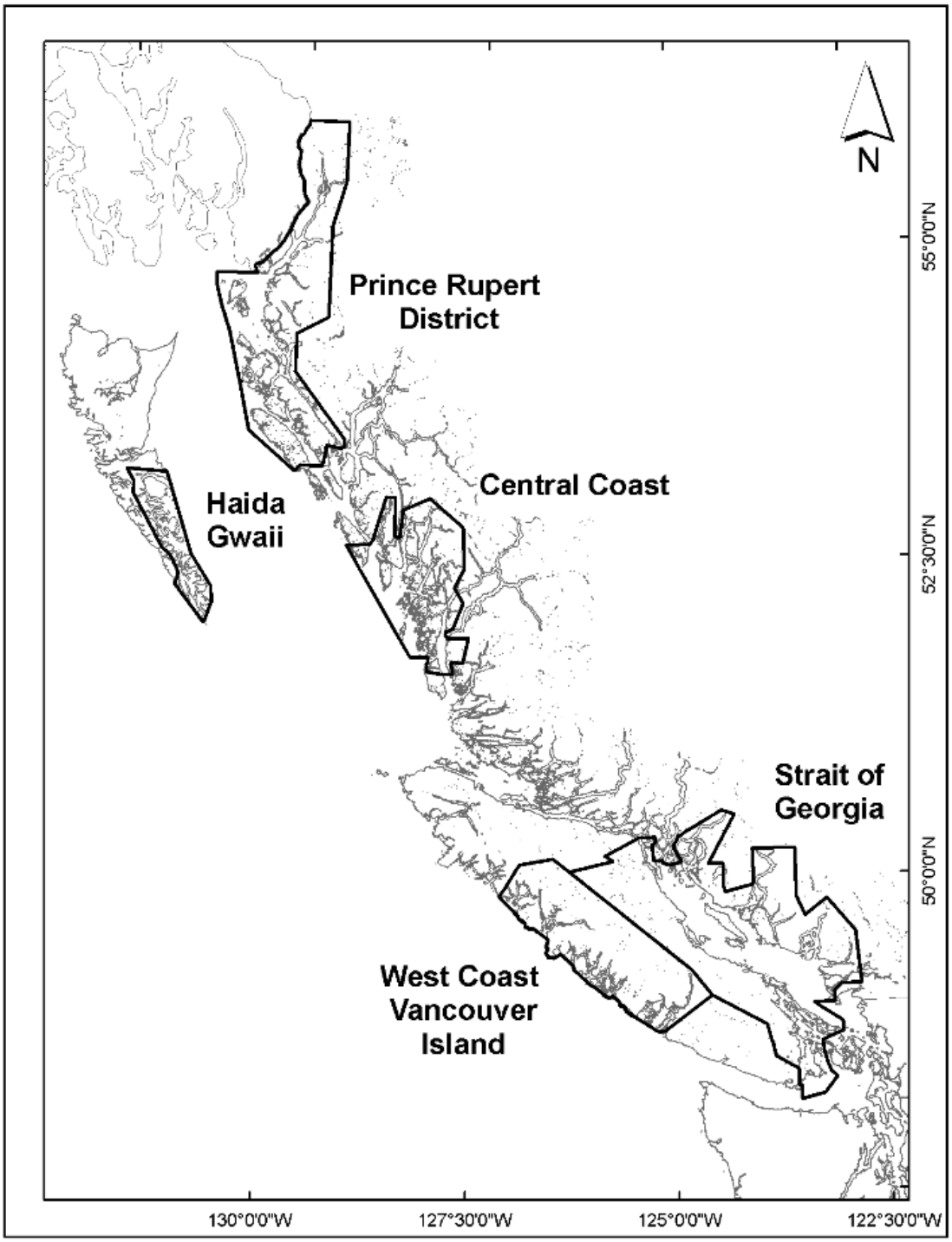


Figure 1. The five major British Columbia herring stock assessment areas.

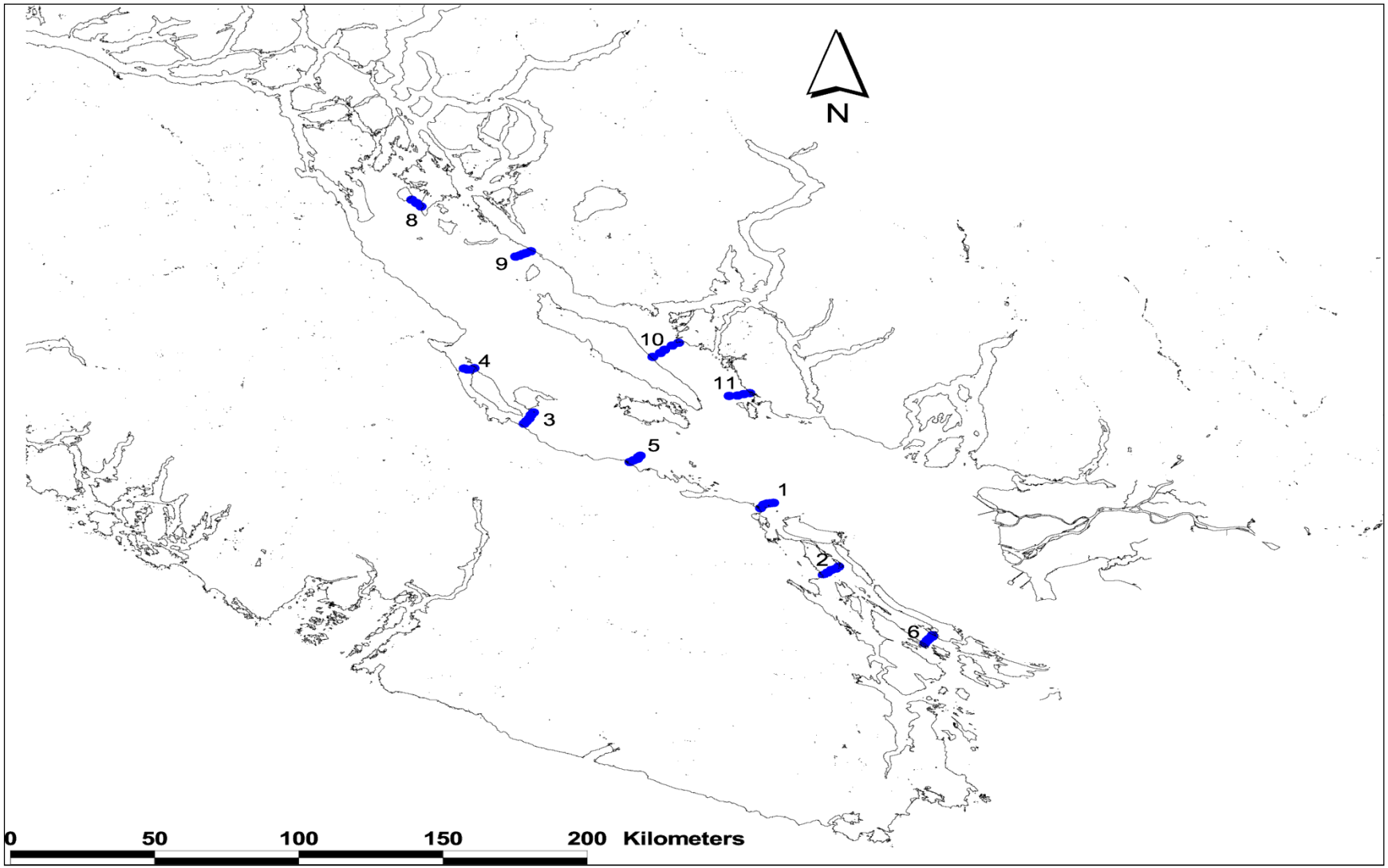


Figure 2. Purse seine set locations for the 2015 Strait of Georgia juvenile herring survey.

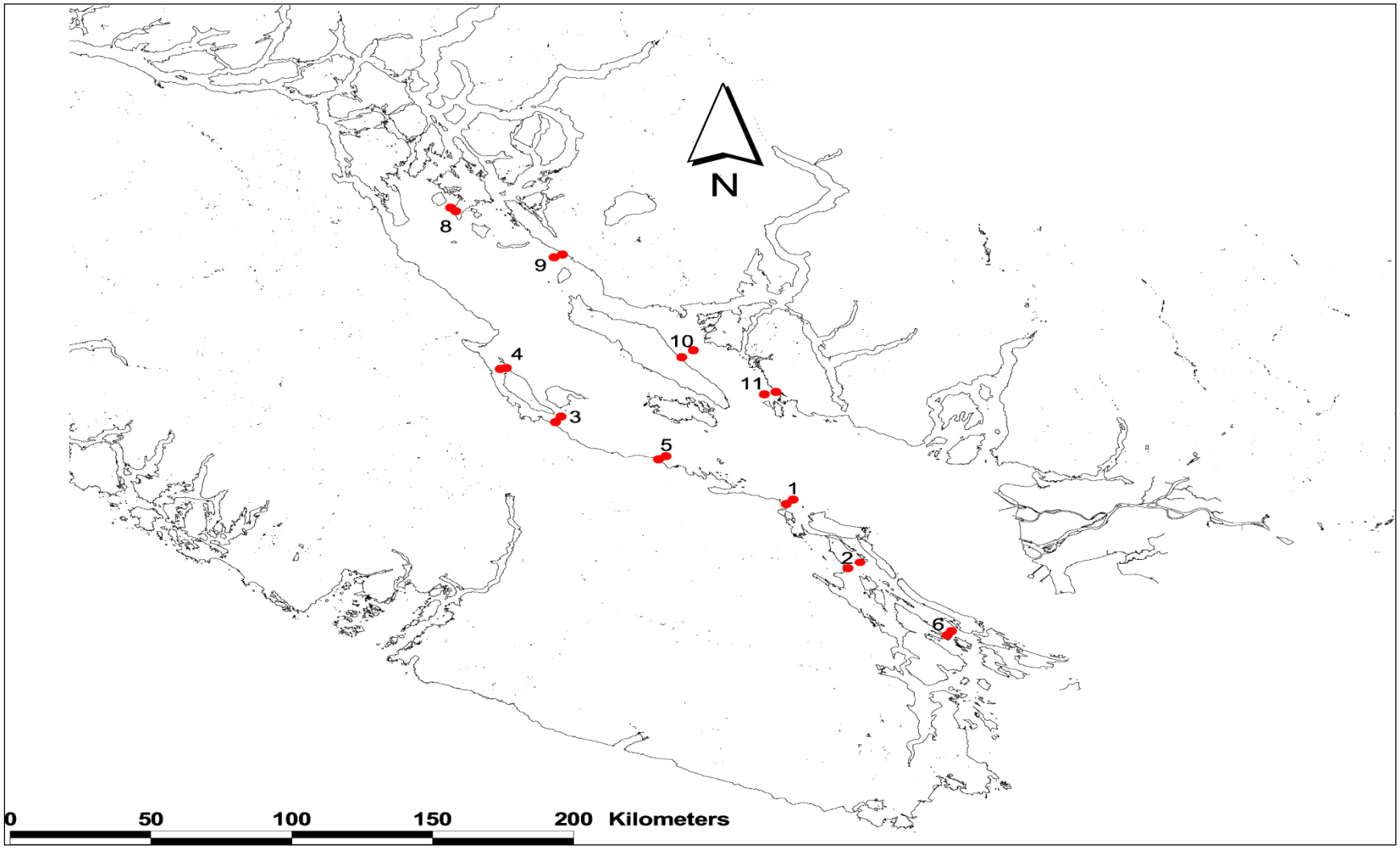


Figure 3. Zooplankton and CTD stations for 2015 Strait of Georgia juvenile herring survey.

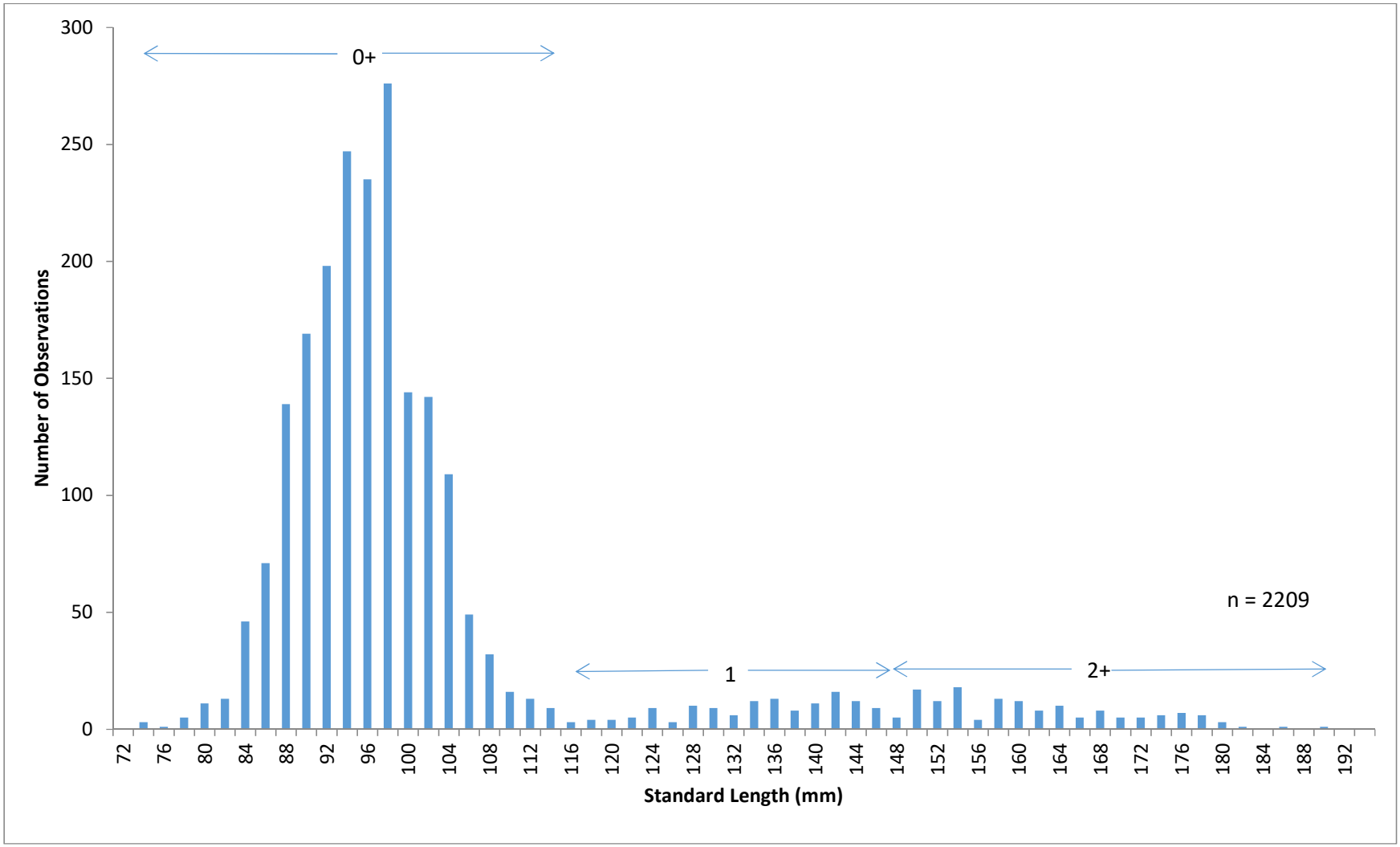


Figure 4. Length-frequency distribution for all herring sampled during the 2015 Strait of Georgia juvenile herring survey.

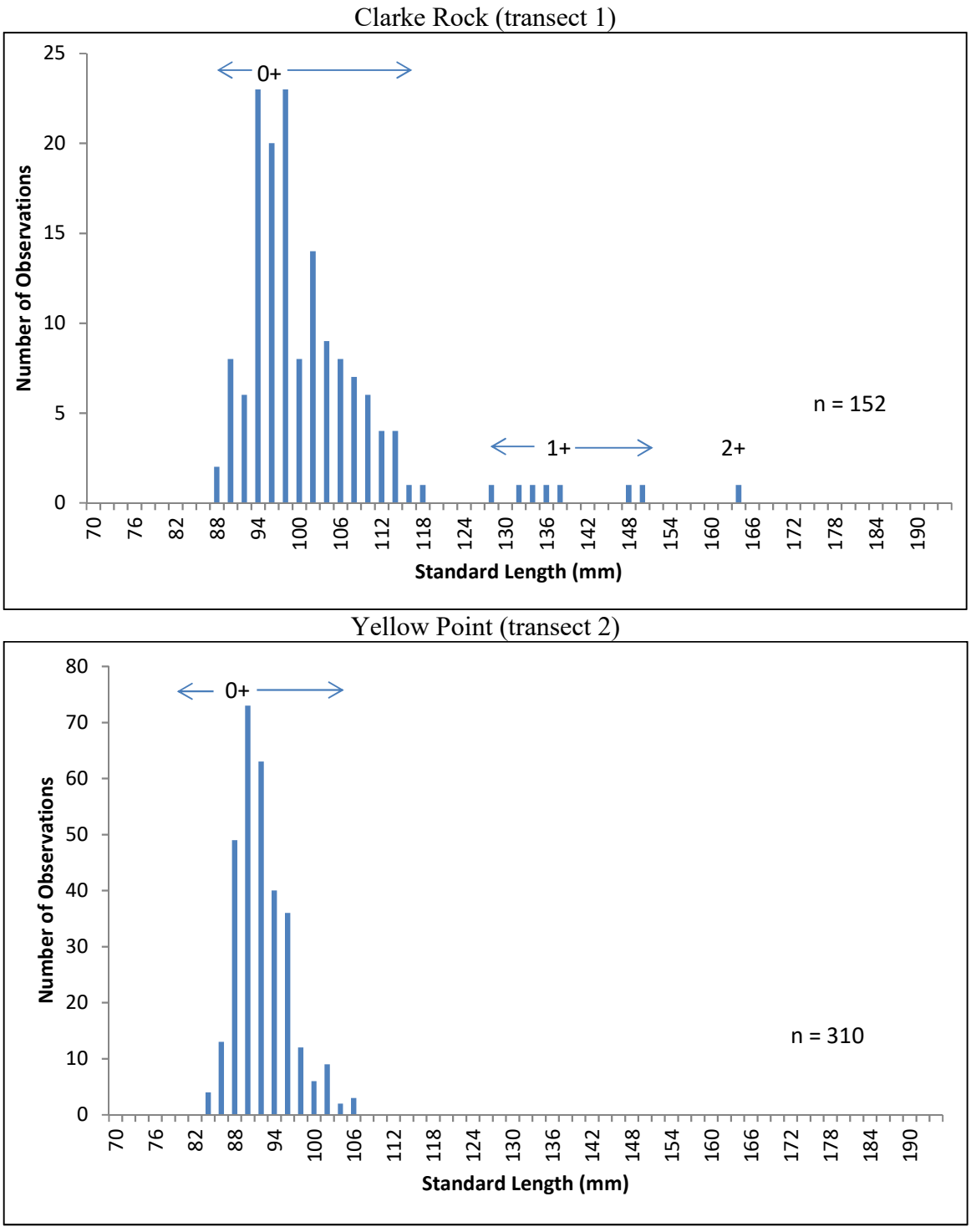
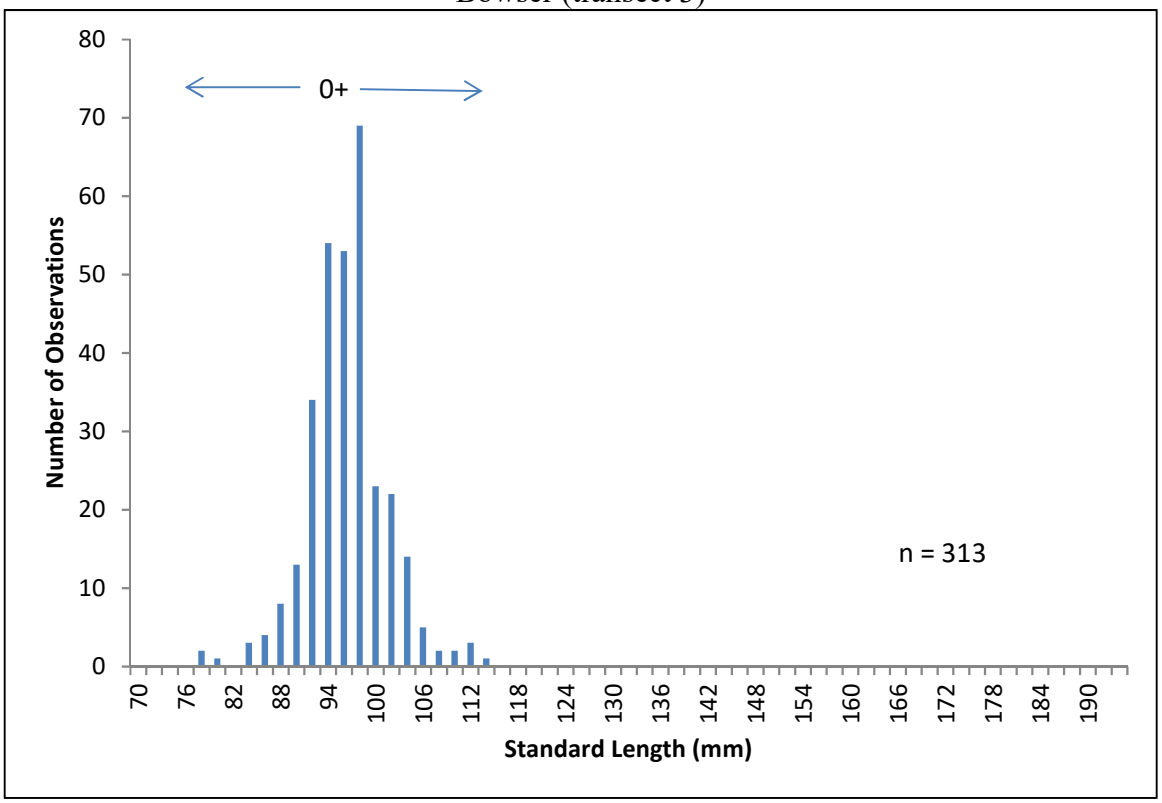


Figure 5. Length-frequency histograms of juvenile herring by transect location for the 2015 Strait of Georgia juvenile herring survey. Transects 8 and 9 are omitted because only 31 and 13 herring were caught respectively.

Bowser (transect 3)



Henry Bay (transect 4)

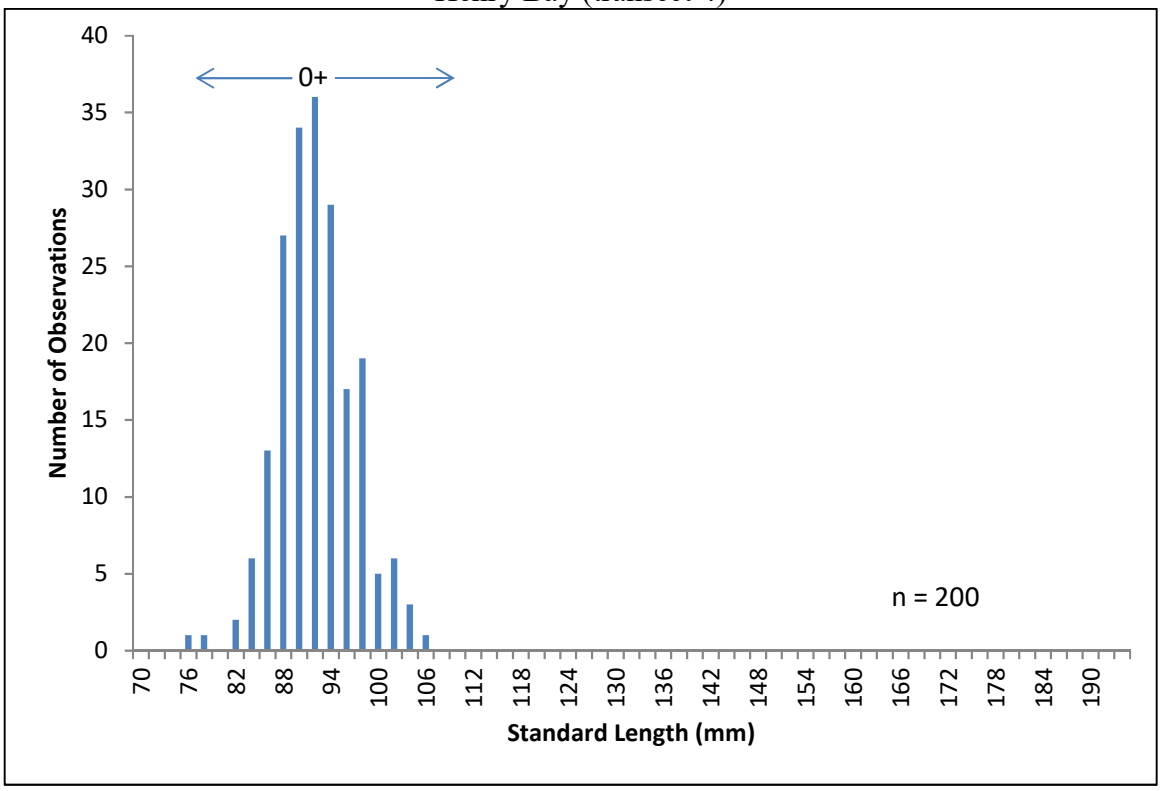
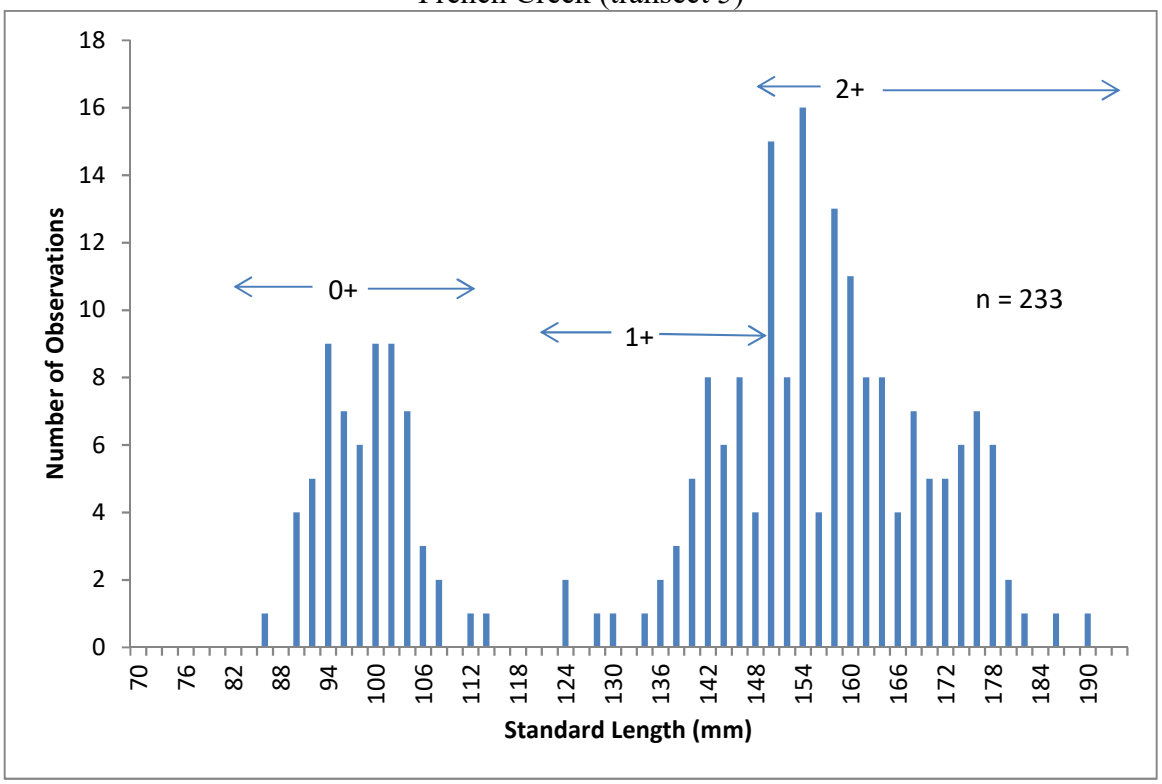


Figure 5 continued.

French Creek (transect 5)



Trincomali Channel (transect 6)

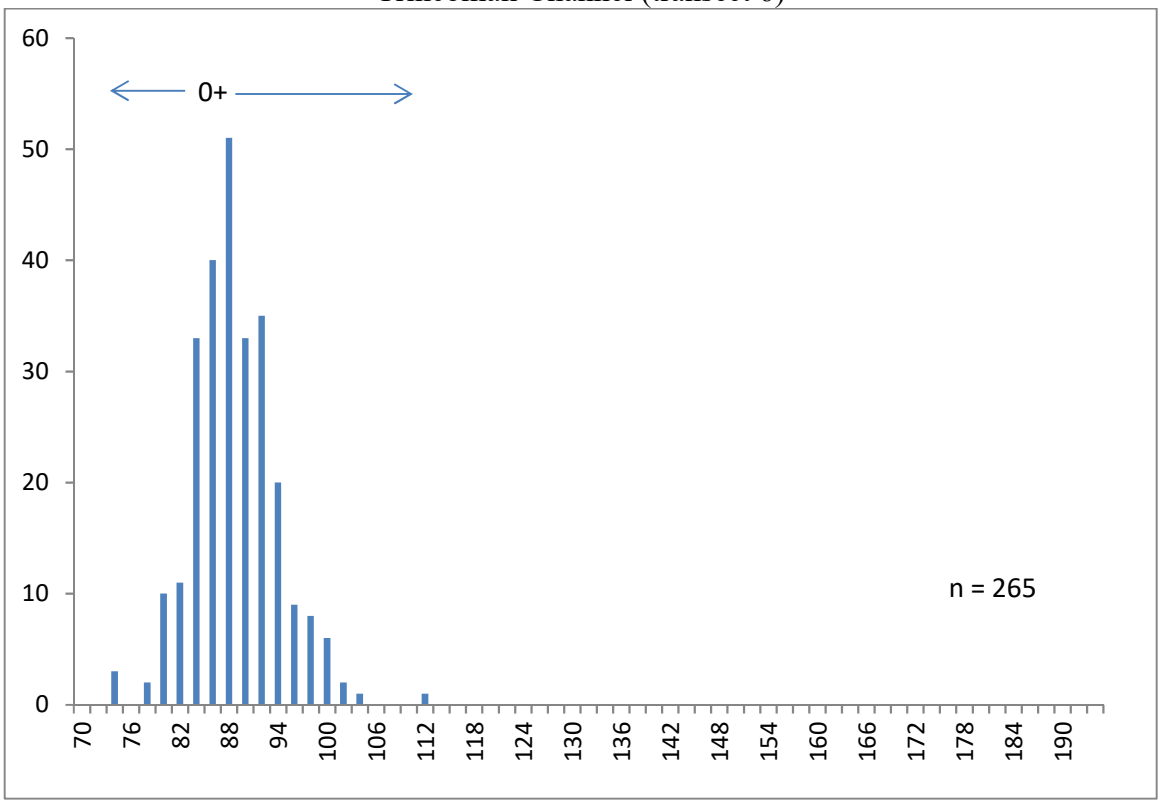
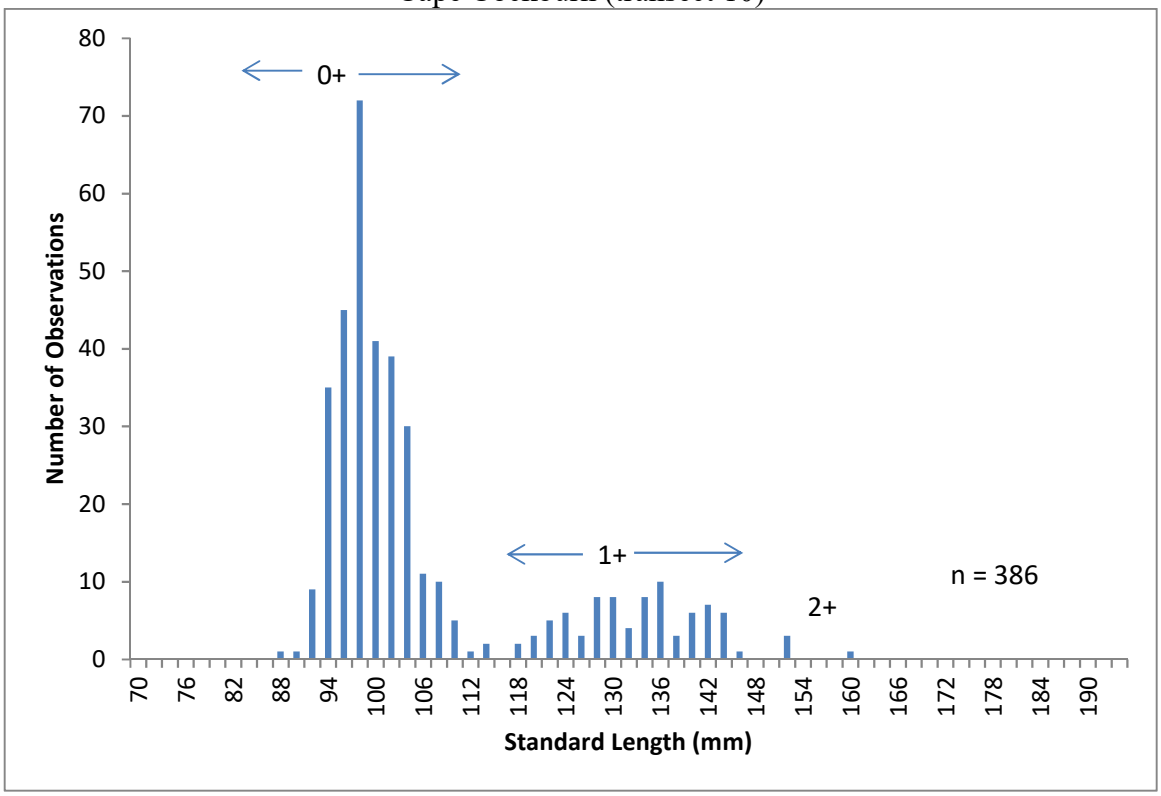


Figure 5 continued.

Cape Cockburn (transect 10)



Secret Cove (transect 11)

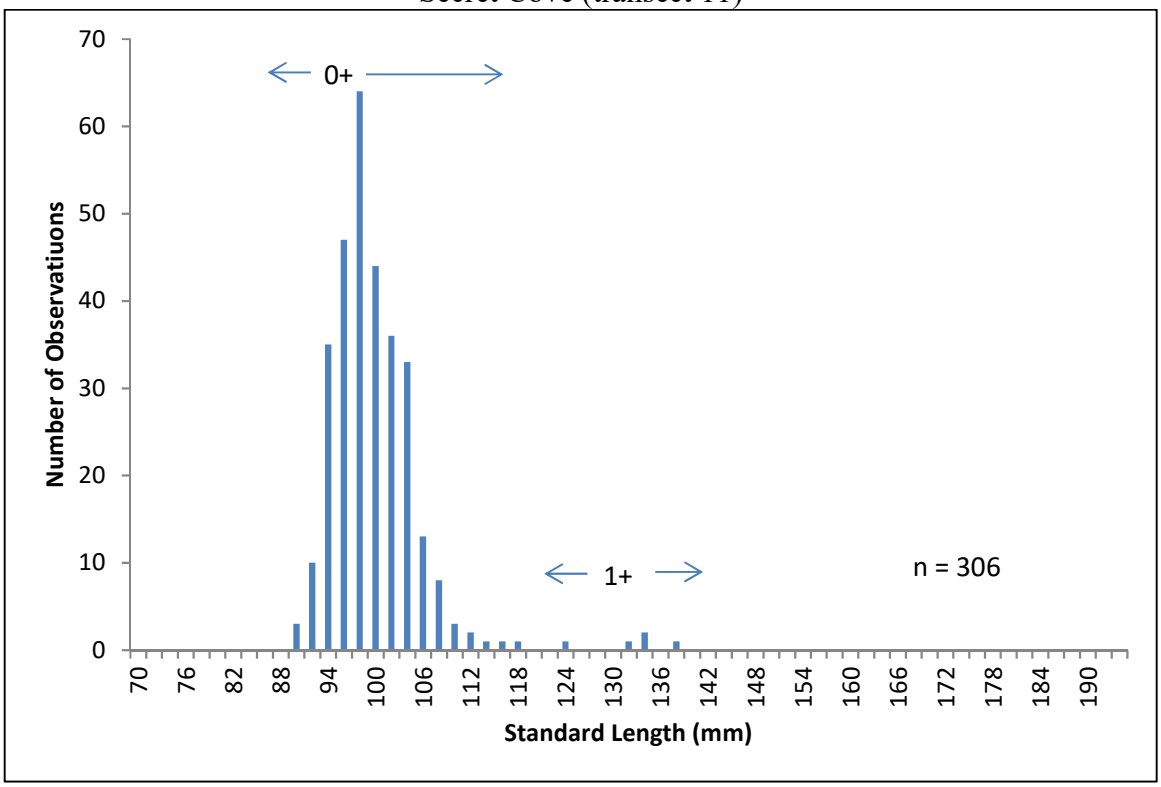


Figure 5 continued.

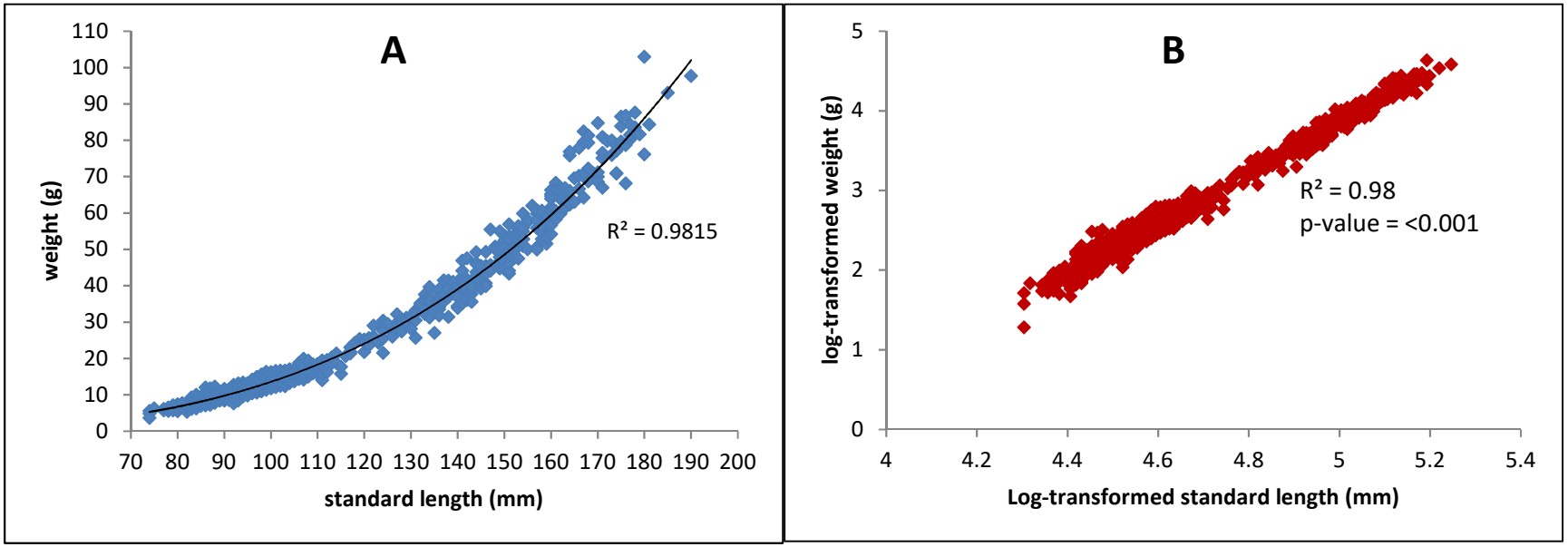


Figure 6. Nontransformed (A) and log-transformed (B) length-weight relationship for all herring sampled during the 2015 Strait of Georgia juvenile herring survey.

Clarke Rock (transect 1)

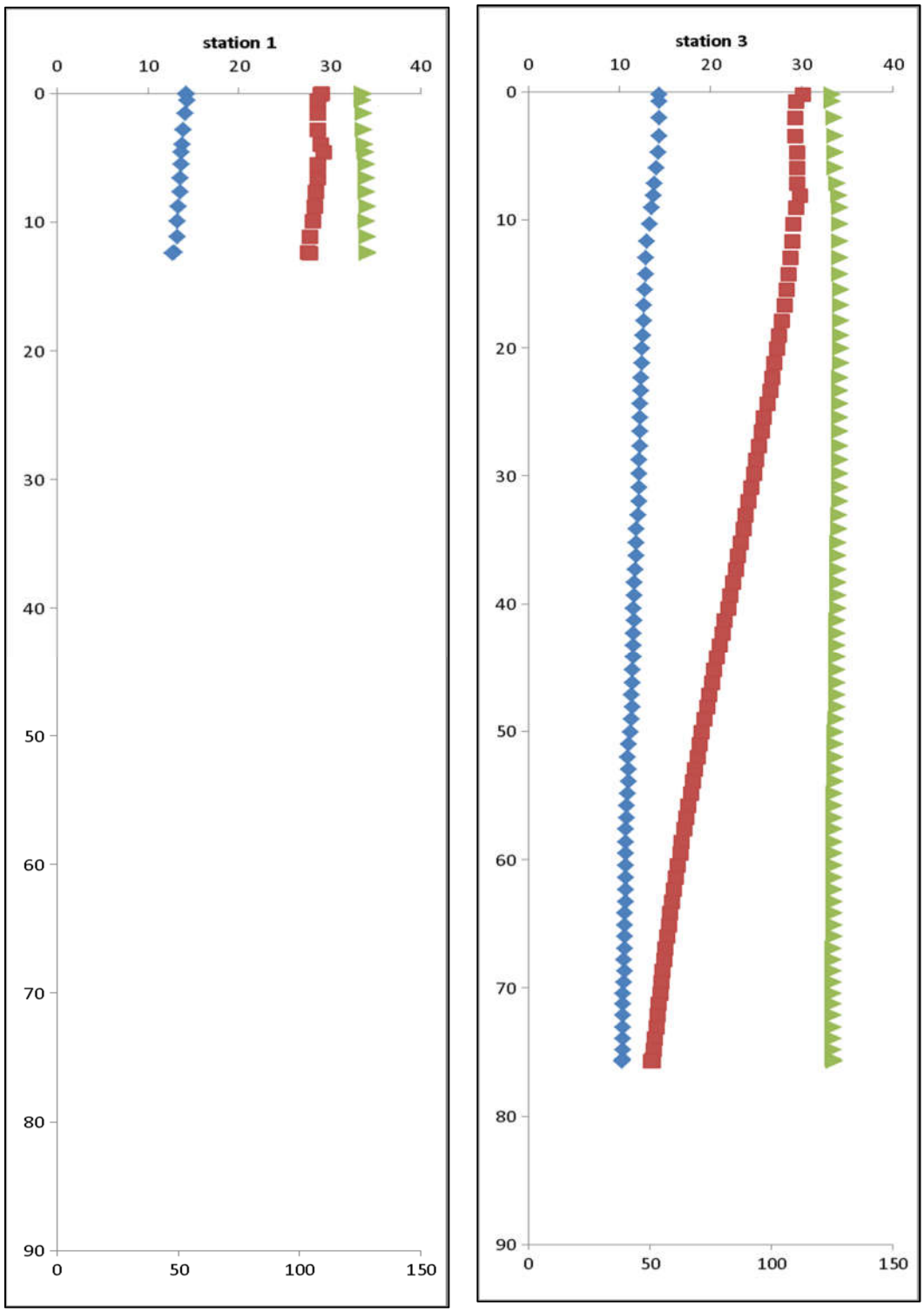


Figure 7. Temperature (blue), salinity (green) and dissolved oxygen (red) profiles from CTD casts during the 2015 Strait of Georgia juvenile herring survey.

Yellow Point (transect 2)

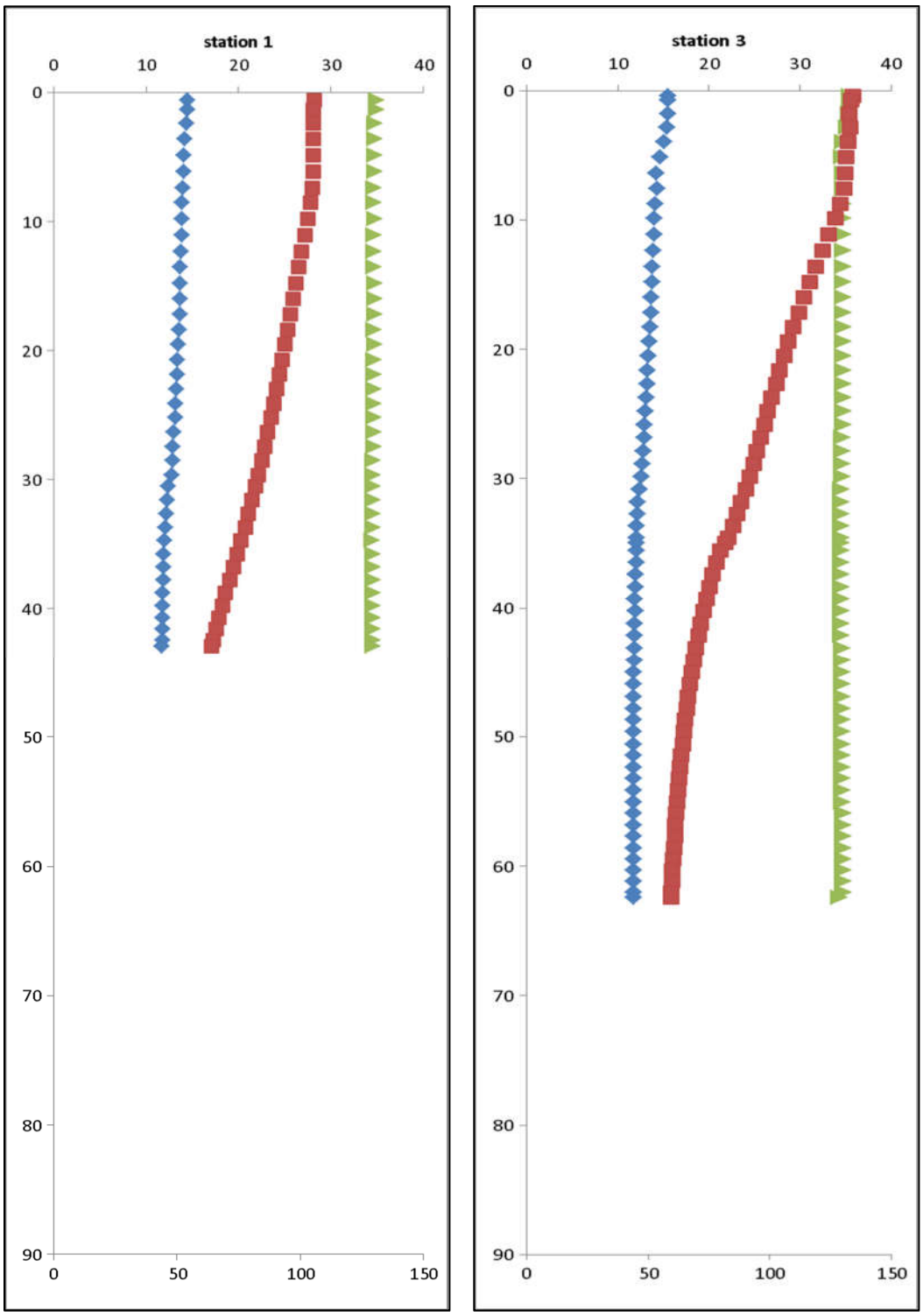


Figure 7 continued.

Bowser (transect 3)

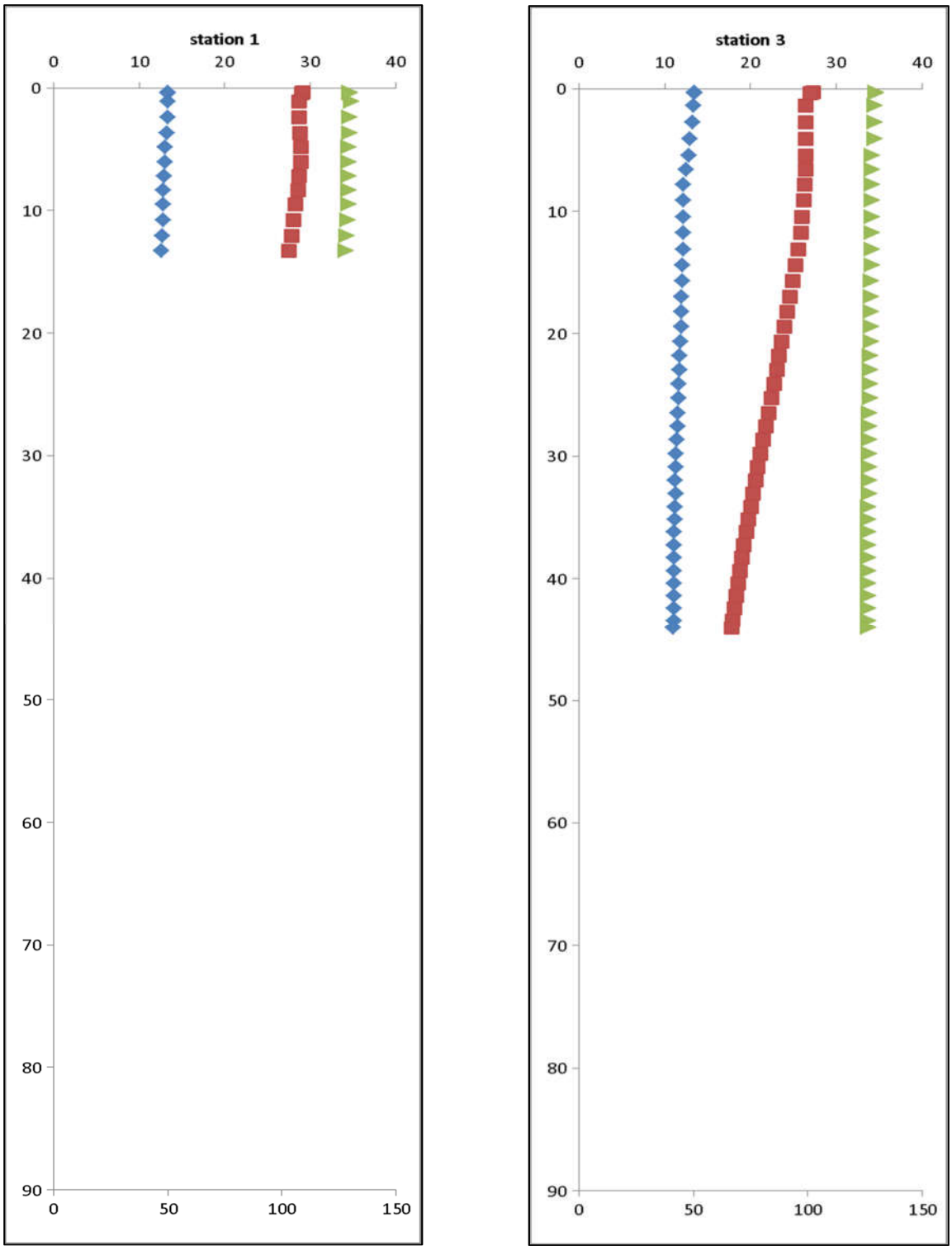


Figure 7 continued.

Henry Bay (transect 4)

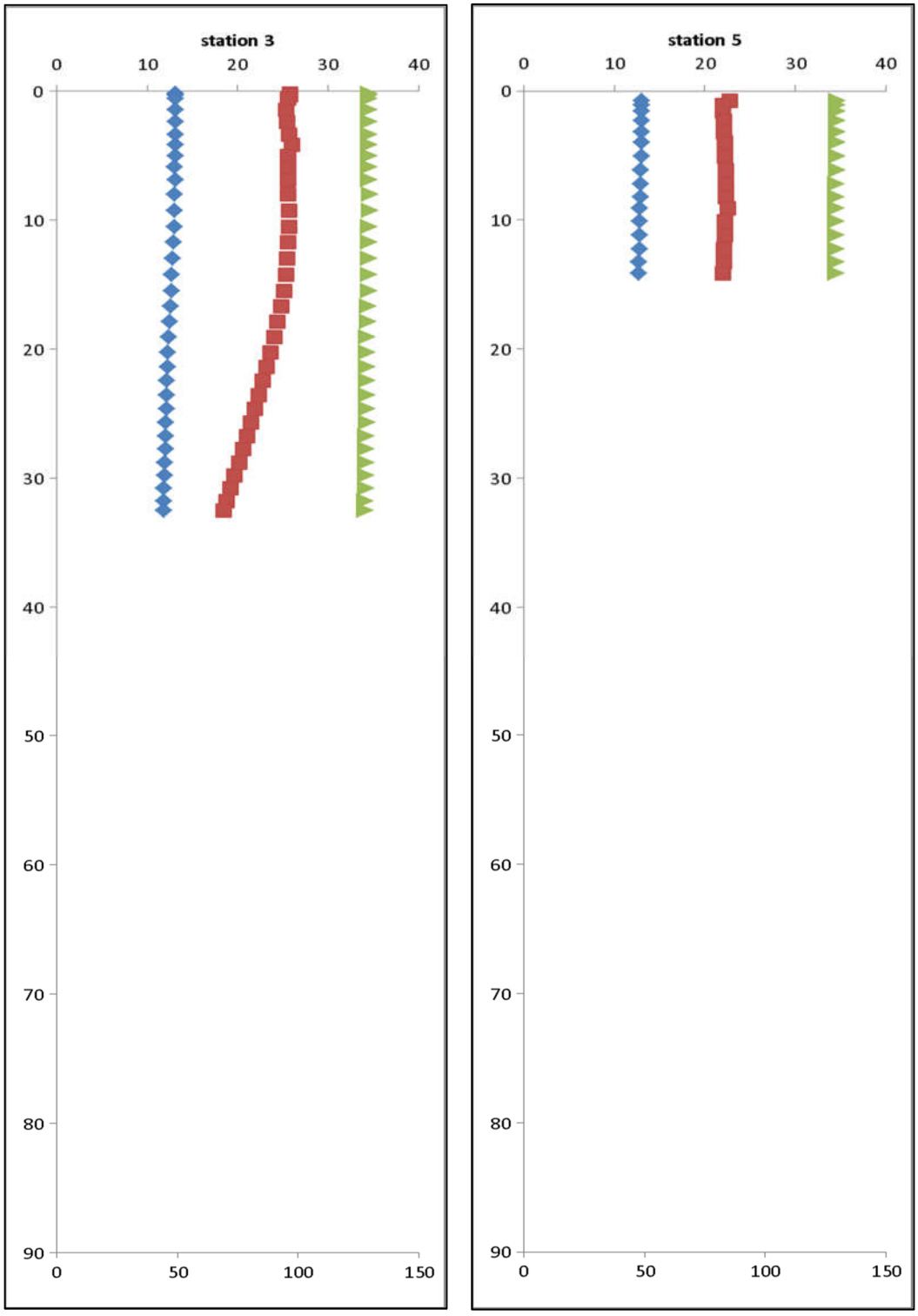


Figure 7 continued.

French Creek (transect 5)

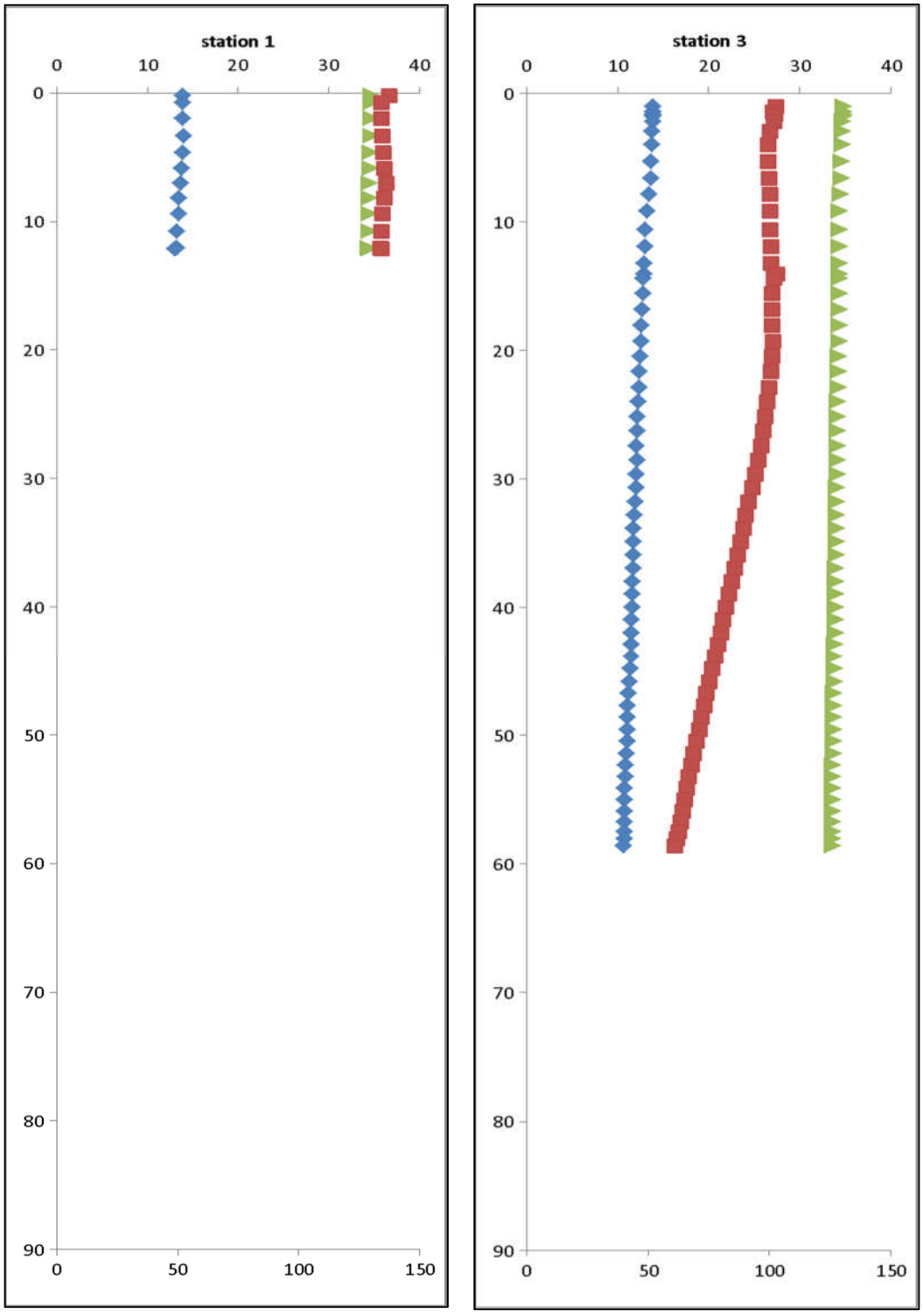


Figure 7 continued.

Trincomali Channel (station 6)

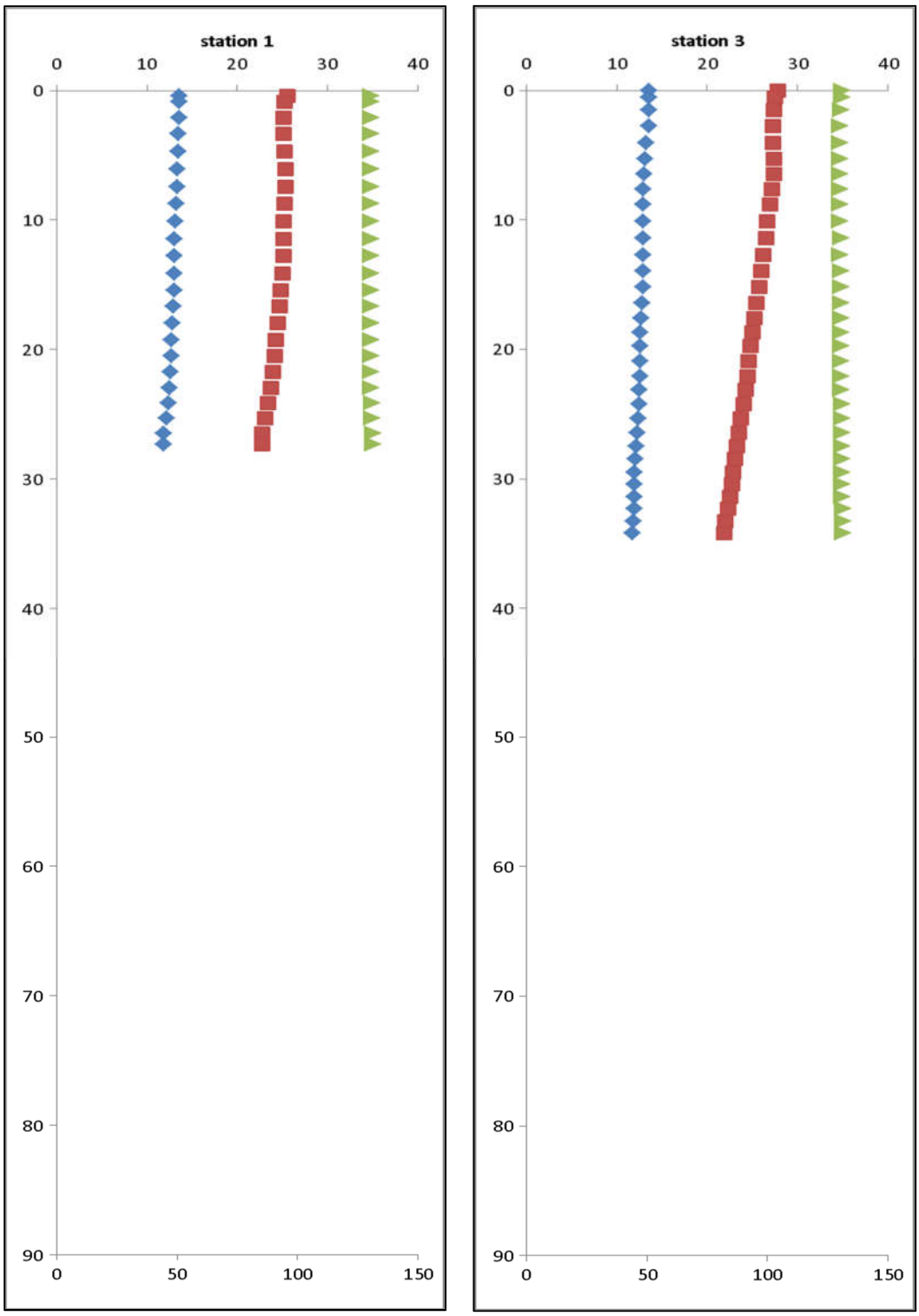


Figure 7 continued.

Smelt Bay (transect 8)

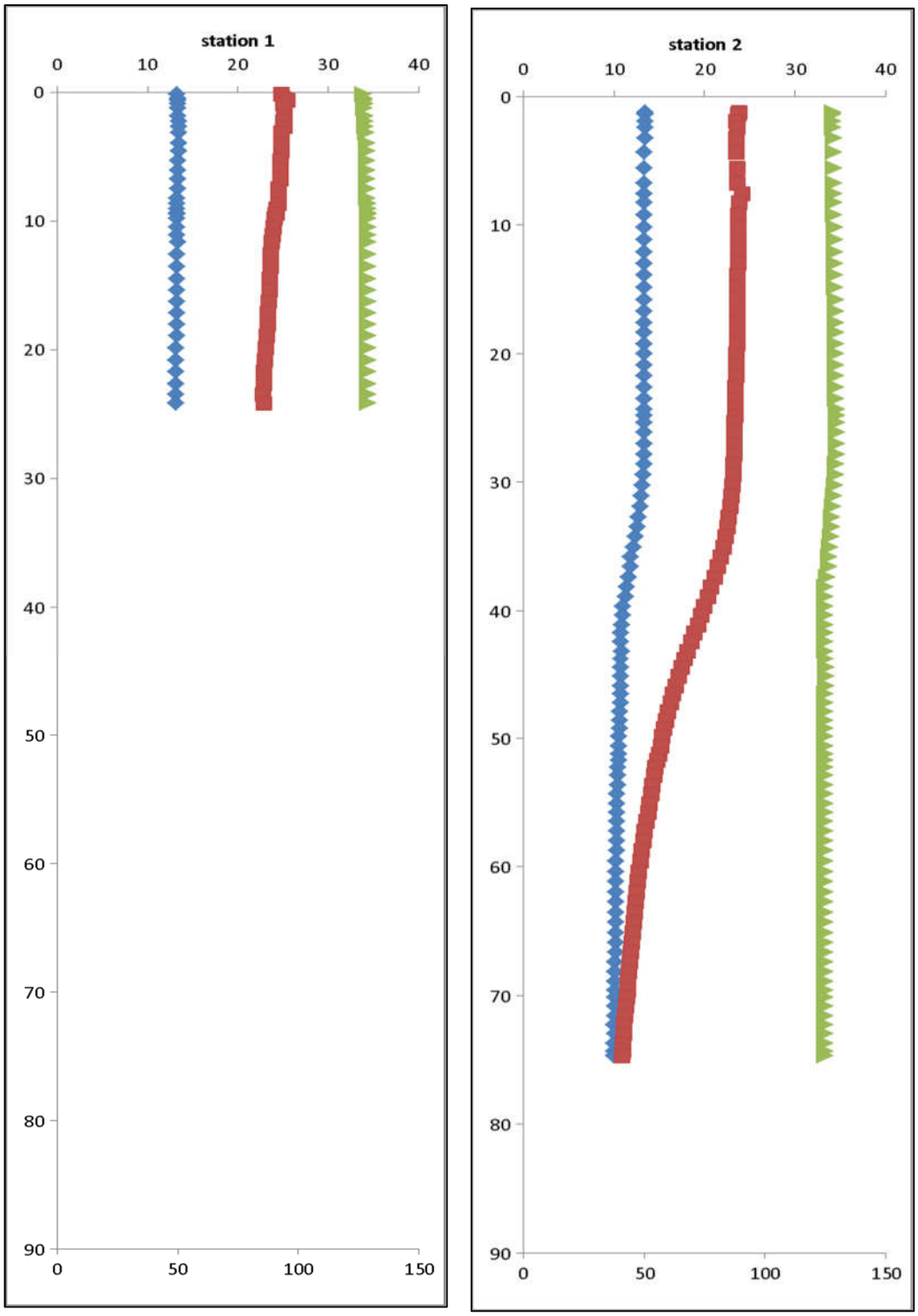


Figure 7 continued.

Atrevida Reef (transect 9)

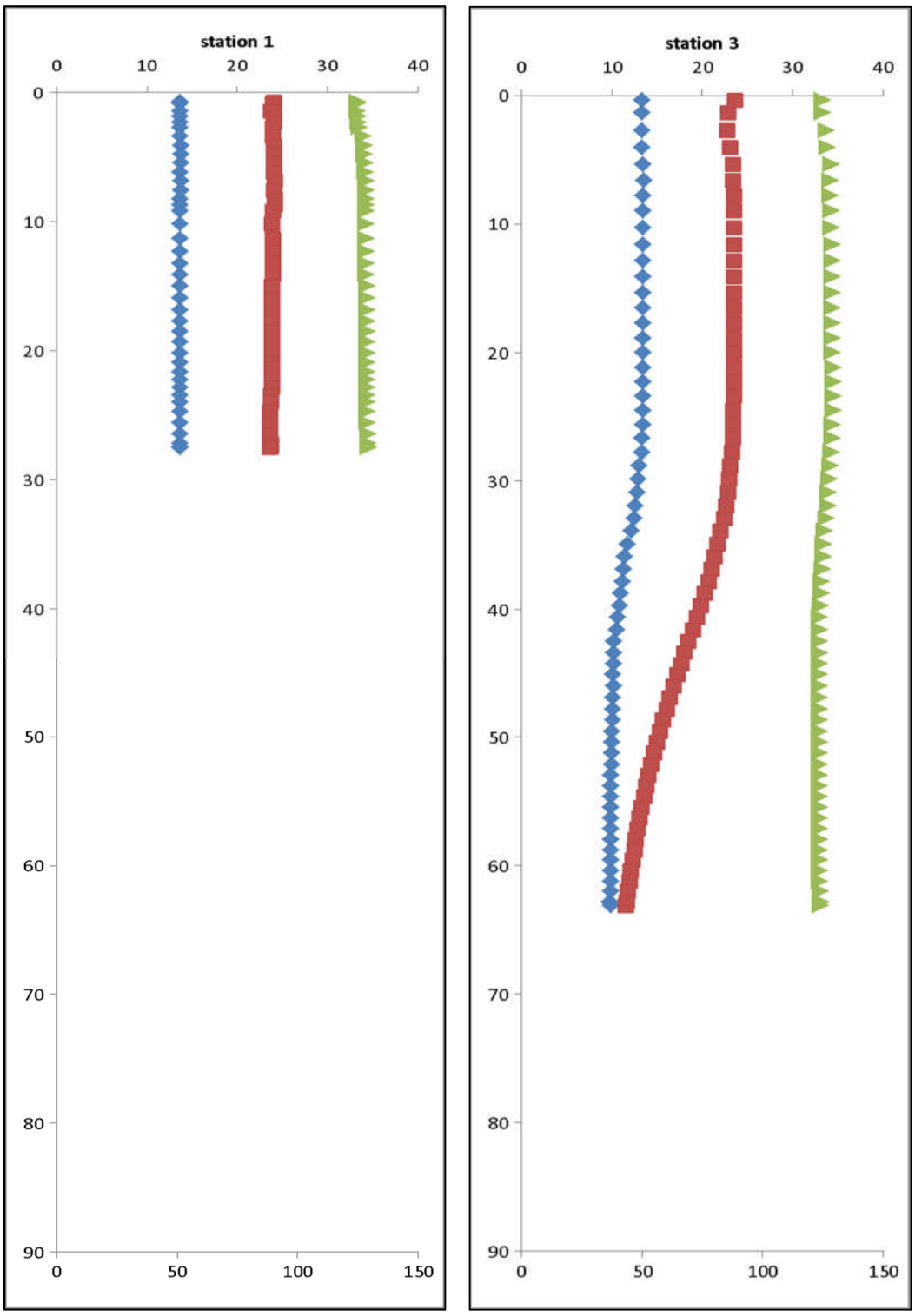


Figure 7 continued.

Cape Cockburn (transect 10)

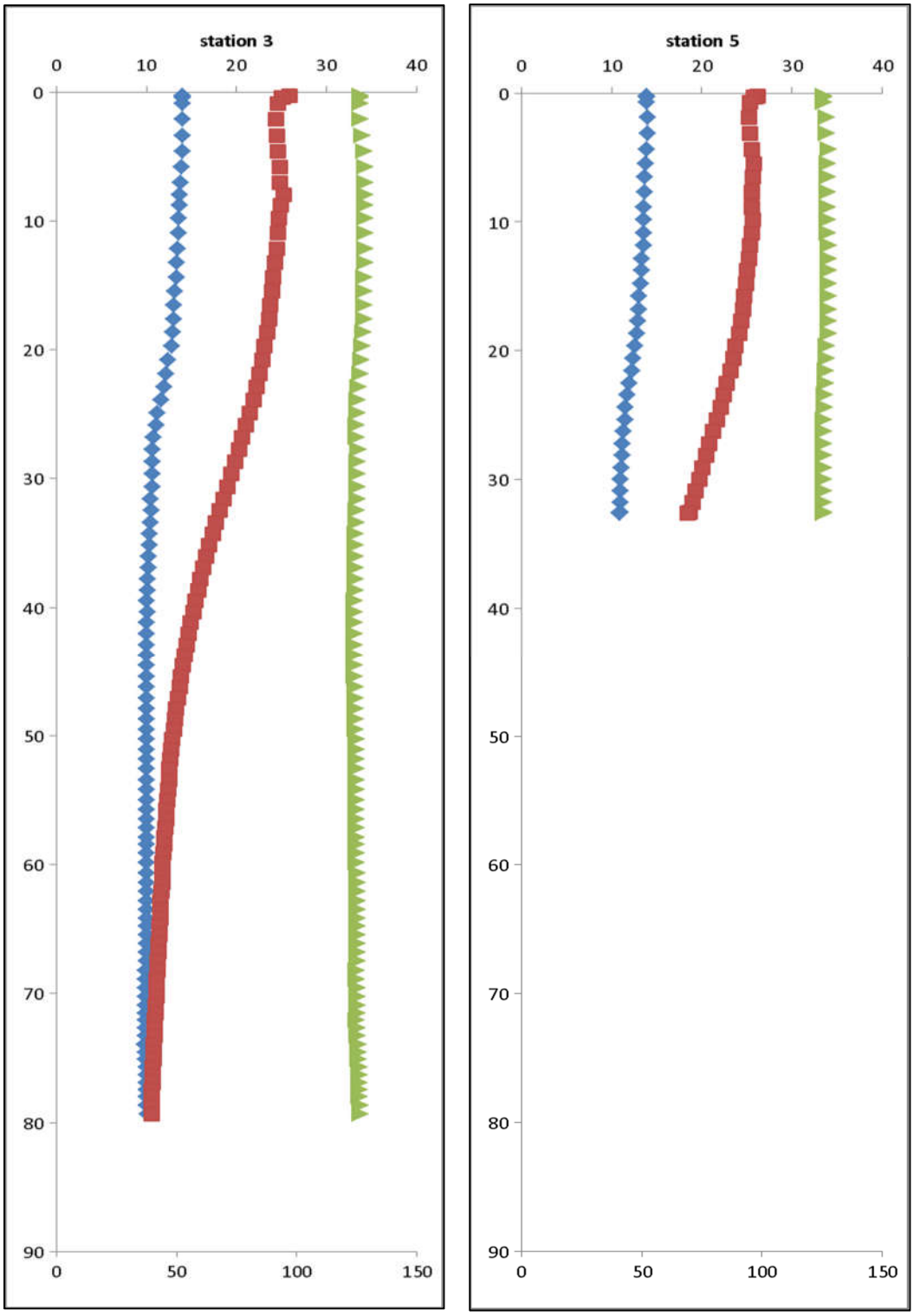


Figure 7 continued.

Secret Cove (transect 11)

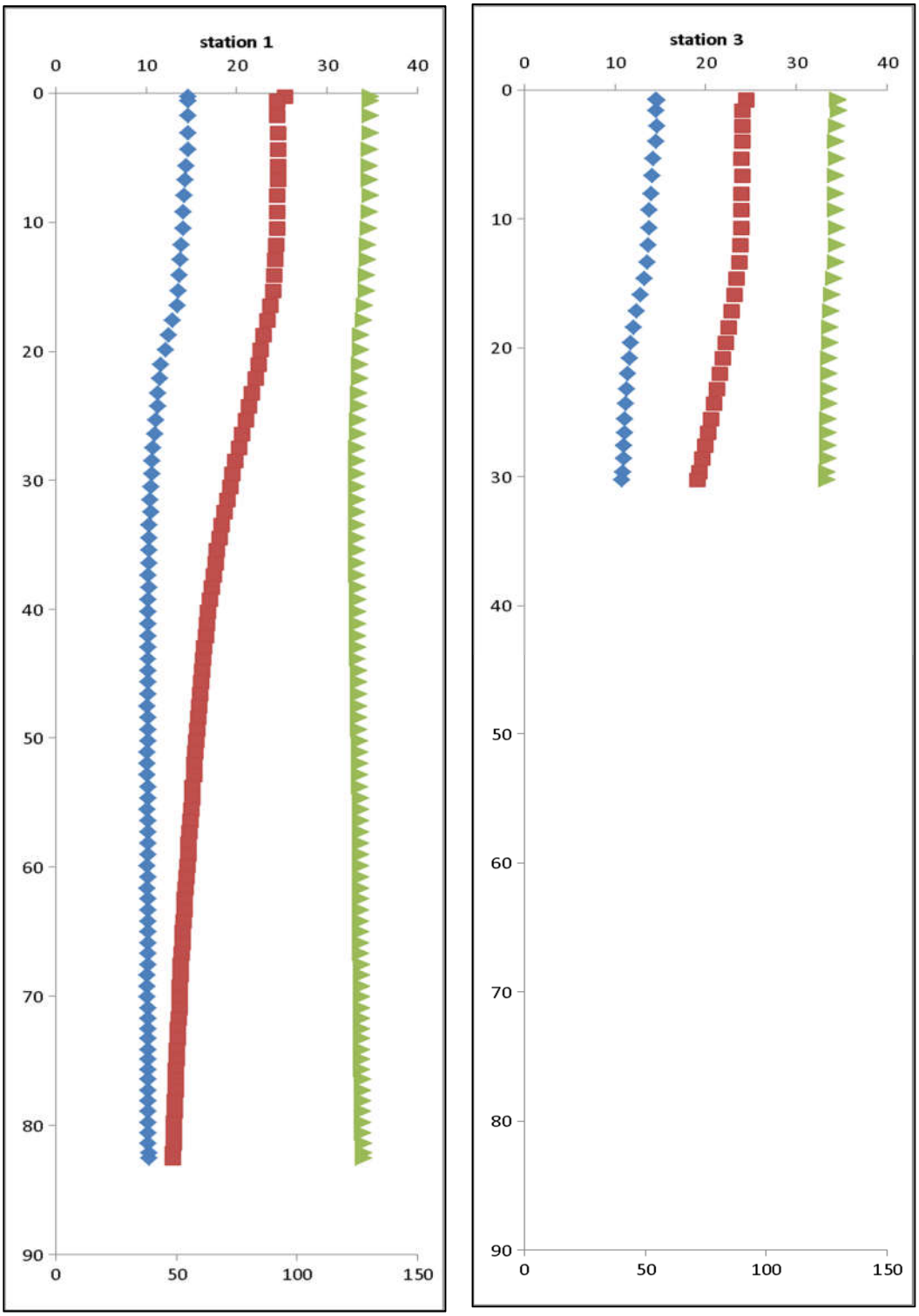


Figure 7 continued.

Table 1. Summary of the purse seine set locations from the 2015 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)
2015	9	17	2	1	2350	Yellow Point	49.042	-123.747
2015	9	17	2	2	2325	Yellow Point	49.050	-123.733
2015	9	17	2	3	2250	Yellow Point	49.056	-123.722
2015	9	17	2	4	2215	Yellow Point	49.060	-123.708
2015	9	17	2	5	2145	Yellow Point	49.066	-123.698
2015	9	18	6	1	2025	Trincomali Channel	48.855	-123.430
2015	9	18	6	2	2050	Trincomali Channel	48.862	-123.423
2015	9	18	6	3	2115	Trincomali Channel	48.867	-123.417
2015	9	18	6	4	2135	Trincomali Channel	48.873	-123.407
2015	9	18	6	5	2200	Trincomali Channel	48.877	-123.407
2015	9	21	11	1	2025	Secret Cove	49.535	-123.977
2015	9	21	11	2	2100	Secret Cove	49.532	-123.995
2015	9	21	11	3	2130	Secret Cove	49.528	-124.014
2015	9	21	11	4	2205	Secret Cove	49.527	-124.040
2015	9	21	11	5	2225	Secret Cove	49.523	-124.060
2015	9	22	10	1	2245	Cape Cockburn	49.670	-124.198
2015	9	22	10	2	2215	Cape Cockburn	49.662	-124.218
2015	9	22	10	3	2150	Cape Cockburn	49.651	-124.242
2015	9	22	10	4	2115	Cape Cockburn	49.642	-124.255
2015	9	22	10	5	2045	Cape Cockburn	49.632	-124.278
2015	9	23	8	1	2110	Smelt Bay	50.036	-125.000
2015	9	23	8	2	2045	Smelt Bay	50.046	-125.016
2015	9	23	8	3	2010	Smelt Bay	50.054	-125.030
2015	9	23	9	1	100	Atrevida Reef	49.916	-124.659
2015	9	23	9	2	125	Atrevida Reef	49.912	-124.673
2015	9	23	9	3	150	Atrevida Reef	49.909	-124.684
2015	9	23	9	4	210	Atrevida Reef	49.906	-124.694
2015	9	23	9	5	230	Atrevida Reef	49.902	-124.707
2015	9	24	4	2	2110	Henry Bay	49.601	-124.866
2015	9	24	4	3	2035	Henry Bay	49.598	-124.856
2015	9	28	3	1	2010	Bowser	49.452	-124.680
2015	9	28	3	2	2040	Bowser	49.459	-124.672
2015	9	28	3	3	2105	Bowser	49.467	-124.663
2015	9	28	3	4	2130	Bowser	49.476	-124.657
2015	9	28	3	5	2200	Bowser	49.482	-124.651

Table 1 continued.

Year	Month	Day	Transect	Station	Seine Set Time	Location Name	DD Lat (N)	DD Long (W)
2015	9	29	5	2	2130	French Creek	49.353	-124.338
2015	9	29	5	3	2105	French Creek	49.358	-124.327
2015	9	29	5	4	2040	French Creek	49.362	-124.323
2015	9	29	5	5	2015	French Creek	49.366	-124.317
2015	9	30	1	1	2205	Clarke Rock	49.224	-123.943
2015	9	30	1	2	2140	Clarke Rock	49.233	-123.932
2015	9	30	1	3	2110	Clarke Rock	49.237	-123.922
2015	9	30	1	4	2045	Clarke Rock	49.237	-123.912
2015	9	30	1	5	2020	Clarke Rock	49.238	-123.902

Table 2. Summary of the number and weight by species, transect, and station for 2015 Strait of Georgia juvenile herring survey.

Transect	Station	Location Name	Species	Number	Weight (Kg)*
1	1	Clarke Rock	**Pacific herring age-0+**	1680	21.34
			Pacific herring age-1+	6	0.18
			Squid	210	1.55
			Shiner perch	36	0.55
			Plainfin midshipman	12	0.01
1	2	Clarke Rock	**Pacific herring age-0+**	14	0.18
			Pacific herring age-1+	3	0.11
			Pacific herring age-2+	1	0.06
			Squid	16	0.10
			Chinook salmon	4	0.48
			Chum salmon	4	0.57
			Coho salmon	2	0.43
			Bay pipefish	1	trace
1	3	Clarke Rock	**Pacific herring age-0+**	10	0.14
			Pacific herring age-1+	1	0.03
			Pacific herring age-2+	1	0.05
			Chinook salmon	4	0.44
			Squid	3	0.06
			Chum salmon	1	0.18
			Plainfin midshipman	1	trace
			Three-spine stickleback	1	trace
1	4	Clarke Rock	**Pacific herring age-0+**	8	0.10
			Chum salmon	4	0.48
			Three-spine stickleback	3	trace
			Chinook salmon	2	0.22
			Hake, juvenile	2	0.02
			Squid	1	0.15
1	5	Clarke Rock	**Pacific herring age-0+**	2	0.03
			Pacific herring age-1+	1	0.05
			Hake, juvenile	16	0.13
			Squid	8	0.10

* weights <0.01 Kg referred to as trace

Table 2 continued.

Transect	Station	Location Name	Species	Number	Weight (Kg)*
2	1	Yellow Point	**Pacific herring age-0+**	49	0.43
			Squid	287	7.61
			Plainfin midshipman	28	0.02
			Shiner perch	7	0.03
2	2	Yellow Point	**Pacific herring age-0+**	812	8.60
			Squid	64	0.33
			Northern anchovy	4	0.09
			Chum salmon	4	0.43
			Plainfin midshipman	4	trace
2	3	Yellow Point	**Pacific herring age-0+**	311	3.20
			Squid	65	0.18
			Plainfin midshipman	2	0.03
			Northern anchovy	1	0.03
			Chinook salmon	1	0.09
			Chum salmon	1	0.11
2	4	Yellow Point	**Pacific herring age-0+**	282	2.91
			Squid	294	1.01
			Northern anchovy	2	0.03
			Chum salmon	2	0.28
			Three-spine stickleback	2	trace
2	5	Yellow Point	**Pacific herring age-0+**	3	0.03
			Squid	184	0.50
			Chinook salmon	2	0.13
			Northern anchovy	1	0.02
			Bay pipefish	1	trace
3	1	Bowser	Squid	450	5.99
			Sculpin	30	0.85
			Flatfish	27	2.40
			Shiner perch	9	0.11
			Plainfin midshipman	6	0.01
			Chinook salmon	3	0.26
			Gunnel	3	0.03
			Bay pipefish	3	0.01

Table 2 continued.

Transect	Station	Location Name	Species	Number	Weight (Kg)*
3	2	Bowser	**Pacific herring age-0+**	7	0.08
			Squid	81	0.60
			Flatfish	5	0.03
			Pink shrimp	5	trace
			Coho salmon	2	0.23
			Sculpin	2	trace
			Plainfin midshipman	1	trace
			Pacific octopus	1	trace
3	3	Bowser	**Pacific herring age-0+**	200	2.33
			Squid	84	0.71
3	4	Bowser	**Pacific herring age-0+**	916	11.11
			Squid	296	3.88
			Chinook salmon	12	1.65
3	5	Bowser	**Pacific herring age-0+**	159	1.97
			Squid	143	1.68
			Coho salmon	8	0.87
4	2	Henry Bay	**Pacific herring age-0+**	2717	30.48
4	3	Henry Bay	**Pacific herring age-0+**	3525	38.81
5	1	French Creek	**Pacific herring age-0+**	5	0.06
			Squid	64	0.98
			Flatfish	6	0.09
			Sculpin	3	0.06
			Shiner perch	2	0.01
			Plainfin midshipman	1	trace
5	2	French Creek	**Pacific herring age-0+**	24	0.29
5	3	French Creek	**Pacific herring age-0+**	35	0.44
			Pacific herring age-1+	12	0.44
			Pacific herring age-2+	2	0.12
			Three-spine stickleback	3	trace
			Chinook salmon	1	0.11

Table 2 continued.

Transect	Station	Location Name	Species	Number	Weight (Kg)*
5	4	French Creek	**Pacific herring age-1+**	24	1.07
			Pacific herring age-2+	46	2.66
5	5	French Creek	**Pacific herring age-1+**	14	0.60
			Pacific herring age-2+	71	4.94
6	1	Trincomali Channel	**Pacific herring age-0+**	79	0.64
			Squid	39	0.21
6	2	Trincomali Channel	**Pacific herring age-0+**	62	0.56
			Squid	42	0.24
			Northern anchovy	2	0.02
			Pacific sand lance	1	trace
6	3	Trincomali Channel	**Pacific herring age-0+**	65	0.61
			Squid	127	0.57
			Three-spine stickleback	1	trace
6	4	Trincomali Channel	**Pacific herring age-0+**	47	0.43
			Squid	28	0.12
6	5	Trincomali Channel	**Pacific herring age-0+**	12	0.11
			Squid	11	0.07
			Northern anchovy	1	trace
8	1	Smelt Bay	**Pacific herring age-0+**	16	0.22
			Squid	5	0.02
			Plainfin midshipman	2	trace
			Bay pipefish	1	trace
8	2	Smelt Bay	**Pacific herring age-0+**	14	0.21
			Pacific herring age-1+	1	0.02
			Squid	9	0.07
8	3	Smelt Bay	Pink salmon	3	0.31
			Squid	273	9.09

Table 2 continued.

Transect	Station	Location Name	Species	Number	Weight (Kg)*
9	1	Atrevida Reef	**Pacific herring age-0+**	2	0.03
			Three-spine stickleback	15	0.01
			Plainfin midshipman	3	trace
			Chinook salmon	1	0.06
			Chum salmon	1	0.15
9	2	Atrevida Reef	**Pacific herring age-2+**	3	0.19
9	3	Atrevida Reef	**Pacific herring age-2+**	4	0.22
9	4	Atrevida Reef	**Pacific herring age-0+**	1	0.02
			Pacific herring age-2+	1	0.10
9	5	Atrevida Reef	**Pacific herring age-0+**	1	0.02
			Pacific herring age-1+	1	0.05
			Chum salmon	1	0.18
10	1	Cape Cockburn	**Pacific herring age-0+**	155	2.03
			Pacific herring age-1+	117	3.82
			Pacific herring age-2+	6	0.29
			Northern anchovy	21	0.15
			Chinook salmon	2	0.08
			Bay pipefish	2	trace
10	2	Cape Cockburn	**Pacific herring age-0+**	103	1.48
			Hake, juvenile	9	0.03
			Chinook salmon	2	0.16
			Plainfin midshipman	2	trace
			Chum salmon	1	0.16
			Three-spine stickleback	1	trace
10	3	Cape Cockburn	**Pacific herring age-0+**	8	0.11
			Hake, juvenile	376	0.76
			Plainfin midshipman	10	0.01
10	4	Cape Cockburn	**Pacific herring age-0+**	10	0.14
			Hake, juvenile	1096	2.92
			Plainfin midshipman	146	0.22
			Bay pipefish	4	trace

Table 2 continued.

Transect	Station	Location Name	Species	Number	Weight (Kg)*
10	5	Cape Cockburn	**Pacific herring age-0+**	88	1.18
			Pacific herring age-1+	1	0.05
			Plainfin midshipman	691	0.92
			Shiner perch	47	0.59
			Walleye pollock, juvenile	8	0.16
			Chinook salmon	4	0.53
			Flatfish	4	0.05
			Bay pipefish	1	trace
11	1	Secret Cove	**Pacific herring age-0+**	13	0.16
			Pacific herring age-1+	1	0.03
			Squid	76	0.13
			Chinook salmon	12	0.55
			Pink salmon	9	0.28
			Sockeye salmon	6	0.16
			Northern anchovy	1	0.01
			Chum salmon	1	0.08
11	2	Secret Cove	**Pacific herring age-0+**	52	0.69
			Pacific herring age-1+	3	0.10
			Hake, juvenile	125	0.83
			Chum salmon	6	0.66
			Sockeye salmon	1	0.03
			Three-spine stickleback	1	trace
11	3	Secret Cove	**Pacific herring age-0+**	318	4.17
			Chum salmon	16	1.70
			Hake, juvenile	6	0.05
			Sockeye salmon	4	0.14
			Chinook salmon	2	0.06
11	4	Secret Cove	**Pacific herring age-0+**	208	2.79
			Pacific herring age-1+	2	0.05
			Chum salmon	18	2.16
			Northern anchovy	2	0.01
			Chinook salmon	2	0.37
			Coho salmon	2	0.37

Table 2 continued.

Transect	Station	Location Name	Species	Number	Weight (Kg)*
11	5	Secret Cove	**Pacific herring age-0+**	32	0.43
			Hake, juvenile	68	0.39
			Chum salmon	5	0.70
			Coho salmon	3	0.52
			Squid	2	0.02

Table 3. Percent occurrence by species in purse seine sets for the Strait of Georgia juvenile herring survey in 2015.

		% Occurrence
Common Name	**Scientific Name**	**2015**
Pacific herring age-0+	*Clupea pallasi* in year of birth	86.7
Pacific herring age-1+	*Clupea pallasi* in first year	31.1
Pacific herring age-2+	*Clupea pallasi* in second or more years	20.0
Bay pipefish	*Syngnathus griseolineatus*	15.6
Chinook salmon	*Oncorhyncus tshawytscha*	33.3
Chum salmon	*Oncorhyncus keta*	31.1
Coho salmon	*Oncorhyncus kisutch*	11.1
Crab	*Metacarcinus magister*	2.1
Flatfish	*Parophyrus vetulus, Lepidopsetta bilineata, Platichthys stellatus, Citharichthys stigmaens*	8.9
Gunnel	*Apodichthys flavidus, Pholis laeta*	2.2
Hake, juvenile	*Merluccius productus*	17.8
Northern anchovy	*Engraulis mordax mordax*	20.0
Pacific octopus	*Enteroctopus dofleini*	2.2
Pacific sand lance	*Ammodytes hexapterus*	2.2
Pink salmon	*Oncorhyncus gorbuscha*	4.4
Pink shrimp	*Pandalus jordani*	2.2
Plainfin midshipman	*Porichthys notatus*	31.1
Sculpin	*Leptocottus armatus*	6.7
Shiner perch	*Cymatogaster aggregata*	11.1
Snake prickleback	*Lumpenus sagitta*	6.3
Sockeye salmon	*Oncorhyncus nerka*	6.7
Squid	*Loligo opalescens, Gonatus fabricii*	57.8
Three-spine stickleback	*Gasterosteus aculeatus*	17.8
Walleye Pollock, juvenile	*Theragra chalcogramma*	10.4

* 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 lengths (mm), mean length, range of weights (g), mean weight, and standard deviations for three age classes sampled during the 2015 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	144	88-117	99	6.53	8.44-21.83	13.02	2.59	1714	21.79
Yellow Point	2	310	83-106	92	4.07	7.57-15.69	10.31	1.37	1457	15.17
Bowser	3	313	77-113	96	5.05	5.68-19.23	11.99	1.74	1282	15.49
Henry Bay	4	200	75-106	92	4.84	6.26-15.57	10.94	1.56	6242	69.29
French Creek	5	64	86-113	98	5.62	8.54-19.62	12.33	2.10	64	0.80
Trincomali	6	265	74-112	88	5.20	3.60-17.60	8.84	1.68	265	2.34
Smelt Bay	8	30	88-112	101	4.75	8.90-16.41	14.42	1.70	30	0.43
Atrevida Reef	9	4	105-115	108	4.57	13.66-17.71	15.69	1.76	4	0.06
Cape Cockburn	10	303	88-117	99	4.43	9.76-23.01	13.66	2.02	364	4.94
Secret Cove	11	301	90-117	99	4.42	9.99-21.38	13.24	1.75	623	8.23
All Locations		1934	74-117	95	6.35	3.60-23.01	11.77	2.45	12045	138.54

Table 4 continued.

Age-1+ Herring

			Length (mm)			Weight (g)				
Location Name	**Transect**	**Number Sampled**	**Range**	**Mean**	**SD**	**Range**	**Mean**	**SD**	**N**	**Wt (Kg)**
Clarke Rock	1	6	128-148	136	6.89	30.45-50.12	36.28	7.25	11	0.37
Yellow Point	2	-	-	-	-	-	-	-	-	-
Bowser	3	-	-	-	-	-	-	-	-	-
Henry Bay	4	-	-	-	-	-	-	-	-	-
French Creek	5	50	124-149	142	6.28	21.53-55.44	42.15	6.50	50	2.11
Trincomali	6	-	-	-	-	-	-	-	-	-
Smelt Bay	8	1	120	120	-	21.75	21.75	-	1	0.02
Atrevida Reef	9	1	141	141	-	46.88	46.88	-	1	0.05
Cape Cockburn	10	79	118-146	132	7.27	23.55-47.52	32.85	5.48	118	3.87
Secret Cove	11	5	123-138	132	5.54	24.32-35.12	31.39	4.16	6	0.18
All Locations		142	118-149	136	8.30	21.53-55.44	36.24	7.46	187	6.60

Age-2+ Herring

			Length (mm)			Weight (g)				
Location Name	**Transect**	**Number Sampled**	**Range**	**Mean**	**SD**	**Range**	**Mean**	**SD**	**N**	**Wt (Kg)**
Clarke Rock	1	2	150-164	157	9.90	46.20-62.91	54.56	11.82	2	0.11
Yellow Point	2	-	-	-	-	-	-	-	-	-
Bowser	3	-	-	-	-	-	-	-	-	-
Henry Bay	4	-	-	-	-	-	-	-	-	-
French Creek	5	119	150-190	163	9.28	43.32-97.63	64.91	12.07	119	7.72
Trincomali	6	-	-	-	-	-	-	-	-	-
Smelt Bay	8	-	-	-	-	-	-	-	-	-
Atrevida Reef	9	8	150-180	161	10.43	44.54-102.91	63.30	19.65	8	0.51
Cape Cockburn	10	4	151-159	153	4.00	44.12-53.13	47.92	3.86	6	0.29
Secret Cove	11	-	-	-	-	-	-	-	-	-
All Locations		133	150-190	162	9.35	43.32-102.91	64.15	12.73	135	8.63

Table 5. Organisms by phylum, and with abbreviations, observed in zooplankton samples collected during the 2015 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 9 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*
MYSI	Mysids
OSTR	Ostracods
SEAL	*Caligus sp.*
SHRI	Shrimp zoea
TLON	*Thysanoessa longipes*
TSPI	*Thysanoessa spinifera*
Echinoderm	
ECHI	Echinoderms
Chaetognatha	
CHAE	Chaetognaths; mainly *Sagitta sp.*
Chordata	
FISHL	Fish larvae
LARV	Larvaceans; mainly *Oikopleura sp.* and some *Fritillaria sp.*
Miscellaneous	
EGGS	Unidentified eggs; either euphausiid or teleost

Table 6. Abbreviations for calanoid and cyclopoid copepods identified in the 2015 zooplankton samples from the Strait of Georgia juvenile herring survey.

Calanoid copepods	
ADIV	*Aetidius divergens*
ALON	*Acartia longiremis*
CABD	*Centropages abdominates*
CALA	*Calanus sp.*
CMAR	*Calanus marshallae*
CPAC	*Calanus pacificus*
EELO	*Eucalanus elongatus*
ELON	*Epilabidocera longipedata*
METR	*Metridia sp.*
MPAC	*Metridia pacifica*
OBOR	*Oncaea borealis*
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*

Table 7. Volume of water filtered and number of zooplankton per m^3 of water in samples collected during the 2015 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	12.052	-	2.7	-	6.1	-	-	-	0.1	10.6
		3	14.486	-	4.4	33.8	16.2	-	85.0	-	1.0	2.2
Yellow Point	2	1	5.705	-	-	-	180.9	-	100.1	12.6	-	-
		4	4.383	-	-	29.2	0.5	-	224.5	43.8	-	-
Bowser	3	1	13.225	-	7.3	-	167.0	-	21.8	-	0.1	19.4
		3	14.689	-	-	4.6	187.4	-	42.5	-	0.7	8.7
Henry Bay	4	3	6.045	-	15.9	-	3726.5	-	16.7	-	-	296.4
		5	6.709	-	3.6	0.3	186.0	-	-	1.2	-	9.5
French Creek	5	1	1.195	-	26.8	-	5996.6	-	-	-	-	-
		3	5.212	-	-	0.2	343.8	-	0.4	-	2.1	-
Trincomali	6	1	5.387	-	23.8	0.2	5607.7	-	357.2	106.9	0.7	47.5
		3	7.627	-	8.4	16.8	2249.0	-	173.7	62.9	1.2	-
Smelt Bay	8	1	8.642	-	1.9	0.5	7.4	-	11.1	-	-	-
		2	9.934	-	3.2	19.3	-	-	125.4	-	-	-
Atrevida Reef	9	1	17.381	-	3.2	2.2	0.2	0.1	3.5	0.1	-	-
		3	19.550	-	-	0.6	-	-	87.6	-	0.5	-
Cape Cockburn	10	3	16.785	-	-	11.4	0.1	-	181.1	-	5.8	0.1
		5	16.147	-	1.0	8.5	0.1	-	26.5	-	0.1	-
Secret Cove	11	1	13.575	0.2	0.7	2.4	9.7	-	3.9	1.5	-	2.4
		3	14.423	-	0.6	4.5	18.9	-	4.1	0.6	-	1.1

Table 7 continued.

Location	Tran	Stn	CMAR	CNAU	COEL	CPAC	CRAM	CRAZ	CTEN	CUMA	ECHI	EELO	EGGS
Clarke Rock	1	1	-	2.7	0.1	0.1	-	-	-	-	-	-	-
		3	-	-	-	2.0	-	-	-	-	2.2	-	-
Yellow Point	2	1	-	44.9	96.7	0.7	-	22.4	55.4	-	-	-	426.3
		4	-	43.8	15.5	27.4	0.5	15.1	29.2	-	29.2	-	29.2
Bowser	3	1	0.1	-	-	0.2	-	-	-	-	2.4	-	-
		3	-	-	0.1	0.1	-	-	-	-	-	-	-
Henry Bay	4	3	-	-	0.3	0.3	0.2	0.3	-	-	-	-	127.0
		5	-	-	10.0	-	-	2.4	-	-	-	-	-
French Creek	5	1	-	16704.8	0.8	-	-	-	-	-	-	-	-
		3	-	1596.4	0.2	2.3	-	-	-	-	-	-	-
Trincomali	6	1	-	-	1.5	2.2	0.2	0.6	3.2	-	-	-	-
		3	-	-	0.1	0.8	-	0.7	2.5	-	16.8	-	-
Smelt Bay	8	1	-	-	1.9	-	-	7.4	30.5	-	-	-	-
		2	-	-	0.2	25.8	-	-	-	-	-	-	-
Atrevida Reef	9	1	-	-	0.4	0.1	-	1.0	-	0.2	-	0.1	-
		3	-	-	-	0.8	-	0.1	-	-	-	0.1	-
Cape Cockburn	10	3	-	0.1	-	3.8	-	-	-	-	-	-	-
		5	-	-	-	-	-	0.1	-	-	-	-	-
Secret Cove	11	1	-	-	0.1	-	-	2.4	0.4	-	-	-	2.4
		3	-	-	1.2	-	-	1.1	1.2	-	1.1	-	-

Table 7 continued.

Location	Tran	Stn	ELON	EUPA	EUPL	FISHL	GAST	LARV	METR	MPAC	MYSI	OATL	OBOR
Clarke Rock	1	1	-	-	-	-	13.3	554.9	-	-	-	2.7	-
		3	-	-	0.1	-	33.1	134.8	-	-	-	26.5	-
Yellow Point	2	1	-	1.4	134.6	-	22.4	717.9	-	-	-	-	-
		4	-	-	30.1	-	29.2	1810.7	-	-	-	-	-
Bowser	3	1	-	-	-	-	21.8	101.6	-	1.2	-	16.9	-
		3	-	-	-	-	47.9	248.3	0.3	0.1	-	139.4	-
Henry Bay	4	3	-	-	0.2	-	296.4	1101.0	3.3	-	-	-	-
		5	-	-	-	-	33.4	76.3	-	-	-	4.8	-
French Creek	5	1	-	-	-	-	856.7	57824.4	-	-	-	53.5	-
		3	-	-	-	-	245.6	3634.8	-	-	-	-	-
Trincomali	6	1	0.6	-	-	-	142.6	5512.5	-	0.2	-	-	-
		3	-	-	-	-	67.1	1695.1	-	-	-	-	-
Smelt Bay	8	1	-	-	-	-	140.7	96.3	-	-	-	-	-
		2	-	0.1	-	-	6.4	206.2	-	-	-	-	-
Atrevida Reef	9	1	-	-	0.1	-	5.6	3.6	0.1	-	0.3	-	-
		3	0.1	0.8	1.6	-	5.6	6.0	-	0.1	-	-	1.6
Cape Cockburn	10	3	-	3.6	0.6	0.1	0.4	0.1	-	-	-	-	-
		5	-	6.4	-	-	-	-	-	-	-	-	-
Secret Cove	11	1	-	-	2.4	-	9.4	308.9	1.1	-	-	-	-
		3	-	-	1.1	-	5.5	135.3	-	-	-	-	0.3

Table 7 continued.

Location	Tran	Stn	OSIM	OSTR	PELE	POLY	PPAR	PSEU	SEAL	SHRI	SIPH	SMIN	TDIS
Clarke Rock	1	1	26.6	-	-	-	19.0	2.2	-	0.4	2.8	-	2.7
		3	128.1	-	-	2.4	12.8	190.9	0.1	0.2	0.2	-	4.4
Yellow Point	2	1	1.4	-	-	22.4	23.3	-	-	22.4	246.1	-	-
		4	29.2	-	29.2	59.3	87.6	14.6	-	21.0	418.9	-	-
Bowser	3	1	164.6	-	-	4.8	2.4	54.4	-	0.4	0.1	-	2.4
		3	113.3	-	-	4.4	21.8	123.6	-	4.9	-	0.3	4.4
Henry Bay	4	3	198.5	-	-	-	13.9	47.6	-	1.0	0.2	-	43.0
		5	13.1	-	-	-	1.2	3.6	-	-	-	-	44.1
French Creek	5	1	-	-	-	428.3	-	-	-	0.8	-	-	-
		3	884.1	-	-	0.2	49.1	417.5	-	-	-	-	-
Trincomali	6	1	71.3	0.7	-	-	118.8	331.9	-	96.0	1.1	-	154.4
		3	8.4	-	-	-	16.8	71.7	-	0.4	17.4	-	4.9
Smelt Bay	8	1	17.6	-	-	-	11.8	14.1	-	8.3	180.5	-	-
		2	38.7	-	-	-	23.0	19.3	-	1.6	81.6	-	0.4
Atrevida Reef	9	1	7.0	-	0.5	-	0.6	4.1	-	2.1	0.1	-	-
		3	8.2	0.1	-	0.4	1.6	24.6	-	1.2	0.6	-	1.6
Cape Cockburn	10	3	1.9	0.5	-	24.2	-	3.8	-	0.1	0.1	-	-
		5	-	-	-	1.0	1.0	49.8	-	-	-	-	-
Secret Cove	11	1	14.0	-	-	-	3.8	1.6	-	5.1	5.7	-	-
		3	28.0	-	-	-	1.4	2.8	-	1.2	135.7	-	-

Table 7 continued.

Location	Tran	Stn	TLON	TSPI	UCAL
Clarke Rock	1	1	-	-	-
		3	-	0.1	-
Yellow Point	2	1	-	-	-
		4	-	-	-
Bowser	3	1	-	-	0.1
		3	-	-	-
Henry Bay	4	3	-	-	-
		5	-	-	-
French Creek	5	1	-	-	-
		3	-	-	122.8
Trincomali	6	1	-	-	0.4
		3	-	-	-
Smelt Bay	8	1	-	-	-
		2	-	-	-
Atrevida Reef	9	1	-	-	-
		3	-	0.1	-
Cape Cockburn	10	3	0.1	-	-
		5	-	-	-
Secret Cove	11	1	-	-	-
		3	-	-	-

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 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 2015 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 1992-2015 (Figures A1 and Table A1). In 2015, mean estimates were slightly lower than those in 2014 (Figure A1 and Table A1). For example, the mean catch weight in 2015 was 4,855 g, but in 2014 was 5,215 g. Estimates of CVs ranged from 23% to 81% with an average of 47% (Figure A1 and Table A1). In 2015, 1,934 age-0 herring were measured; they were heavier and longer than those measured in most years (Figure A2). 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.

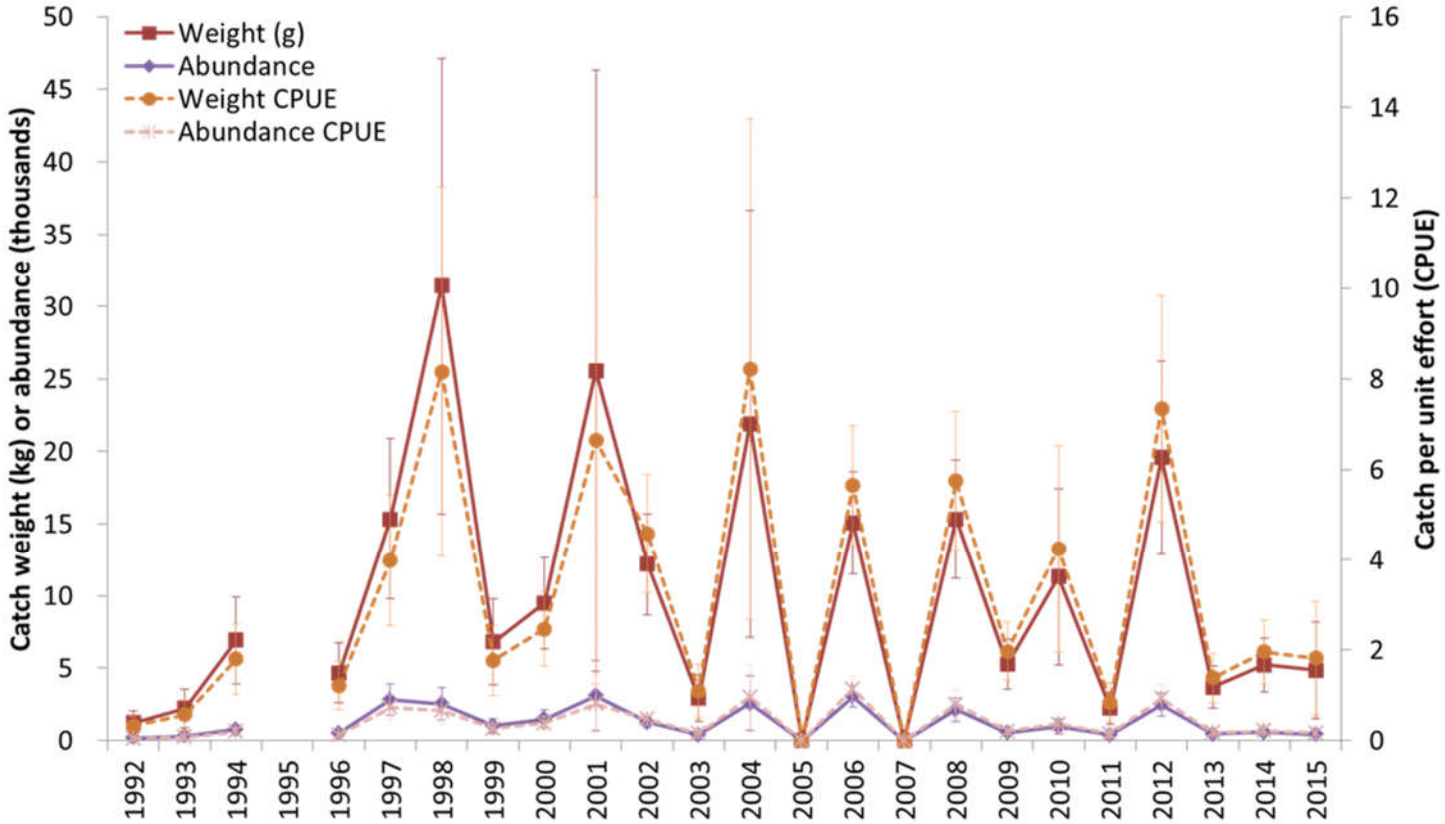


Figure A1. Estimates of catch weight (g), catch weight-per-unit-effort (weight CPUE; g/m^2), abundance, and abundance CPUE (number/m^2) of age-0 herring caught in the Strait of Georgia juvenile herring survey at core transects and stations during 1992-2015 (no survey in 1995). Estimates were calculated 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.

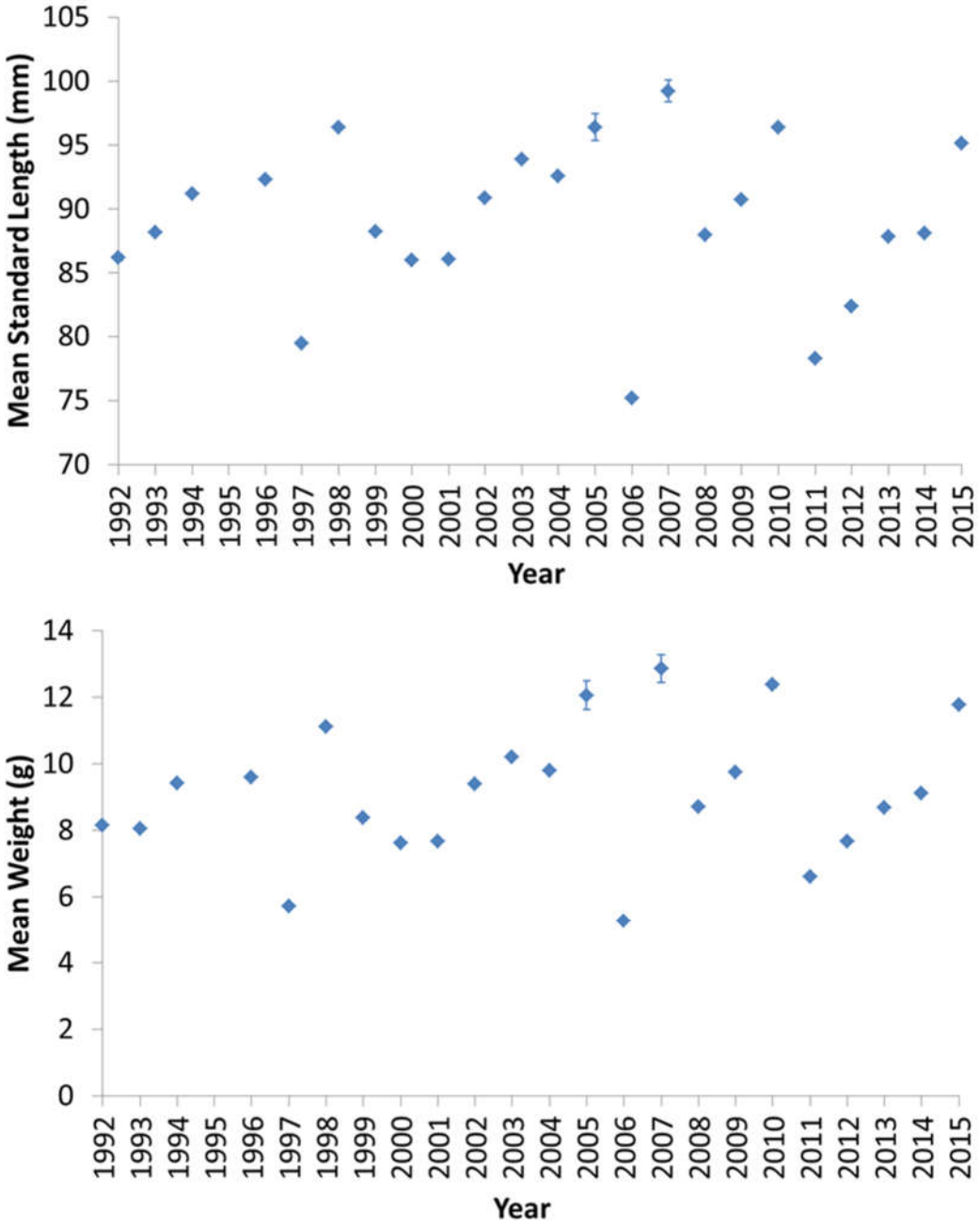


Figure A2. Age-0 herring mean standard lengths (mm; top panel) and weights (g; bottom panel) measured in the laboratory during 1992-2015 (no survey in 1995). Standard error bars are shown.

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 1992-2015 (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