Juvenile Salmon Migration Dynamics in the Discovery Islands and Johnstone Strait in 2018

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ABSTRACT

The majority of out-migrating juvenile Fraser River salmon (*Oncorhynchus* spp.) pass northwest through the Strait of Georgia, the Discovery Islands, and Johnstone Strait. The Discovery Islands to Johnstone Strait leg of the migration is a region of poor survival for juvenile salmon relative to the Strait of Georgia. To better understand the factors that are driving early marine survival through this region the Hakai Institute Juvenile Salmon Program monitors key aspects of this migration. Here we report on the 2018 migration in comparison to averages from the 2015–2018 study period, which we use to define 'normal' in our building time series. In 2018 sockeye (*O. nerka*), pink (*O. gorbuscha*), and chum (*O. keta*) all migrated earlier than normal, though not more than by a week. The median capture date in the Discovery Isalnds was May 23rd for sockeye, five days earlier than normal; and June 12 for pink and chum, which is five days earlier for pink and three days earlier than normal for chum. Sea lice prevalence was lower than normal for sockeye, pink, and chum. Notably, there were no *Lepeophtheirus salmonis* sea lice observed in Johnstone Strait in 2018. Sockeye were longer than normal in 2018 whereas pink and chum were smaller than normal. Pink salmon dominated the catch in 2018, followed by chum, and then socke Sea surface temperatures in May and June were the warmest on record in the study period (2015–2018). ye.

INTRODUCTION

The first months after marine entry have been identified as a potentially critical period (R. Beamish and Mahnken 2001) for salmon stock recruitment, which may ultimately be responsible for inter-annual variability and long term declines in salmon stocks in British Columbia (Peterman et al. 2010; R. J. Beamish et al. 2012). Pathogens, parasites, predators and the impacts of climate change on food web dynamics have emerged as leading causes for the decline. The Hakai Institute Juvenile Salmon Program has been monitoring juvenile salmon migrations in the Discovery Islands and Johnstone Strait (Figure 1) since 2015 in an effort to understand what factors may be influencing early marine survival of sockeye, pink, and chum (Hunt et al. 2018). This report summarizes migration timing, fish length, parasite loads, species composition, and sea-surface temperature observed from the first 4 years of this research and monitoring program. These estimates will provide the context from which to investigate questions and interpret results related to growth, survival, and the conditions salmon experience during their migration through this critical region.

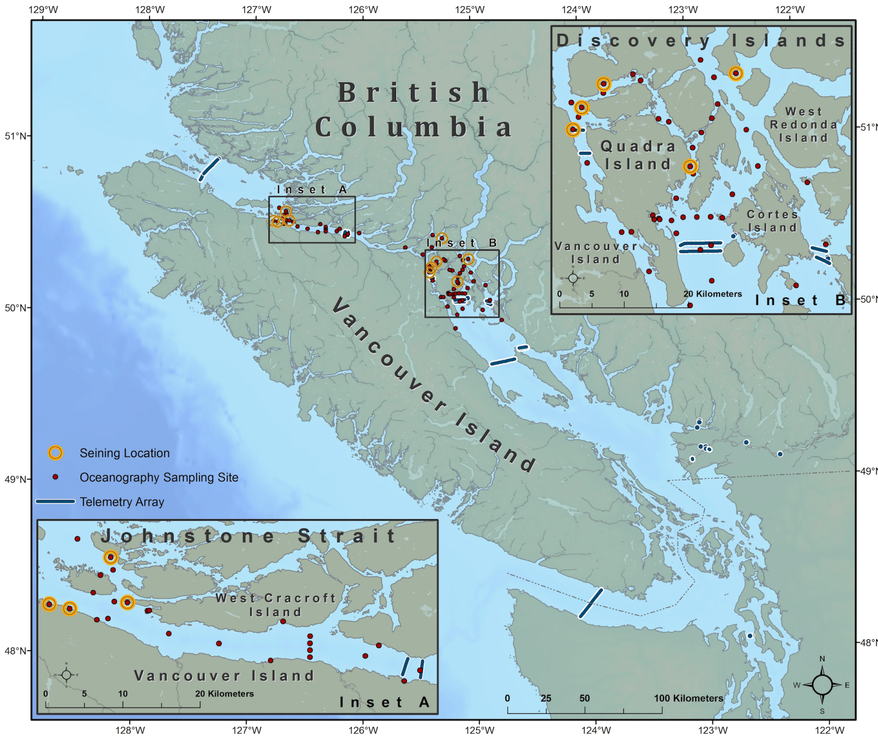


Figure 1. Sampling locations in 2018

METHODS

Field methods

See Hunt et al. (2018) for a detailed description of field and lab methods. Briefly, we collect juvenile salmon weekly from the Discovery Islands and Johnstone Strait during their northward migration from the Strait of Georgia to Queen Charlotte Strait near northern Vancouver Island, British Columbia. Sampling is conducted from May to July each year since 2015 using purse seine nets (bunt: 27 m x 9 m with 13 mm mesh; tow: 46 m x 9 m with 76 mm mesh). We sample in nearshore marine habitats with depth $>$ 10 m and effectively sample sockeye (*Oncorhynchus nerka*), pink (*O. gorbuscha*), chum (*O. keta*) and incidentally capture coho (*O. kisutch*), chinook (*O. tshawytschya*) and Pacific herring (*Clupea pallasii*). All animal care was in accordance with Animal Care Guidelines under permit A16-0101. Temperature data were collected by deploying an RBR conductivity, temperature, and depth profiler to depths $>$ 30 m at station QU39 (Figure 1) in the northern Strait of Georgia.

Statistical methods

All metrics reported are in relation to the time series average (2015-2018). The mean for each parameter of interest was calculated for all years combined, and the z-score was calculated for each parameter to determine the number of standard deviations away from the mean a given parameter was in each year.

The peak migration date for each species was estimated by calculating the median date of capture in the Discovery Islands—the date at which 50 percent of the fish passed through the region. Because very few pink are caught in odd years, only even years were included in the calculation of the time serie average. To visualize migration timing we plotted cumulative catch abundance between May 1st and July 9th each year and fit a logistic growth line. Species proportions were calculated by dividing the total number of each species caught, by the sum of all species caught that season. Only seines that contained sockeye were used in the calculation of species proportions, so in effect this species proportion measure is representative of the salmon community composition that co-migrate with sockeye. Fork length distributions were visualized by calculating kernel density estimates from fork length data. The prevalence, intensity, and abundance of sealice was calculated as detailed in Margolis et al. (1990). The mean sea surface temperature was calculated from the top 30 m of the water column in May and June from all years. To visualize temperature anomalies we applied a loess regression to sea surface temperatures from all four years to develop a model that would represent the seasonal trend.

RESULTS AND DISCUSSION

Migration Timing

Migration timing in the Discovery Islands in 2018 did not differ from the time series average by more than a week for sockeye, pink, or chum (Table 1). The peak migration date for sockeye in the Discovery Islands was on May 23, 5 days earlier than the time series average of May 28 (z-score = -0.71) (Figure 2). The peak migration date for pink in the Discovery Islands was on June 12, 5 days earlier than the average of June 17 (z-score = -0.38). The peak migration date for chum in the Discovery Islands was on June 12, 3 days earlier than the average of June 15 (z-score = -0.29).

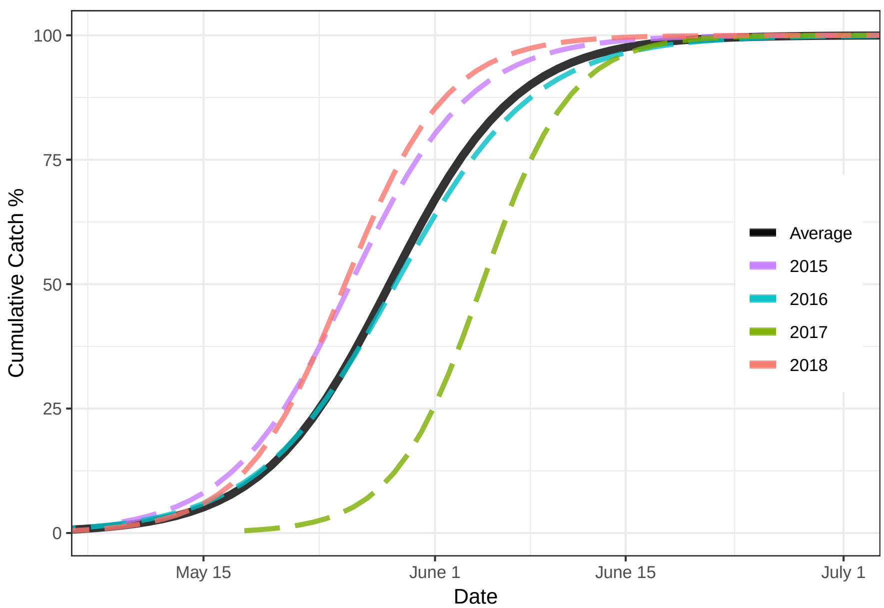


Figure 2. Cumulative catch of juvenile sockeye salmon migrating through the Discovery Islands compared to the average for 2015–2018. Migration curves were predicted by fitting a logistic growth equation to the cumulative percent of sockeye in each year.

Length

Fish lengths varied between regions, species and year (Figure 3). In 2018 in the Discovery Islands and Johnstone Strait combined the average sockeye length was 116.9 mm (Table 2), which is 8.9 mm longer than the time series average ($p < 0.0001$, 95% CI 6.2, 11.7). Average pink lengths were 96.3 mm, which is 8.8 mm shorter than the time series average ($p < 0.0001$, 95% CI 10.9, 6.7). Chum were on average 103.4 mm, which is 7 mm shorter than the time series average ($p < 0.0001$, 95% CI 8.9–5).

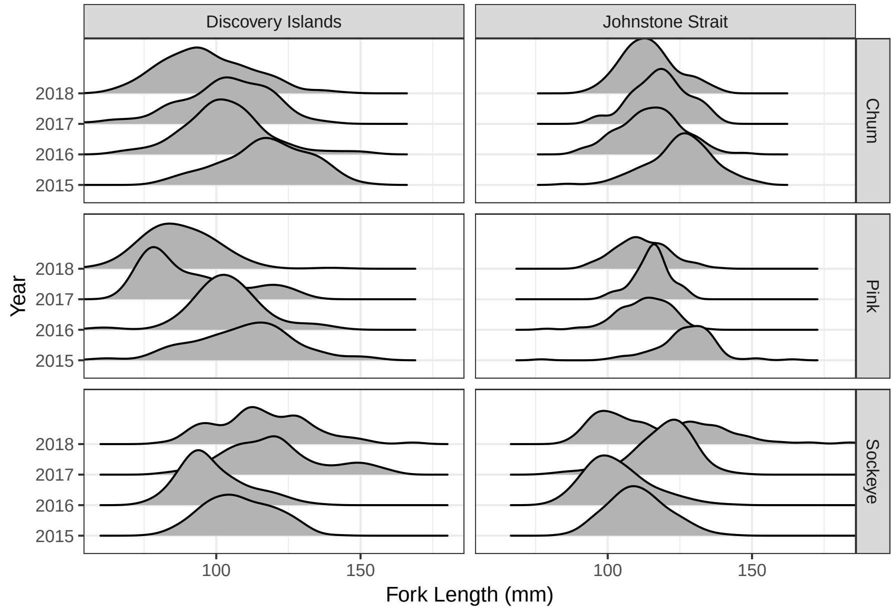


Figure 3. Kernel density distributions of juvenile salmon fork lengths for each year in the selected region. Note that these distributions contain multiple age-classes.

Species Proportions

Pink salmon dominated the catch in the Discovery Islands and Johnstone in 2018 making up 51.9 % of the catch (Table 3) while chum made up 32.4 percent and sockeye 12.9 % (Figure 4).

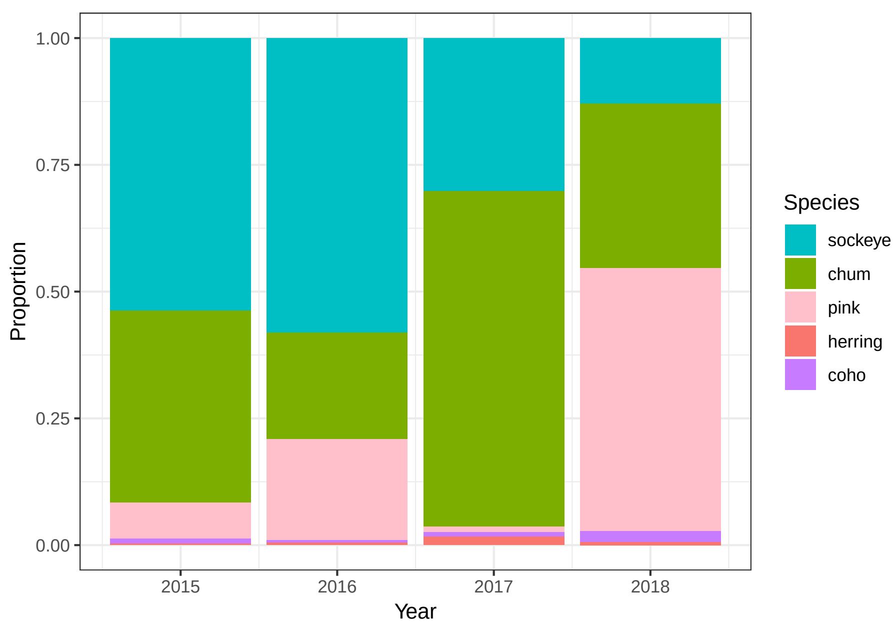
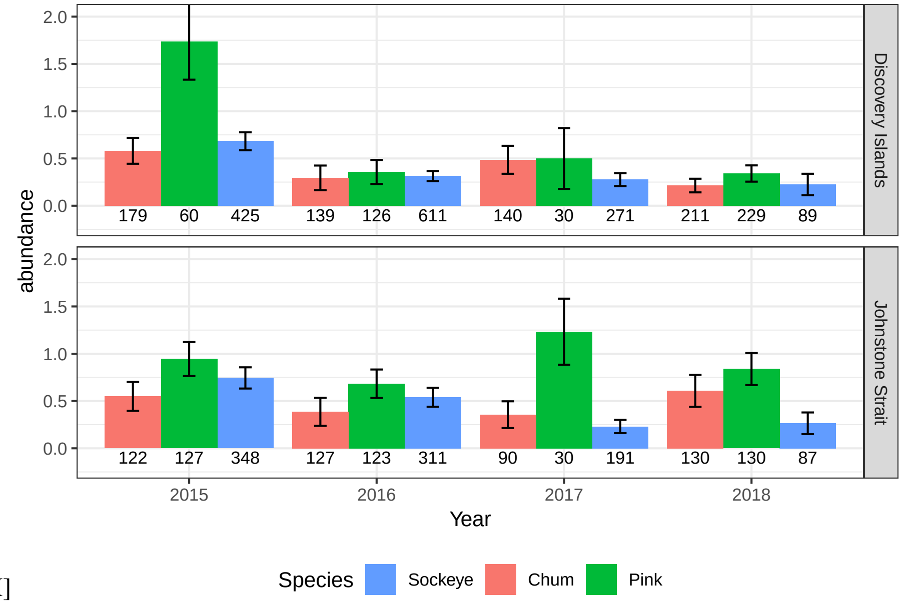


Figure 4. The annual proportion of fish captured in the Discovery Islands and Johnstone Strait combined.

Parasite Loads

The prevalence of motile (pre-adult and adult life stage) sea lice in 2018 was the lowest recorded in the time-series (Figure). Notably, no *Lepeophtheirus salmonis* were detected on sockeye in Johnstone Strait, despite being present in the Discovery Islands. Pink salmon appeared to have higher counts of *Caligus clemensi* in 2018 compared to chum and sockeye. See Table 4,



\begin{figure}[H]
\caption{The abundance (+/- 95% CI) of motile sea lice on juvenile salmon in the Discovery Islands and Johnstone Strait.} \end{figure}

Sea Surface Temperature

Sea-surface temperatures in May and June at QU39 in the northern Strait of Georgia was 0.39 degrees C warmer than normal (Z = 1.33) (Table 5). Sea surface temperatures between May and July of 2018 were warmer than the time series average. (Figure 5)

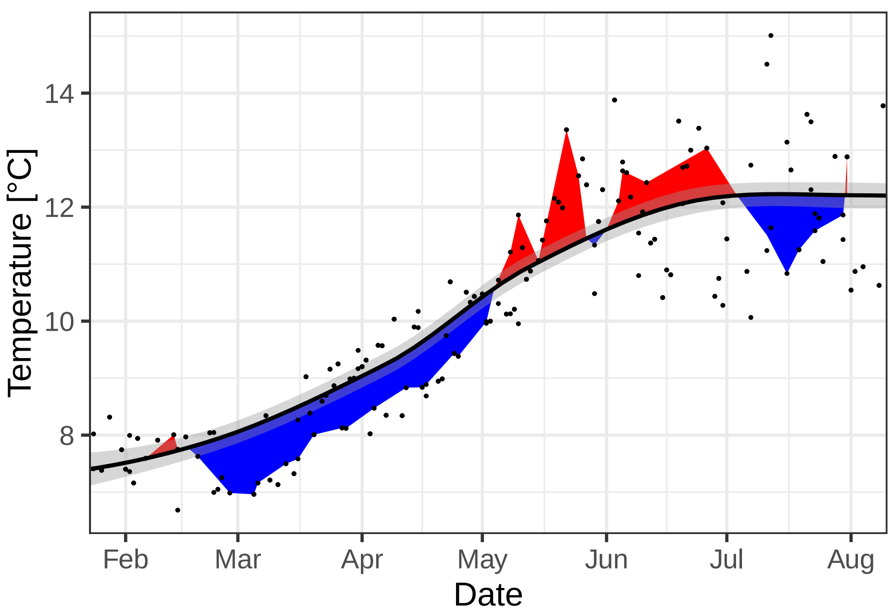


Figure 5. Time series of 30 m depth integrated temperature anomalies observed at Hakai Oceanographic Monitoring station QU39. Blue areas represent temperatures that are below normal, red areas represent above normal temperatures at the selected station in 2018. Normal is the solid black line which is a loess regression based on temperatures from 2015-2018. The shaded grey area is 1 SE of the loess regression. The black dots are the daily minimum and maximum temperatures observed over the time series.

TABLES

Table 1. Migration timing statistics for the cumulative catch of sockeye, pink, and chum salmon in the Discovery Islands in 2018, compared to the time-series average (2015 - 2018). Q1 is when 25 % of the species passed through the regions, peak date is the median when 50 % passed through, and Q3 is 75%. The region DI indicates the Discovery Islands while for species SO is sockeye, PI is pink, and CU is chum.

Year	Region	Species	Q1	Peak Date	Q3
2015 - 2018	DI	SO	May 26	May 28	June 04
2015 - 2018	DI	PI	June 07	June 17	June 23
2015 - 2018	DI	CU	June 06	June 15	June 23
2015	DI	SO	May 23	May 23	June 01
2015	DI	PI	June 13	July 07	July 07
2015	DI	CU	June 03	June 05	June 22
2016	DI	SO	May 24	May 28	June 04
2016	DI	PI	June 02	June 15	June 15
2016	DI	CU	June 02	June 15	June 15
2017	DI	SO	June 05	June 07	June 07
2017	DI	PI	June 05	June 05	June 26
2017	DI	CU	June 13	June 26	July 04
2018	DI	SO	May 23	May 23	June 04
2018	DI	PI	June 07	June 12	June 12
2018	DI	CU	June 07	June 12	June 20

Table 2. Mean fork lengths for each year, species, and region including the time series average (2015 - 2018), with the 95 % confidence interval (95% CI). The column n indicates the number of fish measured, except for the time series where n indicates the number of years averaged.

Year	Region	Species	n	Fork Length (mm)	95% CI
2015 - 2018	DI	SO	4	110.9	95.9 - 125.9
2015 - 2018	DI	PI	4	98.0	81.3 - 114.7
2015 - 2018	DI	CU	4	105.1	91.3 - 118.9
2015 - 2018	JS	SO	4	112.5	101.2 - 123.8
2015 - 2018	JS	PI	4	116.7	105.6 - 127.8
2015 - 2018	JS	CU	4	118.2	110.1 - 126.3
2015	DI	SO	660	108.0	107.1 - 108.9
2015	DI	PI	56	109.6	104.9 - 114.3
2015	DI	CU	157	117.3	114.9 - 119.7
2015	JS	SO	832	110.6	109.9 - 111.3
2015	JS	PI	105	126.9	124.8 - 129
2015	JS	CU	134	125.4	123.5 - 127.3
2016	DI	SO	652	99.0	98.1 - 99.9
2016	DI	PI	96	103.9	101.3 - 106.5
2016	DI	CU	124	103.3	100.7 - 105.9
2016	JS	SO	720	103.4	102.6 - 104.2
2016	JS	PI	94	112.6	110.7 - 114.5
2016	JS	CU	104	115.0	112.9 - 117.1
2017	DI	SO	269	120.1	118 - 122.2
2017	DI	PI	17	90.9	82.3 - 99.5
2017	DI	CU	123	103.0	100.2 - 105.8
2017	JS	SO	181	118.8	117.2 - 120.4
2017	JS	PI	24	115.3	112.8 - 117.8
2017	JS	CU	76	118.2	116 - 120.4
2018	DI	SO	89	116.4	112.9 - 119.9
2018	DI	PI	229	87.4	85.8 - 89

Year	Region	Species	n	Fork Length (mm)	95% CI
2018	DI	CU	211	96.7	94.6 - 98.8
2018	JS	SO	87	117.4	113.1 - 121.7
2018	JS	PI	130	111.9	110.3 - 113.5
2018	JS	CU	130	114.3	112.7 - 115.9

Table 3. The species proportions of total catch in each year for sockeye, pink, chum, herring, coho, and chinook.

Year	Chum	Coho	Herring	Pink	Sockeye
2015	0.378	0.003	0.009	0.072	0.537
2016	0.210	0.006	0.005	0.200	0.580
2017	0.661	0.018	0.008	0.012	0.301
2018	0.324	0.006	0.022	0.519	0.129

Table 4. Mean sea-lice abundance, prevalence, and intensity (Margolis et al. 1990) for the time series (2015-2018) as well as for each species, region, and year with 95% confidence interval calculated from annual averages. The region DI indicates the Discovery Islands and JS Johnstone Strait. Species codes are SO for sockeye, PI for pink, and CU for chum.

Year	Region	Species	n	Abundance, 95% CI	Prevalence, 95% CI	Intensity, 95% CI
2015 - 2018	DI & JS	CU	1138	0.44 +/- 0.01	0.3 +/- 0.01	1.42 +/- 0.01
2015 - 2018	DI & JS	PI	855	0.83 +/- 0.03	0.49 +/- 0.01	1.62 +/- 0.02
2015 - 2018	DI & JS	SO	2333	0.41 +/- 0.01	0.29 +/- 0	1.37 +/- 0.01
2015	DI	CU	179	0.58 +/- 0.14	0.4+/-0.33	1.44 +/- 0.22
2015	DI	PI	60	1.73 +/- 0.4	0.72+/-0.59	2.42 +/- 0.4
2015	DI	SO	425	0.68 +/- 0.09	0.43+/-0.38	1.58 +/- 0.14
2015	JS	CU	122	0.55 +/- 0.15	0.37+/-0.28	1.49 +/- 0.23
2015	JS	PI	127	0.94 +/- 0.18	0.57+/-0.48	1.64 +/- 0.19
2015	JS	SO	348	0.74 +/- 0.11	0.46+/-0.4	1.63 +/- 0.16
2016	DI	CU	139	0.29 +/- 0.13	0.19+/-0.13	1.52 +/- 0.44
2016	DI	PI	126	0.36 +/- 0.13	0.24+/-0.17	1.5 +/- 0.25
2016	DI	SO	611	0.31 +/- 0.05	0.23+/-0.2	1.37 +/- 0.12
2016	JS	CU	127	0.39 +/- 0.15	0.28+/-0.21	1.36 +/- 0.37
2016	JS	PI	123	0.68 +/- 0.15	0.49+/-0.4	1.4 +/- 0.17
2016	JS	SO	311	0.54 +/- 0.1	0.35+/-0.3	1.53 +/- 0.17
2017	DI	CU	140	0.49 +/- 0.15	0.34+/-0.26	1.42 +/- 0.29
2017	DI	PI	30	0.5 +/- 0.32	0.33+/-0.17	1.5 +/- 0.61
2017	DI	SO	271	0.28 +/- 0.07	0.22+/-0.17	1.25 +/- 0.13
2017	JS	CU	90	0.36 +/- 0.14	0.27+/-0.18	1.33 +/- 0.27
2017	JS	PI	30	1.23 +/- 0.35	0.77+/-0.58	1.61 +/- 0.31
2017	JS	SO	191	0.23 +/- 0.07	0.2+/-0.14	1.16 +/- 0.12
2018	DI	CU	211	0.21 +/- 0.07	0.17+/-0.12	1.25 +/- 0.2
2018	DI	PI	229	0.34 +/- 0.09	0.25+/-0.19	1.37 +/- 0.16
2018	DI	SO	89	0.22 +/- 0.11	0.18+/-0.11	1.25 +/- 0.31
2018	JS	CU	130	0.61 +/- 0.17	0.4+/-0.32	1.52 +/- 0.28
2018	JS	PI	130	0.84 +/- 0.17	0.55+/-0.46	1.54 +/- 0.2
2018	JS	SO	87	0.26 +/- 0.11	0.22+/-0.14	1.21 +/- 0.2

Table 5. Thirty meter depth integrated temperature averages from May to the end of June in the Northern Strait of Georgia station QU39.

Year	Temperature (C)
2015	11.55
2016	11.56
2017	11.28
2018	11.97

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