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

Brett T. Johnson[1], Julian C.L. Gan[1], Carly V. Janusson[1], and Brian P.V. Hunt[1, 2, 3]

[1]**Hakai Institute Quadra Island Ecological Observatory, Heriot Bay, BC V0P 1H0**
[2]**Institute for the Oceans and Fisheries, University of British Columbia Vancouver, B.C., Canada V6T 1Z4**
[3]**Department of Earth, Ocean and Atmospheric Sciences, University of British Columbia Vancouver, B.C., Canada V6T 1Z4**

Corresponding author:

Brett T. Johnson[1]

Email address: brett.johnson@hakai.org

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. 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. Sea surface temperatures in May and June were the warmest on record in the study period (2015–2018). Pink salmon dominated the catch in 2018, followed by chum, and then sockeye.

INTRODUCTION

The first months after marine entry have been identified as a potentially critical period (R J 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 (R. M. 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.

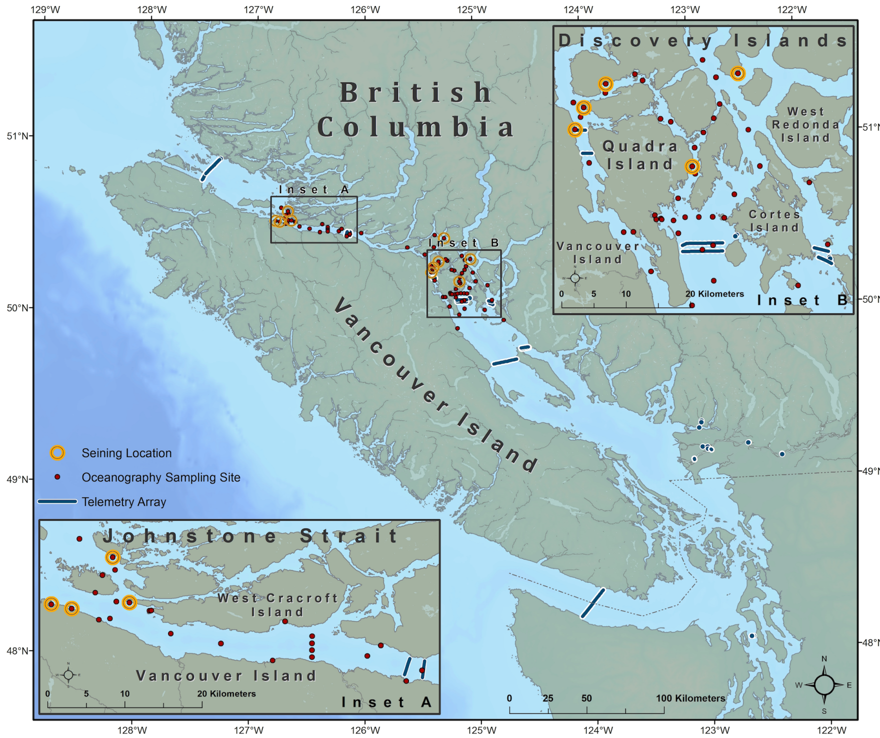


Figure 1. Sampling locations in 2018

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.

Annual migration timing for each species was measured by calculating the median date of capture in the Discovery Islands, the date at which 50 percent of the fish passed through the region. 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 that season across all seines by the sum of all species caught that season. Fork length distributions were visualized by calculating kernel density estimates from fork length data. The prevalence, intensity, and abundance were 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

The peak migration date for sockeye in the Discovery Islands occurred 5 days earlier than average in 2018 (Z = -0.71). (Figure 2). The median date of capture for 2018 sockeye was May 22nd, whereas the time series average was May 27th. Conversely, the 2018 sockeye migration occurred later than normal in Johnstone Strait, where the median date of capture was June 6th, which is two days later than the time-series average. See Table 1 and Table **??** for the interqurtile range of migration timing for sockeye, pink, and chum in 2018, contrasted to the time series averages for the Discovery Islands and Johnstone Strait, respectively. Based on the comparison of peak migration dates between the two zones, we estimate that the average residence time of juvenile salmon in the Discovery Islands for 2018 was approximately two weeks.

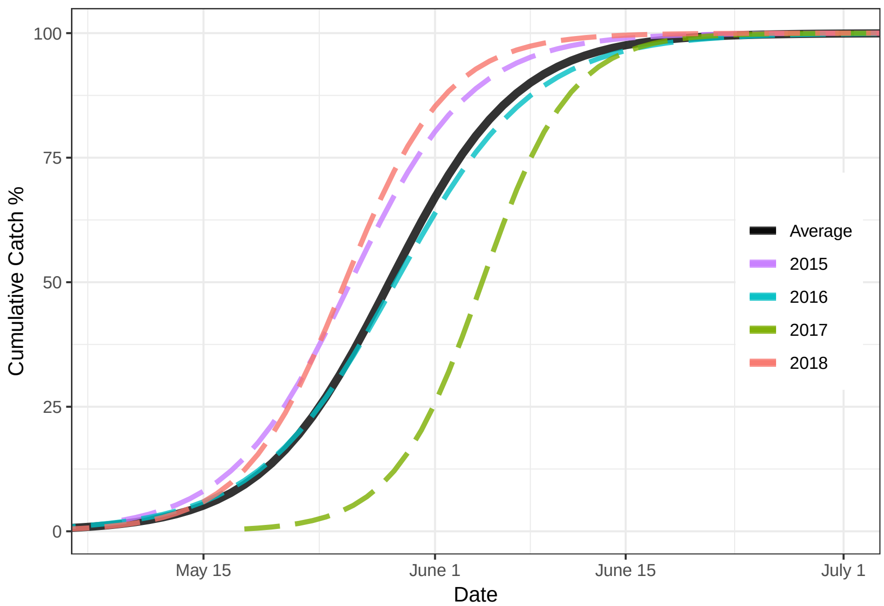


Figure 2. Cumulative catch of juvenile sockeye salmon migrating through the Discovery Islands compared to the average for 2015–2018. Migration curves were predicted by fitting a logistic growth equation to the cumulative percent of sockeye in each year.

Table 1. Interquartile range for the cumulative catch of sockeye, pink, and chum salmon in the Discovery Islands in 2018, compared to the time-series average . Odd years were excluded from the TSA calculation for pink salmon due being the "off" years in the outmigration cycle.

Species	Year	25%	50%	75%
Sockeye	Average	May 26	May 28	Jun 04
	2018	May 23	May 23	Jun 04
Pink	Average	Jun 05	Jun 13	Jun 16
	2018	Jun 07	Jun 12	Jun 18
Chum	Average	Jun 06	Jun 15	Jun 22
	2018	Jun 07	Jun 12	Jun 20

Species Proportions

Pink salmon dominated the catch in the Discovery Islands and Johnstone Strait in 2018, which is the first time observed in the time-series (Figure 3). This may be due to post-smolts being from the dominant odd-year pink returning broodlines (Krkošek et al. 2011; Beacham et al. 2012; Irvine et al. 2014) coupled with Fraser River sockeye from the weak 2016 brood year, which was lowest recorded return in 100 years (McKinnell et al. 2012; Grant, MacDonald, and Michielsens 2017; Pacific Salmon Commission 2017).

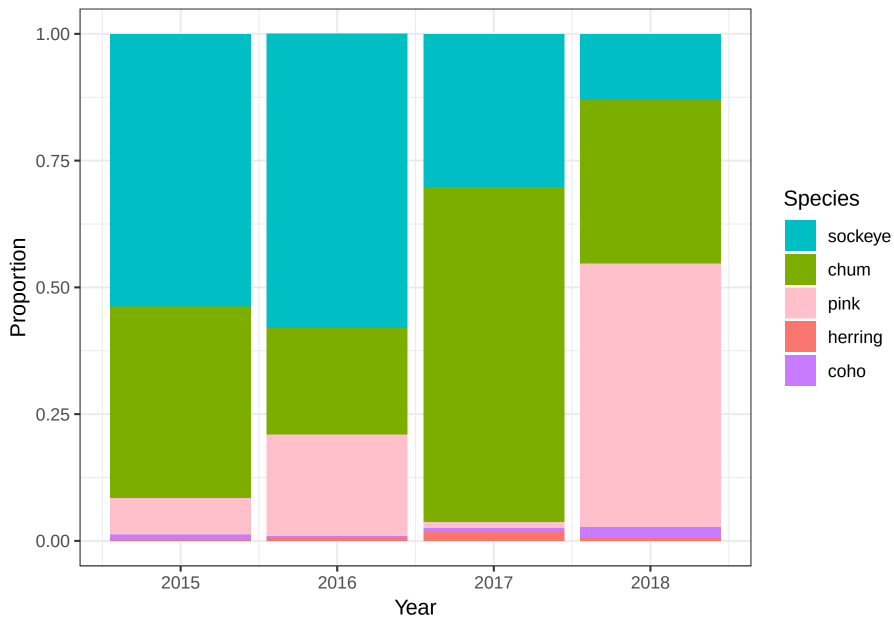


Figure 3. The annual proportion of fish captured in the Discovery Islands and Johnstone Strait combined.

Length

Fish lengths varied between regions, species and year (Figure 4). Sockeye lengths were 5.07 mm longer than average (Z = 0.62. (Discovery Islands mean = 116 mm, 95% CI = 113—120; Johnstone Strait mean = 117 mm, 95% CI = 113—122). However, pink were shorter than average in both regions (8.3 % in the Discovery Islands and 4.4 % Johnstone Strait), as well as chum (8.1 % in the Discovery Islands and 3.6 % Johnstone Strait). Figure and Figure compare and contrast the average lengths in 2018 against the time-series average.

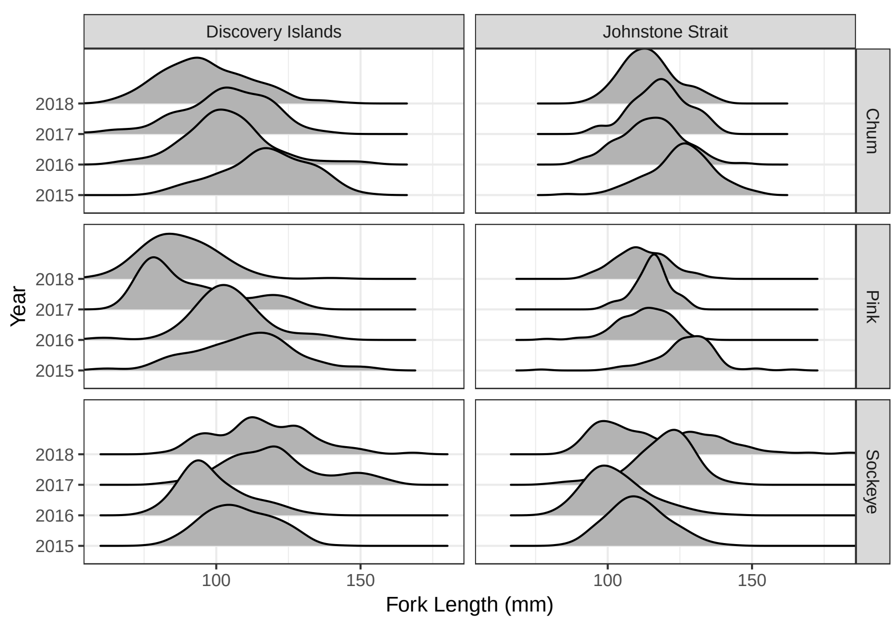
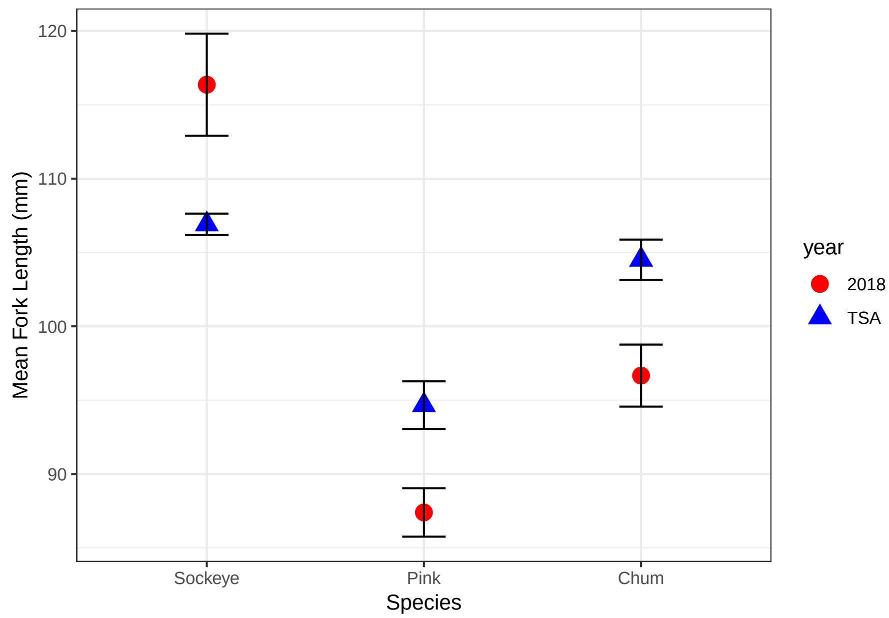
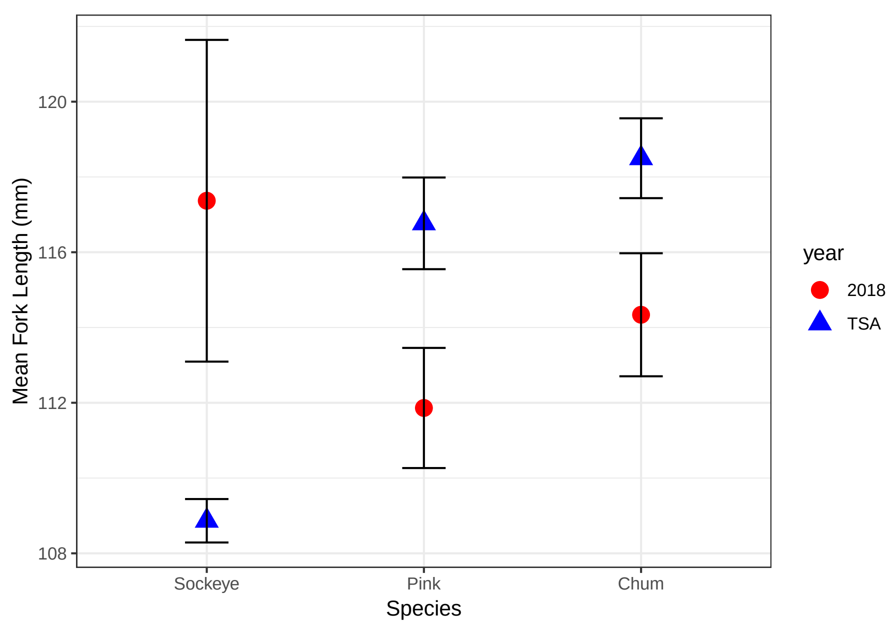


Figure 4. Kernel density distributions of juvenile salmon fork lengths for each year in the selected region. Note that these distributions contain multiple age-classes.



\begin{figure}[H]
\caption{The average fork length +/- 95% C.I. of juvenile salmon in the Discovery Islands. TSA is the Time Series Average taken over 2015 – 2018.} \end{figure}



\begin{figure}[H]
\caption{The average fork length +/- 95% C.I. of juvenile salmon in Johnstone Strait. TSA is the Time Series Average taken over 2015 – 2018.} \end{figure}

Parasite Loads

Across the Discovery Islands and Johnstone Strait, parasite loads were 11.8 percent less than average (Z = -0.98) The prevalence of motile (pre-adult and adult life stage) sea lice in 2018 was the lowest recorded in the time-series (Figure 5). 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.

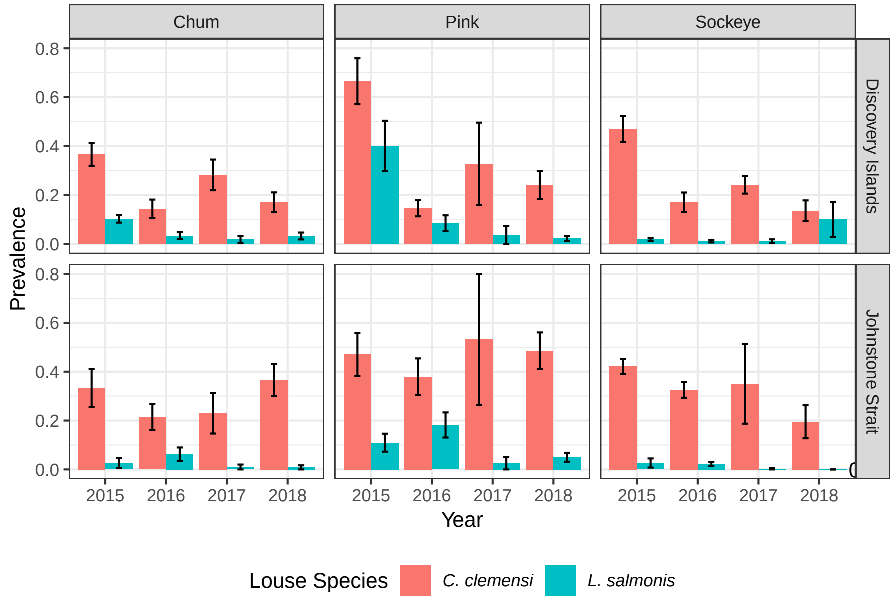


Figure 5. The prevalence (+/-SE) of motile sea lice on juvenile salmon in the Discovery Islands and Johnstone Strait.

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). Sea surface temperatures between May and July of 2018 were warmer than the time series average. (Figure 6)

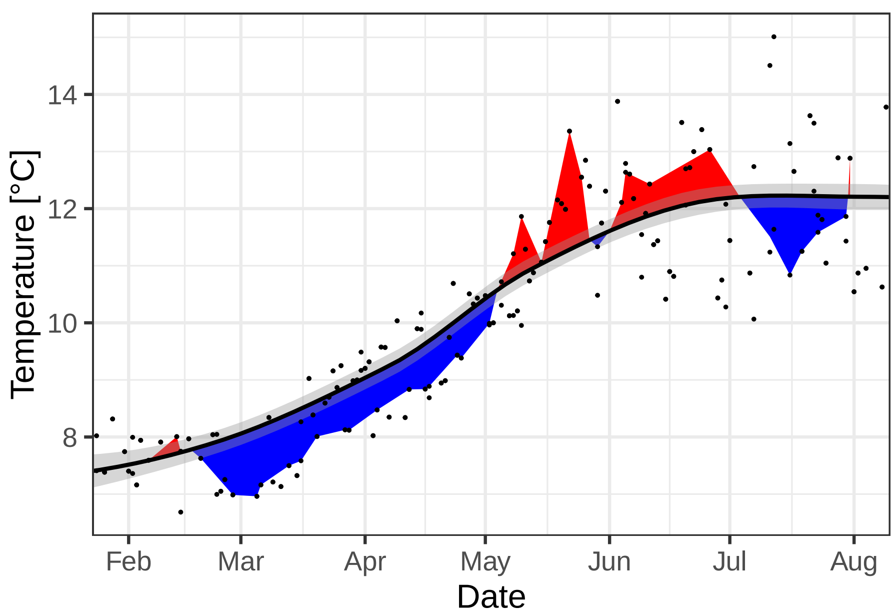


Figure 6. Time series of 30 m depth integrated temperature anomalies observed at Hakai Oceanographic Monitoring station QU39. Blue areas represent temperatures that are below normal, red areas represent above normal temperatures at the selected station in 2018. Normal is the solid black line which is 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.

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