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Juvenile Salmon Migration Dynamics in the Discovery Islands and Johnstone Strait; 2015–2017

by

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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 sockeye salmon (*Oncorhynchus nerka)* relative to the Strait of Georgia. High resolution spatiotemporal measurements of migration timing and abundance of juvenile sockeye salmon and the relative species composition of co-migrating juvenile salmon are needed to understand the factors influencing early marine survival through this region. Here we report on migration dynamics in the Discovery Islands to Johnstone Strait region based on purse seine data collected by the Hakai Institute Juvenile Salmon Program from 2015–2017. The peak migration period in the Discovery Islands in which 50 % of sockeye passed through occurred between May 25 and June 4 and in Johnstone Strait between May 30 and June 12. Peak abundance was observed earlier than normal in 2015 and 2016, likely due to anomalously warm winter and spring weather. Sockeye migrated at 2.0 BL•s^{-1} between the Discovery Islands and Johnstone Strait based on the peak migration date in each region, faster than the 1.1 BL•s^{-1} observed in the Strait of Georgia. Sockeye abundance was much lower in 2017 compared to 2015 and 2016. Species composition was dominated by sockeye in 2015 and 2016, and by chum *(Oncorhynchus keta)* in 2017.

Introduction

Until the mid-1990's much of the effort of salmon fisheries research focused on the freshwater stages of salmon life history assuming this period predominantly determined recruitment (Beamish et al. 2003). However, the first months after marine entry have subsequently been identified as a potentially critical period (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, 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 operating since 2015 in an effort to understand how these factors may be influencing early marine survival of sockeye, pink, and chum (Hunt et al. 2018). This report summarizes the migration timing, rate, abundance, and species composition observed from the first three years of this research and monitoring program. These estimates will provide the context from which to investigate questions and interpret results related to the conditions salmon experience during their migration through this critical region (Figure 1).

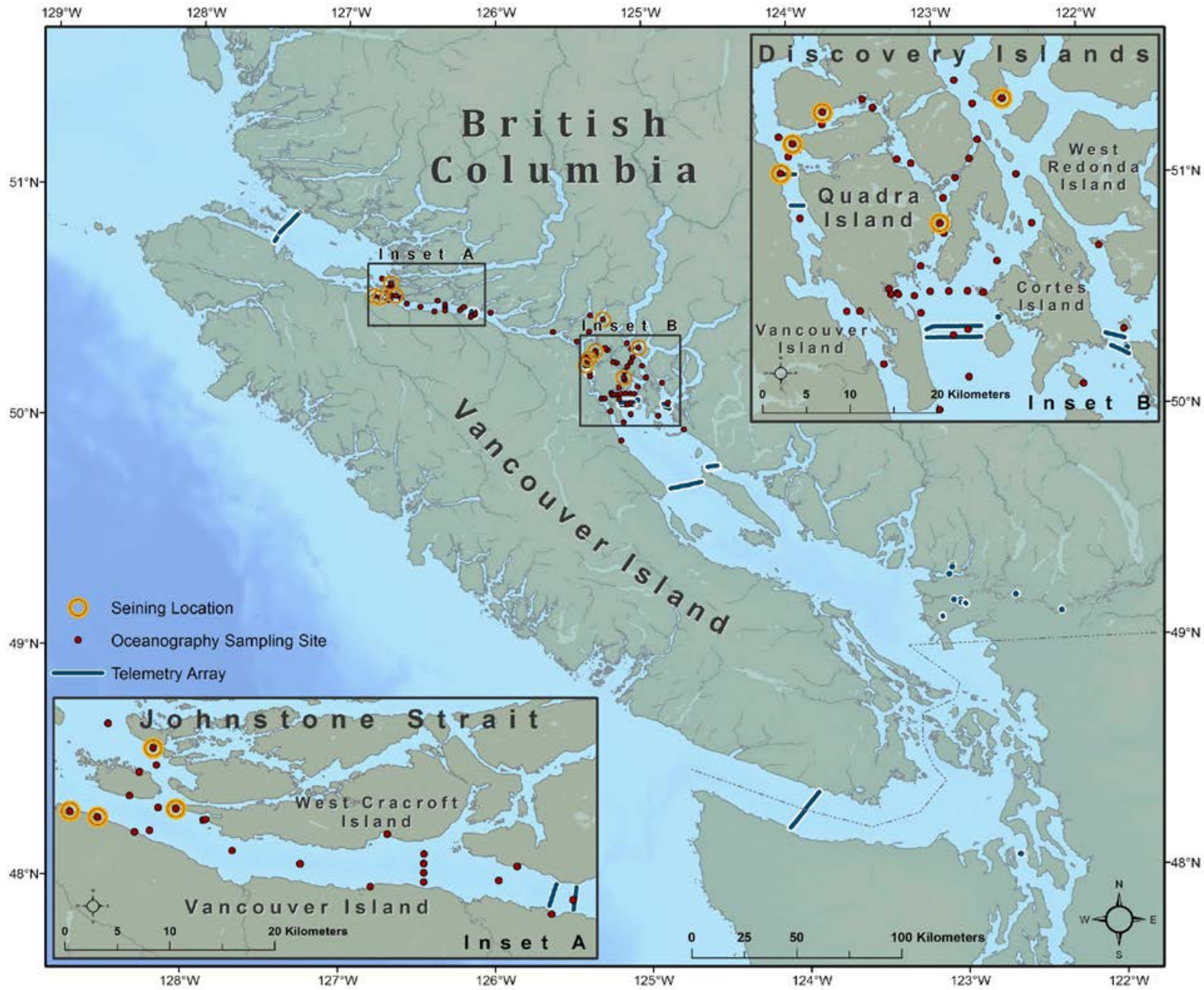

Figure 1. Seining locations and oceanographic sampling sites in the Discovery Islands and Johnstone Strait that were consistently sampled from 2015–2017.

Methods

A detailed description of the sampling methodology used in this program is provided by Hunt et al. (2018). Sockeye abundance and migration timing was calculated using weekly averages of the number of sockeye caught in seines that contained at least 1 sockeye. Surveys that were conducted before sockeye arrived and when no fish surface activity was observed, were recorded as zero catch. Peak annual migration date was determined for sockeye by calculating the mean date of all sockeye that were caught in each region, in each year. Using this peak annual migration date for each region we calculated a coarse estimate of migration rate between the Discovery Islands and Johnstone Strait. We measured the shortest distance in water between the two most common capture locations in each region. We converted that distance to the number of sockeye body lengths based on fork length averaged from all three years. Lastly, we calculated the migration rate between the Discovery Islands and Johnstone Strait in body lengths per second ($BL \cdot s^{-1}$) by dividing body lengths by the average time it took to traverse the region for all years combined. Annual migration rates are not reported individually because the estimate is coarse and not intended for inter-annual comparison.

The skewness of sockeye catch distributions over time was tested using the psych package (Revelle, 2017) in R (R Core Team, 2017). We predicted the median and interquartile range (IQR) of sockeye migration timing by fitting a logistic growth curve to the cumulative abundance of sockeye caught. The IQR produced from fitting a logistic growth curve is useful for interpreting the oceanographic conditions the majority of fish experienced and is preferred to using the mean and standard deviations of fish capture, which would be influenced by skewed distributions. The mean date of capture, however, better characterizes the rate at which fish move through the region because the mean better accounts for abundance over time, which would be lost if the data were simply ranked.

Species abundance was measured by calculating the average number of each species caught in seines that successfully caught sockeye, for each region, and each year. Catch composition was calculated by taking the annual and regional sum of each species and dividing it by the total sum of all species to generate annual proportions.

Results

Sockeye arrived in the Discovery Islands on May 12 in 2015, May 13 in 2016, and May 23 in 2017. The peak migration date for sockeye in the Discovery Islands was May 31 in 2015, May 30 in 2016, and June 7 in 2017 (Table 1). The peak migration date for sockeye in Johnstone Strait occurred on June 3 in 2015, June 6 in 2016, and June 16 in 2017. The average difference in the date of peak sockeye abundance for each region in each year was 6.1 days.

Table 1. Peak migration dates and the interquartile range (IQR) of sockeye abundance in the Discovery Islands (DI) and Johnstone Strait (JS) from 2015–2017.

Year	Region	Mean Date	Date IQR
2015	DI	May 31	May 21–June 1
2015	JS	June 3	May 24–June 6
2016	DI	May 30	May 21–June 2
2016	JS	June 6	May 28–June 8
2017	DI	June 7	June 1–June 9
2017	JS	June 16	June 6–June 22

Given an average sockeye fork length of 107 mm, a distance of 113,980 m between regions, and a difference in peak sockeye abundance of 6.1 days between regions, the average migration rate between the two regions was 2.0 BL•s^{-1}. The seasonal distribution of sockeye catch is right-skewed (g_1 = 0.66, SE = 0.36), indicating that there is a large pulse of sockeye early in the season followed by an attenuation of abundance over several weeks (Figure 2). The cumulative abundance of sockeye indicates that median date—when 50% of sockeye were captured—occurred earlier than the mean (Figure 3) because the distributions are right-skewed.

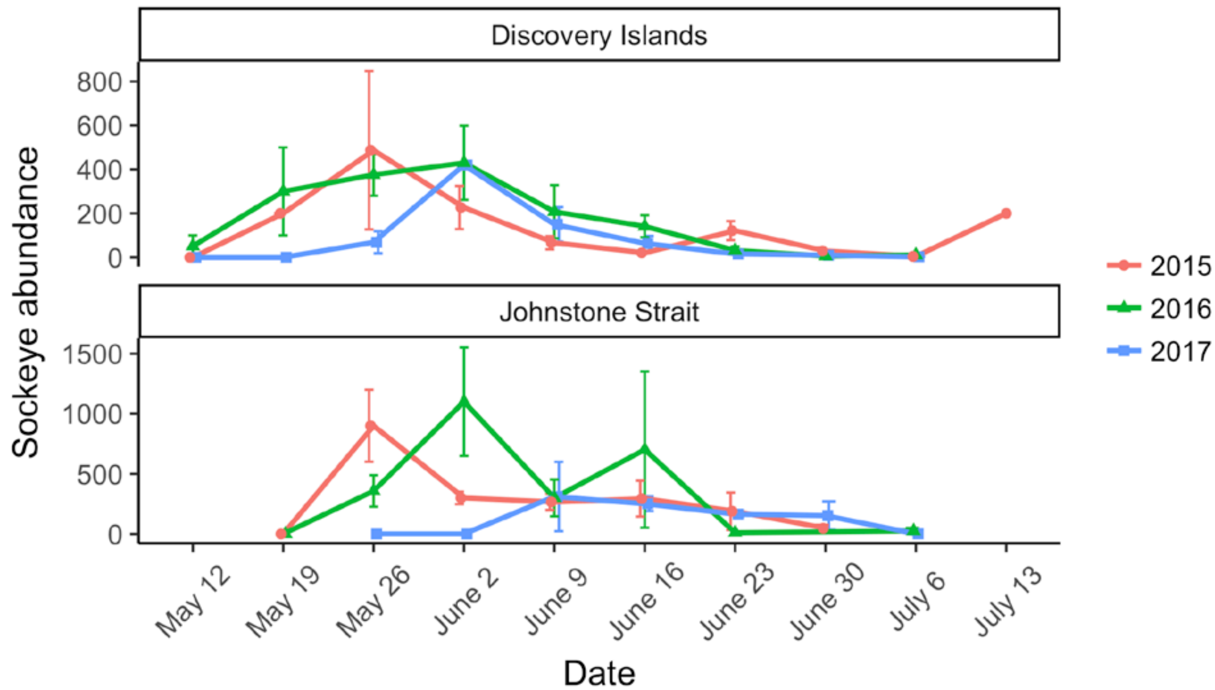

Figure 2. The migration timing and abundance of sockeye (± SE) from the Discovery Islands and Johnstone Strait from 2015–2017.

The abundance of sockeye was similar in 2015 and 2016, but low in 2017 (Figure 4). Juvenile pink catches were higher in 2016 compared to odd years. Chum were more abundant in 2015 compared to 2016 and 2017. Herring and coho are not well sampled by this program and their abundance was correspondingly low. Catch abundance of all species was higher in Johnstone Strait compared to the Discovery Islands. Catch proportions were dominated, in order of highest proportion, by sockeye, pink and chum in 2015; sockeye, chum and pink in 2016; and chum, sockeye and pink in 2017 (Figure 5).

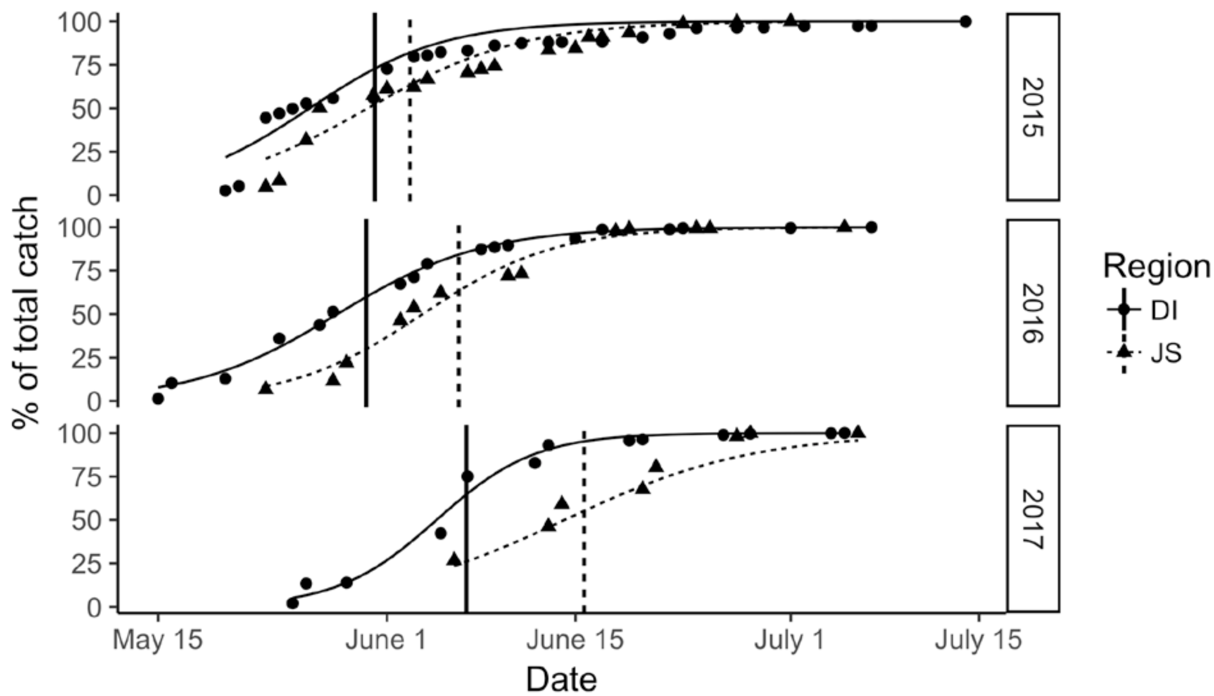

Figure 3. Logistic growth curves fitted to the cumulative abundance of sockeye in Discovery Islands (DI) and Johnstone Strait (JS). The mean date of capture is represented by vertical lines.

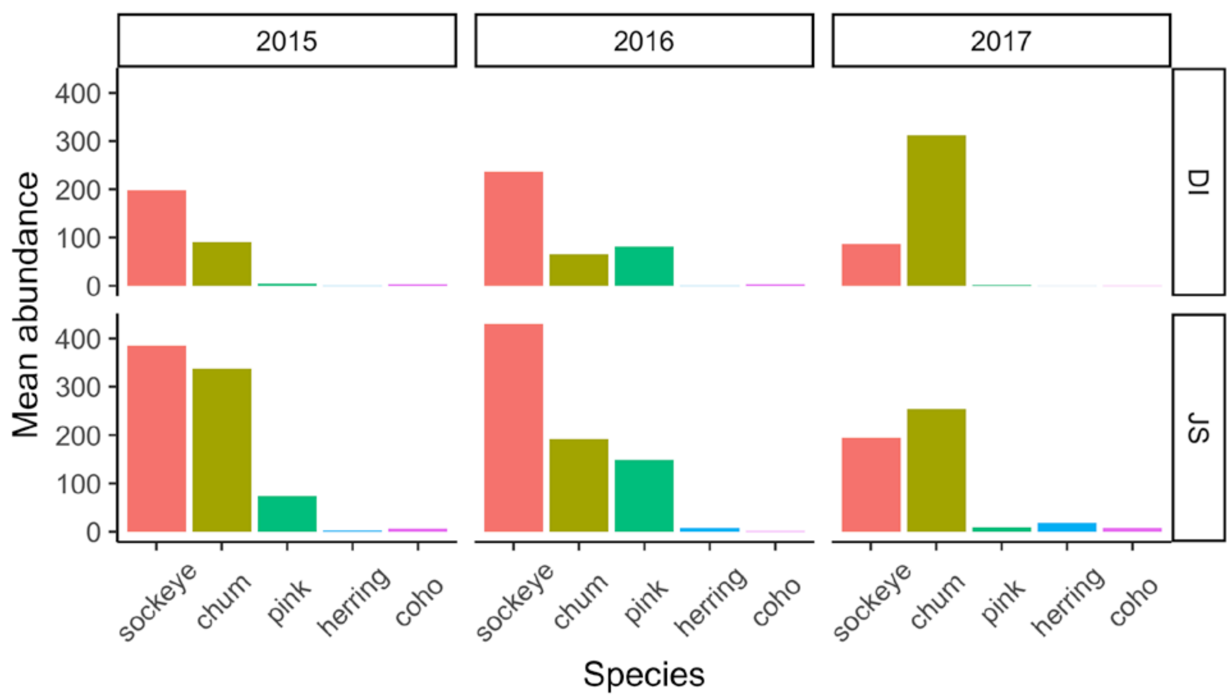

Figure 4. The mean annual abundance of each species caught in seines that contained sockeye, in the Discovery Islands (DI) and Johnstone Strait (JS).

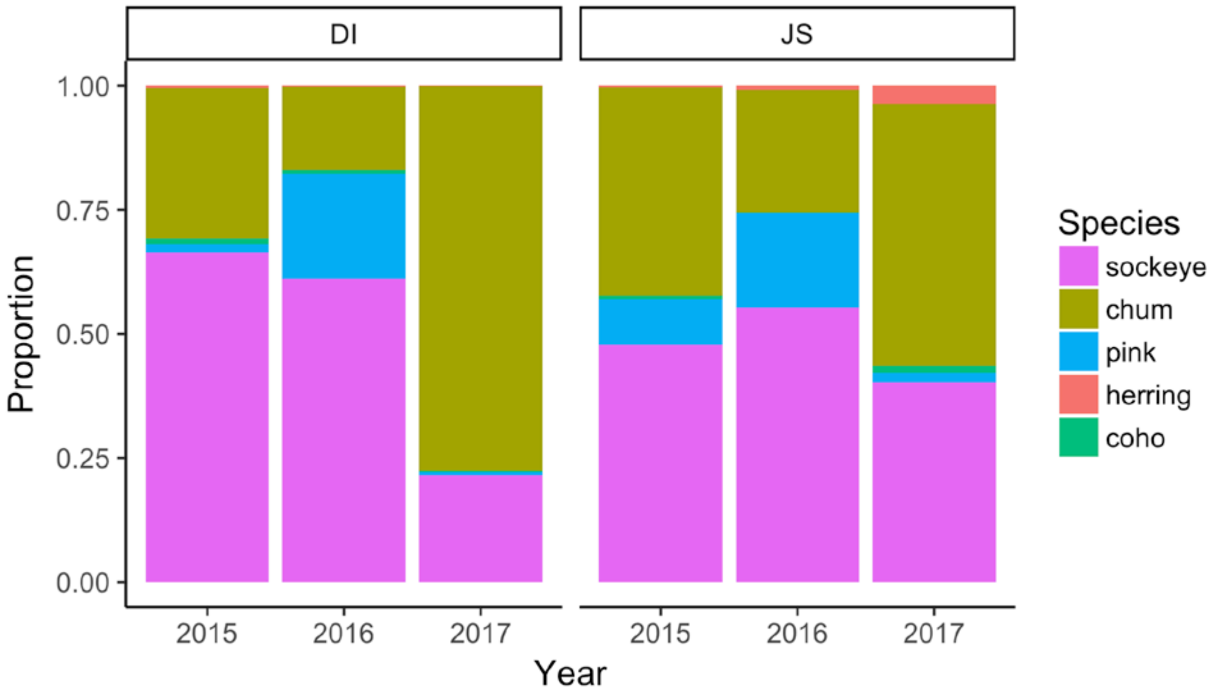

Figure 5. The mean annual proportion of species caught in seines that contained sockeye, in the Discovery Islands (DI) and Johnstone Strait (JS).

Discussion

The higher catch abundance in Johnstone Strait than in the Discovery Islands was likely due to fish being funneled into Johnstone Strait, resulting in a higher density of fish compared to the potential for fish to spread out in multiple channels in the Discovery Islands. Catch composition of pinks varied as a result of the odd-year dominant brood-year cycle for adult pinks in the Fraser River (Gallagher 1979).

Peak migration timing in the Discovery Islands typically occurs in mid-June (Preikshot et al. 2012, Price et al. 2013, Neville et al. 2013). The peak migrations at the end of May in 2015 and 2016 were early, and the peak migration observed on June 7 in 2017 was more typical. The early 2015 and 2016 migration timing was, however, not un-accounted for; Groot and Cooke (1985) found that sockeye arrived in the northern Strait of Georgia and Discovery Islands by May 15 and were in the greatest abundance from May 15–31 from 1982–1984.

Anomalous climate conditions in 2015 and 2016, driven by a strong El Niño, may explain the early migration timing. Air temperatures in B.C. in 2015 set a new record for average annual temperature (Anslow et al. 2015) and the spring phytoplankton bloom in 2015 occurred in mid-March, the earliest on record since 2005 (Allen and Latornell 2015). In 2015, the Fraser River was 1 °C warmer than average from January to May, the rate of discharge was above normal in early 2015, and April flow was the highest in 104 years (Gower and Chandler 2015). In 2016, the daily average air temperature in B.C. was the highest on record (Anslow et al. 2016), the spring phytoplankton bloom timing was close to the mean at the end of March, and the Fraser River discharge occurred earlier than normal due to warm spring conditions.

Warmer lake temperatures accelerate growth rates of lake-rearing sockeye (Edmundson and Mazumder 2001) and warmer spring temperatures have been shown to cause earlier downstream migration dates in Chinook salmon on the Columbia River (Achord et al. 2007). Furthermore, temperature has been shown to be an important factor influencing the rate and timing of smolting (McCormick et al. 2002). We reasoned that our results may indicate that sockeye migrated earlier than normal in the spring of 2015 and 2016 in response to climate anomalies.

That we observed sockeye moving through the Discovery Islands and Johnstone Strait at 2.0 BL•s^{-1} is consistent with observations of 1.8 BL•s^{-1} derived from acoustic telemetry from 2-year old Chilko sockeye (Rechisky et al. 2018). Sockeye moved through this region relatively quickly compared to mean travel rates of 1.1 BL•s^{-1} in the central Strait of Georgia (Rechisky et al. 2018).

Based on the work from Clark et al. (2016) we know there are portions of Chilko Lake sockeye freshwater migration that incur high mortalities. In particular, the clear water of up-river reaches were areas of poor survival and the cause of that mortality was linked to binge-feeding bull trout (*Salvelinus confluentus)* (Furey et al. 2016). In the same way researchers were able to understand what was driving mortality in distinct regions of a freshwater system, we aim to understand what is driving survival in the complex early marine habitat of the Discovery Islands and Johnstone Strait.

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