

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

Brett T. Johnson¹, Julian C.L. Gan¹, and Brian P.V. Hunt^{2, 3}

⁵ **¹Hakai Institute Quadra Island Ecological Observatory, Heriot Bay, BC V0P1H0**

⁶ **²UBC EOS, IOF**

⁷ Corresponding author:

⁸ Brett T. Johnson¹

⁹ Email address: brett.johnson@hakai.org

ABSTRACT

¹¹ The majority of out-migrating juvenile Fraser River salmon pass northwest through the Strait of Georgia,
¹² the Discovery Islands, and Johnstone Strait. The Discovery Islands to Johnstone Strait leg of the
¹³ migration is a region of poor survival for juvenile salmon relative to the Strait of Georgia. The Hakai
¹⁴ Institute Juvenile Salmon Program has been monitoring key components of this migration since 2015 to
¹⁵ better understand drivers of early marine survival. Here we present key aspects of the 2018 migration in
¹⁶ comparison to averages from the 2015—2018 study period, which we use to define ‘normal’. In 2018
¹⁷ sockeye, pink, and chum all migrated earlier than normal. The median capture date was May 23rd for
¹⁸ sockeye, five days earlier than normal, and June 12 for pink and chum which is five days earlier for pink
¹⁹ and three days earlier than normal for chum. Sea lice prevalence was lower than normal for sockeye,
²⁰ pink, and chum. Notably there were no *Lepeophtheirus salmonis* sea lice observed in Johnstone Strait in
²¹ 2018. Sockeye were longer than normal in 2018 whereas pink and chum were smaller than normal. Sea
²² surface temperature in May and June was the warmest on record in the study period (2015—2018). Pink
²³ salmon dominated the catch in 2018, followed by chum and then sockeye.

```
11 # All data used for this analysis is from the hakaisalmon R package v0.2.0 at h  
library(hakaisalmon)  
library(tidyverse)  
  
24 ## Warning: package 'ggplot2' was built under R version 3.4.4  
25 ## Warning: package 'purrr' was built under R version 3.4.4  
26 ## Warning: package 'dplyr' was built under R version 3.4.4  
  
library(lubridate)  
  
27 ## Warning: package 'lubridate' was built under R version 3.4.4  
  
library(knitr)  
library(here)
```

INTRODUCTION

²⁹ Pacific salmon (*Oncorhynchus* spp.) traverse a number of aquatic landscapes during different phases of
³⁰ their lifecycle to reach a habitat which ultimately offers some reward. While undergoing these migrations,
³¹ salmon are subjected to risks associated with each new environment they encounter. The risks and

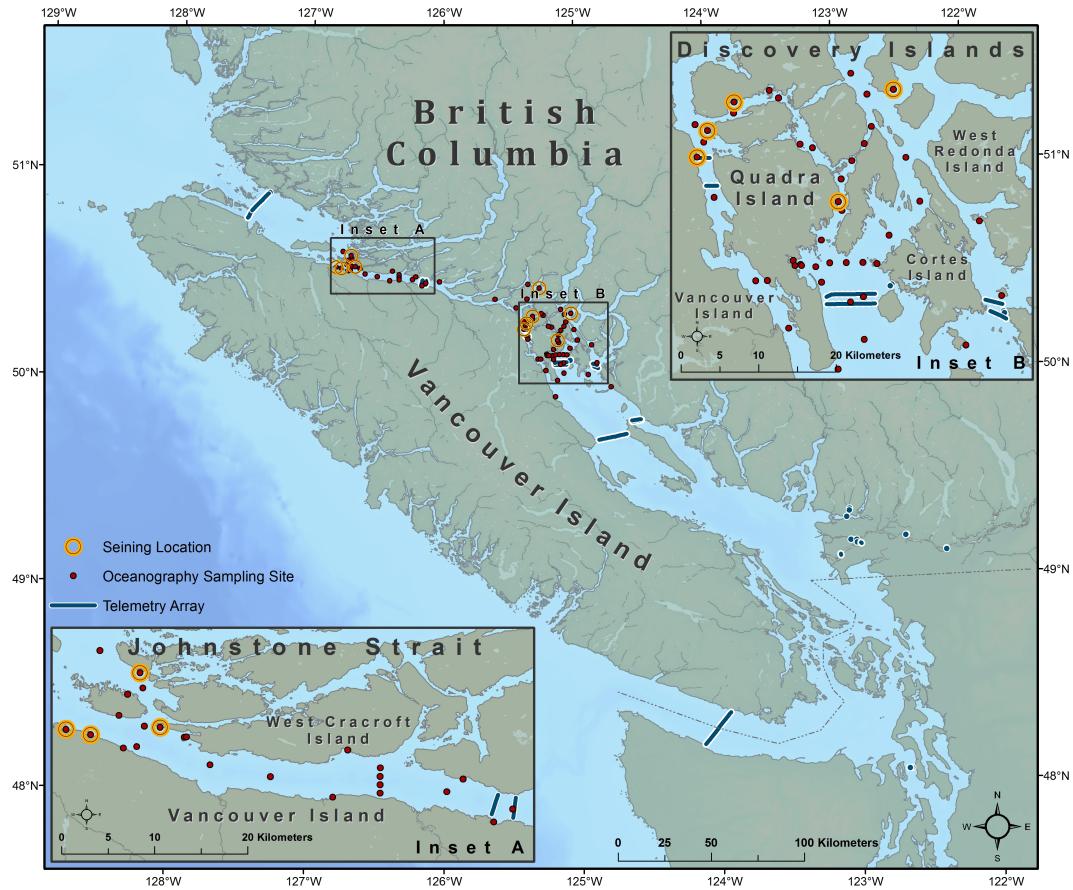


Figure 1. Sampling locations in 2018

32 associated mortality from these migrations can be understood in aggregate by quantifying the productivity
 33 (recruits per spawner) of a certain stock. Salmon are an excellent indicator species because they act as
 34 an integrator of terrestrial, lacustrine, fluvial, estuarine, nearshore marine, and high-seas conditions. A
 35 problem in any one of these environments will be reflected in the productivity of a salmon stocks. To better
 36 manage and predict the productivity of salmon stocks we need estimates of mortality and an understanding
 37 of the factors driving mortality in each landscape that salmon traverse. The early marine environment is
 38 one which estimates of mortality and its drivers, is lacking. Juvenile salmon are particularly vulnerable
 39 during the early marine phase of their life history because they are undergoing physiological adaptations
 40 to a saline environment.

41 The Hakai Institute Juvenile Salmon Program has been monitoring juvenile salmon migrations in the
 42 Discovery Islands and Johnstone Strait (Figure 1) 2015 in an effort to understand what factors may be
 43 influencing early marine survival of sockeye, pink, and chum (Hunt et al. 2018). The effects of pathogens,
 44 parasites, predators, and the impacts of climate change on food web dynamics may be amplified during
 45 this stressful transition period and are the primary aspects of the salmon migration we are monitoring and
 46 reporting on here.

```
include_graphics('map.pdf')
```

47 **About PeerJ**

48 PeerJ is an award-winning open access publisher covering the biological and medical sciences. PeerJ
 49 provides authors with three publication venues: *PeerJ* and *PeerJ Computer Science* (peer-reviewed
 50 academic journals) and *PeerJ PrePrints* (a ‘pre-print server’). See <https://peerj.com/about/publications/> for more information.



Figure 2. An example image.

52 The PeerJ model allows an author to publish articles in their peer-reviewed journal via the purchase of
53 a lifetime Publication Plan. Prices start from just \$99 (a one-off payment) which entitles an author to the
54 lifetime ability to publish 1 article per year for free. Publication in PeerJ PrePrints is entirely free.

55 **SOME L^AT_EX EXAMPLES**

56 Use section and subsection commands to organize your document. L^AT_EX handles all the formatting and
57 numbering automatically. Use ref and label commands for cross-references.

58 **Figures and Tables**

59 Use the table and tabular commands for basic tables — see Table 1, for example. You can upload a figure
60 (JPEG, PNG or PDF) using the project menu. To include it in your document, use the includegraphics
61 command as in the code for Figure 2 below.

62 Standard L^AT_EX references will work as well (e.g. Fig. 2).

Table 1. An Example Table.

Item	Quantity
Widgets	42
Gadgets	13

63 **Citations**

64 LaTeX formats citations and references automatically using the bibliography records in your .bib file,
65 which you can edit via the project menu. Use the cite command for an inline citation, like Figueiredo and
66 Wolf (2009), and the citep command for a citation in parentheses (Figueiredo and Wolf 2009).

67 **Mathematics**

68 L^AT_EX is great at typesetting mathematics. Let X_1, X_2, \dots, X_n be a sequence of independent and identically
69 distributed random variables with $E[X_i] = \mu$ and $\text{Var}[X_i] = \sigma^2 < \infty$, and let

$$S_n = \frac{X_1 + X_2 + \dots + X_n}{n} = \frac{1}{n} \sum_i^n X_i$$

70 denote their mean. Then as n approaches infinity, the random variables $\sqrt{n}(S_n - \mu)$ converge in distribution
71 to a normal $\mathcal{N}(0, \sigma^2)$.

72 **Lists**

73 You can make lists with automatic numbering ...

74 1. Like this,

83 **METHODS**

84 Quisque ullamcorper placerat ipsum. Cras nibh. Morbi vel justo vitae lacinia tincidunt ultrices. Lorem
85 ipsum dolor sit amet, consectetur adipiscing elit. In hac habitasse platea dictumst. Integer tempus
86 convallis augue. Etiam facilisis. Nunc elementum fermentum wisi. Aenean placerat. Ut imperdiet, enim
87 sed gravida sollicitudin, felis odio placerat quam, ac pulvinar elit purus eget enim. Nunc vitae tortor.
88 Proin tempus nibh sit amet nisl. Vivamus quis tortor vitae risus porta vehicula.

$$\cos^3 \theta = \frac{1}{4} \cos \theta + \frac{3}{4} \cos 3\theta \quad (1)$$

89 Fusce mauris. Vestibulum luctus nibh at lectus. Sed bibendum, nulla a faucibus semper, leo velit
90 ultricies tellus, ac venenatis arcu wisi vel nisl. Vestibulum diam. Aliquam pellentesque, augue quis sagittis
91 posuere, turpis lacus congue quam, in hendrerit risus eros eget felis. Maecenas eget erat in sapien mattis
92 porttitor. Vestibulum porttitor. Nulla facilisi. Sed a turpis eu lacus commodo facilisis. Morbi fringilla,
93 wisi in dignissim interdum, justo lectus sagittis dui, et vehicula libero dui cursus dui. Mauris tempor
94 ligula sed lacus. Duis cursus enim ut augue. Cras ac magna. Cras nulla. Nulla egestas. Curabitur a leo.
95 Quisque egestas wisi eget nunc. Nam feugiat lacus vel est. Curabitur consectetur.

96 **Subsection**

97 Suspendisse vel felis. Ut lorem lorem, interdum eu, tincidunt sit amet, laoreet vitae, arcu. Aenean faucibus
98 pede eu ante. Praesent enim elit, rutrum at, molestie non, nonummy vel, nisl. Ut lectus eros, malesuada
99 sit amet, fermentum eu, sodales cursus, magna. Donec eu purus. Quisque vehicula, urna sed ultricies
100 auctor, pede lorem egestas dui, et convallis elit erat sed nulla. Donec luctus. Curabitur et nunc. Aliquam
101 dolor odio, commodo pretium, ultricies non, pharetra in, velit. Integer arcu est, nonummy in, fermentum
102 faucibus, egestas vel, odio.

103 **Paragraph** Sed commodo posuere pede. Mauris ut est. Ut quis purus. Sed ac odio. Sed vehicula
104 hendrerit sem. Duis non odio. Morbi ut dui. Sed accumsan risus eget odio. In hac habitasse platea
105 dictumst. Pellentesque non elit. Fusce sed justo eu urna porta tincidunt. Mauris felis odio, sollicitudin sed,
106 volutpat a, ornare ac, erat. Morbi quis dolor. Donec pellentesque, erat ac sagittis semper, nunc dui lobortis
107 purus, quis congue purus metus ultricies tellus. Proin et quam. Class aptent taciti sociosqu ad litora
108 torquent per conubia nostra, per inceptos hymenaeos. Praesent sapien turpis, fermentum vel, eleifend
109 faucibus, vehicula eu, lacus.

110 **Paragraph** Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas.
111 Donec odio elit, dictum in, hendrerit sit amet, egestas sed, leo. Praesent feugiat sapien aliquet odio.
112 Integer vitae justo. Aliquam vestibulum fringilla lorem. Sed neque lectus, consectetur at, consectetur
113 sed, eleifend ac, lectus. Nulla facilisi. Pellentesque eget lectus. Proin eu metus. Sed porttitor. In hac
114 habitasse platea dictumst. Suspendisse eu lectus. Ut mi mi, lacinia sit amet, placerat et, mollis vitae, dui.
115 Sed ante tellus, tristique ut, iaculis eu, malesuada ac, dui. Mauris nibh leo, facilisis non, adipiscing quis,
116 ultrices a, dui.

117 **Subsection**

118 Morbi luctus, wisi viverra faucibus pretium, nibh est placerat odio, nec commodo wisi enim eget quam.
119 Quisque libero justo, consectetur a, feugiat vitae, porttitor eu, libero. Suspendisse sed mauris vitae
120 elit sollicitudin malesuada. Maecenas ultricies eros sit amet ante. Ut venenatis velit. Maecenas sed mi
121 eget dui varius euismod. Phasellus aliquet volutpat odio. Vestibulum ante ipsum primis in faucibus orci
122 luctus et ultrices posuere cubilia Curae; Pellentesque sit amet pede ac sem eleifend consectetur. Nullam
123 elementum, urna vel imperdiet sodales, elit ipsum pharetra ligula, ac pretium ante justo a nulla. Curabitur
124 tristique arcu eu metus. Vestibulum lectus. Proin mauris. Proin eu nunc eu urna hendrerit faucibus.
125 Aliquam auctor, pede consequat laoreet varius, eros tellus scelerisque quam, pellentesque hendrerit ipsum
126 dolor sed augue. Nulla nec lacus.

127 Reference to Figure 3.

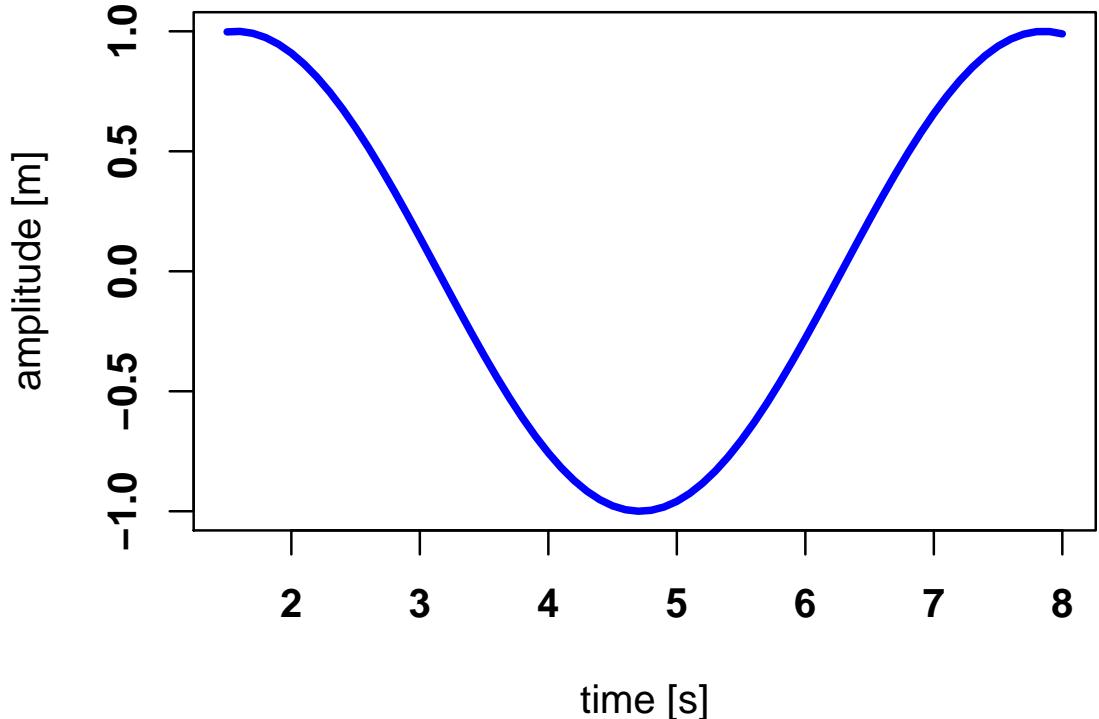


Figure 3. In-text Picture

RESULTS AND DISCUSSION

128 **RESULTS AND DISCUSSION**

129 Suspendisse vitae elit. Aliquam arcu neque, ornare in, ullamcorper quis, commodo eu, libero. Fusce
 130 sagittis erat at erat tristique mollis. Maecenas sapien libero, molestie et, lobortis in, sodales eget, dui.
 131 Morbi ultrices rutrum lorem. Nam elementum ullamcorper leo. Morbi dui. Aliquam sagittis. Nunc
 132 placerat. Pellentesque tristique sodales est. Maecenas imperdiet lacinia velit. Cras non urna. Morbi eros
 133 pede, suscipit ac, varius vel, egestas non, eros. Praesent malesuada, diam id pretium elementum, eros sem
 134 dictum tortor, vel consectetur odio sem sed wisi.

135 **Subsection**

136 Sed feugiat. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Ut
 137 pellentesque augue sed urna. Vestibulum diam eros, fringilla et, consectetur eu, nonummy id, sapien.
 138 Nullam at lectus. In sagittis ultrices mauris. Curabitur malesuada erat sit amet massa. Fusce blandit.
 139 Aliquam erat volutpat. Aliquam euismod. Aenean vel lectus. Nunc imperdiet justo nec dolor.

140 **Subsubsection**

141 Etiam euismod. Fusce facilisis lacinia dui. Suspendisse potenti. In mi erat, cursus id, nonummy sed,
 142 ullamcorper eget, sapien. Praesent pretium, magna in eleifend egestas, pede pede pretium lorem, quis
 143 consectetur tortor sapien facilisis magna. Mauris quis magna varius nulla scelerisque imperdiet. Aliquam
 144 non quam. Aliquam porttitor quam a lacus. Praesent vel arcu ut tortor cursus volutpat. In vitae pede quis
 145 diam bibendum placerat. Fusce elementum convallis neque. Sed dolor orci, scelerisque ac, dapibus nec,
 146 ultricies ut, mi. Duis nec dui quis leo sagittis commodo.

147 **Subsubsection**

148 Etiam ac leo a risus tristique nonummy. Donec dignissim tincidunt nulla. Vestibulum rhoncus molestie
 149 odio. Sed lobortis, justo et pretium lobortis, mauris turpis condimentum augue, nec ultricies nibh arcu
 150 pretium enim. Nunc purus neque, placerat id, imperdiet sed, pellentesque nec, nisl. Vestibulum imperdiet
 151 neque non sem accumsan laoreet. In hac habitasse platea dictumst. Etiam condimentum facilisis libero.
 152 Suspendisse in elit quis nisl aliquam dapibus. Pellentesque auctor sapien. Sed egestas sapien nec lectus.
 153 Pellentesque vel dui vel neque bibendum viverra. Aliquam porttitor nisl nec pede. Proin mattis libero vel

154 turpis. Donec rutrum mauris et libero. Proin euismod porta felis. Nam lobortis, metus quis elementum
155 commodo, nunc lectus elementum mauris, eget vulputate ligula tellus eu neque. Vivamus eu dolor.

156 **Subsection**

157 Nulla in ipsum. Praesent eros nulla, congue vitae, euismod ut, commodo a, wisi. Pellentesque habitant
158 morbi tristique senectus et netus et malesuada fames ac turpis egestas. Aenean nonummy magna non leo.
159 Sed felis erat, ullamcorper in, dictum non, ultricies ut, lectus. Proin vel arcu a odio lobortis euismod.
160 Vestibulum ante ipsum primis in faucibus orci luctus et ultrices posuere cubilia Curae; Proin ut est.
161 Aliquam odio. Pellentesque massa turpis, cursus eu, euismod nec, tempor congue, nulla. Duis viverra
162 gravida mauris. Cras tincidunt. Curabitur eros ligula, varius ut, pulvinar in, cursus faucibus, augue.

163 Nulla mattis luctus nulla. Duis commodo velit at leo. Aliquam vulputate magna et leo. Nam
164 vestibulum ullamcorper leo. Vestibulum condimentum rutrum mauris. Donec id mauris. Morbi molestie
165 justo et pede. Vivamus eget turpis sed nisl cursus tempor. Curabitur mollis sapien condimentum nunc. In
166 wisi nisl, malesuada at, dignissim sit amet, lobortis in, odio. Aenean consequat arcu a ante. Pellentesque
167 porta elit sit amet orci. Etiam at turpis nec elit ultricies imperdiet. Nulla facilisi. In hac habitasse platea
168 dictumst. Suspendisse viverra aliquam risus. Nullam pede justo, molestie nonummy, scelerisque eu,
169 facilisis vel, arcu.

170 Curabitur tellus magna, porttitor a, commodo a, commodo in, tortor. Donec interdum. Praesent
171 scelerisque. Maecenas posuere sodales odio. Vivamus metus lacus, varius quis, imperdiet quis, rhoncus a,
172 turpis. Etiam ligula arcu, elementum a, venenatis quis, sollicitudin sed, metus. Donec nunc pede, tincidunt
173 in, venenatis vitae, faucibus vel, nibh. Pellentesque wisi. Nullam malesuada. Morbi ut tellus ut pede
174 tincidunt porta. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam congue neque id dolor.

175 Donec et nisl at wisi luctus bibendum. Nam interdum tellus ac libero. Sed sem justo, laoreet vitae,
176 fringilla at, adipiscing ut, nibh. Maecenas non sem quis tortor eleifend fermentum. Etiam id tortor ac
177 mauris porta vulputate. Integer porta neque vitae massa. Maecenas tempus libero a libero posuere dictum.
178 Vestibulum ante ipsum primis in faucibus orci luctus et ultrices posuere cubilia Curae; Aenean quis mauris
179 sed elit commodo placerat. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos
180 hymenaeos. Vivamus rhoncus tincidunt libero. Etiam elementum pretium justo. Vivamus est. Morbi a
181 tellus eget pede tristique commodo. Nulla nisl. Vestibulum sed nisl eu sapien cursus rutrum.

182 Nulla non mauris vitae wisi posuere convallis. Sed eu nulla nec eros scelerisque pharetra. Nullam
183 varius. Etiam dignissim elementum metus. Vestibulum faucibus, metus sit amet mattis rhoncus, sapien
184 dui laoreet odio, nec ultricies nibh augue a enim. Fusce in ligula. Quisque at magna et nulla commodo
185 consequat. Proin accumsan imperdiet sem. Nunc porta. Donec feugiat mi at justo. Phasellus facilisis
186 ipsum quis ante. In ac elit eget ipsum pharetra faucibus. Maecenas viverra nulla in massa.

187 Nulla ac nisl. Nullam urna nulla, ullamcorper in, interdum sit amet, gravida ut, risus. Aenean ac
188 enim. In luctus. Phasellus eu quam vitae turpis viverra pellentesque. Duis feugiat felis ut enim. Phasellus
189 pharetra, sem id porttitor sodales, magna nunc aliquet nibh, nec blandit nisl mauris at pede. Suspendisse
190 risus risus, lobortis eget, semper at, imperdiet sit amet, quam. Quisque scelerisque dapibus nibh. Nam
191 enim. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nunc ut metus. Ut metus justo, auctor at,
192 ultrices eu, sagittis ut, purus. Aliquam aliquam.

193 **ACKNOWLEDGMENTS**

194 So long and thanks for all the fish.

195 **REFERENCES**

196 Figueiredo, Aurelio José, and Pedro S. A. Wolf. 2009. "Assortative Pairing and Life History Strategy."
197 *Human Nature* 20 (3). Springer Nature: 317–30. doi:10.1007/s12110-009-9068-2.