Hello Superintendent Miller and Dr. Jones

I wanted to give you an update regarding progress on the Sitka pink salmon modeling project. I’ve spent the past year focused on how best to approach the issue of modeling and making inferences related to estimating abundances of pink salmon in the Indian River and the role of hatchery strays. To that end, I’ve had a number of meetings with ADF&G seeking additional data and spent time trying out different models and approaches that best suit these objectives. I’ve also had to focus on writing my dissertation/research proposal based on that trial-and-error approach. Last month, I presented that proposal formally to my committee and will be finalizing the draft, based on feedback, later this month.

To summarize, the research seeks to assess whether the abundances of pink salmon observed in recent decades at Indian River exist within a natural range of variation relative to pink salmon streams elsewhere in the region. The additional and related objective is to quantify the effect Sheldon Jackson Hatchery (SJH) operations has had on abundances of pink salmon at Indian River over time. My focus has been based on the assumption that harm to ecosystems can be driven by the hyperabundance of a native species due either to shifting regional trends in habitat suitability, to direct (and often anthropogenic) intervention, or to a combination of these factors. As you know numbers of pink salmon have increased rapidly in the last 30 years, coincident with operations of the SJH, and there have been instances when high fish densities have impacted the Indian River’s ability to sustain other resident fish species by crashing in-stream dissolved oxygen concentrations. The questions described above will form the basis of my dissertation, as well as two stand-alone manuscripts to be submitted for publication, which I hope will be of value to you.

My approach involves integrating data from Indian River and the wider region to make inferences about trends in pink salmon populations, and to consider the impact of SJH releases of pink salmon on Indian River populations using data from operations reports filed by the hatchery with ADFG. To these ends, I’m utilizing ADFG surveys of 700 pink salmon index streams in SEAK, which includes 35 streams grouped near Sitka and the Indian River, as well as data collected intermittently by ADFG of pink salmon escapement at Indian River. SJH annual operations reports (filed with ADFG) provide data regarding annual juvenile releases and estimates of returning adults. Finally, this research hopes to make use of stray rate data sourced from SJH reporting and intermittent sampling efforts at Indian River. However, these data are only available sporadically from 2011 onwards and are collected at inconsistent periods from year to year.

For estimating abundance and trends, I’ve decided on an approach (MARSS) that’s well suited for parsing time series data. Figure 1 below describes time series data from the 35 ADFG index streams in the vicinity of Sitka. Figure 2 conveys MARSS estimates of abundances at Indian River compared to a regional average (controlling for stream length and observer). I don’t want to mislead by inferring that these results are the final, but preliminary estimates demonstrate IR pink salmon are higher than average but not outlying. These results demonstrate that Indian River pink salmon follow the region-wide trend of increases in pink salmon, meaning that the Indian River would expect to see increases even if SJH operations didn’t exist.

In order to quantify the impacts of SJH operations, I employ a two-stage approach. The first stage makes use of a difference-in-difference (DD) analysis to establish a causal effect of hatchery operations on Indian River pink salmon populations. The second stage again leverages MARSS models to identify the impact of hatchery releases on Indian River abunances.

DD is a quasi-experimental approach that examines a treatment group and control group in pre- and post-treatment periods, in this case Indian River (treatment) and nearby index streams (control). Two models will consider two treatment periods: the first being commencement of hatchery operations began in 1975, and the second being in 2010 when hatchery permits increased the number of pink salmon juveniles allowed to be released annually from 1 million to 3 million. Preliminary results from this approach indicate a strong effect of time period and insignificant effect treatment effect. To understand impact of hatchery releases on Indian River pink salmon abundance MARSS models evaluate the impact of Indian River abundance and hatchery releases in year *t-1* on Indian River abundance in year *t*. Separate models will consider impact of hatchery releases (known) and impact of estimated numbers of returning adult hatchery fish. This approach is intended to provide the most direct quantification possible of the impact of hatchery releases on pink salmon abundances in the Indian River.

The results of this work are intended to provide you/the park management with a comprehensive description of both the impacts of Sheldon Jackson Hatchery operations and of the population dynamics of pink salmon throughout the broader region. Included below are a timeline outlining the remainder of this project, the figures referenced above, as well as more detailed descriptions of the modeling approaches used. I really value all the support that’s come from the park as well as your familiarity with the Indian River system, so please let me know if you have any questions or comments.

Thank you so much for your interest in this work!

Brian McGreal

**Timeline**

August/September 2025: Finish and finalize dissertation proposal

May 2026: Finish draft manuscript focused on Indian River pink salmon abundances relative to those observed at ADFG index streams throughout the region

August 2026: Finish draft manuscript focused on causal impact of SJH releases on abundances of pink salmon in the Indian River

September 2026: Meeting at SITK to present preliminary results and seek feedback on how to enhance its utility for you. Invite managers at the Science Center and hatchery managers, as well as ADFG biologists.

**Figure 1**

A graph showing the number of states

AI-generated content may be incorrect.*Peak pink salmon escapement observed annually from 1960 to 2023 in 35 index streams across ADFG’s designated Northern Southeast (Outside) region. Spawner counts are scaled against stream length (km), then log transformed and standardized at the level of each stream.*

A graph showing the growth of salmon

AI-generated content may be incorrect.**Figure 2**

*MARSS model results estimating the underlying states of even-year pink salmon abundance at Indian River (highlighted in pink) and throughout north southeast (outside) region (grey). Uncertainty is higher at Indian River due to fewer observations.*

**Models**

MARSS models are composed of a process (or state) model and an observation model, generically formulated as follows:

Observation equation: **yt** = **Zxt** + **a** + **Ddt**, + **vt**, where **vt**∼MVN(0,**R**)

Process/state equation: **xt** = **Bxt−1** + **u** + **Cct** + **wt**, where **wt**∼MVN(0,**Q**)

In the above, observed data in a given time period (**yt**) are used to estimate the underlying state of a system of interest (**xt**). In the observation equation, **Z** determines which time series observations in the observation equation will inform which underlying states in the process model. In the case of Indian River and the 35 index streams in its vicinity, specifying **Z** as a 36x36 identity matrix would allow each time series to be representative of a separate (in this case stream-level) state, while specifying **Z** as a 36x1 vector of 1s would force all time series in the data to represent samples from one comprehensive underlying state. **a** allows for trends in the observation process to be asserted or captured (depending on whether a is specified or estimated), and any correlation in observation error between time series is defined by **R**, the variance-covariance matrix. In the process equation, **B** defines the interaction between state estimates through time (i.e., **xt** and **xt−1**). If **B** is specified as an identity matrix, **u** then represents trends in the underlying state(s), otherwise **B** and **u** together determine the underlying mean and how quickly the time series would return to the mean following some perturbation. Finally, the correlation of process error is defined by **Q**. Finally, **ct** and **dt** are covariate data related to the state or sampling procedure respectively, with **C** and **D** capturing the effect of said covariates.

Difference-in-difference models compare a treatment group to a control group across two time periods, pre- and post- intervention. The general structure of a difference-in-difference model is as follows:

yi,t = β0 + β1Dtreatment + β2Dpost  + β3Dpost\*Dtreatment + ei,t

In the above, i indexes whether an observation (yi,t) relates to the treatment or control group, while t indexes whether that same observation comes from before or after the treatment is applied. Dtreatment is equal to 1 when yi,t is part of the treatment group and equal to 0 otherwise. Similarly Dpost is equal to 1 when yi,t is observed after treatment is applied, and equal to 0 when yi,t is observed before. These indicator variables allow for the estimation of a net effect of treatment on the treatment group (β3) by first controlling for differing characteristics in the treatment and control group (β1) and differences in the pre- and post-treatment time periods (β2). Additional control covariates may be included in order to further isolate the effects of interest.