**Objectives**

This 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. In addition, this research seeks to quantify the effect SJH operations has had on abundances of pink salmon at Indian River over time.

**Background**

* National Park Service (NPS) mandate to preserve the resources under their stewardship such that they represent ‘vignettes of primitive America’
* 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
* Indian River known for hosting runs of a variety of Pacific salmon species
  + Perhaps most notably pink salmon
  + Most abundant species at Indian River
  + Numbers have increased rapidly in the last 30 years
  + High fish densities can impact the Indian River’s ability to sustain other resident fish species by crashing in-stream dissolved oxygen concentrations
* Increases in Indian River pink salmon abundance coincided with the commencement of operations at Sheldon Jackson Hatchery (SJH)
  + Located approximately 1 km from the mouth of the Indian River
  + Water for hatchery operation taken from Indian River diversion upriver of the park boundary
    - Salmon fry imprint on chemical signature
    - Water released into bay to attract returning adults during spawning season
  + Since 2010, hatchery has been permitted to propagate 3 million pink salmon eggs annually
* Evidence suggests Indian River may see higher than average levels of straying due to the proximity of SJH
  + Surveys at Indian River have at times have found stray pink salmon from SJH making up one third of all individuals sampled
  + At other times, surveys observed rates of straying closer to 10%
  + Disparity likely due to sampling occurring at different points in the run

**Methods**

* Data
  + ADFG surveys 700 pink salmon index streams in SEAK
    - In order manage commercial fishery
    - 1960 to 2023.
    - Streams are chosen because they are believed to reflect the natural condition of pink salmon populations in the region
    - 35 streams grouped near Sitka and the Indian River
      * Index stream abundances plotted in Figure 1
  + ADFG has intermittently monitored pink salmon escapement at Indian River
    - Data available from 1962-67, 1969, 1971-73, 1977-88, 1990, and 1993-2024
      * n = 45 annual observations
  + SJH hatchery operations reports
    - Filed annually with ADFG
    - Quantifies annual juvenile releases and estimated returning adults
      * ADFG suspects estimates may be biased downward
  + Stray rate data
    - SJH reports percentage of wild born fish in broodstock and cost recovery
    - Intermittent sampling efforts at Indian River
    - Combined data is only available from 2011
    - Sampling efforts occur intermittently throughout the season
* Analysis and preliminary results
  + Comparison with wild abundances at ADFG index streams
    - MARSS statistical models well suited for parsing time series data
    - Indian River pink salmon abundance higher than average for the region
      * Results in Figure 2
      * Higher than average but not outlying
      * Controlled for stream length and observer
  + Difference-in-difference analysis
    - Seeks to isolate the causal impact of hatchery operations on Indian River pink salmon populations
    - Quais-experimental approach examines treatment group and control group in pre- and post-treatment periods
      * Indian River (treatment) and nearby index streams (control)
      * Will consider two treatments:

Hatchery operations begin in 1975

Operations expand in 2010

* + - Preliminary results indicate a strong effect of time period and insignificant treatment effect
  + 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 hatchery returning adults
    - Most direct quantification of the impact of hatchery releases on Indian River abundances

**Significance**

The results of this work are intended to provide management at Sitka National Historical Park 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. Understanding whether or not pink salmon at Indian River exist within a ‘natural range of variation’ requires context, and placing Indian River within this context will enable park officials to better interpret their duties with regard to a potential overabundance of these fish. Additionally, estimating the effects of various levels of hatchery releases/returns on pink salmon abundance may enable park officials to better understand when and tow what extent abundances are being driven by hatchery strays.

**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.