

# **Final report for Phase II of “A spatially-explicit ecosystem model for quantifying marine mammal impacts on Chinook salmon in the Northeast Pacific Ocean”**

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## **Executive Summary**

Over the last decade, models of intermediate complexity (MICE) models have emerged as a tool for addressing tradeoffs between fisheries management and conservation. As marine mammal predator populations have largely rebounded on the west coast of North America, there is an increasing need to use simple ecosystem models to understand the relative impacts of fishing and predation on the natural mortality of commercially valuable species, like Chinook salmon. Our project addressed these questions by integrating data from marine mammal diets, trends in marine mammal abundance, knowledge about the spatiotemporal overlap between predators (marine mammals) and prey (Chinook salmon), and information about the seasonal shifts or migrations that affect these species and interactions.

## **Description of Phase I and II**

This report represents an overview of the 2014-2015 Pacific Salmon Commission funded project by Kaplan et al. “A spatially-explicit ecosystem model for quantifying marine mammal impacts on Chinook salmon in the Northeast Pacific Ocean”. **In Phase I** of this project, we compiled multiple datasets related to marine mammal abundance and diet, synthesized existing approaches to modeling bioenergetics for marine mammal predators, and implemented a detailed bioenergetics model of Chinook salmon consumption in Washington State inland waters (Puget Sound). The diet synthesis was published as Adams et al. (2016), in which we compiled a large database (> 250 records) of published marine mammal diet records from the west coast of Canada and the United States, 1930 – present. The associated diet database is available with the publication and publicly online ([https://github.com/eric-ward/marine\\_mammal\\_salmon\\_diet\\_database](https://github.com/eric-ward/marine_mammal_salmon_diet_database)). Modeling of marine mammal bioenergetics and abundance was not completed during Phase I, but the work contributed to two related papers: (Marshall et al. 2016, Ward et al. 2016).

**Phase II** of this project completed the modeling of marine mammal bioenergetics and consumption of Chinook salmon in Puget Sound, published as Chasco et al. (2017). This paper estimated consumption of Chinook salmon by killer whales, California sea lions, Steller sea lions, and harbor seals, including

consideration of impacts on smolt as well as adult salmon. The full methods including code base and input data are publicly available on <https://github.com/bchasco/Inland>, and are already being used in other ecosystem modeling efforts for Puget Sound (Kaplan and Girardin, NOAA NWFSC and Long Live the Kings).

The final steps of Phase II have been to develop the bioenergetics and consumption estimate on a coastwide basis, including multiple Chinook salmon stocks, migration between regions, and seasonal movement of predators. The results of this analysis are in a manuscript draft that we aim to submit in March 2017; all code and data are also available on Github, to aid future collaboration and synthesis.

### **Project Deliverables**

All deliverables regarding data and consumption model development have been met to date.

### **Project Schedule**

Despite initial delays in processing contracts (largely at NWFSC), this project was completed largely on schedule. Brandon Chasco was hired as a contractor to start in fall 2014, and worked full time through December 2016. A second short term contractor (Jesse Adams) was hired for three months in spring 2015 to assist with database and diet analyses.

### **QA/QC**

The PIs (Kaplan, Ward) and contractors have had weekly progress meetings to evaluate analyses, and anticipate future needs. We've also engaged a diverse and knowledgeable group of coauthors and collaborators (see for example coauthors on Chasco et al. (2017)). These experts have contributed data and a deep understanding of each of the modeled species. Brandon Chasco in particular has been able to learn from and coordinate this diverse group.

### **Benefits**

This project has generated several products that will be of value to the greater scientific community. First, we've generated multiple databases (time series of marine mammal trends, detailed database of marine mammal diets) that are publicly available through repositories on GitHub. Second, we have completed a detailed, integrated bioenergetics framework in open source R code, for killer whales and three pinniped species. This synthesizes existing bioenergetics literature and implements previously disparate efforts into a single code base. Finally, we've generated four reviewed papers (with a fifth to be submitted next month) that are of management importance; we presented results of the bioenergetics and consumption modeling to staff from NOAA's West Coast Regional Office on 12/16/16, and expect additional engagement with these managers in the future.

## Works Cited

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