Revised Population Viability of Willamette River Winter Steelhead

An assessment of the effect of sea lions at Willamette Falls with data through 2023

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Summary: This document describes results from updating a prior analysis (Falcy 2017) with steelhead and sea lion mortality data through 2023 (adding seven years). The goal of the analysis is to assess the effects of sea lions at Willamette Falls on population viability of four populations of Willamette winter steelhead: North Santiam, South Santiam, Calapooia, Molalla. The results of the current analysis include:

- Quasi-extinction probabilities were higher for Willamette winter steelhead populations than when they were estimated using data through 2016.

- Quasi-extinction probabilities increased with sea lion mortality, but the effect of sea lions varied by population.

- Although these higher quasi-extinction risks were estimated after sea lion removals, they cannot serve as an indicator of the success or failure of the sea lion removal effort.

- Ecological factors are the likely proximate cause of recent low steelhead returns and are not evaluated here.

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Background

A previous analysis suggested that California sea lions have a large negative effect on the viability of Willamette River winter steelhead (Falcy 2017). This previous analysis occurred when winter steelhead returns were at their lowest to date and prompted a sea lion removal effort at Willamette Falls from 2018 to 2022.

The goal of the current analysis was to repeat the prior analysis with additional data from 2017 through 2023. The updated data includes winter steelhead spawning surveys, counts at Willamette Falls, and estimates of sea lion mortality. These data influence multiple components of the full analysis by altering spawner and recruit estimates and providing more years in the stock-recruitment analysis. Subsequently, these changes affect the PVA through initialized spawners and draws of stock-recruitment curves.

Methods

See a full description of methods in (Falcy 2017). There were no notable changes to methods except for a few minor code updates when translating the previous MATLAB code to R. The final simulations were run over 500 random parameter values each with 10 replications for a total of 5,000 simulations per population per scenario. The previous analysis ran over 1000 random parameters and 100 replications, but we were limited with processing power.

We kept **sea lion harvest scenarios** in the PVA the same as the previous analysis and added one representative of 2023 sea lion mortality (Table 1). Originally the "2015 sea lions" scenario was chosen to represent the lowest, "2016 sea lions" the middle, and "2017 sea lions" the highest observed sea lion mortality rate. Recent years (2018 to 2023) had lower sea lion mortality rates.

Table 1. *Sea lion harvest scenarios used in the PVA, which were chosen as a combination of incidental angling mortality and sea lion mortality.*

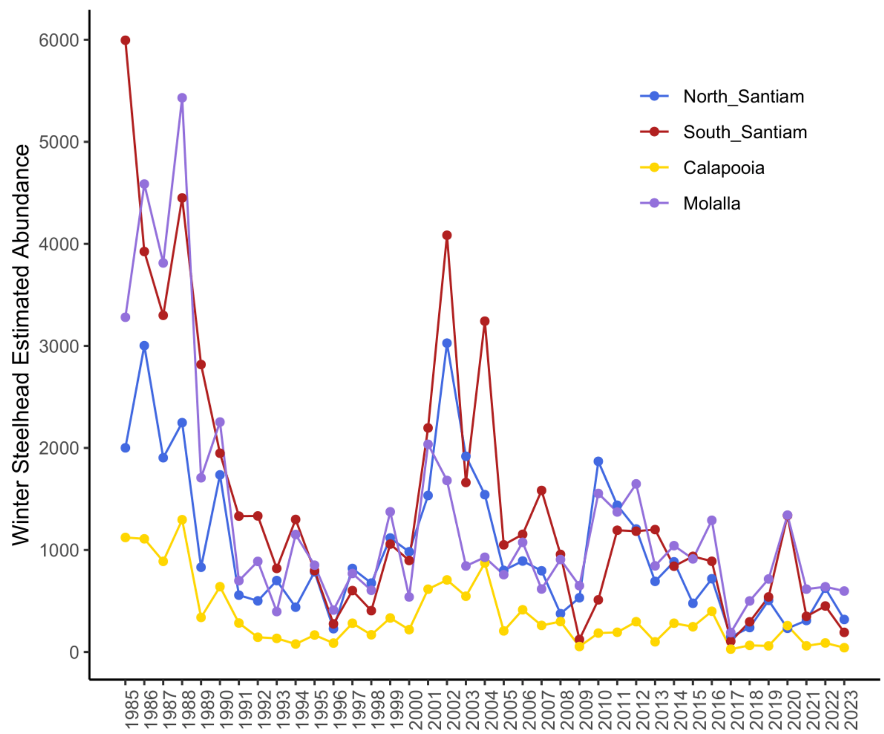
Sea lion scenario	**Incidental angling mortality harvest rate**	**Sea lion mortality harvest rate**	**Total mortality rate used in PVAs**
No sea lions	0.07	0	**0.07**
2015 sea lions	0.07	0.1335	**0.2035**
2016 sea lions	0.07	0.2358	**0.3058**
2017 sea lions	0.07	0.33	**0.4**
2023 sea lions	0.07	0.0167	**0.0867**

Results

Estimating Spawners by Population

Winter steelhead population-specific abundances were estimated for the current time series (Figure 1).

Figure 1. *Wild spawner abundances estimates after expansion, redistribution, and imputation.*



Spawner-Recruit Analysis

The full data set of spawners and recruits (1986 to 2023) were fit to a Ricker stock-recruitment model using Bayesian methods. The productivity parameter (α) was shared among populations, while the rate of compensatory density dependence parameter (β) and variation (σ) were estimated unique to each population.

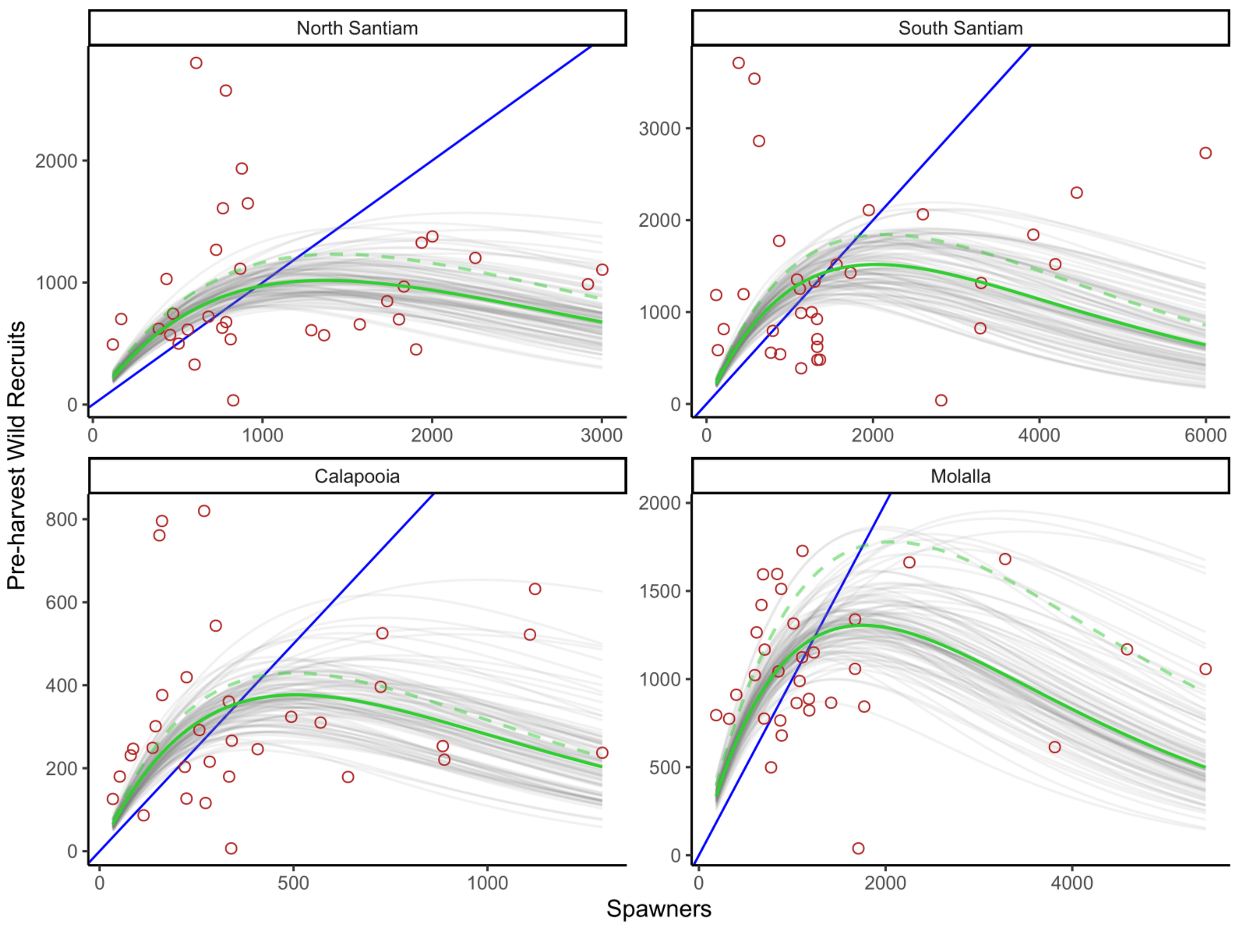
$$R_{t,p} = \alpha S_{t,p} e^{-\beta_p S_{t,p}} e^{\epsilon}, \epsilon \sim N(0, \sigma_p)$$

Mean parameter estimates from the best fit Ricker stock-recruitment model are compared between the current and previous analyses (Table 2; Figure 2). The current productivity parameter (α) estimate (Table 2) and subsequent height of the best Ricker curves (Figure 2) were lower than in the previous analysis due to the inclusion of recent years, which saw low abundances relative to the historic dataset (Figure 1). Compensatory density dependence parameters (β_p) remained at similar values compared to the prior analysis.

Table 2. *Best fit Ricker stock-recruitment model mean parameter estimates. Spawning years used in the respective analysis time series included for current (1985 to 2017) and previous (1985 to 2010) estimates.*

Parameter	**Current estimates**	**Previous estimates** (Falcy 2017)
α	1.896	2.335
$\beta_{\text{N Santiam}}$	0.00071	0.000697
$\beta_{\text{S Santiam}}$	0.00048	0.000466
$\beta_{\text{Calapooia}}$	0.00194	0.002000
β_{Molalla}	0.00055	0.000483

Figure 2. *Posterior predictions of Ricker stock-recruitment models. Gray lines represent a random selection of 100 posterior parameter combinations. Green lines represent mean parameter values where the solid lines are values from the current analysis and dashed green lines are from the previous analysis. Red circles are the estimated wild spawners and their subsequent pre-harvest recruits. The blue line is a 1:1 line indicating perfect population replacement.*



Population Viability Analysis

Updated quasi-extinction probabilities were estimated following the same prior PVA methods but drawing from new sets of posterior stock-recruitment models (e.g., gray lines in Figure 2) (Table 3.). **Current quasi-extinction probabilities were higher than estimated for the previous analysis.** The increased risk is driven by the smaller mean productivity parameter (α) estimate (Table 2). Simulations were initialized with mean spawners from the entire dataset. Therefore, because recent years with low returns are included in the updated PVA, slightly lower abundances of initial spawners may also contribute to increased quasi-extinction probabilities, but the α parameter estimate is likely the dominant driver.

We examined the effect of sea lions on quasi-extinction probability as the difference between extinction probabilities with sea lion mortality and the no sea lion scenario (baseline). The Calapooia population had little change to risk with sea lion mortality because extinction risk remained very high in all scenarios (Figure 3; Table 3). The North and South Santiam populations experienced the greatest increase in quasi-extinction probability with increasing sea lion mortality (Figure 3).

Simulated PVA population dynamics appeared similar to those of the historic time series for all populations (Figure 4).

Table 3. *Quasi-extinction probabilities from the PVA by population and sea lion mortality scenario.*

Scenario	Population			
	N. Santiam	S. Santiam	Calapooia	Molalla
No sea lions	0.081	0.050	0.893	0.002
2015 sea lions	0.232	0.144	0.970	0.015
2016 sea lions	0.515	0.324	0.995	0.093
2017 sea lions	0.819	0.622	1.0	0.366
2023 sea lions	0.088	0.066	0.905	0.001

Figure 3. *Effect of sea lion mortality on quasi-extinction probability. The y-axis represents the difference in quasi-extinction probability between the no sea lion scenario (baseline) and the other four scenarios.*

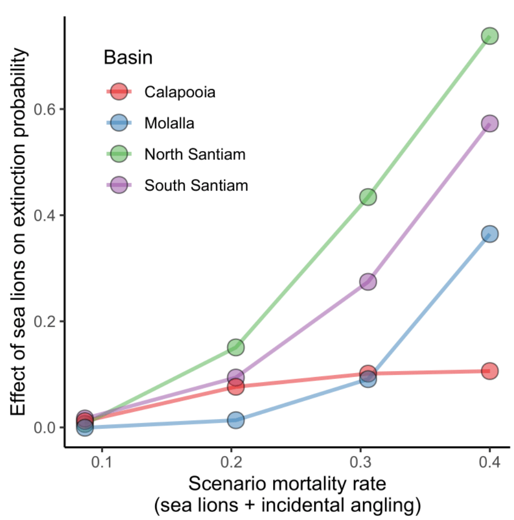
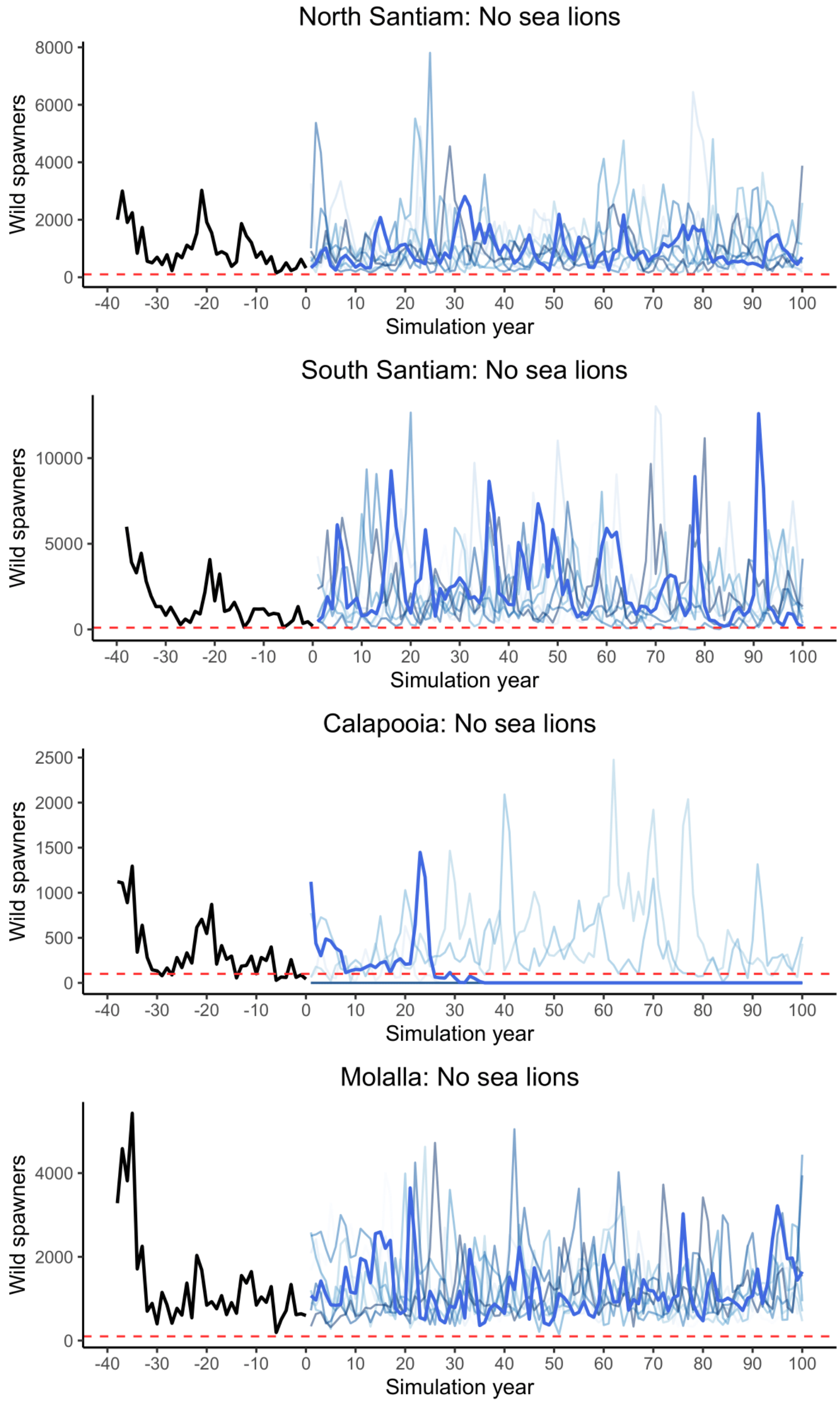


Figure 4. *PVA time series for the no sea lion scenario for all populations. Black line is the observed spawners, blue lines are random samples of predictions, red dashed line is the QET of 100 spawners.*



Conclusions

- **Quasi-extinction probabilities were higher for Willamette winter steelhead populations than when they were estimated using data through 2016.** This result is driven by the inclusion of recent years with low steelhead returns in the analyses, which causes the PVA to simulate fewer recruits per spawner on average.

- **Quasi-extinction probabilities increased with sea lion mortality, but the effect of sea lions varied by population.** North and South Santiam populations experienced the greatest sea lion effect, followed by the Molalla population, and, finally, the Calapooia population. These population differences are driven by the proximity of their abundances to the same quasi-extinction threshold (QET) of 100 spawners.

- **Although these higher quasi-extinction risks were estimated after sea lion removals, they cannot serve as an indicator of the success or failure of the sea lion removal effort.** All recruits have not yet returned for the important spawning years affected by the sea lion removals. The most recent spawning year, from which all recruits have returned, is 2017 and sea lion removal efforts did not start until 2018.

- **Ecological factors are the likely proximate cause of recent low steelhead returns and are not evaluated here**. Instead, recent low steelhead returns caused the mean productivity parameter (α) to decrease in the stock-recruitment analysis.

References

Falcy, M. 2017. Population Viability of Willamette River Winter Steelhead. Oregon Department of Fish and Wildlife.