Redesigning Modern Portfolio Theory to Improve Spatial Recovery Planning for Oregon Coast Coho Salmon

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Problem Statement

Due to overfishing and habitat changes, Oregon Coast (OC) coho salmon populations have significantly decreased, negatively affecting the food web and those who rely on their populations. Conservation managers need to efficiently allocate their budgets to make the most impact, but a framework to do so currently does not exist.

Key Findings

- Across three budget scenarios, conservation investments to populations lead to increase of salmon returns
- Prioritizing critical populations for Indigenous Tribes can be successfully integrated into an optimal budget allocation
- We developed a framework that can be applied to different scenarios with other species and conservation actions

Background

OC coho salmon habitat is currently highly impacted by man-made barriers.

There are

~12,500

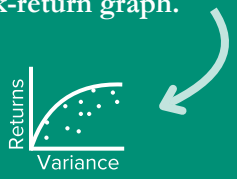
barriers to fish passage across their 21 populations.

Salmon are an essential component to the ecology of forests and rivers; they are prey to bears, birds, and wolves, and restore nutrients to the soil.

Salmon are also sacred to Indigenous Tribes living in Oregon and are integral to preserving their culture.

Modern Portfolio Theory (MPT) is used in finance to inform the effects on returns and variance from investing in a portfolio.

This is visualized in a risk-return graph.



Project Objectives

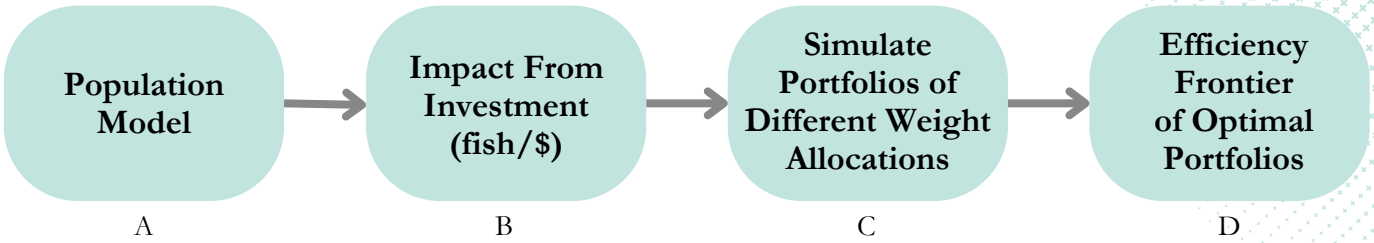
Direct Application: Use Modern Portfolio Theory (MPT) to identify which salmon populations most strongly affect the mean, variance, and covariance of the aggregate populations across the evolutionary significant unit (ESU).

Redesign: Redesign Modern Portfolio Theory as an endogenous conservation framework for conservation of the Oregon Coast coho salmon.

Simulate Portfolios: Implement the endogenous conservation framework to generate optimized portfolios, which maximize returns for a given level of variance, under several budgets.

Share: Organize and annotate reproducible code to create a tool for simulating portfolios under different budgets and restoration actions.

Flow Diagram



Methods and Results

We redesigned Modern Portfolio Theory to improve conservation of OC coho salmon. We estimated equilibrium salmon population abundance for each watershed using the Beverton-Holt population model, as seen in panel A in the flow diagram above. We then designed a new framework to model conservation investment returns, such as barrier removal, and understand how to differentially allocate a fixed budget across the ESU to maximize returns for a given level of variance. To estimate the impact from investment in each population, shown in panel B, we combined the population model, the cost to remove a barrier, and scientific literature. As shown in panel C, we then simulated portfolios using three conservation budgets. Each scenario had 10,000 simulated portfolios, with an additional 2,000 portfolios that prioritized environmental justice (EJ) for populations known to be harvested by Indigenous Tribes. They were prioritized by guaranteeing they had a higher likelihood of receiving a proportion of the budget, to ensure they continue to have access to salmon. Portfolios are simulated budget allocations between OC coho salmon populations. Variance is a measure of the annual change in salmon abundance. Panel D is visualized in Figure 1, with light blue points symbolizing standard portfolios, green points symbolizing environmental justice portfolios, and the black line symbolizing the efficiency frontier. Portfolios that fall along the efficiency frontier represent different optimal budget allocations that a conservation manager could decide between depending on their management goals. If they want to prioritize reducing the volatility of populations, they can pick a portfolio that is lower on the efficiency frontier. If they want to maximize abundance, then they can choose a portfolio higher up the curve. The initial steep curve shows that there can be a large increase of returns from investments, with a relatively low increase of variance. Our results also show that while a majority of equitable portfolios are not optimal, there are several along the efficiency frontier, meaning that equity does not need to be sacrificed to spend budgets efficiently.

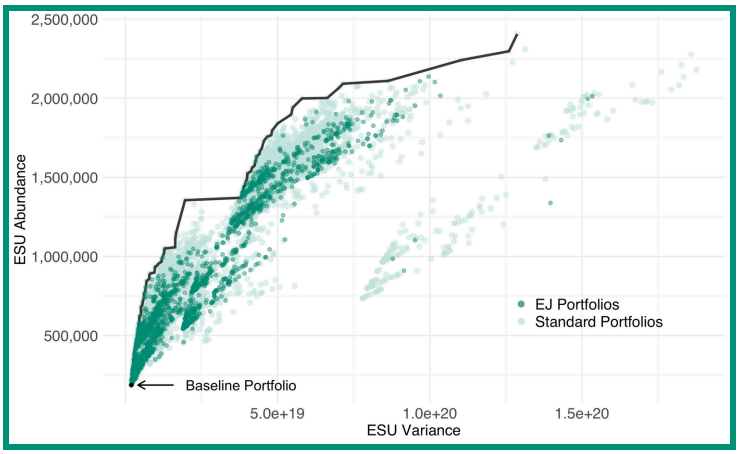


Figure 1. Simulated efficiency frontier for a conservation budget.

Impact and Future Directions

Our results are represented by a case study of utilizing our framework, but our impact is represented by the framework itself. This framework can be used by any conservation manager in any location, with any budget, or any species. It can even be applied beyond species to compare different conservation actions. This versatility is an integral part of our framework and is one of its primary attributes. Our framework will be publicly available on GitHub, along with a "README!" document, for any conservation manager to use at their discretion. To check it out, visit this link.