Overview of a new Management Strategy Evaluation approach for salmonids in WA state

Science Division, Fish Program, Washington Department of Fish & Wildlife

Jan Ohlberger, Thomas Buehrens, and Neala Kendall

August 10, 2023

Question

WDFW's mission is "to preserve, protect and perpetuate fish, wildlife and ecosystems while providing sustainable fish and wildlife recreational and commercial opportunities"

Which management approach 'best' balances biological and socio-economic objectives?


Photo: NOAA fisheries


Photo: Steve Goetz


Photo: Lenny Turcios


Photo: Denis Law


Photo: Michael Schroeder


Photo: Emily Grabowsky


Photo: Gary Kramer

What is a Management Strategy Evaluation?

Management Strategy Evaluation (MSE)

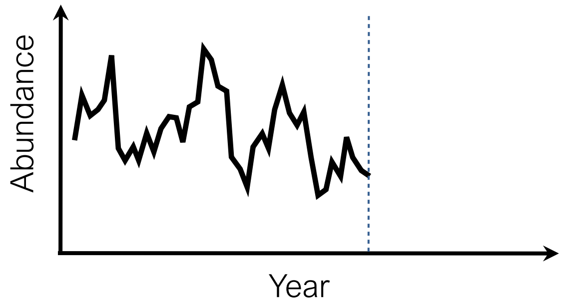
MSE is used to identify the best management strategy among a set of candidate strategies

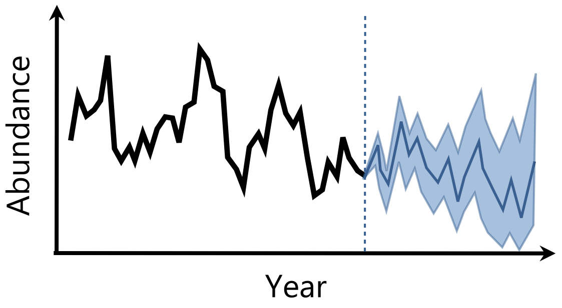
- Evaluates the relative performance of alternative management strategies by modeling the long-term effects of different Harvest Control Rules (HCRs) and quantifies trade-offs among multiple potentially competing objectives

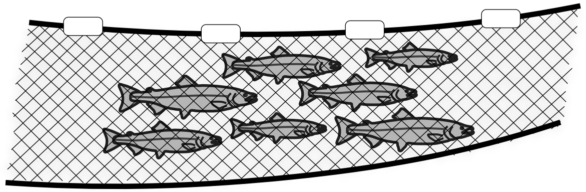
Given what we know about a population from our past observations

How might the future look like if we manage using strategy x, y, z

What does that mean for conservation risks and fishing opportunities?







Management Strategy Evaluation (MSE)

State-of-the-art approach that is increasingly adopted worldwide

Bunnefeld et al. 2011 TREE

Opinion

Cell PRESS

Management strategy evaluation: a powerful tool for conservation?

Nils Bunnefeld[1], Eriko Hoshino[1,2] and Eleanor J. Milner-Gulland[1]

Punt et al. 2016 Fish & Fisheries

FISH and FISHERIES

FISH and FISHERIES, 2016, **17**, 303–334

Management strategy evaluation: best practices

André E Punt[1,2], Doug S Butterworth[3], Carryn L de Moor[3], José A A De Oliveira[4] & Malcolm Haddon[2]

Cunningham et al. 2019 CJFAS

NRC Research Press

ARTICLE

A management strategy evaluation of the commercial sockeye salmon fishery in Bristol Bay, Alaska[1]

Curry J. Cunningham, Christopher M. Anderson, Jocelyn Yun-Ling Wang, Michael Link, and Ray Hilborn

Management Strategy Evaluation (MSE)

How can WDFW use MSEs to improve management plans for salmon and steelhead?

- Evaluate current practices relative to alternative approaches
- Quantify risks and benefits of different management strategies
- Standardize science support to management across regions and species


Photo: NOAA fisheries


Photo: Morgan Bond


Photo: Jason Ching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Fishery Management Plans

Use harvest control rules (HCRs) to determine the total allowable fishing-related mortality

Different types of HCRs

- Fixed harvest rates
- Harvest surplus above escapement goal
- Abundance-based harvest rate tiers

Diversity of methods used to develop HCRs

- Based on stock-recruit analyses
- Habitat capacity estimates
- Professional opinion

Common deficiencies

- No assessment of alternatives
- Conservation risks not quantified
- Not updated as new data become available

Fishery Management Plans

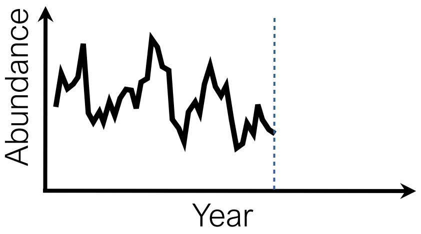
How can Management Strategy Evaluation help?

- Allows comparison of multiple alternative harvest control rules
- Can be used to evaluate conservation risks and fishing opportunities
- Could aid management plans for fisheries that impact ESA-listed populations

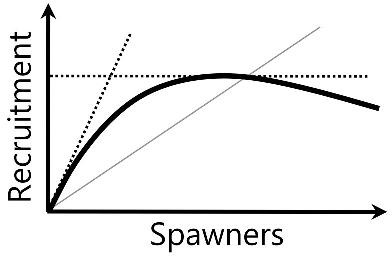
Conceptual outline of proposed MSE process

Conceptual illustration of the MSE process

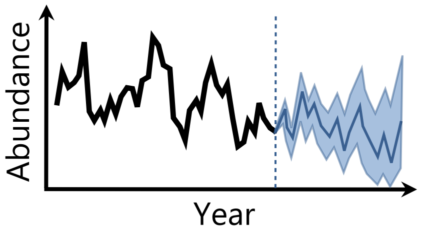
1. Collect available population data



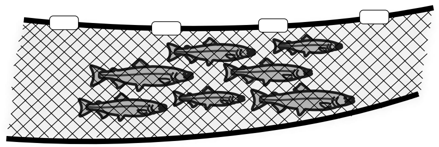
2. Build statistical model given observed data



3. Design management strategies and project population forward



4. Quantify performance trade-offs to inform management plans



Population data

→ Data input →

Integrated Population Model

→ Parameter estimates →

Management Strategy Evaluation

→ Performance metrics →

Fishery Management Plan

Part I – Population Data

Observational data input to population model

- Estimates of escapement abundance (spawner / redd / carcass survey, etc.)
- Harvest estimates and estimates of non-retention mortality
- Age structure information (e.g., scales samples)
- *Smolt abundance estimates (e.g., smolt traps)*

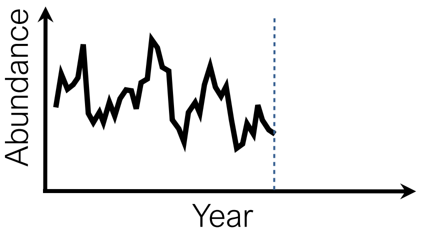

Photo: Devin West

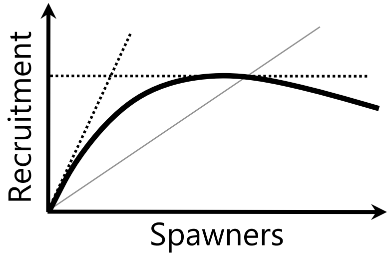

Photo: Marcus Reaves

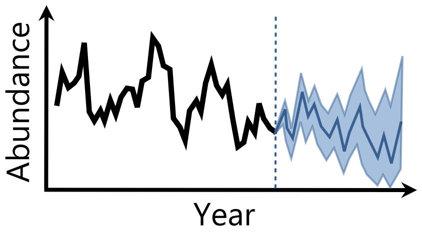

Photo: Elise Olk

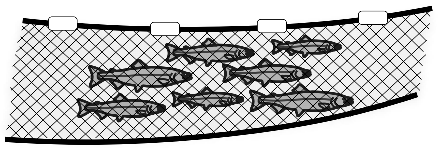

Photo: Pete Verhey

Part II – Integrated Population Model (IPM)

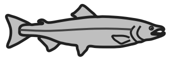








Population data



→ Data input →

Integrated Population Model

→ Parameter estimates →

Management Strategy Evaluation

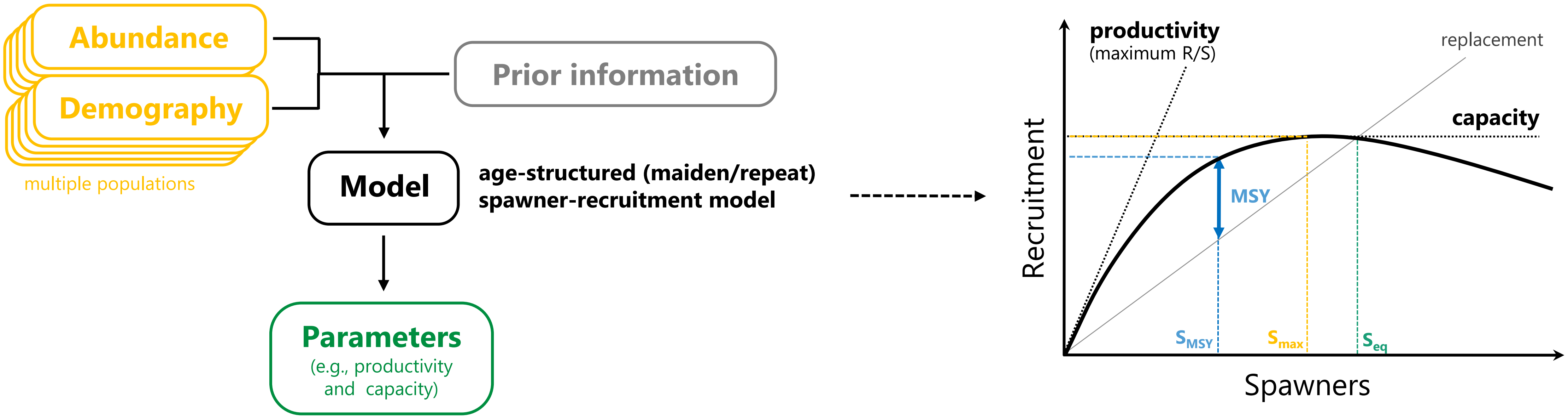
→ Performance metrics →

Fishery Management Plan

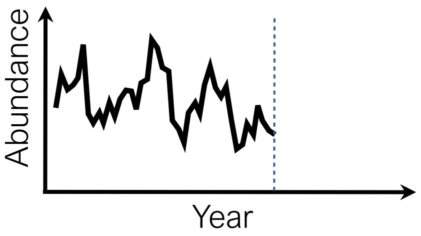
Part II – Integrated Population Model (IPM)

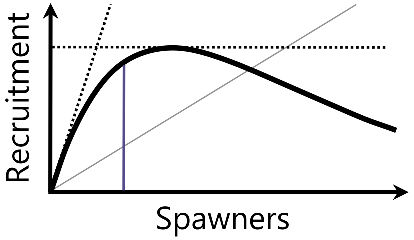
IPMs are statistical population models that integrate multiple sources of information to estimate important population parameters (productivity, capacity, etc.)

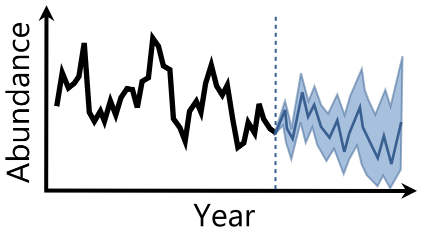
- Integrate information on population abundances and demography (e.g., age structure)
- Allow for sharing of information across populations when fit hierarchically (‘Robin Hood’ approach)
- Can incorporate independent prior information using a Bayesian approach (e.g., observation error)
- Capture full uncertainty in the data by estimating a joint likelihood (propagated to the MSE)

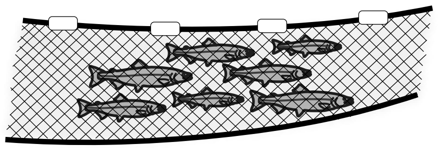


Part III – Management Strategy Evaluation (MSE)

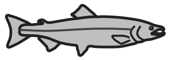








Population data



→ Data input →

Integrated Population Model

→ Parameter estimates →

Management Strategy Evaluation

→ Performance metrics →

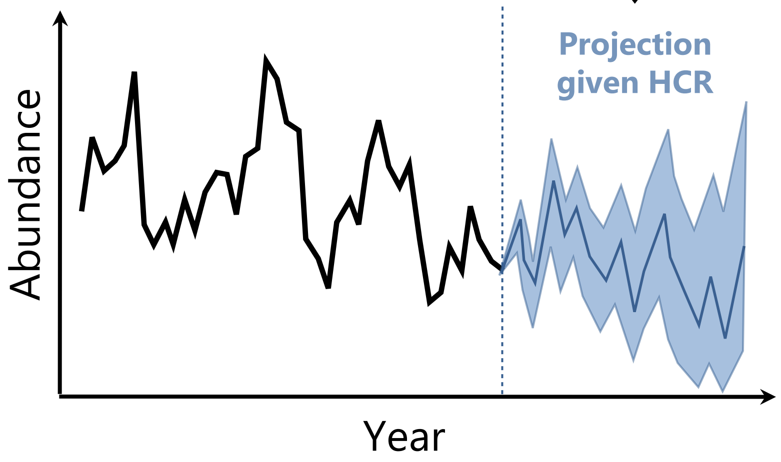
Fishery Management Plan

Part III – Management Strategy Evaluation (MSE)

Project forward given HCR and calculate performance metrics that reflect our objectives

Harvest Control Rules

- Current approach (e.g., escapement goal)
- Escapement goal at MSY (IPM-estimated)
- Fixed harvest rate goals at varying levels
- Hybrid of different state and tribal HCRs
- Abundance-based harvest rate tiers (tied to estimated biological reference points)



Performance metrics

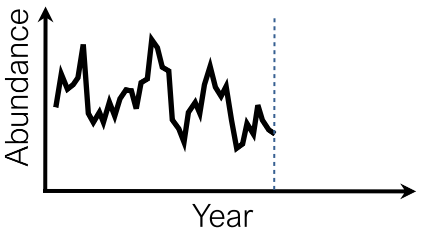
Opportunity metrics

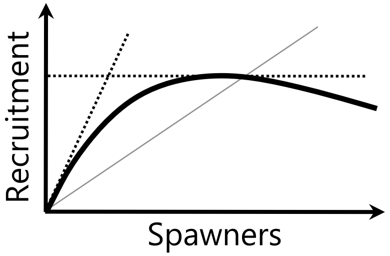
- Mean harvest
- Stability in harvest
- Probability of open fishery

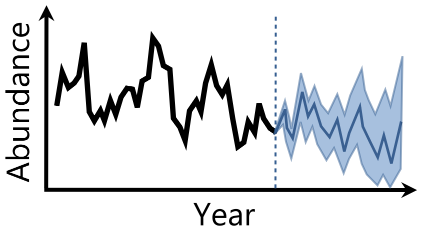
Conservation metrics

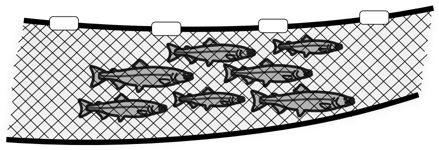
- Mean escapement
- Probability above threshold
- Probability of recovery or quasi-extinction?

Part IV – Fishery Management Plan

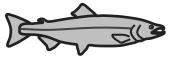








Population data



Data input

Integrated Population Model

Parameter estimates

Management Strategy Evaluation

Performance metrics

Fishery Management Plan

Science → **Policy**

Example: MSE for WA coastal steelhead

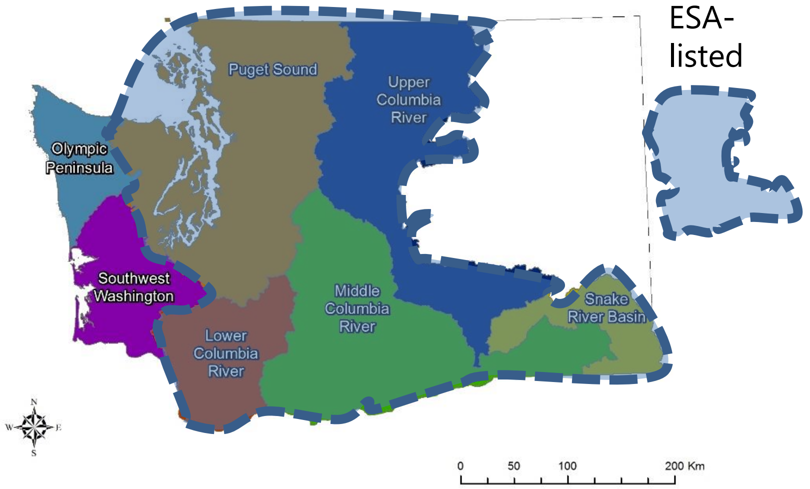
Background

Washington coastal steelhead

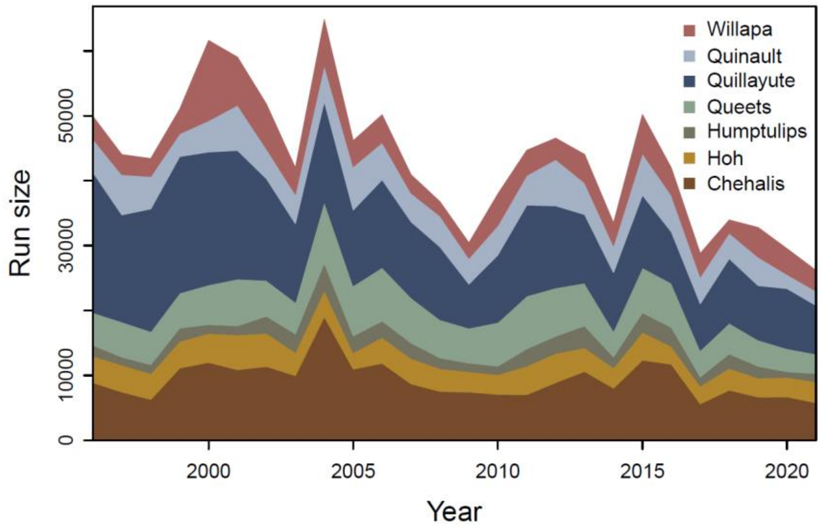
- Olympic Peninsula and southwest WA steelhead not listed under the ESA
- Recent concern over declining trends in steelhead survival and abundance
- Management goals were established in the 1980s using limited data

➢ Assess risks and benefits of alternative fishery management strategies

WA steelhead DPSs (Distinct Population Segments)



Run sizes of WA coastal steelhead populations

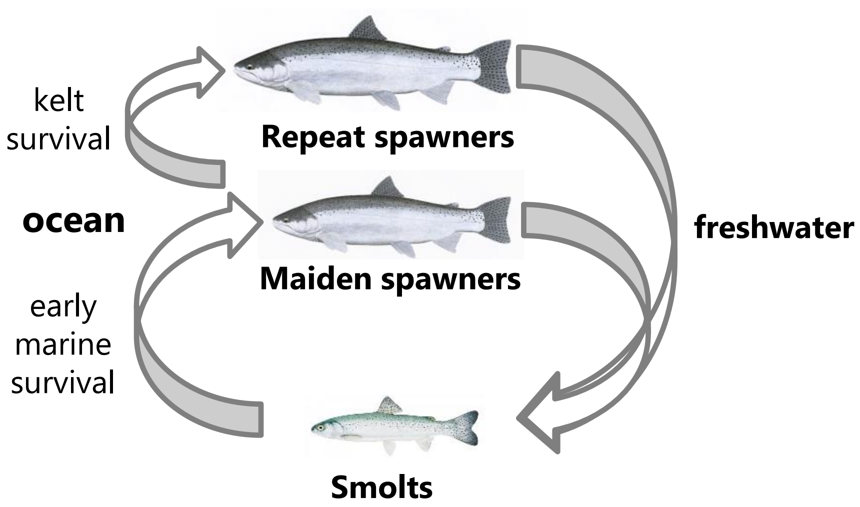


Steelhead IPM

IPM that explicitly models iteroparity

- Uses age composition of maiden and repeat spawners (plus estimates of harvests and escapements)
- Estimates time-varying recruitment residuals and changes in kelt survival rate over time
- Fit to multiple populations: Chehalis, Hoh, Humptulips, Queets, Quillayute, Quinault, and Willapa

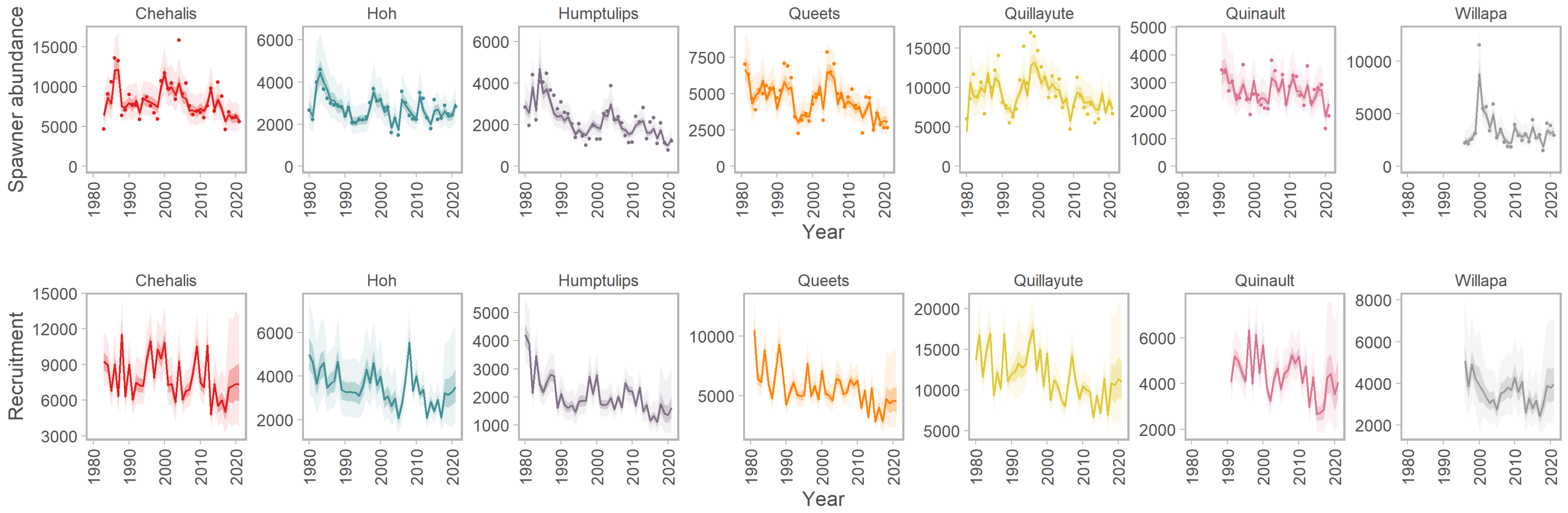
Steelhead life-cycle



Steelhead IPM – multi-population model output

PRELIMINARY RESULTS

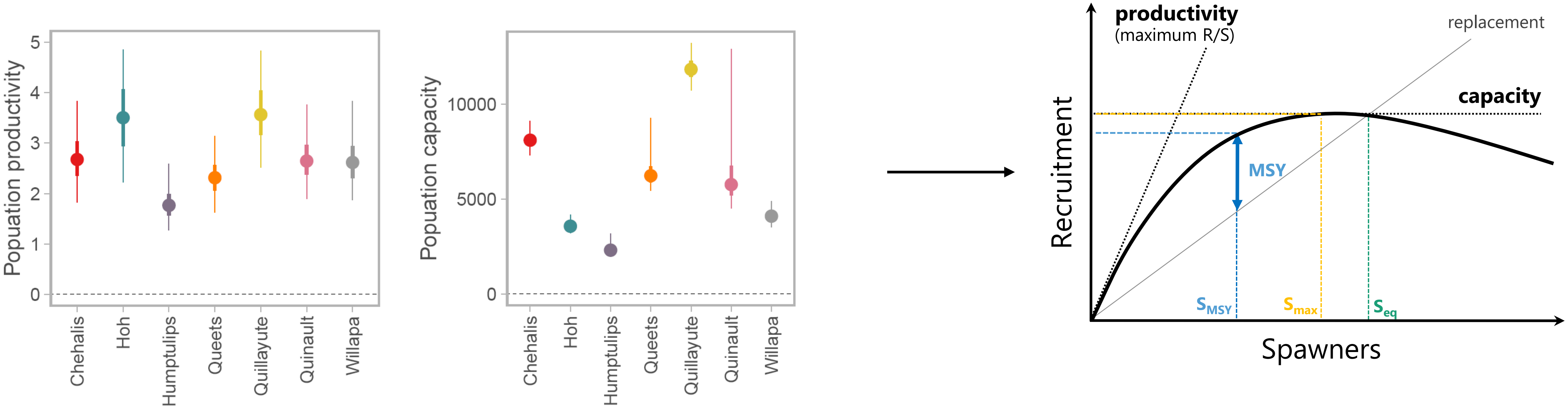
Estimates of spawner abundance and recruitment



Steelhead IPM – multi-population model output

PRELIMINARY RESULTS

Estimates of population productivity and capacity

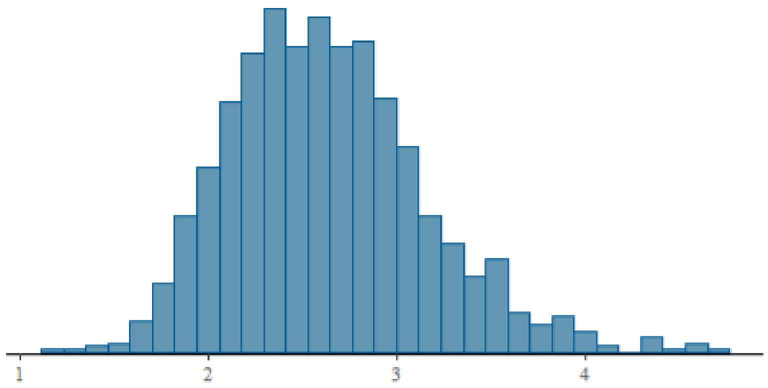


From IPM to MSE

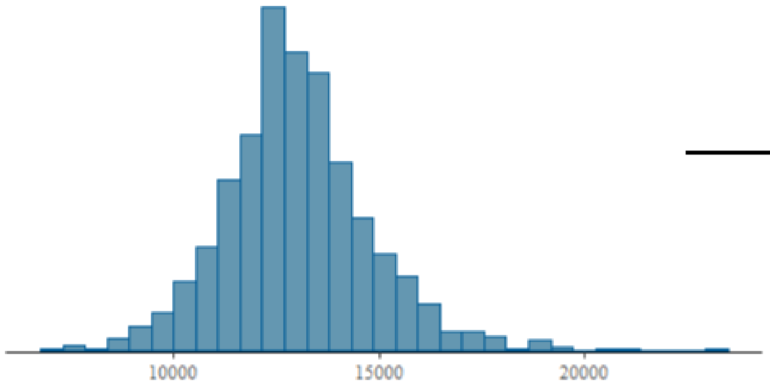
PRELIMINARY RESULTS

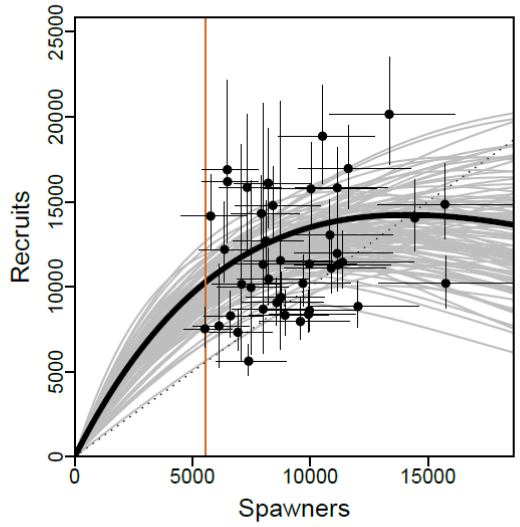
Example: Quillayute River winter steelhead

Productivity
(α or maximum recruits/spawner)



Capacity
(R_{max} or maximum recruitment)





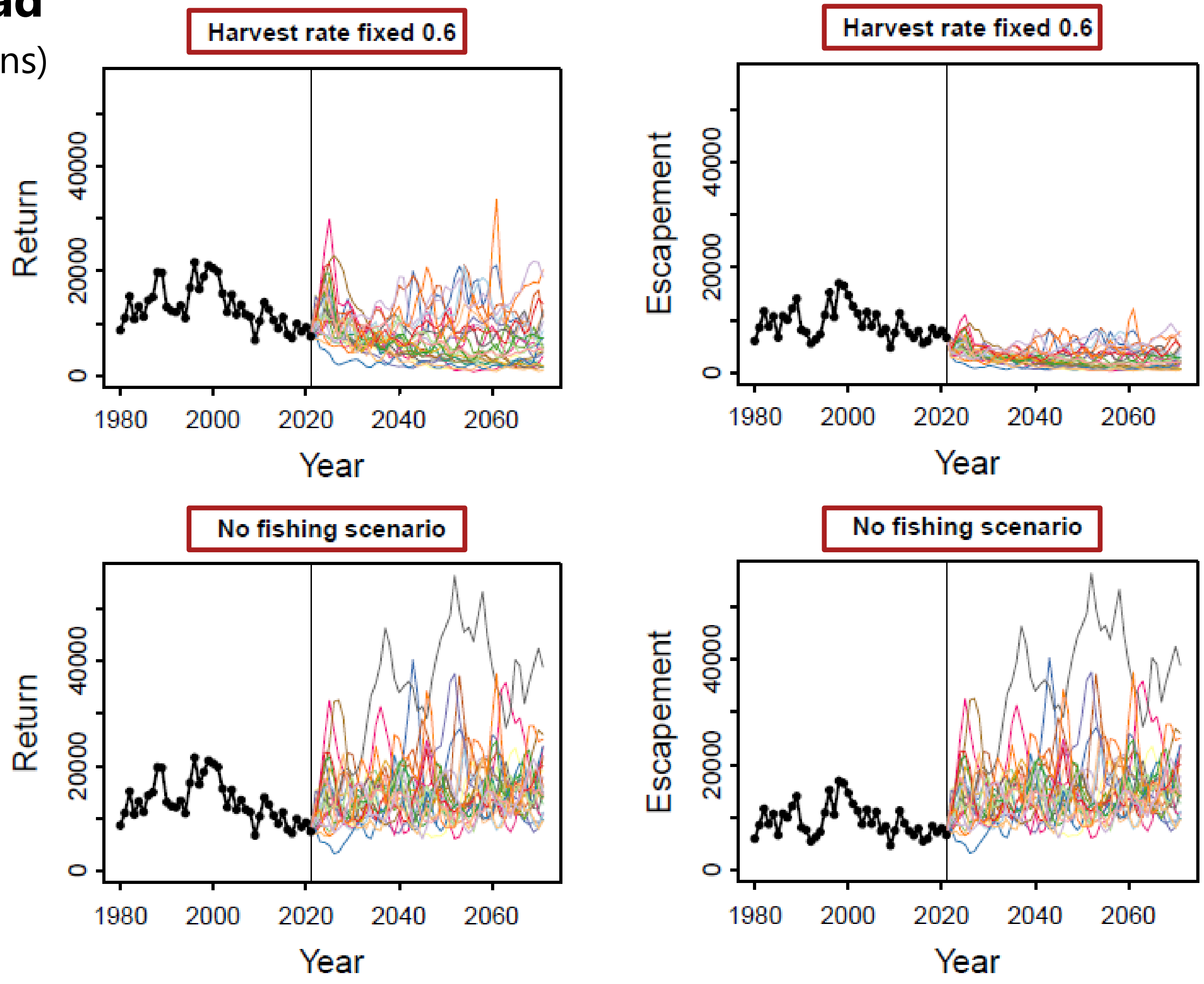
Procedure:

1. Sample one value from joint posterior distribution (productivity, capacity, age proportions, etc.)
2. Project population forward by applying each harvest control rule (e.g., over a period of 50 years)
3. Repeat 1000s of times for each HCR to account for stochasticity (recruitment), parameter uncertainty, and fishery implementation uncertainty

MSE projections

Example: Quillayute River steelhead

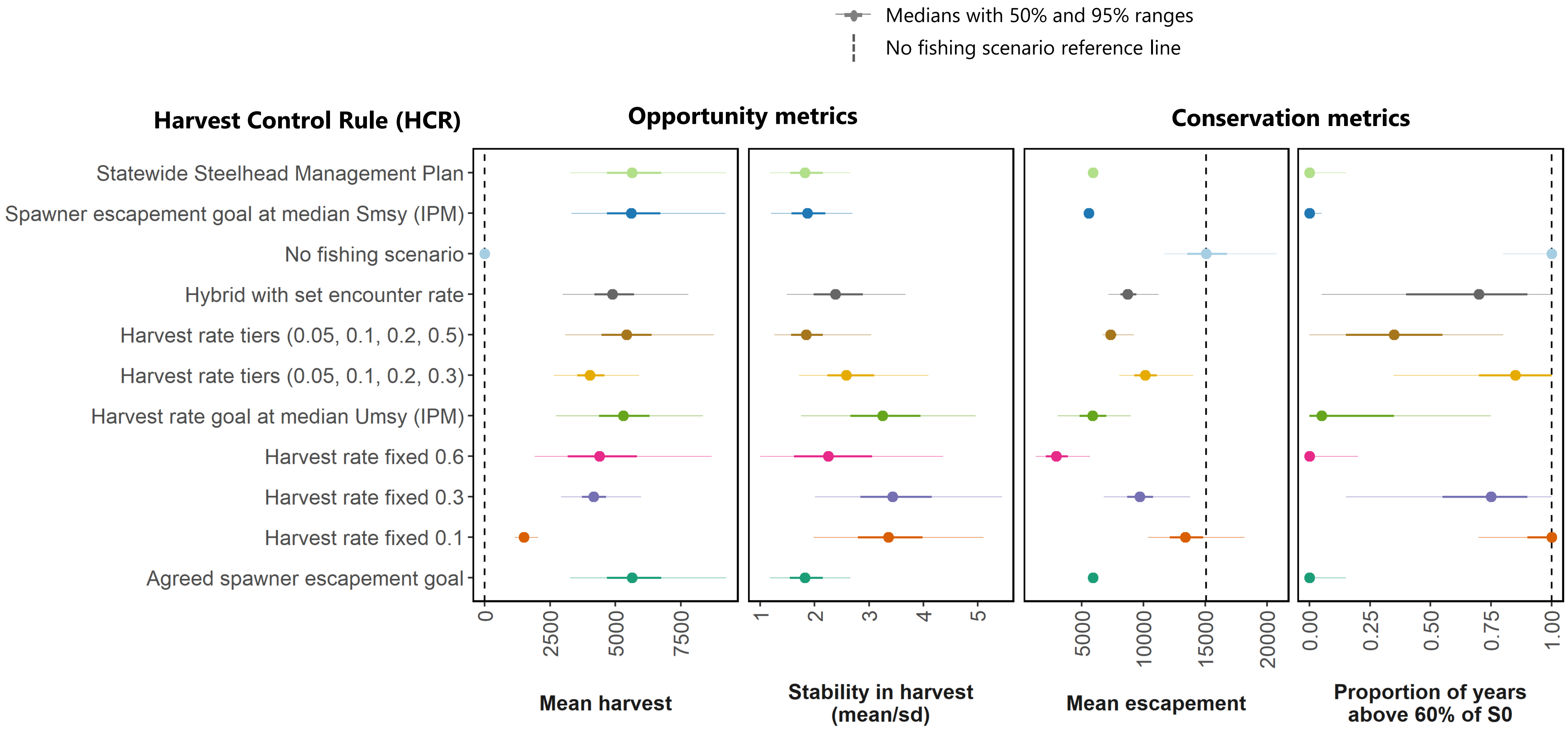
(figures show 25 randomly sampled projections)



Alternative HCRs - performance metrics

PRELIMINARY RESULTS

Example: Quillayute River steelhead



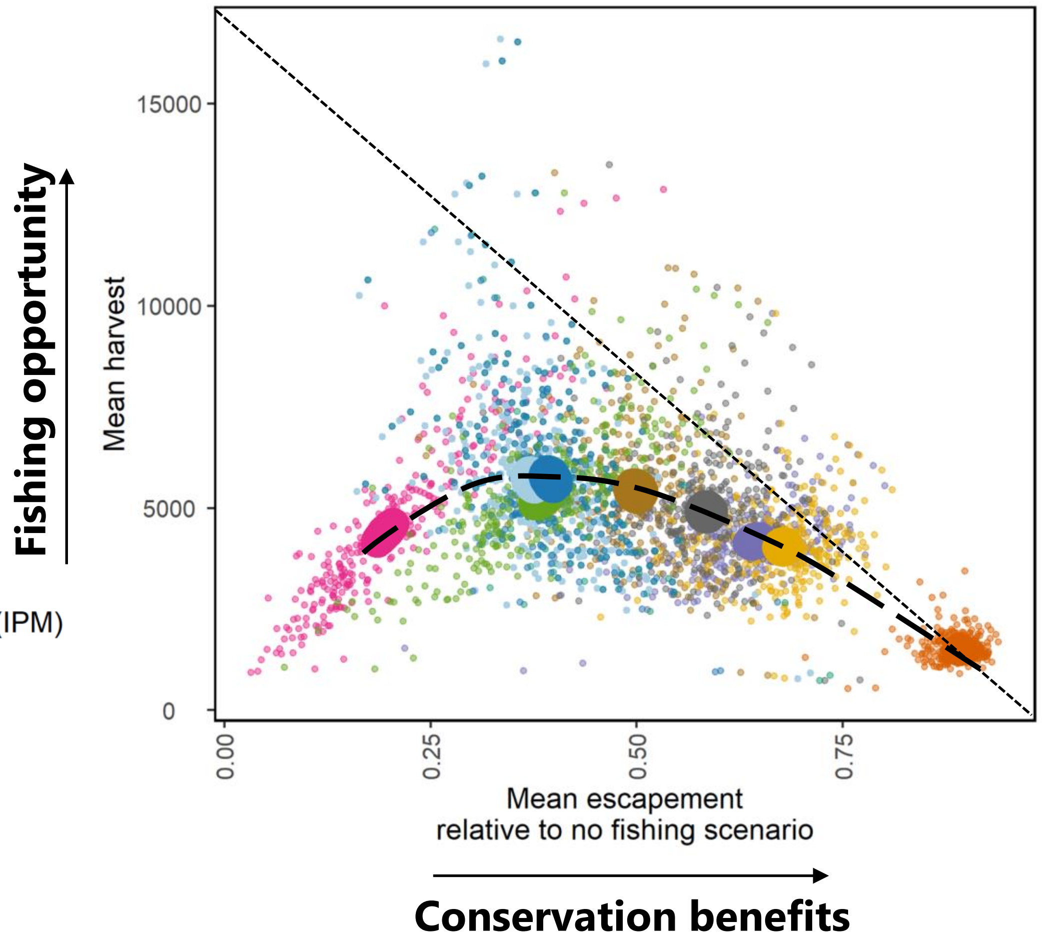
Trade-off between two performance metrics

PRELIMINARY RESULTS

Example: Quillayute River steelhead

Harvest Control Rule (HCR)

- Agreed spawner escapement goal
- Harvest rate fixed 0.1
- Harvest rate fixed 0.3
- Harvest rate fixed 0.6
- Harvest rate goal at median Umsy (IPM)
- Harvest rate tiers (0.05, 0.1, 0.2, 0.3)
- Harvest rate tiers (0.05, 0.1, 0.2, 0.5)
- Hybrid with set encounter rate
- Spawner escapement goal at median Smsy (IPM)
- Statewide Steelhead Management Plan



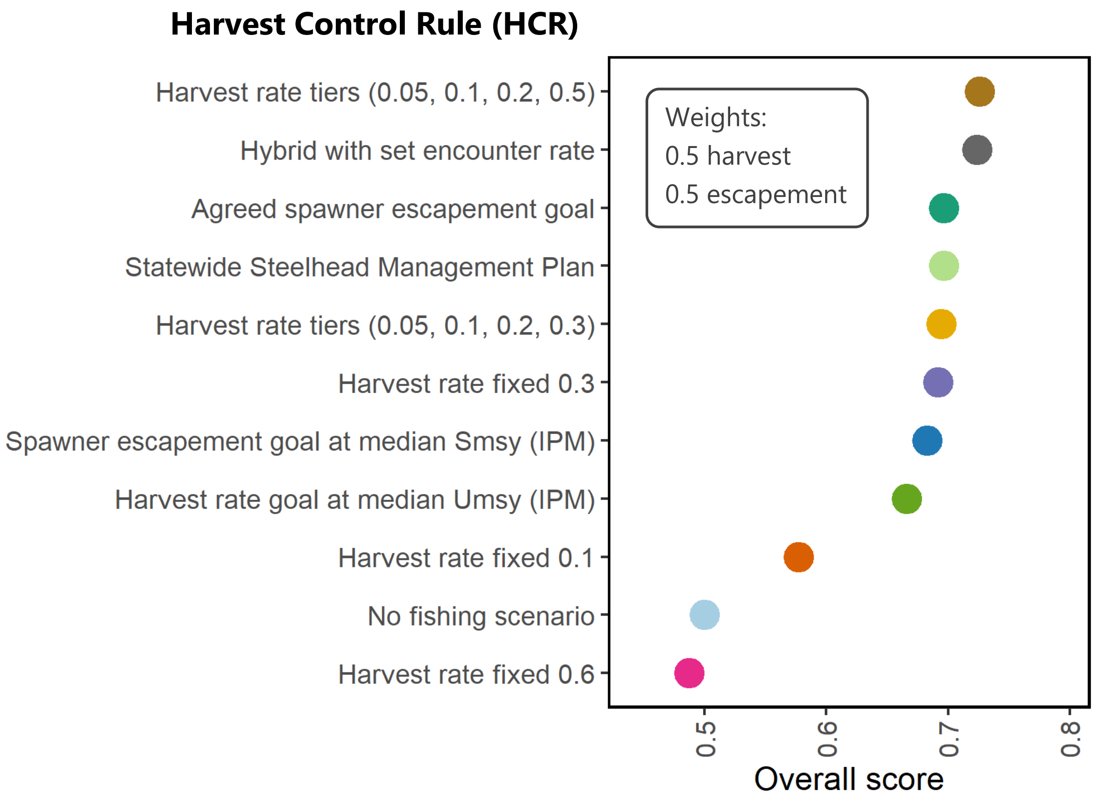
HCR overall scores

PRELIMINARY RESULTS

Based on two or more performance metrics and relative weights

Example:
- Metrics: mean harvest and mean spawner escapement
- Weights: equal for the two performance metrics (0.5/0.5)

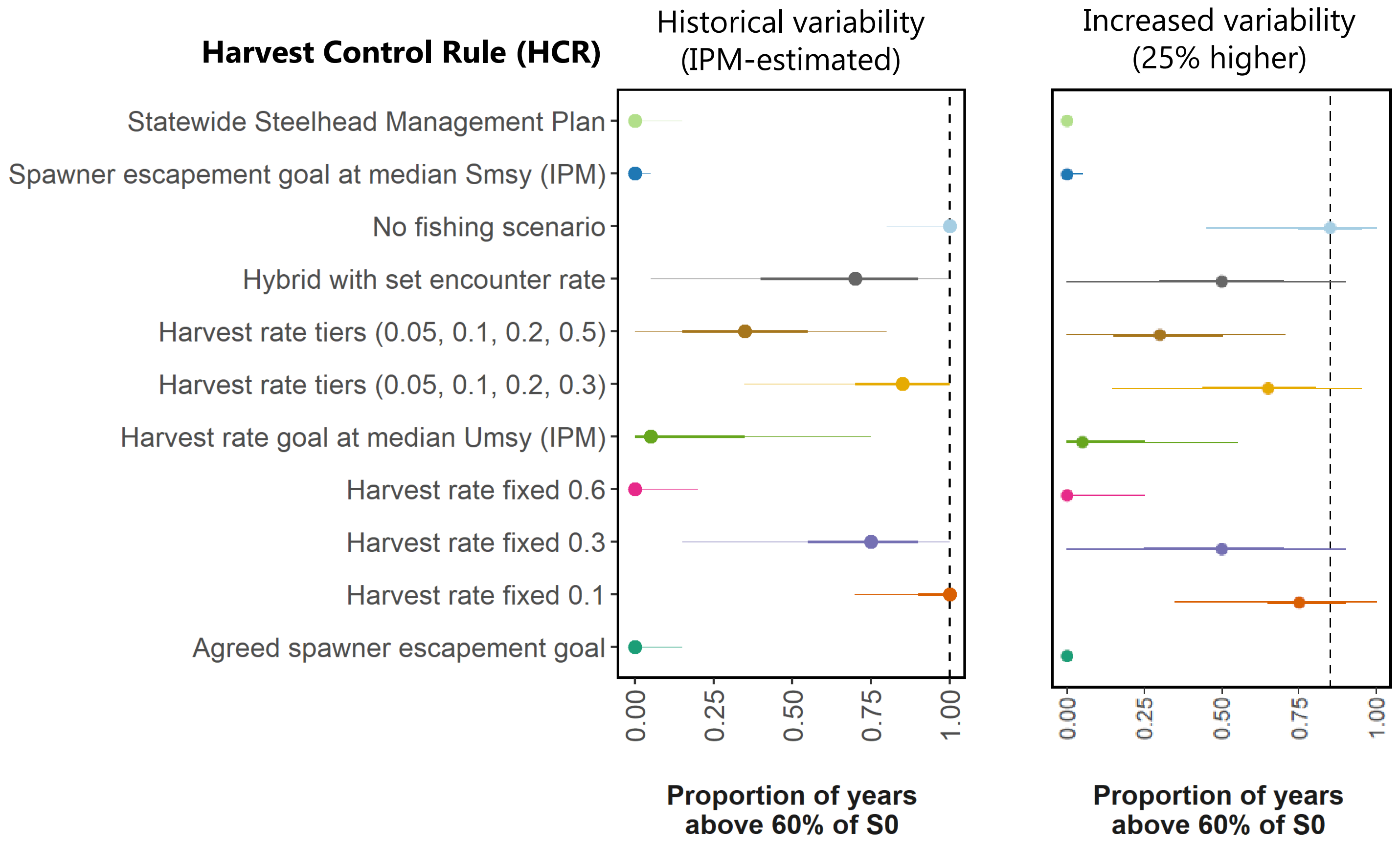
Calculation:
- Metric score: proportion of maximum value across HCRs
- Overall score: sum(metric score * weight)



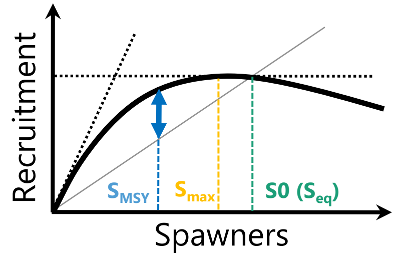
Recruitment variability

What are the effects of increasing recruitment variability on opportunities and risks?

Example: compare IPM-estimated degree of recruitment variability with presumed higher variability in the future



- **Similar relative performance of HCRs but consistently higher conservation risks** (lower proportions of years >60% S0)



Environmental change

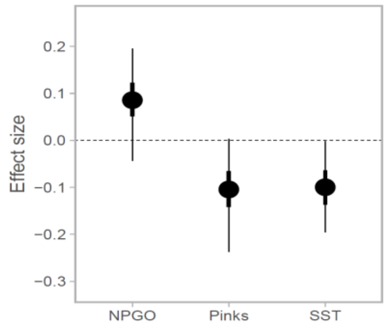
Incorporating future climate or ecosystem change into simulations

Example: use estimated covariate effects on <u>recruitment residuals</u> together with output from climate models

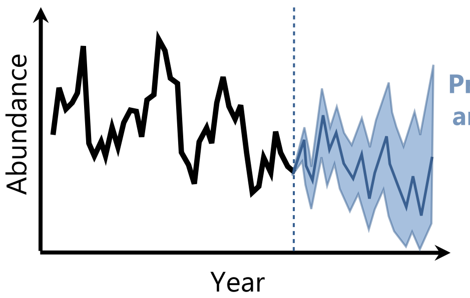
Covariate effects (e.g., climate indices, competition, predation) → Estimate effect → **IPM**

IPM → Parameter estimates → **MSE**

Future projections (e.g., climate projections or ecosystem models) → Apply effect → **MSE**



- NPGO index, NE Pacific pink salmon abundance, and summer SST explain much of the variance (>50%) in recruitment residuals



Projection given HCR and climate scenario

- MSE not yet linked to output from climate or ecosystem models

Summary

Summary

MSE approach can be used to inform resource management plans

- Evaluates the relative performance of any number of alternative management strategies
- Accounts for many sources of uncertainty (observations, estimation, implementation)
- Quantifies fishing opportunities, conservation risks, and their trade-offs
- Can help balance socio-economic and biological objectives
- Several processes have not yet been considered in this MSE framework such as:
  - Accounting for and projecting environmental change (e.g., climate, competition, predation)
  - Incorporating future changes in habitat availability (e.g., development or restauration)
  - Potential contingency plans for unprecedented extreme events (e.g., drought, heat waves)?