Declining patterns of Pacific Northwest steelhead trout adult abundance and smolt survival in the ocean

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Understanding steelhead abundance and marine survival

• What are steelhead abundance & marine survival patterns?

• What environmental variables explain steelhead marine survival?
  • Do similar variables explain marine survival for steelhead from different regions?
  • Do similar variables explain steelhead and Pacific salmon marine survival?
Declining steelhead trout abundance in Puget Sound populations

• Are Puget Sound abundance & marine survival trends different than those in other regions?
• How have they changed over time?
• What environmental and fish characteristics are most related to marine survival trends?
Are marine survival trends spatially correlated among populations?

• For pink, chum, sockeye, Chinook, and coho salmon:
  – Mostly positive correlations across North Pacific Ocean—demonstrating general regional coherence
  – Closer populations are more tightly correlated—demonstrating local coherence

Pyper et al. 2001 CJFAS—pink salmon

What about for steelhead??
Abundance data from 34 wild pops

SAR data from 48 stocks/pops:

- Puget Sound:
  10 hatchery, 2 wild

- Strait of Juan de Fuca:
  1 hatchery, 5 wild

- Coast:
  11 hatchery, 2 wild

- Lower Columbia:
  12 hatchery, 4 wild

- Johnstone Strait:
  1 wild
Steelhead spawner abundance data
Abundances changes 1980s vs. 2000s

Puget Sound average = -53%
Strait of Juan de Fuca average = -34%
Washington coast average = -22%
Lower Columbia River average = -13%
Georgia Basin
Johnstone Strait average = -43%
West coast Vancouver Island

Percent abundance change from 1980s to 2000s
Steelhead marine survival trends

Photos by Morgan Bond
Hatchery & wild marine survival: smolt-to-adult return rates (SAR)

- Percent of smolts leaving freshwater that survival to return as adults

\[
\text{Smolt survival} = \frac{\text{# spawners/hatchery returns} + \text{# catch}}{\text{# smolts}}
\]

Photo: Morgan Bond
How to determine the best groupings?

Multivariate Auto-Regressive State-Space (MARSS)

• Fit models to time-series data using maximum likelihood, includes both process and observation error

• Does not require all data series to cover the same time period

• Provides statistical support for various population/stock groupings $\rightarrow$ best-supported models determined by $AIC_c$
Steelhead marine survival by region

- Washington and Oregon coast
- Lower Columbia River
- Strait of Juan de Fuca
- Puget Sound and Keogh River
Marine survival correlation by distance
Range and strength of marine survival spatial synchrony

• Range:
  – Steelhead: 248 km (95% CI of 200-310 km)
  – Coho: 294 km, 217 km, Chinook: 1019 km, 497 km
  – Pink: 431 km, chum: 564 km, sockeye: “larger than for pink and chum”

• Strength:
  – Steelhead: 0.42 (95% CI of 0.37-0.48)
  – Coho: 0.84
  – Chinook: 0.44, 0.33
Steelhead marine survival time series—breakpoints
Steelhead marine survival summary

• Puget Sound steelhead marine survival has declined over time, especially low since early 1990s

• Puget Sound, Strait of Juan de Fuca, coast, and lower Columbia River steelhead have exhibited different marine survival trends

• Marine survival correlation by distance results support hypothesis that much of the marine mortality occurs during early marine life. Environmental conditions influencing marine survival have unique smaller-scale characteristics.

• Breakpoint analysis suggests different trends among groupings
Next steps (with Kathryn Sobocinski)

• Relating marine survival rates to environmental variables and fish characteristics

• Objectives:
  1.) Develop candidate indicators based on mechanistic understanding
  2.) Aggregate datasets that might be useful as indicators
  3.) Use a combination of statistical tools to evaluate candidate indicators and conduct a retrospective analysis of survival
  4.) Use indicators within a modeling framework to predict future survival (hopefully)

– To be of greatest use, indicators must summarize complex mechanisms and processes related to salmonid survival
Steelhead survival candidate indicators

- **Boundary conditions**
  - Freshwater (e.g., spring river discharge, temperature, turbidity)
  - Ocean (e.g., temperature, upwelling index, sea level)
  - Atmosphere/climate (multivariate ENSO index, wind speed/direction, PDO)

- **Salish Sea conditions**
  - Temperature, chlorophyll concentrations, turbidity, dissolved oxygen, etc.

- **Predators and competitors**
  - Forage fish, finfish, pinnipeds, birds

- **Salmon characteristics**
  - Abundance of outmigrants in the system, including hatchery releases
  - Timing of outmigration
  - Size/growth
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