Ecosystem Indicators Across the Seascape: Integrating Marine and Riverine Processes to Understand Salmon Survival



MAKE WAVES.

Kathryn L. Sobocinski, PhD Skagit Climate Consortium October 27, 2020



COASTAL CONNECTIVITY AND COMPLEXITY

Many species are obligate or facultative users of estuaries and coasts

Understanding the structure and function, interactions, dependencies, feedbacks, and thresholds in these systems is critical for sustainability

Made more critical by anthropogenic change

Management of coastal species and habitats in light of human impacts—and changing systems—is complex

ESTUARIES AS FISH HABITAT

Nurseries (estuarine and coastal habitats) support recipient ecosystems



Sheaves et al. 2015. True value of estuarine and coastal nurseries for fish: Incorporating complexity and dynamics. *Estuaries and Coasts* 38: 401-414.

SALMON AS ECOSYSTEM INTEGRATORS



https://www.fisheries.noaa.gov/west-coast/science-data/pacific-salmon-life-history-research

DECLINE IN MARINE SURVIVAL

Received: 31 August 2016	Accepted: 29 March 2017	
DOI: 10.1111/fog.12222		
		IERIES

ORIGINAL ARTICLE

WILEY FISHERIES COCEANOGRAPHY

Salish Sea Chinook salmon exhibit weaker coherence in early marine survival trends than coastal populations

Casey P. Ruff¹ | Joseph H. Anderson² | Iris M. Kemp³ | Neala W. Kendall² | Peter A. Mchugh^{2,4} | Antonio Velez-Espino⁵ | Correigh M. Greene⁶ | Marc Trudel^{5,7} | Carrie A. Holt⁵ | Kristen E. Ryding² | Kit Rawson⁸

Declining patterns of Pacific Northwest steelhead trout (*Oncorhynchus mykiss*) adult abundance and smolt survival in the ocean 1275

Taylor & Francis

ARTICLE

Neala W. Kendall, Gary W. Marston, and Matthew M. Klungle

Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science

Research Press

Marine and Coastal Fisheries Dynamics, Management, and Ecosystem Science

ISSN: (Print) 1942-5120 (Online) Journal homepage: http://www.tandfonline.com/loi/umcf20

Spatial and Temporal Patterns in Smolt Survival of Wild and Hatchery Coho Salmon in the Salish Sea

Mara S. Zimmerman, James R. Irvine, Meghan O'Neill, Joseph H. Anderson, Correigh M. Greene, Joshua Weinheimer, Marc Trudel & Kit Rawson

BUT IS IT JUST "MARINE"?

ECOSYSTEM INDICATORS ACROSS THE SEASCAPE



What factors influence marine survival in coho and Chinook salmon and steelhead trout?





Sobocinski, Greene, Schmidt, 2017, *Environmental Conservation* Sobocinski, Kendall, Greene, and Schmidt 2020, *Progress in Oceanography* Sobocinski, Greene, Anderson, Kendall, Schmidt, Zimmerman, Kemp, Kim, and Ruff *In review, Ecological Indicators*

CONCEPTUAL FRAMEWORK AND HYPOTHESES



e.g. Human Pop. 🔶

INDICATORS

Indicators should be:

- Theoretically sound
- Respond predictably to ecosystem change
- Integrative
- Relevant to management concerns
- Hypothesis-driven

H1: Predation

-Increases in marine mammals increase early marine mortality



e.g. Seal Abundance

Changing over time



Available



(Niemeijer and de Groot 2008, O'Neill et al. 2008, Kershner et al. 2011)

POTENTIAL INDICATORS

Boundary Conditions

Freshwater (e.g., spring river discharge, timing of max flow, day of year of cumulative flow at 25/50/75%)
Ocean (e.g., temperature, upwelling index, sea level)
Atmosphere/Climate (multivariate ENSO index, NPGO, PDO, NPI)

Salish Sea Conditions

oTemperature, chlorophyll concentrations, stratification

Predators and Competitors

•Forage fish abundance, pinnipeds, other mammals

Salmon Characteristics

Abundance of outmigrants in the system, including hatchery releases
 Timing of outmigration
 Size/Growth

TIME SERIES OF POTENTIAL INDICATORS

Local, Regional, and Global Indicators





Year (Ocean Entry)

ECOSYSTEM CONTEXT MATTERS... AND IT'S NOT STATIC



Figure 5. Non-stationary SST–salmon relationships in the Gulf of Alaska , from Litzow et al. 2018, Proc. R. Soc. B 285: 20181855.

Figure. 9 from Möllmann and Diekmann 2012, Advances in Ecological Research

REGIONAL CONDITIONS INFLUENCE LOCAL CONDITIONS



Estuaries and inland waters are influenced by larger scale ocean processes that are continually changing with warming temperatures, hypoxia, acidification, and other effects of climate change.

Long term sampling at relevant spatial and temporal scales is critical to understanding changing environmental conditions.

From Peterson et al. 2013

NEEDS FOR THE SALISH SEA AND THE SKAGIT ECOSYSTEM

How do relationships between climate indicators and the local expressions of those indicators change (e.g. PDO and SST in the Salish Sea) ?

How do changing freshwater regimes influence estuarine conditions?



WARMING SHIFTS FOOD WEB STRUCTURE AND METABOLISM





O'Connor, MI, Piehler, MF, Leech, DM, Anton, A, Bruno, JF. 2009. Warming and Resource Availability Shift Food Web Structure and Metabolism. PLoS Biol 7(8).

 Temperature is a fundamental driver of fish metabolism (size, growth, energy demand) • Temp. can be predicted from models, but also need information on biological response. Many local species are adapted to temperate systems; temperature (especially summer highs) are increasing faster than evolutionary processes act (i.e. adaptation or selection)

BEYOND SALMON

Salmon integrate across the seascape, but other resident species may be adversely effected

Some of these species support salmon



Thank You!

kathryn.sobocinski@wwu.edu





Results: Driver Groups and Salmon Metrics



Proportion of stable models with negative (dark bars) or positive (light bars) results

From "Data-Free" Conceptual Model to Data-Informed Analysis



 $Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots \beta_n X_n + \varepsilon$

- Many datasets have been identified
- Many are in hand and undergoing preliminary processing (especially boundary conditions)
- Standardizing from 1970-2015 (but getting raw data for the full extent possible)
- Monthly and annual datasets (for versatility in later analysis)
- As spatially discrete as possible (sub-basin scale, if possible)