Variability in North Pacific Ocean Conditions: Assessing Habitat-specific Vital Rates and Thresholds for Fishes

Stephen Brandt and Cynthia Sellinger
Department of Fisheries and Wildlife
Habitat Quality defined by species-specific vital needs
Waters and substrate necessary for spawning, breeding, feeding or growth

EFH often defined geographically

Presence ➔ Densities ➔ Vital Rates ➔ Production
What is good habitat for a pelagic fish in a spatially dynamic system?

How do we define it, measure it and compare it among species and in response to environmental drivers?

Can habitat use be inferred from info on habitat requirements?

What about temporal changes in habitat need or availability?
Pacific Northwest Chinook Salmon

- Spend most of their life (2-4 years) at sea

- Juvenile and Adult marine phase important to survival and reproductive potential

- What defines Marine Habitat Quality for Chinook Salmon??

Adult fall Chinook salmon. (Courtesy of Pacific Northwest National Laboratory)
Chinook Salmon West Coast States Essential Fish Habitat (EFH)


MAP: Chinook Salmon EFH (2014) - Marine Salmon EFH (2014) - 4th Field Hydrologic Unit (HU)
Habitat Quality = Growth Rate Potential

Expected daily growth rate of a fish if placed in a volume of water with known conditions such as prey type, prey size, prey density, temperature, oxygen and light
Why Fish Growth Rate?

- Integrative Response of fish performance – related to survival and reproductive capacity
- Based on fish’s requirements and prevailing environmental conditions
- Differs among species and life stages
- Varies in time and space
- Nonlinear response
G = growth
C = consumption
R = respiration
SDA = standard dynamic action
F = egestion
U = excretion

Consumption = Growth + Respiration + Wastes
Sea Surface Temperature off NW Coast of America

Large-scale Climatic cycles due to El Nino Southern Oscillation (ENSO), Pacific Decadal Oscillation (PDO) and Climate Change

Ted Strub, OSU
Salinity, Temperature and Oxygen Data

Data base = 37,838 CTD, XBT casts for years spanning 1929 - 2013
Fall Spatial Temperature Plots

Year = 1972
Min Depth = 0.60
Max Depth = 10.00

Year = 1984
Min Depth = 0.60
Max Depth = 10.00

Year = 2002
Min Depth = 0.60
Max Depth = 10.00
North Pacific Study Sites

Deep Site

Shallow Site

California Site
Deep Site --2006

Water Temperature (°C)

Dissolved Oxygen (ml/l)

Growth Rate Potential (10^-03) g/g*day
2007

Deep Site

Salmon Growth Rate Potential

Shallow Site

Salmon Growth Rate Potential
Depth in Meters Chinook Salmon Growth Rate Potential Across Different Years

Growth Rate Potential (10^-03) g/g•day (Shallow Site)

2003

2005

Depth in Meters

2006

2007

Chinook Salmon Growth Rate Potential Across Different Years
Salmon Growth Rate Potential
Time Series California Water Temperature

Average = $9.00^\circ$ C
Time Series California Dissolved Oxygen

California DO

Average = 3.62 mg/l
Annual Differences between Warm and Cold year

California 1984

California 1998
Average = 6.00 *E-03 g/g*day
Growth Rate Potential and Statewide Catches of Chinook Salmon

Wilcoxon Rank Sum Test $p = 0.5$—Same mean distribution
$R^2 = .474$
CHINOOK SALMON GRP (G/G*DAY) VS. LANDINGS (LBS)

$R^2 = 0.31$

GROWTH RATE POTENTIAL
Climate Change Impacts on Chinook Salmon
2002 Upwelling Event

- Surface winds push surface water away from an area.
- Warmer surface water moves offshore.
- Deeper, colder, nutrient-rich water rises up from beneath the surface to replace the water that was pushed away.

Phytoplankton and zooplankton are shown in the diagram.
Obtained Wind Speeds and Directions from 27 NOAA Moored Data Buoys with years ranging from 1972 - 2014
Nearshore Hypoxia from 2002 Upwelling

- Development of inner-shelf (<70m) hypoxia
- Between July and September, bottom dissolved oxygen (DO) concentrations of 0.2 – 1.6 ml/l were found.
- DO deficient bottom water occupied 40m of the water column.
- Large numbers of dead fish and invertebrates washing ashore in the affected area.
Applying GRP to Upwelling Events

Oregon 1999

Oregon 2002
Consumption

Function of:
Predator Consumption Capabilities
- predator size, foraging capabilities, temperature, oxygen, light

Prey density
How effective is the species at exploiting the prevailing habitat conditions?
**Growth Rate Potential**
- Measure of habitat conditions
- Quality defined by fishes energetic needs and foraging abilities
- Independent of fish distribution

**Observed Growth**
- Measure of response of fish to habitat conditions
- Depends on fish behavior and distribution (actual or modeled)
Take-Home Messages

- Nonlinearity – Correlations
- Spatial Scales – average across habitats
- Time Scales (events – climate)
- Time Duration (seasonal scope for growth)
- Fish physiology and vital needs filter environmental conditions and thresholds
- Habitat choice options
  (Habitat quality = Habitat use but is a predictor)
Future Research

- Expand Space to 3D Maps of Habitat Quality for Chinook in the NW Pacific Ocean
- Examine multiple year life in the sea
- Link to Observing and global circulation models to forecast changes in Chinook Essential Fish habitat
- Sensitivity to prey densities
- Thresholds or regions of persistent habitat quality
- Add albacore
Questions?

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