Environmental and geographic relationships among (juvenile chinook) forage assemblages in the California Current

Whitney Friedman, Brian K. Wells, Jarrod A. Santora, Isaac D. Schroeder, David D. Huff, Richard Brodeur, John C. Field.
Environmental and geographic relationships among juvenile salmon forage assemblages in the California Current

- **Early Ocean Entry:**
  - Critical period, survival likely affected by availability of resources
  - In turn, hydrographic processes
- **Regional continuity:**
  - Salmon survival (700km)
  - Hydrographic processes
  - Diets match regional forage
- **Objectives**
  - *Examine the biogeographic breaks in juvenile chinook salmon forage assemblages along the CCLME*
  - *Characterize the environmental conditions associated with those geographic breaks*

Environmental and geographic relationships among salmon forage assemblages in the California Current

Outline:

1. Methods, selection of prey species
2. Characterize differences in assemblage composition with NMDS
3. Environmental conditions associated with variability in forage assemblage
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Survey design

- NWFSC Pre-recruit Groundfish Survey (R. Brodeur)
- SWFSC Rockfish Recruitment & Ecosystem Assessment Survey (J. Field)
- Standardized in 2011
  - Mid-water trawl (30m)
  - Night sampling
  - May-June
  - Organisms identified to lowest possible taxon
- Used in analysis:
  - Depth ≤ 200m
  - 2011, 2013-2015
  - 298 hauls, 72 stations

Ralston et al 2015, Brodeur et al 2014
Juvenile salmon forage

- Epipelagic micronekton
- Grouped into lowest taxonomic group (genus or family)
- Known / likely juvenile salmon prey
- Mean size = 37.72 mm
- ≥ 5 hauls
- Krill analyzed separately
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N/S differences in assemblage composition

- NMDS (non-parametric)
- 3 axes (stress = 0.146)
- **Southern species**
  - Market squid
  - Rockfish
  - Sanddabs
- **Northern species**
  - Pacific Sandlance
  - Butter sole

Program R (R Core Team 2015), package {vegan}
N/S differences in assemblage composition

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2015

Northern Anchovy *

Pacific Sardine *

Pacific Hake
N/S differences in assemblage composition

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- 3 axes (stress = 0.146)
- Southern species
  - Market squid
  - Rockfish
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  - Butter sole
- *Diversity & richness - breakpoint @ 40-41’N (Cape Mendocino)*
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Data-assimilative ROMS

Jarrod A. Santora, Isaac D. Schroeder
UCSC

Shchepektin, A. F., and J. C. McWilliams (2005)
Environmental conditions associated with variability in forage assemblage

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* Max correlation among variables < 0.60

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Regression Tree analysis (non-parametric)

- Recursive splitting algorithm based on best value among set of predictor variables that produces two maximally homogenous groups (based on NM score) ⁵
- Pruning: minimize complexity & misclassification

Environmental conditions associated with variability in forage assemblage — CART Results: Axis 1

* $R^2 = 0.57$, RMSE = 0.48
Environmental conditions associated with variability in forage assemblage — *CART Results: Axis 1*

**South***
- North - 2013
  - Slight upwelling, deep isopycnal

**North 2011**
- Stronger downwelling, deep isopycnal
- Stronger downwelling, shallower isopycnal
Environmental conditions associated with variability in forage assemblage — *CART Results: Axis 1*

**South**
North - 2013

**North 2011**

**North 2011**
* butter sole

Slight upwelling, deep isopycnal

Stronger downwelling, deep isopycnal

Stronger downwelling, shallower isopycnal

NMS Sites & Lat

Leaf

- {4}
- {5,6}
- {7}
Environmental conditions associated with variability in forage assemblage — **CART Results: Axis 1**

**South***

North - 2013

- Slight upwelling, deep isopycnal

**North 2011**

- Stronger downwelling, deep isopycnal

- *butter sole*

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Environmental conditions associated with variability in forage assemblage — *CART Results: Axis 2*
Environmental conditions associated with variability in forage assemblage — **CART Results: Axis 3**

\[ R^2 = 0.131, \ RMSE = 0.445 \]
Environmental conditions associated with variability in forage assemblage — **CART Results: Axis 3**
Environmental conditions associated with variability in forage assemblage — **CART Results: Axis 3**

*Mid/Deep*  
**on-shore derived**  
2011, 2014*

*Deep*  
**mixed on/off shore**  
all years

*Shallow, South*  
**off-shore derived**  
2011*, 2013

**NMDS & Taxa**

- Leaf
  - {3}  
  - {4}  
  - {5}

- Taxa:
  - Pacific Hake
  - Sablefish
  - Rockfish
  - Turkeyfish
  - Northern Anchovy
  - Bonito/Rock Sole
  - Market Squid

*Leaf values denote numbers of species sampled within a taxon:*  

- 3
- 4
- 5
Krill

![Graph showing the distribution of Krill with longitude and latitude axes. The graph uses color gradients to indicate the concentration levels of Krill, with darker shades representing higher concentrations. The legend on the right side of the graph indicates the concentration levels, ranging from 5 to 10.]
### Krill

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<th>GAM Results</th>
<th>df</th>
<th>AICc</th>
<th>ΔAICc</th>
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<tr>
<td>log(krill) ~ iso26_depth_m4 + ui_m4 + temp_m0</td>
<td>8</td>
<td>1644.30</td>
<td>0.00</td>
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<td>log(krill) ~ iso26_depth_m4 + ui_m4 + temp_m0 + u_m0</td>
<td>9</td>
<td>1646.00</td>
<td>1.70</td>
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<tr>
<td>log(krill) ~ iso26_depth_m4 + temp_m0</td>
<td>7</td>
<td>1646.13</td>
<td>1.83</td>
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- **26.0 Isopycnal depth** 4 months prior
- **Upwelling Index** 4 months prior
- **Temperature @ haul month**

**Predicted Abundance**
Conclusions

• N/S, on-shore/off-shore differences in hydrographic conditions and forage communities
• Split at Mendocino / Blanco in juvenile Chinook forage assemblages, related to differences in the timing, intensity and structure of upwelling.
• Spatial variability in the forage community matches this spatial co-variability of Chinook salmon survival (Kilduff et al 2014)
• Indicator species in South were consistent across years (rockfish, market squid, sanddabs)
• Interesting increases in 2015 in South (N. Anchovy, Rex Sole, Pacific Hake)
• Northern indicator species were fewer and year-specific:
  • Butter sole was most consistent, but also showed increase in 2011, along with increased downwelling in late-winter (and increased westward Ekman transport in spring).
• Coast-wide community comprised largely of off-shore species.
• Diversity of Nth / Sth species matches diet analyses
• Differences in resilience between Nth / Sth assemblages and juvenile salmon survival?
Acknowledgements

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Keith Sakuma

NWFSC Pre-recruit Groundfish Survey Teams
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