Cross-shelf Variability in Hydrography, Zooplankton and Juvenile Chinook Salmon Diets in Relation to the Columbia River Plume

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Columbia River Plume

1) Columbia River is the largest river on Pacific Coast of North America (90% of freshwater entering the Pacific between San Francisco and the Strait of Juan de Fuca)

2) Plume effects can extend 300-400 km seaward and 500 km southward during summer where it interacts with winds, tides, and currents

3) Substantial interannual and seasonal variability in flow patterns

Columbia River Plume can be an extremely dynamic feature in space and time
1) Columbia River is important source of nutrients to the coastal environment: Fe, Si and N

2) Chlorophyll peaks as N is supplied by mixing and input from river

June 1997 observations, Bruland et al.
AVHRR imagery for day 143, 1999, showing a warm plume influencing a large region of the coast (thin warm, fresh water)
SeaWiFS Satellite Imagery: Columbia River Plume

8-day Composites: May 1999

(A. Thomas, Univ. of Maine)
RADARSAT-1 SAR Sea Surface Roughness

Tide: early-flood

Wind: 4.2 m/s

(P. Clemente-Colon, NESDIS)
RADARSAT-1 SAR
Sea Surface Roughness

Shipboard and aerial data show rapid propagation of the plume into coastal waters

(P.Orton, OGI)
Columbia River Plume Definitions

- Temperature not very satisfactory especially at outer margin
- Chlorophyll or turbidity also not reliable along inside margin
- Nutrients may be a good indicator of plume but not conservative
- Salinity may be the best measure but what level do you use (31.0 or 32.5 psu?)
Objectives

1) Examine physical, chemical and biological measurements along a single transect through the plume to determine objective measures of plume habitat

2) Compare zooplankton composition and food habits and feeding intensity of salmon inside and outside the Columbia River Plume.

3) Make quantitative comparisons of the prey selectivity of juvenile chinook salmon relative to what is available in the water column
Methods

- CTD casts down to 60 m with bottle collections at 3 m
- Oblique meter net tows from 30 m to surface neuston tows at every trawl station
- Plankton identified to species and counted for larger size fraction eaten by salmon
Methods

- Surface trawls along transects from northern Washington to Newport, Oregon
- Salmon frozen at sea and stomachs removed and prey analyzed to species in the laboratory
Species (or lowest identified taxa) data were used in cluster and Nonmetric Multidimensional Scaling analyses of Meter Net, Neuston Net and Salmon Stomach Composition.
Methods

Temp. (3 and 10 m)
Salinity (3 and 10 m)
PO₄
Si(OH)₄
NO₃
NO₂
NH₄
Stability
Chlorophyll (1 m)

Abiotic variables were also analyzed in a similar manner and compared to biotic variables.
Results
Inshore-Offshore Variability

May 18-25, 1999
1m Salinity

May 18-25, 1999
Chinook Salmon Catches (#/Km²)
0.0 (square), 1.0 (circle), 0.1 or 1.1 (triangle)
Columbia River Transect (May 20-21, 1999)

- **Salinity (PSU)**
  - Y-axis: 0 to 32
  - X-axis: 0 to 50

- **Chlorophyll (mg l⁻¹)**
  - Y-axis: 0 to 5
  - X-axis: 0 to 50

**Plume**
Columbia River Transect (May 20-21, 1999)

Distance Offshore (nm)

Si(OH)₄ (micromolar)

Total N or PO₄ (micromolar)

Plume
Environmental Data Cluster by Station

Five variables (3 m T, 3 and 10 m S, Si(OH)$_4$, and NO$_3$) account for 96% of the difference among groups.
Meter Net Composition

- Fish
- Decapods
- Euphausiids
- Hyperiids
- Pteropods
- Copepods
- Other

%N

CR07  CR10  CR15  CR20  CR25  CR30  CR40

Plume
Meter Net Cluster

Similarity

Plume

10 15 20 30D 30N 7 25 40
Neuston Net Cluster

Similarity

Plume
Chinook Diet Composition

%N

Fish
Decapods
Euphausiids
Hyperiids
Pteropods
Copepods
Other

CR07  CR10  CR15  CR20  CR25  CR30  CR40

Plume
Salmon Stomach Content Cluster

Similarity

Plume
<table>
<thead>
<tr>
<th></th>
<th>Meter</th>
<th>Neuston</th>
<th>Stomachs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gelatinous ZP</td>
<td>Some inshore and in plume</td>
<td>Lots inshore and in plume</td>
<td>Very few</td>
</tr>
<tr>
<td>Copepods</td>
<td>Many in plume</td>
<td>Few in plume</td>
<td>Very few</td>
</tr>
<tr>
<td>Euphausiids</td>
<td>Many offshore</td>
<td>Some in plume</td>
<td>Mostly offshore</td>
</tr>
<tr>
<td>Decapods</td>
<td>Some inshore and in plume</td>
<td>Few in plume</td>
<td>Mostly inshore and plume</td>
</tr>
<tr>
<td>Pteropods</td>
<td>Some in plume</td>
<td>Some offshore</td>
<td>Mostly in plume</td>
</tr>
<tr>
<td>Hyperiids</td>
<td>Few inshore and in plume</td>
<td>None in plume</td>
<td>Mostly in plume</td>
</tr>
<tr>
<td>Fishes</td>
<td>Few, mostly larvae</td>
<td>Some in plume</td>
<td>Many in all habitats</td>
</tr>
</tbody>
</table>
Larger and more heavily pigmented prey are apparently selected over smaller and more cryptic colored prey.

- Fishes, decapod larvae, and hyperiids are positively selected
  - Euphausiids (adults and juveniles) and copepods negatively selected

Log of Odds Ratio (O)

\[ L = \ln \left( \frac{p_d \cdot q_e}{p_e \cdot q_d} \right) \]

- \( p_d \) = % of diet of taxon
- \( p_e \) = % of taxon in environment
- \( q_d \) = % of diet of all other taxa
- \( q_e \) = % of all other taxa in environment
Similarity of Matrices

- **Meter and Neuston**
  \[ \rho = 0.37; \ p = 0.07 \]

- **Meter and Stomachs**
  \[ \rho = 0.33; \ p = 0.12 \]

- **Neuston and Stomachs**
  \[ \rho = 0.57; \ p = 0.003 \]
Conclusions

• Distinct cross-shelf variation was observed in biotic and abiotic variables

• Some plume effects are apparent on zooplankton composition and diets

• Salmon appear to feed selectively on most conspicuous prey (large/heavily pigmented) and show more similarity overall to the composition in the neuston than in the whole water column
Acknowledgments

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## Percent Similarity Indices by Station

Columbia River Transect
May 1999 Day Samples Only

<table>
<thead>
<tr>
<th>Station</th>
<th>Meter - Neuston</th>
<th>Meter - Diet</th>
<th>Neuston - Diet</th>
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<tbody>
<tr>
<td>CR07</td>
<td>24.39</td>
<td>3.36</td>
<td>1.37</td>
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<td>CR10</td>
<td>--</td>
<td>1.83</td>
<td>--</td>
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<td>CR15</td>
<td>20.04</td>
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<td>14.11</td>
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<td>20.56</td>
<td>21.23</td>
</tr>
<tr>
<td>CR40</td>
<td>60.52</td>
<td>0.03</td>
<td>0.02</td>
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