Resource Partitioning and Life History Patterns Among Salmonids in the Estuarine Habitat Mosaic

Bethany Craig, Chris Eaton, and Si Simenstad

University of Washington
May 26, 2010
Salmon in the Estuarine Nursery

Estuary hypothesized to provide:

1. Acclimatization to salinity
2. Protection from predators
3. Optimal foraging opportunity

Simenstad et al. 1982
Resource Partitioning

“differences in the way species in the same community utilize resources”  
Schoener 1974

Resource Axes:

• Temporal
• Spatial  
  (habitat)
• Trophic (diet)
Life history patterns

• The particular pathway that a individual or group takes through space and time (Liss et al 2006)
  – Movements/migrations between habitats and amount of time (residence) spent in habitats
Objectives

• Examine how different salmon species and life histories use heterogeneous estuarine habitats
  – Resource partitioning among juvenile coho, chum, and Chinook salmon
  – Life history patterns among juvenile coho salmon
Grays River Estuary

Columbia River Estuary

Grays Bay

Grays River
Johnson Farm
Restoring Emergent Wetland

Natural Forested Wetland
JOHNSON FARM
RESTORING EMERGENT WETLAND
NATURAL FORESTED WETLAND
Resource Partitioning
Results: Temporal Partitioning

- Bimodal migration
- Chum earlier than coho/Chinook
- Coho/Chinook early peak in 2008
Results: Spatial Partitioning

Jan - Mid-May 2008
Jan - Mid-May 2009
Mid-May - Jul 2008
Mid-May - Jul 2009

- Forested
- JohnsonE
- JohnsonW
- River

- Coho >60mm
- Coho <60mm
- Chum
- Chinook >60mm
- Chinook <60mm
Results: Trophic Partitioning

Relative gravimetric diet composition

- Larger fish - epibenthic prey
- Smaller fish - drift insects
Schoener’s Index of Overlap

\[ \alpha = 1 - 0.5 \sum |p_{xi} - p_{yi}| \]

for all \( i \), where \( p_{xi} \) is the proportion of item \( i \) in group \( x \) and \( p_{yi} \) is the proportion of item \( i \) in group \( y \)

\[ 0 \leq \alpha \leq 1 \]

1 - complete overlap
0 - complete partitioning
\(<0.60 - some partitioning\)
## Indices of Overlap

<table>
<thead>
<tr>
<th>Species Pair</th>
<th>Temporal</th>
<th>Spatial</th>
<th>Trophic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chinook ≤60mm – Chinook &gt;60mm</strong></td>
<td>0.464</td>
<td>0.821</td>
<td>0.384</td>
</tr>
<tr>
<td>– Chinook &gt;60mm</td>
<td>0.481</td>
<td>0.446</td>
<td>0.442</td>
</tr>
<tr>
<td>– Chum</td>
<td>0.481</td>
<td>0.446</td>
<td>0.442</td>
</tr>
<tr>
<td>– Coho ≤60mm</td>
<td>0.650</td>
<td>0.489</td>
<td>0.299</td>
</tr>
<tr>
<td>– Coho &gt;60mm</td>
<td>0.530</td>
<td>0.408</td>
<td>0.250</td>
</tr>
<tr>
<td><strong>Chinook &gt;60mm – Chum</strong></td>
<td>0.039</td>
<td>0.410</td>
<td>0.409</td>
</tr>
<tr>
<td>– Coho ≤60mm</td>
<td>0.331</td>
<td>0.397</td>
<td>0.432</td>
</tr>
<tr>
<td>– Coho &gt;60mm</td>
<td>0.715</td>
<td>0.389</td>
<td>0.264</td>
</tr>
<tr>
<td><strong>Chum – Coho ≤60mm</strong></td>
<td>0.440</td>
<td>0.752</td>
<td>0.482</td>
</tr>
<tr>
<td>– Coho &gt;60mm</td>
<td>0.052</td>
<td>0.423</td>
<td>0.257</td>
</tr>
<tr>
<td><strong>Coho ≤60mm – Coho &gt;60mm</strong></td>
<td>0.405</td>
<td>0.734</td>
<td>0.352</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>0.411</td>
<td>0.538</td>
<td>0.357</td>
</tr>
</tbody>
</table>

Primary | Secondary
• Hypothesis: Expect greater ration sizes when overlap is minimal

• Results: Not apparent from regression of ration against any indices of overlap
Conclusions: Resource Partitioning

- Dominant mechanism: Trophic
  - Ontogenetic diet shifts
  - Surface vs. Epibenthic feeding (Coho v. Chinook)

- Secondary mechanism: Temporal
  - Migration timing

- Spatial partitioning?

- No realized benefit?
  - Low juvenile salmon densities?
  - Wrong measure?
Juvenile coho salmon life history patterns

Patterns of movements and residence
• **Resident** - fish that remains in the upriver part of a watershed during its first year
• **Migrant** - fish that moves downstream
Results: Migrations and Estuarine Residence

- Estuary catches persist past migrations
Results: Migrations and Estuarine residence

- Emigrate at threshold size
- Residents smaller than migrants/estuary residents
Scale pattern analysis

(Lee 1920, Francis 1990, Ricker 1992)
Scale pattern analysis

Faster growth=
• Widely spaced circuli
• Thicker circuli

Slower growth=
• Narrowly spaced circuli
• Thinner circuli

• Direct comparisons of the same circuli → compare fish collected at different times
• Migrant 1 - NO scales

• Early Estuary
  - Estuary growth signature

• Migrant 2

• Estuary Late
  - Mix of upriver and estuary-formed circuli
Results: Growth trajectories and life history patterns

- Late estuary= migrate after migrant trap shut down in Aug?
- From another river? OR slow growth in estuary?
Results: Life history patterns

Do migrants return back upriver?

- Yearlings group with Residents and Late Estuary

- May be Upriver Residents OR may be Late Estuary that return back upriver for the winter
Conclusions: Coho salmon life history patterns

- Diversity of patterns
  - Multiple migrations
  - Estuary utilization

- Benefits may vary among years
Synthesis

- Estuary used by multiple species
  - Resource partitioning among species
    - Trophic dominant
    - Temporal secondary
  - Multiple patterns within coho salmon
- Heterogeneous habitats, diverse habitat use
Conservation Implications

- Manage from a watershed perspective
- Conserve/restore broad range of habitats
- Conserve/restore interconnected habitats
Acknowledgements

- Chris Eaton
- WET lab
- Field help

- Washington Dept of Fish and Wildlife
- NOAA
- CREST
Schoener 1974

• Habitat/spatial partitioning dominant in terrestrial systems

Ross 1994

• Trophic partitioning dominant in aquatic systems
  – Less habitat heterogeneity
  – Greater resource mobility
Mean Diet Composition

Chinook >60mm
Chinook ≤60mm
Coho >60mm
Coho ≤60mm

Mean Gravimetric Proportion

Other
Epibenthic
Insect Larva
Insect
Diptera Larvae
Diptera

e.g. Collembolans, Hemipterans

Photos c/o Jeff Cordell
### Dominant Prey

**Index of Preponderance**  
(Marshall & Elliott 1997)

\[
IP_i = \frac{p_i f_i}{\sum p_i f_i}
\]

- \(p_i\) = mean gravimetric proportion of prey item \(i\) in diets
- \(f_i\) = frequency of occurrence of prey item \(i\) in diets

<table>
<thead>
<tr>
<th>Chinook ≤60mm</th>
<th>Chinook &gt;60mm</th>
<th>Coho ≤60mm</th>
<th>Coho &gt;60mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prey</td>
<td>IP</td>
<td>Prey</td>
<td>IP</td>
</tr>
<tr>
<td>Emergent Chironomid</td>
<td>0.56</td>
<td>Emergent Chironomid</td>
<td>0.56</td>
</tr>
<tr>
<td>Epibenthic</td>
<td>0.30</td>
<td>Epibenthic</td>
<td>0.30</td>
</tr>
<tr>
<td>Drift</td>
<td>0.14</td>
<td>Drift</td>
<td>0.14</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grouping</td>
<td>Order(s)</td>
<td>Primary Taxa</td>
<td></td>
</tr>
<tr>
<td>------------------</td>
<td>------------</td>
<td>------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Americorophium</td>
<td>Amphipoda</td>
<td><em>A. spinicorne</em>, <em>A. salmonis</em></td>
<td></td>
</tr>
<tr>
<td>Anisogammaridae</td>
<td>Amphipoda</td>
<td><em>Eogammarus, Ramellogammarus</em></td>
<td></td>
</tr>
<tr>
<td>Annelida</td>
<td>Clitellata (class)</td>
<td><em>Oligochaeta, Hirudinea</em></td>
<td></td>
</tr>
<tr>
<td>Brachycera</td>
<td>Diptera</td>
<td><em>Empididae, Ephydridae</em></td>
<td></td>
</tr>
<tr>
<td>Brachycera larvae</td>
<td>Diptera</td>
<td>unknown</td>
<td></td>
</tr>
<tr>
<td>Chironomidae</td>
<td>Diptera</td>
<td><em>Chironomidae</em></td>
<td></td>
</tr>
<tr>
<td>Chironomidae larvae</td>
<td>Diptera</td>
<td><em>Chironomidae</em></td>
<td></td>
</tr>
<tr>
<td>Coleoptera</td>
<td>Coleoptera</td>
<td><em>Staphylinidae, Cantharidae</em></td>
<td></td>
</tr>
<tr>
<td>Collembola</td>
<td>Collembola</td>
<td><em>Isotomidae, Sminthuridae</em></td>
<td></td>
</tr>
<tr>
<td>Other Diptera</td>
<td>Diptera</td>
<td>unknown</td>
<td></td>
</tr>
<tr>
<td>Ephemeroptera</td>
<td>Ephemeroptera</td>
<td><em>Baeotidae</em></td>
<td></td>
</tr>
<tr>
<td>Ephemeroptera larvae</td>
<td>Ephemeroptera</td>
<td><em>Baeotidae</em></td>
<td></td>
</tr>
<tr>
<td>Fish</td>
<td>Gasterostieformes</td>
<td><em>Eggs &amp; juveniles</em></td>
<td></td>
</tr>
<tr>
<td>Hemiptera</td>
<td>Hemiptera</td>
<td><em>Aphidoidea, Cicadellidae, Psyllidae</em></td>
<td></td>
</tr>
<tr>
<td>Hymenoptera</td>
<td>Hymenoptera</td>
<td><em>Ichneumonidae, Chalcidoidea</em></td>
<td></td>
</tr>
<tr>
<td>Other Insecta</td>
<td>Insecta (class)</td>
<td><em>Thysanoptera, Psocoptera, Neuroptera</em></td>
<td></td>
</tr>
<tr>
<td>Insecta larvae</td>
<td>Insecta (class)</td>
<td><em>Coleoptera, Hymenoptera, Neuroptera</em></td>
<td></td>
</tr>
<tr>
<td>Nematocera</td>
<td>Diptera</td>
<td><em>Ceratopogonidae, Sciaridae, Psychodidae</em></td>
<td></td>
</tr>
<tr>
<td>Nematocera larvae</td>
<td>Diptera</td>
<td><em>Ceratopogonidae</em></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>n/a</td>
<td>Hatchery food</td>
<td></td>
</tr>
<tr>
<td>Other Epibenthic</td>
<td>Various</td>
<td><em>Isopoda, Mysidacea, Amphipoda</em></td>
<td></td>
</tr>
<tr>
<td>Other Terrestrial</td>
<td>Various</td>
<td><em>Acarii, Araneae, Pseudoscorpionida</em></td>
<td></td>
</tr>
<tr>
<td>Plecoptera</td>
<td>Plecoptera</td>
<td>unknown</td>
<td></td>
</tr>
<tr>
<td>Plecoptera larvae</td>
<td>Plecoptera</td>
<td>unknown</td>
<td></td>
</tr>
<tr>
<td>Trichoptera</td>
<td>Trichoptera</td>
<td><em>Hydroptilidae</em></td>
<td></td>
</tr>
<tr>
<td>Trichoptera larvae</td>
<td>Trichoptera</td>
<td>unknown</td>
<td></td>
</tr>
</tbody>
</table>
Results: Fish size

Median fork length (mm)

Year

2008

2009

Feb
Aug

Feb
Aug

Migrant1

Migrant2

Log (Mean daily fish count)

1

2
Results: Fish size

- Size remains constant
  = migrate following emergence
Results: Fish size

- Size increases
- Migrants larger than residents
Chapter 2B: Methods- Scale pattern analysis

Growth trajectories
Mean circuli spacing

- Reduced growth
  - Narrowly spaced, thin circuli

Resident

- Consistent growth
  - Widely spaced, thick circuli

Migrant group 1 in estuary
Migrant group 2
Results: Mean circuli spacing

Mean growth rates

- Early Estuary and Migrant 2 highest growth rates
- Late Estuary different pattern than Early Estuary

Circuli 4-10 = approx late April - early June