Growth and Fecundity of *Euphausia pacifica* off the Oregon Coast, Compared With Populations Around the North Pacific

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Introduction to *Euphausia pacifica*
Purpose:

1. Compare vital rates for *E. pacifica* determined from our study of the population off Oregon to those from published studies around the North Pacific

2. Compare and discuss vital rates derived from field census data and laboratory experiments

3. Provide data for population dynamics modelling within GLOBEC program
Background: Our Current Research

- Part of Northeast Pacific GLOBEC program
  - Biweekly cruises (8+ year time series)
    - 25 mile transect off Newport, Oregon
  - Coast-wide Survey cruises
    - At least 3 times/year, Newport to N. California
  - Laboratory Experiments
    - (at sea and on land, 10.5 °C)
      - Growth
      - Fecundity
      - Development
      - Feeding
      - Reared animals for age determination using lipofuscin
Outline:

- Growth Rates (Total Length)
- Longevity
- Age at Maturity
- Fecundity
  - Brood size (BS)
  - Egg size
  - Interbrood period (IBP)
Growth measured in 3 ways

- **Cohort Analysis** (Modal Progression)
  - Repeated sampling of a field population over regular intervals

- **Instantaneous Growth Rate** (IGR)
  - Incubations of individual animals to determine inter-molt period (IMP) and molt increment (mm) in 24 h incubations

- **Observation of Laboratory Reared Animals**
  - Follow growth of animals for extended periods in the laboratory by measuring molts
Growth Rates: Current Study

<table>
<thead>
<tr>
<th>Cohort Analysis:</th>
<th>Per Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub-adult (spring/summer)</td>
<td>0.07mm</td>
</tr>
<tr>
<td>Sub-adult (winter)</td>
<td>0.03mm</td>
</tr>
<tr>
<td>Adult (winter and spring)</td>
<td>0.04mm</td>
</tr>
</tbody>
</table>

IGR (averages):

<table>
<thead>
<tr>
<th>Age Category</th>
<th>Per Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub-adult (spring/summer)</td>
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</tr>
<tr>
<td>Adult (winter)</td>
<td>0.03mm</td>
</tr>
<tr>
<td>Adult (spring/summer)</td>
<td>0.04mm</td>
</tr>
<tr>
<td>range:</td>
<td>(0 - 0.09mm)</td>
</tr>
</tbody>
</table>

Laboratory Development Experiments 10.5°C:

<table>
<thead>
<tr>
<th>Age Category</th>
<th>Per Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egg-Juvenile (0→2 months)</td>
<td>0.09mm</td>
</tr>
<tr>
<td>Juvenile→1yr (&lt;~17mm)</td>
<td>0.04mm</td>
</tr>
<tr>
<td>1→2yr (&gt;~17mm)</td>
<td>0.01mm</td>
</tr>
</tbody>
</table>
Growth Rates:
Winter vs. Spring/Summer

<table>
<thead>
<tr>
<th></th>
<th>Winter</th>
<th>Spring/Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iguchi et al. 1993</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taki &amp; Ogishima 1997</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cooney 1971</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fulton &amp; Le Brasseur 1984</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bollens 1992</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Growth in mm/day (Total length)

- Winter
- Spring/Summer
Growth Conclusions:

- Growth is greater for sub-adults than adults and greater in spring/summer than in winter.
- All methods give a similar range of growth rates. Cohort analysis often suggests faster growth rates for adults than experimental rates.
- Growth rates may not be regionally specific.
- Shrinkage can occur in any season.
Age at Maturity:

• 1+ for most field studies (4-7 months S. California)
  • maturity often determined indirectly in preserved animals (spermatophores, ovarian maturity)
  • age was determined by size
• Our work on living animals: Spawn at 9 months
• Smallest spawner in our field incubations ~9 months!

Longevity:

• NW Pacific, Japan: ~2+
• S. California: 6-13 months
• NE Pacific 1 - 1+
• “Uncle Chester” (maintained in our lab) was ~32 months old when he died in May 03!
Fecundity Methods:

\[ F = \left( \frac{\text{Spawning Season}}{\text{IBP}} \right) \times \text{avg.BS} \]

- Regular Sampling of Eggs and Females
  - Length of spawning season, egg and female abundance, & proportion of ripe females \( \rightarrow \) IBP (Ross, Current Study)

- Egg Production Incubations
  - 12-48 hour incubations of gravid females (from field) to determine BS (Ross et al., Iguchi & Ikeda, Current Study)

- Fecundity Measured in the Laboratory
  - Daily observations of BS and IBP for laboratory maintained animals, >30 days. (Current Study)

- Enumerate Eggs in Ovaries of Preserved Females
  - Count and stage oocytes to estimate BS and number of broods (Brinton, Mauchline, Ponomareva)
Brood Size: EP incubations

- BS Iguchi & Ikeda (1995) (Toyama Bay, Japan)
- BS Ross et al. (1982) (Puget Sound, WA USA)
- BS Gómez-Gutiérrez et al. (Oregon coast USA)
Egg Weights

Oregon: 3.2 µg carbon  
Puget Sound: 3.2 µg carbon  
S. California: 2.5 µg carbon  
Toyama Bay: 2.5 µg carbon  
Toyama Bay: 1.5 µg carbon

Our work  
Ross 1982  
Lasker 1967  
Iguchi & Ikeda 1999  
Iguchi & Ikeda 1994

Implications for calculation of daily or annual production.
Laboratory experiment:
One Example

Six small females, 9 months old, raised in the lab from eggs
Interbrood Period Results

**Experimental IBP** (results from 6 long-term experiments)

- Oregon: 6.5 ± 1.5 (SE) days, Range: 1-37 days
- Santa Barbara: 4.8 ± 0.8 (SE) days, Range: 1-78 days
- Barkley Sound: Poor survival, few eggs
- Dabob Bay: Poor survival, no eggs

**Calculated IBP** (based on ovary ripeness of preserved females)

- Oregon: 5.9 ± 1.5 (SE) days, Range: 1-40 days
- Washington: 4.2 days (Ross et al.)
### Calculation of Fecundity in one spawning season:

<table>
<thead>
<tr>
<th>Locations</th>
<th>Mean BS (eggs)</th>
<th>Mean IBP (days)</th>
<th>Length of Season (days)</th>
<th>Fecundity (Eggs/female /season)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oregon, Field</td>
<td>Small:95</td>
<td>5.9</td>
<td>244</td>
<td>Small: <strong>3929</strong></td>
</tr>
<tr>
<td></td>
<td>Large:161</td>
<td></td>
<td></td>
<td>Large: <strong>6658</strong></td>
</tr>
<tr>
<td>Oregon, Laboratory</td>
<td>Small:66</td>
<td>6.5</td>
<td>244</td>
<td>Small: <strong>2478</strong></td>
</tr>
<tr>
<td></td>
<td>Large:156</td>
<td></td>
<td></td>
<td>Large: <strong>5856</strong></td>
</tr>
<tr>
<td>S. Barbara Laboratory</td>
<td>140</td>
<td>4.8</td>
<td>365?</td>
<td>10,646?</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>180</td>
<td>5,250</td>
</tr>
<tr>
<td>Puget Sound, Laboratory (Ross)</td>
<td>Small:60</td>
<td>4.2</td>
<td>73</td>
<td>Small: <strong>1043</strong></td>
</tr>
<tr>
<td></td>
<td>Large:132</td>
<td></td>
<td></td>
<td>Large: <strong>2294</strong></td>
</tr>
</tbody>
</table>
Fecundity Conclusions:

- Brood sizes are significantly greater for the largest females (>19mm) in Oregon and Japan as compared to Puget Sound in Washington.
- Most spawning may occur in animals > 1 year.
- *E. pacifica* females spawn multiple broods.
- Interbrood Period and Brood Size vary greatly.
- Average field estimates and experimentally determined IBPs were quite similar.
  - Range nearly identical
The Year of the Euphausiid

- Expand our BS and IBP (fecundity) measurements to other populations from the N. Pacific under the same laboratory conditions.
  - Dabob Bay, Gulf of Alaska, Russia, Japan, Korea

- Expand our measurements of development, survival and mortality to other populations.

- Compare latitudinal differences in *E. pacifica* with several populations of *Thysanoessa spinifera* in the coastal waters of the Eastern Pacific.
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