A tale of two krill: who, when, where, and how many? The euphausiids *Euphausia pacifica* and *Thysanoessa spinifera* in the coastal upwelling zone off the Oregon Coast, USA.
Time series off Newport, OR (NH line)

- Sampled twice per month starting in 1996
- Adult euphausiids sampled with night bongo tows from 2001-present (13 years so far)
- Environmental conditions
  - warm & cold PDO phases
  - timing of spring and fall transition dates
  - duration of upwelling
- 2002 – anomalously cold due to intrusion of subarctic water
Target Species

- **Euphausia pacifica**
  - Generally found at and beyond the shelf break (>200 m depth)
  - Intense period of spawning during summer upwelling season
  - Present in cool & warm ocean conditions
  - Do not store lipids

- **Thysanoessa spinifera**
  - Generally found on the shelf (<200 m depth)
  - Spawn before & during upwelling, no intense period
  - Prefer cooler ocean conditions
  - Store lipids

Adults of both species ~1-2 mg C per individual
<table>
<thead>
<tr>
<th>Year</th>
<th>Spring transition (ST)</th>
<th>Fall transition (FT)</th>
<th>Duration of upwelling (mo)</th>
<th>Ocean temp. (PDO phase)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>2-Mar</td>
<td>12-Nov</td>
<td>8.5</td>
<td>Cool</td>
</tr>
<tr>
<td>2002</td>
<td>21-Mar</td>
<td>6-Nov</td>
<td>7.7</td>
<td>Cool</td>
</tr>
<tr>
<td>2003</td>
<td>22-Apr</td>
<td>15-Oct</td>
<td>5.9</td>
<td>Warm</td>
</tr>
<tr>
<td>2004</td>
<td>20-Apr</td>
<td>7-Nov</td>
<td>6.7</td>
<td>Warm</td>
</tr>
<tr>
<td>2005</td>
<td>25-May</td>
<td>29-Sep</td>
<td>4.2</td>
<td>Warm</td>
</tr>
<tr>
<td>2006</td>
<td>22-Apr</td>
<td>31-Oct</td>
<td>6.4</td>
<td>Warm</td>
</tr>
<tr>
<td>2007</td>
<td>15-Mar</td>
<td>27-Sep</td>
<td>6.5</td>
<td>Cool</td>
</tr>
<tr>
<td>2008</td>
<td>30-Mar</td>
<td>24-Oct</td>
<td>6.9</td>
<td>Cool</td>
</tr>
<tr>
<td>2009</td>
<td>8-Mar</td>
<td>6-Oct</td>
<td>7.1</td>
<td>Cool</td>
</tr>
<tr>
<td>2010</td>
<td>9-Apr</td>
<td>13-Oct</td>
<td>6.2</td>
<td>Cool</td>
</tr>
<tr>
<td>2011</td>
<td>31-Mar</td>
<td>16-Sept</td>
<td>5.6</td>
<td>Cool</td>
</tr>
<tr>
<td>2012</td>
<td>3-May</td>
<td>11-Oct</td>
<td>5.4</td>
<td>Cool</td>
</tr>
</tbody>
</table>
Biomass – *E. pacifica* adults

- Climatology 5-10 mg C m$^{-3}$ year-round (but averages aren’t everything)
- High interannual variability (or is it patchiness?)
- Lowest biomass consistently in June
- High biomass occurs in both cool and warm years
Biomass – *T. spinifera* adults

- Nov-June ~0.5 mg C m\(^{-3}\)
- July-Oct 1-2 mg C m\(^{-3}\)
- High interannual variability (or patchiness?)
- Higher biomass values occur in cold years, rare in warm years
Cross-shelf biomass essentially the same for cool and warm PDO

*E. pacifica* might even prefer a little warming
**T. spinifera** cross-shelf biomass
cool vs. warm PDO

- Biomass offshore essentially the same for cool and warm PDO
- Biomass inshore decidedly higher during cool conditions
No distinct pattern 2001-2004 (PDO cool ➔ warm)
Predominantly positive 2005 until mid-2008 (PDO warm ➔ cool)
Predominantly negative mid-2008 to present (PDO cool)
PDO & biomass anomaly

- Positive anomaly 2001-2003 even though PDO warm starting 2003
- Largely negative 2004-2012 even though PDO cool starting 2008
Biomass – the general answer

<table>
<thead>
<tr>
<th>Average biomass (mg C m⁻³)</th>
<th>NH05-NH25</th>
<th>NH20-NH25</th>
</tr>
</thead>
<tbody>
<tr>
<td>E. pacifica</td>
<td>16.45</td>
<td>34.41</td>
</tr>
<tr>
<td>T. spinifera</td>
<td>1.41</td>
<td>1.49</td>
</tr>
</tbody>
</table>

- *E. pacifica* more abundant than *T. spinifera*
- *E. pacifica* clearly concentrated offshore
- *T. spinifera* biomass similar inshore and offshore
- Averages are not what matter to predators
Lipid Data Caveats

• Lipid samples are from 2010-2012
  – All lipid measurements from krill collected during cold conditions
  – No data on how lipid content might be affected in warm years

• Lipid data may not represent:
  – Abundance
  – Species composition
  – Length frequency
  – Full range of possible values per length or month category
Large range of lipid content for animals of similar lengths
Cannot use length as a proxy for lipid content
Lipids by month

- Lipid >2mg/animal exclusively *T. spinifera*
- Available May-October (~upwelling season)
Adult Density (monthly average)

<table>
<thead>
<tr>
<th>Month</th>
<th>Density (krill m⁻³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>E. pacifica</td>
</tr>
<tr>
<td>2</td>
<td>T. spinifera</td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
</tr>
</tbody>
</table>
Adult Biomass (monthly average)

![Graph showing adult biomass (monthly average)]

- **E. pacifica**
- **T. spinifera**
Adult Lipid (monthly average)

*T. spinifera* – lower density than *E. pacifica* but higher lipid content could make them an equally valuable food source.
Krill math

- Biomass: 1-2 mg C per adult, both species

- Lipid content (max. per adult)
  - *T. spinifera* = 11 mg  
  - *E. pacifica* = 2 mg
Things to consider…

• Abundance isn’t everything
  – *E. pacifica* much more abundant than *T. spinifera*
  – *T. spinifera* may also be an important food source:
    • higher potential lipid per krill
    • inshore distribution
    • availability during upwelling

• Are we measuring what we should be measuring?
  – Density/biomass/carbon may not be the important factors from the perspective of foraging predators
  – How does patchy distribution affect density and biomass estimates?
  – How does this impact modeling efforts?
Value of long-term time series data

How would our view of euphausiid population dynamics off the Oregon coast differ if it were based on any consecutive 3-year time period from the last 12 years?

*T. spinifera* biomass anomaly
Future Plans?

• Zooplankton ecologist specializing in krill

• Experience includes:
  – Work in Antarctica, Bering Sea, Oregon Coast, Yellow Sea
  – Sorting preserved zooplankton samples
  – Experiments with live euphausiids
  – Working at sea on large and small research vessels

• Available January 2014

• Contact: tracy.shaw@noaa.gov
  tracy.shaw@oregonstate.edu
  croaker555@gmail.com
Acknowledgements

• Research vessels: *Elakha, Wecoma, Atlantis, Frosti, Miller Freeman, McArthur II, New Horizon, Shimada*

• Funding sources: NOAA/NWFSC, ONR/NOPP, NSF/CoOP/COAST, NOAA-GLOBEC, NSF/CoOP/RISE, NOAA-SAIP

• My co-authors (and Jay):