Status of Krill
(*Euphausia pacifica* and *Thysanoessa spinifera*)
in the northern California Current:
a review of sampling methods and data sets

Jennifer Menkel and William T. Peterson

“Most marine species (including humans) are only one or two trophic levels away from krill. That is, they are either prey of krill, predators of krill or predators of krill predators.”

California Current

California Current flows from Vancouver Island, Canada towards California

*Euphausia pacifica* (Epac) and *Thysanoessa spinifera* (Tspin) are the dominant euphausiids in the California current

They have a very patchy spatial distribution

Increased upwelling = increased biomass

Aggregations possibly due to ocean bottom topography and flow fields (Mackas, 1997)

Adult Epac biomass is concentrated at the shelf break

Tspin is concentrated on the shelf and in retention areas such as Heceta bank.

“Epac is more abundant than Tspin”
Outline

- Review of the coast-wide data sets – Starting at Vancouver Island, Canada working south to California
- Trends in the data – What is the current pattern?
- Net review – “Catchability” by different nets
- Acoustics and Patchiness
- Trophic Interactions
Euphausiid anomalies are logarithmic: an annual anomaly of +1 means that the euphausiids were on average ten times more common than their within-region average seasonal cycle; an anomaly of -1 means they were one tenth as common.

**Biomass Anomaly (log10)**

**Northern**

**Southern**
Vancouver Island

Ron Tanasichuk – personal communication

Samples Collected
17 year data set 1991-2008
Comprised of 580 samples
Monthly: March-November and January

Net – Bongos 60cm 330µm black mesh

Log of the yearly medians mgC/m³

All samples
Epac 4 ± 2.3 mgC/m³
Tspin 3.3 ± 2.5 mgC/m³

1998-2006
Epac 3.5 ± 1.5 mgC/m³
Tspin 2.8 ± 2.8 mgC/m³
Washington and Oregon

Peterson Group

Samples Collected
12 year data set 1996-2008
1998 - 2006 presented

Nets
Vertical ½ meter net
  202µm white mesh
  3056 samples
  432 night-time
Bongos 70cm
  Black 333µm mesh
  1137 samples
  383 night-time
NH line samples
MOCNESS net 1sq meter
  Black 333µm mesh
  401 stations
  41 stations
Washington and Oregon

Euphausia pacifica

Northern OR and WA
Epac 1.31 ± 0.94 mgC/m³
Tspin 0.02 ± 0.02 mgC/m³
n=61

Central OR
Epac 2.34 ± 3.14 mgC/m³
Tspin 0.14 ± 0.13 mgC/m³
n=183

Southern OR
Epac 2.00 ± 1.70 mgC/m³
Tspin 0.23 ± 0.51 mgC/m³
n=119

Northern CA
Epac 3.09 ± 3.88 mgC/m³
Tspin 0.12 ± 0.17 mgC/m³
n=69

Thysanoessa spinifera

“Good years”
Epac 3.0 ± 0.73 mgC/m³

“Bad years”
Epac 0.87 ± 0.42 mgC/m³
California: Northern


**Samples Collected**
2000 – June (28 samples)
2001 - May and June (32 samples)
2002 – January (27 samples)

**Net**
Bongo - 335 and 500µm mesh
200m to the surface or 5m of the bottom

Used juvenile and adult Epac and Tspin animals 3mm or greater

**2000 (June)**
Epac 7.9±1.63 #/m³
Mean Size 9.16±0.06mm
3.7 mgC/m³

**2001 (May-June)**
Epac 3.6±1.03 #/m³
Mean Size 11.19±0.01mm
3.2 mgC/m³
California: Southern and Central


56 years of sampling
(32 for this data)

1951-1968 1m ring net
0.55mm mesh
depth 140m

1969-1977 1m ring net
0.505mm mesh
depth 210m

Dec. 1977-present
0.71m bongo net
0.505mm mesh
depth 210m

Spring Cruises: March through April or May

Legend: Symbol diameter is proportional to the number of times each station is represented in the zooplankton time series.
California: Central and Southern

Geometric mean carbon biomass

**Central CA** 294.0 mgC/m²
**Southern CA** 141.0 mgC/m²

**Euphausiids** - not just Epac and Tspin - **Stages**?
(Nyctiphanes simplex, and Nematoscelis difficilis?).

Fig. 5, pg. 50. Mean biomass ± 95% confidence intervals in three climate periods (cool [1951–1976], warm [1977–1998], and **recent** [1999–2005]) in (c) Southern California alone and (d) Southern California compared with Central California. Stations shallower than 140m or 210m were omitted from the pooled samples. The total number of nighttime samples selected for SC was 619 (8-19 per cruise) and 266 for CC (2-16 per cruise).
## Overall Trends

<table>
<thead>
<tr>
<th>Region</th>
<th>Species</th>
<th>Epac</th>
<th>Tspin</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vancouver Island</strong></td>
<td>Tanasichuk bongo</td>
<td>3.55 ± 1.58</td>
<td>2.83 ± 2.83</td>
</tr>
<tr>
<td><strong>Central Oregon</strong></td>
<td>Peterson vert</td>
<td>2.34 ± 3.14</td>
<td>0.14 ± 0.13</td>
</tr>
<tr>
<td><strong>Southern Oregon</strong></td>
<td>Peterson vert</td>
<td>2.00 ± 1.70</td>
<td>0.23 ± 0.51</td>
</tr>
<tr>
<td><strong>Northern California</strong></td>
<td>Peterson vert</td>
<td>3.09 ± 3.88</td>
<td>0.12 ± 0.17</td>
</tr>
<tr>
<td></td>
<td>Dorman bongo</td>
<td>3.45</td>
<td></td>
</tr>
<tr>
<td><strong>Central California</strong></td>
<td>CalCOFI</td>
<td>294.0 mgC/m² ÷ 175m = 1.7mgC/m³</td>
<td></td>
</tr>
<tr>
<td><strong>Southern California</strong></td>
<td>CalCOFI</td>
<td>141.0 mgC/m² ÷ 175m = 0.80mgC/m³</td>
<td></td>
</tr>
</tbody>
</table>

*Confounded with other warm water species and timing of sampling*
Calculation of mean biomass for the EEZ

We are getting close……..

We have long term, spatially distributed sampling programs.
We have standardized the collection system – 60-70cm bongos.

The data suggests

“Good years”
Epac ~ 3 - 4 mgC/m³

“Bad years”
Epac ~ 1 mgC/m³

But……

What stages are in the “biomass summaries”?
Depth of tow over which numbers are integrated?
Patchiness – use “known areas” of abundance i.e. shelf break, and areas of retention?
Patchiness within the water column.
The weighted mean depth of adult euphausiids during the night-time is less than 30m from the surface. (Vance et al. AGU 2003)
Paired Vertical and MOCNESS nets

<table>
<thead>
<tr>
<th></th>
<th>Epac</th>
<th>Tspin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical</td>
<td>4.8 ± 7.7</td>
<td>0.6 ± 1.0</td>
</tr>
<tr>
<td>MOCNESS</td>
<td>99 ± 214</td>
<td>26.7 ± 84.6</td>
</tr>
</tbody>
</table>

Or in other words......
The MOCNESS net catches 21 times more Epac and 45 times more Tspin.
Net Comparisons
Central OR only non-paired samples

Lengths mm

<table>
<thead>
<tr>
<th></th>
<th>Epac</th>
<th>Tspin</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>Vertical</td>
<td>16.7</td>
<td>16.8</td>
</tr>
<tr>
<td>Bongo</td>
<td>15.6</td>
<td>16.2</td>
</tr>
<tr>
<td>MOCNESS</td>
<td>18.2</td>
<td>19.1</td>
</tr>
</tbody>
</table>

Vertical n = 183
Bongo n = 383
MOC n = 37
Acoustics


Acoustics
July through August 2000
36 east – west transects
38 and 120 kHz data only
Day time only
8 - 150m depth

Patches were detected along only 17% of the tracks

Euphausiids are concentrated at Heceta Head (HH) and Cape Blanco (CB)

Fig. 5
Acoustics
Jarrod Santora, William Sydeman, personal communication
Presented S9 BIO Topic Session 14:50

Central California Current:
Kernel Density 2002-2006

Persistent Hotspots
Blue whales in Monterey Bay fed primarily upon Tspin 80 ± 22.6%, Epac 13%

Net samples collected at the same time consisted of only 30.17 ± 34.95% Tspin

Lengths of what the whales are feeding on are significantly larger than what the net catches

Tspin t=9.12, d.f. = 260, p<0.001; Epac t=9.99, df = 180, p<0.001

Auklet breeding – The primary prey species in the diet are Epac and Tspin. “Tspin seems to be the most important prey species in terms of growth and productivity”
Conclusions

We are underestimating *Thysanoessa spinifera* in our study area.

We have moved toward a standardized sampling system, 60-70cm bongos
But is this enough………

Acoustics help to resolve the patchiness, biomass estimations are considerably higher

We need standardized acoustic backscatter to estimate distribution and biomass of both species - integrated with the net collection data

Where possible net samples need to be collected at night when the euphausiids are concentrated in the upper 20-50m of the water column…. avoiding the need to integrate the biomass over the whole water column

Biomass varies by a factor of 10, rates vary by a factor of 2 – therefore, we need to worry more about getting accurate estimates of the biomass

**No matter which net we use we don’t capture euphausiids as efficiently as whales do**
Acknowledgements

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