Modeled Krill Distribution in the California Current, 1991 – 2008

Jeffrey G. Dorman¹, Thomas Powell¹, William Sydeman², Steven Bograd³, Jarrod Santora²

¹University of California, Berkeley - Berkeley, CA
²Farallon Institute for Advanced Ecosystem Research - Petaluma, CA
³NOAA-NMFS, Environmental Research Division - Pacific Grove, CA
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Roadmap

1. Overview of Study Area
2. Methodology
   Ocean Model – ROMS
   IBM – POPCYCLE
3. Results
   Seasonal & Longer Trends
   Links to Higher Trophic Levels
4. Concluding Thoughts
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Overview of the Study Area

(FIELD JC et al., Prog Ocean, 2006 68:238-270)
Physical Forcing

How do seasonal conditions impact krill abundance (mortality, advection) condition, and spatial distribution of krill respond to seasonal and long time scale forcing (i.e. Pacific Decadal Oscillation)?

Higher Trophic Level Connections

How does modeled krill correlate with higher trophic level indices (auklets and salmon)?
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Methods – Regional Ocean Modeling System (ROMS)

- Forcing: NCEP-NARR (3hr)
- Boundary: ECCO2 (climatology)
- NPZD Model (Powell et al. 2006)
- Daily output
- Years Run – 1991 to 2008
Methods – Individual Based Model (POPCYCLE)

1. Get Individual Physical Data
2. Get Domain Physical Data
3. Reseed Population
4. Begin Population Loop
   - Calculate Growth
   - Assign Life Stage
     - Adult Female?
       - yes: Calculate Reproductive Weight
       - no: Mortality
     - no: Update Position
6. all individuals evaluated?
   - yes: Update Population and Output Population Stats
     - new individuals via eggs
   - no: End Time?
7. yes: Close Output Files and Stop Program
8. no: Evaluate all individuals? (loop back)

Get ROMS Data
Bioenergetics
Particle Tracking
Output Data
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Methods - Individual Based Model (POPCYCLE)

Bioenergetics

Egg Development
- Temperature Dependent

Growth
- Food & Temp. Dependent

Reproduction
- Life Stage Dependent
- Growth & Time Dependent

Stage Progression
- Weight Dependent

Mortality
Predation
Starvation

[Graph showing critical concentration (ug C) vs. temperature (C) for Adult, Juveniles, and Larvae.]
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Methods – POPCYCLE Initial Conditions

Initial Conditions
~ 10,500 particles
All Same Weight

Day 0
Day 25
Day 50
Day 75
Day 100
Day 180
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Methods – POPCYCLE Initial Conditions

- Mean Particle Weight
- Mortality Numbers
- Number Adveected

Years Modeled: 1991 – 2008
Runs Per Year: 8
Initial Weight: Eggs or Adults
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Results – Seasonal Trends

Seasonal Response

Growth

Larval Population Growth

Adult Population Growth

Monthly Mean Growth


Month

2  4  6  8  10  12

Larval

Adult
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Results – Seasonal Trends

Seasonal Response
Mortality

Larval Mortality

Adult Mortality

Monthly Mean Starvation

Seasonal Response
Mortality
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Results – Long Time Scale Trends (PDO)

**Long Time-Scale Response Growth**

**PDO**

Monthly De-trended Adult Weight

- $r = -0.37$
- $p < 0.01$
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Results – Long Time Scale Trends (PDO)

Long Time-Scale Response Mortality

De-trended Adult Mortality

PDO

r = 0.45
p < 0.01
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Results – Long Time Scale Trends (PDO)

Long Time-Scale Response
Advection

PDO

Adult Southern Advection

r = 0.03
p > 0.05
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Results – Links to Northern California predators

Higher Trophic Level Connections
Northern California

Cassins’s Auklet

Chinook Salmon

Reproductive Success

Returning Salmon


0 0.4 0.8 1.2

0 0.5 M 1M

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Results – Links to Northern California predators

Number of Adult Particles

Northern California Region
Particle Abundance
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Results – Links to Northern California predators

Northern California Region
Winter Summer Number of Particles

<table>
<thead>
<tr>
<th>Year</th>
<th>Winter</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992</td>
<td></td>
<td></td>
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<tr>
<td>2000</td>
<td></td>
<td></td>
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<tr>
<td>2008</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

No Retained

- 0
- 150
- 300

Winter

Summer
Northern California Region – Particle Retention

Cassins’s Auklet

\[ r = 0.15 \]
\[ p > 0.05 \]

Chinook Salmon

\[ r = 0.47 \]
\[ p > 0.05 \]
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Results – Links to Northern California predators

Northern California Region
Mean Start Latitude of Particles

- Blue circles = Winter
- Red circles = Summer

- Year 1992
- Year 2000
- Year 2008

Latitude:
- 37
- 39
- 41
- 43

Year:
- 1992
- 2000
- 2008
Conclusions

Different Responses of Adult and Egg Populations indicated the value of modeling *Euphausia pacifica* with an Individual-Based Model.

**Seasonal and Long-Time Scale Trends**

- Seasonal peaks in growth during upwelling season
- Peak adult mortality in summer due to temperature-driven higher metabolic demands offshore.
- Abundance and Condition of krill correlate with PDO. Advection does not.

**Higher Trophic Levels**

- Wintertime particle abundance in the Northern California Region correlates with predator success. Particles are primarily retained in the region, not advected into the region.
Funding and Support

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Model Development

• Regional Ocean Modeling System (ROMS): Developers & Community
• Hal Batchelder, Oregon State University

Data Sources

• National Centers for Environmental Prediction (NCEP)
• Estimating the Circulation and Climate of the Ocean (ECCO)
• National Aeronautics and Space Administration (NASA)
• Monterey Bay Aquarium Research Institute (MBARI)