Pacific Coast Krill Biology and Status

Oct-Nov 2005

From Chap.3, Briefing Document Agenda Item D.2.a Attachment 1 - Alternatives Analysis – Management of Krill off the U.S. West Coast

NMFS Southwest Region/Southwest Fisheries Science, 8604 La Jolla Shores Drive, La Jolla, CA
Krill Species of Concern

- Only 2 species likely to be targeted by a fishery because of their swarming characteristics:
  - *Euphausia pacifica*
  - *Thysanoessa spinifera*
Why Bother If There’s No Harvest?

- Tho banned in state waters, out-of-state vessels could fish >3 nm and land elsewhere. Freezer vessels self-contained, do not need nearby landing ports.

- Sanctuaries concerned over potential krill fishing in their waters, where krill-dependant predators converge.

- Increased interest in krill as aquaculture feed and for various biochemical products (krill oil etc, high in Omega 3 fatty acids, antioxidants, phospholipids)
And fisheries for *E. pacifica* already exist in Japan and British Columbia, Canada.

- Japan fishery (~100,000 t yr\(^{-1}\)) self-regulated mainly to keep prices up.

- British Columbia regulated by quota and closed season--annual catch set at 500 t.
Energy dispersal from euphausiids with respect to other intermediate energy sources in the Northern California Current. Box size and connecting bar width scaled to log of standing biomass (within max-min levels) and biomass flow, respectively. Energy from euphausiids production in blue; from other sources, red.

From John C. Field, Groundfish Analysis Team, NMFS, Santa Cruz, CA.
Ecosystem Importance

Not Only

• Important forage for fish, marine mammals and birds….

Other ecosystem roles as well…. 

• Krill casts (high in N, C, Vit A and chitinoclastic bacteria) are an important food source for other organisms (molt once every 5 days; produce 7x dry weight production in one year)

• Important in Vit A cycle in sea—can synthesize and store it in high concentrations-esp. in eyes.

• Krill remove and recycle vast amounts of primary production from coastal waters and may hold algal and dinoflagellate blooms in check.

• Swarms of krill influence carbon flux by physically fragmenting sinking organic particles, or “marine snow” with the collective beating of their appendages—thought to increase residence of carbon in upper water column, helping enrich the upper ocean.
Both species occur coastwide and beyond the EEZ- but krill and krill predators also known to converge in certain “hot spots”, associated with major upwelling areas…….candidates for HAPCs?
“Hot Spot” Convergence Areas Part of the Problem..

- Krill vessels will likely be highly efficient at locating these ‘hot spots’ in search of commercial densities of krill ($\sim > 3$ g wet weight/m$^3$)

- Raises likelihood of bycatch and/or protected species interactions, with marine life of all types drawn to the same areas to feed on krill or krill predators.
Sampling data show the bulk of krill occur in the inner quarter of the EEZ (EFH Option 2), where upwelling and primary productivity is richest...BUT offshore areas are under sampled...and upwelling jets do carry enriched waters far offshore.
Both are ...

- Cool-water sub arctic species.
- Biomass can plummet in extreme warm water years; times of reduced upwelling and primary production.
- But resilient, can rebound from extreme El Niño lows (Brinton & Townsend (2003)).
50-year CalCOFI time series shows extreme abundance fluctuations that can change rapidly with oceanographic conditions...

- From Brinton & Townsend (2003). Scripps Institution of Oceanography
June 2005 Meeting Krill Experts

- To discuss ‘best available science’ on krill (sponsored by NMFS SWR)
  - Krill status, distribution, best available data and stock assessment methods, also research needs.

(Summary of meeting is Appendix A of Krill Alternatives Doc.)

- Major points were:
  - Our review of what is known to date seems accurate,

- BUT
  - Still no reliable estimates of standing stock exist for either species, only very rough ‘first cut’ numbers.
  - No EEZ-wide estimates of predator/ecosystem needs
  - Estimates of distribution and abundance need to be improved
Krill Meeting Points, cont. . .

• 2 modeling exercises suggested to improve stock assessment in short-term
  – Expansion of an existing ecosystem model to better gauge the ecosystem impacts of krill harvest
  – Single-species probabilistic yield model to determine the likelihood of a fishable krill surplus occurring beyond ecosystem needs.

But krill experts point out...

  – Even if more reliable yield estimate could be calculated, setting an allowable catch based on MSY may not be practical or appropriate, as krill fluctuate rapidly and extremely from year to year and even season to season depending on oceanographic conditions.

• To improve stock assessment survey methods in both short and longer term need to --
  – Standardize/agree upon measurement methodology (conversion factors, net density and acoustic data to convert to coast-wide, or even regional biomass estimates).
  – Convene meeting of krill bioacoustic experts to develop best survey techniques.
  – Reach agreement on spatial bounds of primary krill habitat.
Provisional $B_o$ and MSY Estimates

- **Caveats**
  - Numbers based on densities observed in one area off Oregon, extrapolated to EEZ-wide area(s) presumed to represent the area(s) occupied by krill, on which experts still disagree.
  - Numbers in Table 3-3 presented in way to imply precision—not our intent. Range of uncertainty varies greatly—
  - Standing stock may be reduced as much as 90% in extreme El Nino years, as observed from stock variability.
  - Predator/Ecosystem needs not specified.
  - SSC consulted concerning better assessment approaches.

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Provisional EEZ Biomass Estimates (W.T. Peterson, NMFS, Newport, OR)

Table 3-3. Preliminary estimates of standing stock ($B_0$) and $B_{MSY}$ (0.5 $B_0$) based on assumption of average adult densities of 136 m$^{-2}$ and 16 m$^{-2}$ for *E. pacifica* and *T. spinifera*, respectively$^1$, for two habitat area assumptions$^2$. Uses length-biomass conversions of Miller (1966) and conversion of combined species totals to fresh wet weight from W.T. Peterson and L. Feinberg (NMFS, NWFSC, Newport Oregon).

<table>
<thead>
<tr>
<th>Species</th>
<th>Est. avg. density$^1$, adults m$^{-2}$</th>
<th>Est. avg. Adult weight$^3$ (g)</th>
<th>Kg Km$^{-2}$</th>
<th>Est. (mt) Habitat Assumption A$^3$</th>
<th>$B_0$ (mt) Habitat Assumption A$^3$</th>
<th>Est. (mt) Habitat Assumption B$^2$</th>
<th>$B_0$ (MSY) Habitat Assump. A$^3$</th>
<th>$B_0$ (MSY) Habitat Assump. B$^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>E. pacifica</em></td>
<td>6.8</td>
<td>136</td>
<td>0.064</td>
<td>8700</td>
<td>610,531</td>
<td>1,766,535</td>
<td>305,266</td>
<td>883,268</td>
</tr>
<tr>
<td><em>T. spinifera</em></td>
<td>0.8</td>
<td>16</td>
<td>0.100</td>
<td>1600</td>
<td>112,282</td>
<td>324,880</td>
<td>50,141</td>
<td>162,440</td>
</tr>
<tr>
<td><strong>Total Metric Tons</strong></td>
<td><strong>Preserved Weight (Miller 1966)</strong></td>
<td></td>
<td></td>
<td></td>
<td>722,813</td>
<td>2,091,415</td>
<td>361,407</td>
<td>1,043,708</td>
</tr>
<tr>
<td><strong>Total Metric Tons</strong></td>
<td><strong>Fresh Weight (Peterson et al$^4$)</strong></td>
<td></td>
<td></td>
<td></td>
<td>1,221,301</td>
<td>3,533,759</td>
<td>610,651</td>
<td>1,766,880</td>
</tr>
</tbody>
</table>

Total EEZ Krill $B_0 = 1.2 - 3.5$ million mt, $MSY = 0.6 - 1.8$ million mt

**Habitat Assumption A:** Main krill densities extend 20nm on either side of shelf break, continuously length of EEZ.

**Habitat Assumption B:** Main krill densities extend throughout inner quarter of EEZ (approx 3x Habitat Assumption A).

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$^1$ *E. pacifica* and *T. spinifera* avg. overall mean adult density from W. T. Peterson, NMFS, NWFSC, Newport OR, pers. comm. 9/8/05 (see text).

$^2$ Habitat assumption A assumes area main krill concentration 70, 176 km$^2$ (W. Peterson, *ibid.*, see text); Assumption B assumes area of main krill concentration within inner quarter EEZ (~203,050 km$^2$).

$^3$ Avg. adult *E. pacifica* (11-25 mm TL) from A. Townsend (Scripps Inst. Oceanogr., Invertebrate Collections); avg. adult *T. spinifera* 22 mm TL from Summers (1993); all weights calculated in preserved weight (Miller 1966) and converted to fresh for combined total (see Table 4).

$^4$ W.T. Peterson and L. Feinberg, NMFS, NWFSC, Newport OR. Carbon weight mg x 2.22 = Dry Weight (DW) assuming carbon 45% of DW; DW x 10 = WW (90% water). Fresh biomass est. approx. 1.7 x preserved biomass.
Summary

• Krill stocks are important in the California Current food web and have other ecosystem roles as well.

• Both stocks exhibit extreme and rapid fluctuations with environmental conditions.

• Much is known about relative abundance and long and short term variability—but little work has been done to calculate absolute abundance in the EEZ (much less stock-wide).

• Very provisional EEZ $B_o$ and MSY estimates* have been assembled (W.T. Peterson) — but they do not include ecosystem needs and require further refinement, esp. agreement among researchers on methods and krill habitat occupied.

• A modest amount of additional effort —expansion of an existing regional California Current ecosystem model, and development of a probabilistic yield model is recommended. (Would help measure ecosystem effects of various harvest levels and determine the likelihood of a harvestable krill surplus occurring, respectively).

• Longer term needs include standardizing survey techniques and effort.

* $B_o = 1.2-3.5$ million mt, $MSY= 0.6-1.8$ million mt
LIST OF AGENCIES AND PERSONS CONSULTED, INCLUDING KRILL MEETING ATTENDEES)

- NOAA Marine Sanctuaries: Dan Howard, Pam van der Leeden (Cordell Bank NMS); Barbara Blackie (Olympic Coast NMS)
- NMFS: (SWFSC): John Field, Andrew Leising, Lisa Ballace, Paul Fiedler, Kevin Hill, Roger Hewitt, Christian Reiss; Rand Rasmussen
- (NWFSC) Bill Peterson
- PRBO -Point Reyes Bird Observatory: Bill Sydeman, Jaime Jahncke, Ben Saenz
- Oregon State University: Leah Feinberg
- U.C. San Diego, SIO-Scripps Institution of Oceanography: Mark Ohman, Ed Brinton, Annie Townsend
- U.C. Santa Cruz: Don Croll, Baldo Marinovic
- California Dept. Fish Game: Dale Sweetnam
- Coastal Pelagic Species Mgt Team
- Washington Dept. Fish and Wildlife: Michele K. Culver
- Oregon Dept. Fish and Wildlife: Jean McCrae
- National Ocean Services, NOAA

Acknowledgements
EFH OPTIONS

• Option 1. Status Quo. Do not designate EFH.

• Option 2. Adopt EFH as described in section 3.8.6.

• Option 3: Designate the full EEZ as EFH
Habitat Areas of Particular Concern (HAPCs)

- **HAPC Option 1.** Status Quo—Do not designate HAPCs
- **HAPC Option 2.** Designate for krill and feeding baleen whales and other krill predators the ocean area within the boundaries of Cordell Bank, Gulf of the Farallones, Monterey Bay, Channel Islands, and Olympic Coast NOAA Marine Sanctuaries as HAPCs. These sanctuaries encompass the most important consistently krill-rich, predator feeding areas around California islands as well as important submarine canyons, bank, shelf and slope areas (e.g., Gulf of the Farallones, Pescadero Canyon, Ascension Canyon, Monterey Bay Canyon area, Channel Islands)
- **HAPC Option 3.** Designate for krill and feeding baleen whales and other krill predators the ocean area within the boundaries of Cordell Bank, Gulf of the Farallones, Monterey Bay, Channel Islands and Olympic Coast NOAA Marine Sanctuaries, and Heceta Bank area (east of longitude 125° 30’ W Long, between 43°50’ and 44° 50’ Lat), off Cape Blanco (east of longitude 125° 30’ between 42°20’ and 43° 000’ Lat), and the Bodega Canyon area as HAPCs.
- **HAPC Option 4.** Designate for krill and feeding baleen whales and other krill predators the ocean area within the boundaries of Cordell Bank, Gulf of the Farallones, Monterey Bay, Channel Islands and Olympic Coast NOAA Marine Sanctuaries as HAPCs and all other waters of the EEZ federal coastal and island waters off Washington, Oregon and California out to 60 nautical miles from shore.