Krill of the California Current: Relevance to Salmon in the Greater Gulf of the Farallones

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Salmon entering the ocean in 2000 and 2001 produced great recruitment/returns

5 yr later (2005-2006), early ocean survival was so low that the stock collapsed…

leading to an unprecedented emergency closure of fisheries off California and Oregon

(Lindley et al. 2009)

What controls this variability?
Is Early Survival Related to Timing of Local Upwelling?

Timing of Upwelling – Point Arena

Year-day of transition


Year

2002, EARLY

2010, LATER

Bograd et al. 2009, updated
Peak in ocean survival ~80-100 days after the transition to upwelling.

Why?

Lag suggests food.
Notable Interannual Covariance Between RRFC and SRFC, But “Early” and “Late” Can Result in High Return Rate
1) correlations between environmental drivers and fish population dynamics tend to break down over time (Myers 1998)

2) mechanistic hypotheses needed to improve understanding of fish population dynamics and management.

E.g. Predator-prey trophic dynamics

“Fish don’t eat chlorophyll hypothesis”

H: salmon survival/cohort strength related to zooplankton availability during initial time at sea (very important for hatchery-based fisheries)
Match-mismatch dynamics and the relationship between ocean-entry timing and relative ocean recoveries of Central Valley fall run Chinook salmon

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\[ \text{Peak } \sim \text{day 150} = \text{end of May} \]
# NOAA Fisheries Hydro-acoustic Surveys Processed by Farallon Institute to Study Krill, 2000-2014

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</table>

- 26 surveys processed to date
- 14 years (missing 2007)
- ~44,000 nmi surveyed
- ~20,000 nmi in Greater GOF “core” region

**Acknowledgements**

"JRS" (PI = John Field)
"Salmon" (PI = Sean Hayes)
“Others” (PI = William Peterson)

Jarrod Santora, Jason Hassrick, Ramona Zeno, Marcel Losekoot
Sensing Krill

Discriminate krill from other signals using 3-frequency $\Delta S_v$ method, based on target strength model

- Depth-integrated Nautical Area Scattering Coefficient (NASC, m$^2$ nmi$^{-1}$)

What Does it Indicate?

- Correlation between NASC and net samples: corresponds to abundance of *Euphausia pacifica*, but not *Thysanoessa spinifera*

Santora et al. 2011, Sydeman et al. 2013
Krill Abundance (Log NASC) and RRFC and SRFC Indices (aligned to 3 year lag)
Russian River FC and Krill
SRFC and Krill

The graph shows a positive correlation between Sacramento River Returns (lagged 3 years) and Krill (log NASC) in Regions 3 and 4. The data points for the years 2000, 2001, 2003, 2009, 2010, 2011, and 2008 are plotted, with the values increasing as the years progress from 2000 to 2011.
2004-2006?: relatively high NASC, but southerly dist’n
Greater GoF “Hotspots”/Aggregation Analysis, 14 years
GoF Krill – Local Scale Oceanographic Relationships

(April-May SST and Nutrient-Upwelling Index, Bodega Bay, CA)

Garcia-Reyes et al. 2014
Regional “Hotspots”  Ln-Transformed = habitat  Raw NASC = “peak values”
Next Steps

- Model Abundance and Distribution

- Seasonality of Krill Availability in GoF (observations [mooring sensor?] and models)

- What is Local? Investigation of Krill Effects on Growth and Survival of Salmon from Different Regions of the CCS

- Build Coordination Between Hatchery and Ocean Ecology/ Bio Oceanog. Science
  - Given food availability is variable, less variable release timing is unwise
  - Share the Krill Data
Figure 2. Particle density (number per 0.1° latitude) within 100 km of the coastline during (a) 2001 and (b) 2005. Note the northward advection of particles in January 2005 and greater number of particles in 2001.

Dorman et al. 2011
Other Prey: Birthdate Distributions for Shortbelly Rockfish (Sebastes jordanii)

Figure 18. Back-calculated birthdate distribution of pelagic YOY shortbelly rockfish captured by the Tiburon midwater trawl survey.

Lenarz et al. 1995
Comparison of RRFC and SRFC with Krill Abundance

Abundance and Timing of Hatchery Releases

Huber and Carlson 2015