Cohort data for the euphausiidiid
*Euphausia pacifica* off Newport, OR, USA

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Time series off Newport, OR (NH line)

- 1996 - Start of biweekly sampling by the Peterson lab
  - Chlorophyll-\(a\) (surface)
  - Euphausiid eggs & larvae
- 2001 – Start of sampling adult euphausiids with nighttime bongo tows
- Instantaneous growth rate (IGR) experiments on live animals since 2001
- Cohort data & IGR expts from station NH25 (★) at the shelf break (40km offshore, ~300m)
Motivation & Objectives

• *Euphausia pacifica* are present in our study area year-round
• We see spawning activity as early as Feb and as late as Oct, in association with phytoplankton blooms
• There is a period of intense spawning activity in July-August which could initiate a cohort that can be followed over time
• *E. pacifica* develop from egg to juvenile in an average of 60 days (Feinberg et al. 2006) - therefore, a cohort that appears about two months after a spawning event could be attributed to those eggs
• Based on biweekly data from 2001-2008:
  – Identify cohorts based on lengths of juveniles and adults
  – Look for interannual variability in cohorts in relation to environmental conditions
  – Compare cohort growth rates to growth rates measured in live animal experiments
  – Create survivorship curves
Note: local SST off Newport, OR lags behind the PDO so while the PDO was warming in 2002 the ocean in our study area was still cold.
Cumulative Upwelling Index
2001-2008

- CUI positive during upwelling season 2001-2002, 2005-2008
- Shortest upwelling seasons:
  - 2003 (5.9 mo.)
  - 2005 (4.2 mo.)
  - Long-term average 6.7 mo.
- 2005 upwelling started ~1 mo. later than average

http://www.pfle.noaa.gov/products/PFEL MODELED/indices/upwelling/upwelling.html
Methods

• Counted euphausiid eggs from 1/2m vertical net samples to determine timing of high egg density ("egg peak")
• Counted and measured juvenile and adult *E. pacifica* from nighttime bongo nets
• Identified cohorts using maximum likelihood method in Matlab
• Cohorts based on lengths of juveniles and adults since larval stages were not present in sufficient numbers to identify a size mode
Chlorophyll climatology at Newport

Egg densities associated with chlorophyll blooms
Cohort caveats

- Cohort analysis assumes resampling of the same population over time
- Patchy distribution of euphausiids may explain disappearance & reappearance of size modes
- Krill grow more slowly at cooler temperatures and can shrink under certain conditions
  - Our sampling interval is longer in winter due to weather which, combined with potentially shrinking animals, can make it difficult to follow a cohort
  - Some krill may overwinter as juveniles which can skew the timing between egg peaks & appearance of juveniles
- Cohort size modes may merge as krill grow due to individual variability in development rates
Cohort Data
2003

Traditional cohort analysis subjective with size modes identified by eye.
Cohorts from maximum likelihood method

- This technique identifies overlapping distributions.
- We calculated growth rates from change in mean length of each size mode from one sampling date to the next.
Cohorts 2001-2008

Similar slopes suggest *E. pacifica* growth rates similar among years of this study.
## Cohort Details

<table>
<thead>
<tr>
<th>Cohort</th>
<th>Start date</th>
<th>End date</th>
<th>Duration (years)</th>
<th>R²</th>
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</table>
• Each year except 2006 has a <1yr cohort and a >1yr cohort.
• Start dates of shorter cohorts usually earlier or later in the year (not during upwelling conditions)
2+ yr cohorts start in association with high chl and experience high chl each summer.
Growth rates: cohorts & experiments

- **Cohorts:**
  - Growth rate calculated from change in mean length of cohort between sampling dates

- **Instantaneous Growth Rate (IGR) experiments:**
  - Measures growth of individual krill that molt during a 48h experiment
  - Krill may grow, shrink, or remain the same size
  - Molt approximately every 7 days in our study area
  - Two-week sampling interval probably covers at least two intermolt periods
  - Individual animals could potentially grow and shrink within one sampling interval
Cohort growth rates

- Growth rates usually 0.01-0.17 mm d\(^{-1}\)
- Growth rates above 0.4 mm d\(^{-1}\) only in 2001
- Growth rates usually positive, negative growth more common when animals ≥10 mm

Cohort growth rates consistent among years. Interannual variability minimal if at all.
Cohort growth rates (red) show that growth tends to slow as animals reach maturity. IGR growth rates (gray) show range of individual variability.
We don’t have measured stage durations for juveniles and adults. The stage duration estimates that best fit these curves were:

• Juveniles - 6 months
• Adults - 2 years

2005: late upwelling, lots of eggs, few survivors
Summary & Conclusions

• Cohort analysis using maximum likelihood method and sufficiently short sampling interval can:
  – yield growth rates comparable to IGR experiments
  – identify some incidences of negative growth

• Cohort initiation and growth were similar among years in spite of differences in ocean conditions – variability so far is within tolerance range for *E. pacifica*

• Two or three cohorts initiated per year, often one short duration (<1yr) and one longer (>1.2yr) – implications?

• Survivorship from egg to furculia was similar among years except in 2005: delayed upwelling → delayed spawning → lower survivorship

• Survivorship curves suggest the juvenile stage lasts about 6 months and that adults live about 2 years
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