IS THE CONDITION AND GROWTH OF EARLY LIFE STAGES OF NORTHERN ANCHOVY RELATED TO THE BIOCHEMICAL CLIMATOLOGY OF THE NORTHERN CALIFORNIA CURRENT?

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Background: Northern anchovy (*Engraulis mordax*)

- Spawn mid-May to mid-September (12-15°C)
- Hatch at 2.5-3.0 mm TL
- Rapid growth, short lifespan (<7 yr), early maturity (1 yr)

Figure 2. Distribution of northern anchovy (from Pacific Fishery Management Council 1978).
Early feeding & growth

Stable Ocean Hypothesis

(Hjort 1914; Lasker 1975; Peterman & Bradford 1987)

No relationship between larval abundance and Age-1 recruits – focus on older larvae more informative (Peterman et al. 1988)

Abundance of Age-1 related to boreal copepod biomass during ELH stages (Litz et al. 2008)

Evidence that interannual variation in growth during ELH related to copepod community composition & biomass of boreal copepods (Takahashi et al. 2012)
The sign of the PDO is associated with relatively warm or cold water along the coast.

“warm” and “cold” water zooplankton communities in coastal waters are associated with positive or negative phases of the PDO, with a lag.

Variation in the copepod community composition has been well correlated with salmon survival (Peterson & Schwing 2003, Bi et al. 2011), marine growth of juvenile salmon (Tomaro et al. 2012), and the early growth and survival of northern anchovy (Litz et al., 2008, Takahashi et al. 2012).

Bill Peterson, NOAA.
Prey Quality/Essential Fatty Acid Hypothesis

Climate-mediated changes in the availability of essential fatty acids can have community-level effects (Litzow et al. 2006).

Greater lipid content of the boreal copepods results in higher growth and survival of juvenile salmon and northern anchovy (Bill Peterson and others).

The relative importance of prey composition, abundance, and quality are not yet well understood.
**Hypotheses & Objectives**

**Ho$_1$**: The lipid and fatty acid composition of the copepod community covaries with the CCI. Greater lipid levels during spring/summer & in cooler years -- more negative CCI values.

**Ho$_2$**: Growth rates of early stage northern anchovy are positively related to lipid levels and certain fatty acids in the copepod community.

Characterize seasonal & interannual variation in lipid classes and fatty acids in particulate organic matter, zooplankton, and early stages of northern anchovy and relate that variation to early growth in anchovy.
Methods: Copepod community composition

• Biweekly collections
• NH05, 60 m depth
• 50-cm diameter, 202-\(\mu\)m mesh ring net
  • “Copepod Patty”
• 20-\(\mu\)m mesh sample – POM/phytoplankton

• Copepod Community Index (CCI)
• Northern Copepod Biomass Anomaly
• Southern Copepod Biomass Anomaly
Methods: Copepod community composition

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Methods: Early stages of northern anchovy (*Engraulis mordax*)

- 264-rope trawl with a small-mesh liner
- Light traps
- Condition Index (length-mass residuals)

- Age, hatch date, growth rate:
  otolith analysis

*Yaquina Bay*  
*Willapa Bay line*
Methods: Lipid classes and fatty acid composition

OSU Cooperative Institute for Marine Resources (CIMRS) Lipid Lab (Dr. Louise Copeman)

- Phytoplankton, copepod patty, *Calanus marshallae*, northern anchovy
- Modified Folch procedure (extraction)
- TLC-FID (lipid classes)
- GC-FID (fatty acids)
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Methods: Temporal coverage

- **Phytoplankton & Copepods**

  - **Northern anchovy**

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Results: Copepod Community Index

- **DHA/EPA** = docosahexaenoic acid/eicosapentaenoic acid (~dinoflagellates/diatoms)

Biochemical response precedes change in Community Copepod Index (CCI)

- in total lipids after fall transition
- in DHA/EPA after fall transition

**Copepod Community Index (CCI)**

**Lipids, mg/g wet weight**

**10/25/2012**
Results: Growth & condition of early stages of northern anchovy

- 96 individuals collected
- 36.8 (±7.6 SD) mm SL
- Mean age: 82 d (±20) (n = 73)
- Age range: 42-129 d

![Graph showing hatch date distribution across months and days of the year with bars representing the proportion of hatchlings for each hatch date. The x-axis represents hatch date (day of year) from May 14 to Aug. 12, and the y-axis represents proportion. The graph indicates a peak in hatchings during Early June.]
## Results: Growth & condition of early stages of northern anchovy

### Cohorts based on hatch date:

- **Growth**
  - **May**: 14-20, n = 15
  - **Early June**: 3-18, n = 25
  - **Late June**: (June 23-July 8), n = 16
  - **July**: (July 18- Aug 2), n = 11

### Capture date:

- **Size & Condition**
  - **July 21-22**, n = 19
  - **August 23**, n = 28
  - **October 7-8**, n = 15
  - **October 22-23**, n = 18
  - **Nov. 4**, n = 3

- **Lipids**
  - n = 12
  - n = 14
  - n = 10
  - n = 10
  - n = 2
Results: Northern anchovy condition at capture

Higher condition when boreal, lipid-rich species are dominant and have greater biomass.

$r = -0.797$

$r = 0.813$
Results: Northern anchovy cohort growth

![Graph showing mean otolith increment width and NH36 temperature over a range of days from late May to July. The graph plots the mean otolith increment width in micrometers (µm) against the day of the year. The NH36 temperature is also plotted against the day of the year, showing fluctuations throughout the period.]
Results: Temperature effects on growth

Early otolith growth positively correlated with temperature

Temperature (°C) (NH 36 km, 128 m)

Mean otolith increment width (µm) (initial 10 d)

$r = 0.99$
Results: Growth & condition of early stages of northern anchovy

**Potential Growth**

\[ y = 0.048x - 0.207 \]

\[ R^2 = 0.808 \]

**Observed Growth**

\[ y = -0.083x^2 + 0.914x - 0.176 \]

\[ R^2 = 0.990 \]

98.8% ± 9.2 SD
Results: Growth & condition of early stages of northern anchovy

northern anchovy residual growth

10 d means centered around copepod sample

Day of year

Northern anchovy residual growth (mm/day)

-0.30
-0.20
-0.10
0.00
0.10
0.20

135 160 185 210 235 260 285

Northern anchovy residual growth

northern anchovy observed growth

northern anchovy potential growth

10 d means centered around copepod sample
Results: Growth of early stages of northern anchovy & copepods

- Copepod Community Index
  - Northern anchovy residual growth (mm/day)
  - Southern Copepod Biomass Anomaly
  - Northern Copepod Biomass Anomaly

Correlation coefficients:
- $r = -0.68$
- $r = 0.59$
Results: Growth of early stages of northern anchovy
Clear seasonal variation in lipids classes and FA within the copepod community

Substantial intra-annual variation in anchovy growth – related to temperature and copepod community composition

Intra-annual variation in early growth of northern anchovy related to FA in copepod community (diatom indicators)

Those diatom indicators are better described by variation in the biomass of northern copepods than the Copepod Community Index (CCI) (r = 0.55 vs. r = 0.30)

Early growth of northern anchovy influenced by both the community and relative biomass/abundance (individual size, abundance, and density)

**Analysis ongoing**....second year of data collection, multivariate approaches, more detailed analysis of how changes in the copepod community relate to FA variation and anchovy growth
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