Fighting a hard battle: effects of hypoxia and temperature on euphausiids in the North Pacific

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Coastal hypoxic systems

Diaz, and Rosenberg Science 2008
Projected future ocean: Increasing temperature and decreasing $O_2$
Importance of euphausiids in the North Pacific

Field & Francis (2006)
Oxygen and temperature effects on *Euphausia pacifica*

- **Field: avoidance of high temperature (> 15°C)**
  - Taki 2008

- **Field: avoidance of low oxygen**
  - Jaffe et al. 1999; Mackie & Mills 1983

- **Lab: 1.5 mg O$_2$/l + 10°C**
  
  Adult mortality: Low
  - Tremblay & Abele 2015
Goals of this study

#1. Do *E. pacifica* show threshold responses to oxygen and temperature?

#2. How does their distribution covary with environmental conditions?
Coastal hypoxic systems in the North Pacific

Hood Canal

Diaz, and Rosenberg Science 2008
Seasonal hypoxia

Long history of fish kills

Two stations: Dabob and Union
Field collections at Union & Dabob
2012 & 2013, monthly June-Oct cruises

Depth-stratified MultiNet® plankton net
  • Day & night oblique tows
  • 200 & 335 µm mesh

CTD: SeaBird Electronics SBE911 plus
  • Temperature
  • Dissolved oxygen
    (calibrated with Winkler titration)
  • Salinity
  • Fluorescence
  • PAR (Photosynthetically Active Radiation)
Life stages of *Euphausia pacifica*

- Juveniles and adults
- Eggs and nauplii
- Calyptopes I-III
- Furcilia IV-VII
- Furcilia I-III

Images by Amanda Winans
Goals of this study

1. Do *E. pacific* show threshold responses to oxygen and temperature?
   - Piecewise regressions

2. How does their distribution covary with environmental conditions?
Threshold searching: dissolved oxygen

Dissolved oxygen (mg/l)

Eggs & nauplii
Weak swimmers

Calyptopes
Strong swimmers

- F I-III
- F IV-VII

Dissolved oxygen (mg/l)

Density of *E. pacifica* (#/m³)

- Weak swimmers
- Strong swimmers

3.6* 5.6***
Furcilia I – III density

Density of *E. pacifica* (#/m³)

Average depth (m)

Day

Night

- Purple dots: High DO
- Orange dots: Medium DO
- Black dots: Low DO
Threshold searching: temperature

Density of *E. pacifica* (#/m$^3$)

**Weak swimmers**

- Eggs
- Calyptopes

**Strong swimmers**

- F I-III
- F IV-VII

Temperature (°C)

- Weak swimmers: X
- Strong swimmers: ??
Goals of this study

1. Do *E. pacific* show threshold responses to oxygen and temperature?

2. How does their distribution covary with environmental conditions?
   - GLMM (Generalized Linear Mixed Models)
     - Random effects: tow
     - Fixed effects: depth, temperature, and dissolved oxygen
   - Corrected AIC as a model selecting criterion
Binomial candidate models for each stage

- Presence/Absence  The best model for each stage
  - Depth  Juveniles & adults
  - Oxygen
  - Temperature  Eggs & nauplii
  - Depth + Temperature
  - Depth + Oxygen
  - Temperature + Oxygen  Calyptopes; Furcilia I-III
  - Depth + Temperature + Oxygen
  - With/without confounding effects (Year, Month & Station)

- Strong random effects***
- Oxygen and temperature interactions excluded
Conclusions

• Within our oxygen range, furcilia I-III is the only stage that demonstrated clear avoidance of low oxygen (<3.6mg/l)
• We need more high temperature observations to study the thermal limit of *E. pacifica*
• Furcilia I-III distribution is most related to both temperature and oxygen
Next steps: *E. pacifica* habitat and stress comparison in the North Pacific
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