Zooplankton species composition is linked to ocean transport in the Northern California Current

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U.S. GLOBEC:
Pacific Ocean Boundary Ecosystems and Climate
Objectives

• Assess to what extent, and by what mechanisms, large-scale climate modes drive changes across Pacific boundary ecosystems.

• Quantify and explain how changes in regional ocean processes (e.g. upwelling, mixing and mesoscale structure) at each boundary control phytoplankton and zooplankton dynamics.
Location of zooplankton time series data:

- Seattle
- San Francisco
- Canada
- United States
- Oregon
- California
**Seasonal upwelling**

- **Winter:**
  Poleward downwelling winds
  Poleward alongshore currents

- **Spring Transition**
  in March/April

- **Summer:**
  Equatorward (upwelling) winds
  Equatorward alongshore transport

- **Fall Transition**
  in September/October
Not all copepods are created equal!

Higher lipid content in cold-water, northern species.
Large-scale climate indices relate to zooplankton and salmon survival:
A working mechanistic hypothesis: source waters change:

- Transport of boreal coastal copepods into NCC
- Transport of sub-tropical copepods into NCC
Zooplankton sampling since 1996:

- Bi-weekly net tows:
  Vertical tows from near bottom
  (½-m diameter, 202-μm mesh)

Laboratory/Statistical Methods:

- Microscope identification of zooplankton to species
- Non-metric Multidimensional Scaling (NMS) ordination of copepods
- “Rigidly-rotated” variance to load on Axis 1
Ordination of zooplankton time series data

Ordination axis (71%) vs. Ordination axis (13%)
Time series of ordination scores = the “Copepod Community Index”

Non-seasonal anomalies of the Index
The Copepod Community Index tracks the PDO

Community Index
PDO

$ r = 0.68, p < 0.01 $
The Model

**ROMS model**

- 1950-2008
- Nested within the OFES model (global 10 km hindcast)
- 10 km resolution
- 30 vertical layers
- nudged at open boundaries
- forced by NCEP fluxes (winds and heat)

Passive tracers experiments to diagnose transport pathways.
Model representation of the Pacific Decadal Oscillation
Positive (warm) phase

EOF of SST (color) and current anomalies (vectors) closely match the PDO pattern
Regional model PDO dynamics match observations

Correlation between the PDO and the 1st EOF of model SST

PDO versus Model PDO
(R=0.60 99.9%)
Seasonality in advection is captured by model passive tracers.
Changes in advection with phase of the PDO

Positive PDO

Negative PDO

Tracer concentration

High

Low
The “Copepod Community Index” (CCI)

Non-seasonal anomalies of the Index

Advection from north:  
R= -0.56  
(99.0%)

Advection from south:  
R= 0.56  
(99.0%)

Advection from west:  
R= 0.21  
(58.6%)

Warm taxa  
Cold taxa
Reconstruction of Copepod Community Index using model passive tracers:

\[ \text{CCI} = \alpha_N \text{NORTH} + \alpha_S \text{SOUTH} + \alpha_E \text{EAST} + \alpha_W \text{WEST} + \epsilon \]

- \( \alpha_N = -0.59 \)
- \( \alpha_S = 0.20 \)
- \( \alpha_E = 0.25 \)
- \( \alpha_W = 0.17 \)

All Tracers

Two Tracers

\[ \text{CCI} = \alpha_W \text{NORTH} + \alpha_S \text{SOUTH} + \epsilon \]

- \( \alpha_N = -0.54 \)
- \( \alpha_S = 0.25 \)
Changes in advection with phase of the PDO

Positive PDO

Negative PDO

Tracer concentration

High

Low
Conclusions

• Model experiments confirm that a large portion of the change in zooplankton species composition at our coastal station is explained by changes in north/south (alongshore) surface transport.

• Farther offshore, downwelling dynamics are also important (as indexed by the WEST tracers).

• Advection, and therefore species composition, changes on climate scales.

• Changes in species composition are important to predator growth and survival.
• **Future experiments planned:**

- To explain remaining variance in NEP region:
  
  - examine the role of deep advection (using passive tracer experiments)
  - examine the role of growth and mortality (using future NPZ model)

- To compare with other Pacific boundary regions

Ultimately, aim to determine the extent to which basin-scale processes control Pacific boundary systems versus regional and local processes through the regional experiments and comparisons.
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