Inland sea versus coastal ocean zooplankton response to “The Blob.”

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2-Hatfield Marine Science Center, Newport, OR
3-Department of Fisheries and Oceans, Canada
4-NOAA Northwest Fisheries Science Center
Record high temperatures occurred during the Pacific Warm Anomaly, a.k.a. “The Blob”

Developed offshore during winter 2013-14

NANOOS Visualization System:
http://www.nanoos.org/
Summer 2014 – Warm water held offshore by upwelling in summer 2014

July 2014

NANOOS Visualization System:
http://www.nanoos.org/
Dramatically advected onto shelf in Fall 2014 with shift to downwelling.

October 2014

NANOOS Visualization System: http://www.nanoos.org/
Very warm water at >50 m depth on shelf in October.

Cha’ba buoy off La Push, WA
Oregon coast temperatures remained high Fall 2014 through Fall 2016:
Reported biological impacts during the Blob:

- Unprecedented copepod species richness off Oregon (Peterson et al. 2017; Jacobson yesterday)
- Unprecedented negative cold-water copepod anomalies
- Near-record positive warm-water copepod anomalies
- Extremely low juvenile/adult euphausiid biomass

- Massive Cassin’s auklet die offs (J. Parrish)
- Extremely low salmon returns
- Abandoned and starved sea lion pups
- Unprecedented, wide-spread toxic *Pseudo-nitzschia* bloom (Du et al. 2016)
How was this big anomaly reflected in inland sea systems?

Were responses coherent throughout the region?

Nutrients
  ↓
Chlorophyll
  ↓
Zooplankton
  ↓
Salmon
Zooplankton time series:

**Strait of Georgia:**
Inland Fjord
1995-present
DFO Canada (D. Mackas, I. Perry, et al.)
• 300 m average depth

**Puget Sound:**
Inland Fjord
2014-present (zooplankton, J. Keister et al.)
1997-present (hydrography, King Count)
Collaborative program
• 200 m average depth

**Newport Line:**
Continental shelf upwelling system
1996-present
NOAA NWFSC (W. Peterson et al.)
• 65 m depth
Puget Sound: Water column heat content anomalies

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- Red = higher than expected (> *IQR)
- Black = expected (= *IQR)
- Green = lower than expected (< *IQR)
- Light green = higher than previous measurements
- Gray = no data

*IQR = Interquartile Range (25th – 75th percentiles); n = 17
Oregon coast – Nutrient and Chlorophyll anomalies
Relative to 1997-2018 mean

Nutrient anomalies

Chlorophyll anomalies

NH-5 Surf NO$_2$ + NO$_3$

NH-5 Surf Chl-a
Puget Sound – Nutrient and Chlorophyll anomalies
Relative to 1997-2011 mean

Nutrient anomalies

Chlorophyll anomalies
Zooplankton biomass anomalies: Relative to 2014-2017 mean

Oregon coast – Zooplankton biomass anomalies

Puget Sound – Zooplankton biomass anomalies
Annual cumulative zooplankton biomass:

Oregon Coast

Central Puget Sound
Central Strait of Georgia – zooplankton biomass increase 2014-17

Young et al., Salish Sea Ecosystem Conference, 2018
Coastal salmon that out-migrated in 2014 and 2015 had some of lowest returns on record:

“Juvenile salmon growth was high in all years, 2014-2017.”
(B. Beckman unpub. June IGF-1 data)

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Coho survival and Chinook returns were lower in 2015.
Puget Sound Juvenile Chinook salmon growth and size:
Tended to be higher and less variable in **2015** than **2014**

**IGF-1 index of growth for 3 regions:**

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**N. Whidbey juvenile salmon size:**

Fork length (mm)

- **2014**
- **2015**

Chamberlain et al. 2017

Courtesy of C. Greene et al., NOAA

http://www.fpc.org
Puget Sound Coho salmon survival rate was higher for 2015 out-migrants than 2014:
Puget Sound - salmon prey taxa much higher biomass in warm years:

Prey Field = Decapods + amphipods + ichthyoplankton + euphausiids
Big difference between systems

Mechanisms?

Hypotheses?
H1: Fundamental differences between systems

Deeper, warmer, more stratified system. Circulation limited by sills.

- 2015 drought decreased stratification $\rightarrow$ higher production

Shallower, colder upwelling site. Strongly influenced by water mass advection.

- Upwelling of warmer, less saline deep water, low NO$_3$, increased stratification $\rightarrow$ lower production
Strong evidence for advection-driven changes in California Current zooplankton

Very few unusual species observed in Puget Sound

I go with the flow!
H2: Different temperature optima of resident dominant species?

North Pacific warm-water species

\{ Puget Sound dominants: \\
\quad Calanus pacificus \\
\quad Corycaeus anglicus \\
\quad Paracalanus \\
\quad Pseudocalanus moultoni \}

Boreal cold-water species

\{ Oregon Upwelling dominants: \\
\quad Calanus marshallae \\
\quad Pseudocalanus mimus \\
\quad Acartia longiremis \}

“Typical” Summer SST
Working Hypothesis:

**Puget Sound:**

Higher temperature → higher growth of resident species, supported by sufficient primary production.

**Oregon Coast:**

Advection of high temperature, nutrient poor water & oceanic species assemblage.

→ Insufficient primary production, only small species present
Conclusions

During Blob years:

Large regional contrasts in zooplankton observed:
  • Lower zooplankton biomass on continental shelf
  • Higher zooplankton biomass in Puget Sound

Mixed response in salmon:
  • High juvenile growth in both regions during warm years
  • Indication of better survival from Puget Sound rivers in 2015; worse on coast.
  • But...2016-17 returns low in both regions (lag in PS?)

Mechanisms under investigation!

2017 conditions returning to ~normal (at least in Puget Sound).
Partnerships & Funding

Innumerable field crew!
All of the co-authors

Additional data from:
Kim Stark
Gabriela Hannach
Cheryl Morgan
Karen Suchy