The climate shift of 1998: something old or something new?

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Recent changes in hydrography and zooplankton in the N. California Current

OUTLINE

- Pacific Decadal Oscillation
- Hydrography
- Copepod Biomass
- Northern and Southern Species Anomalies
- Copepod biodiversity



North Pacific Pressure (colors) and Winds (arrows) (from Peterson and Schwing 2003)

RED = Warm temperatures; high atmospheric pressure **BLUE** = Cool temperatures: low atmospheric pressure

North Pacific Sea Surface Temperature1970-19761977-19831999-2002



•70-76: N. America winds equatorward
•77-83: N. America winds poleward
•99-02: N. America winds eastward

Differences are indexed by the Pacific Decadal Oscillation 1970-1976 1977-1983 1999-2002





However, a reversal in conditions was initiated in September 2002, two years ago



Focus talk on events of the past 9 years, a time period that includes several extreme changes in the northern California Current including:



- El Nino in 1997/98
- La Nina in 1999 and a 4-year climate shift
- Change in sign of PDO in 2002 to weakly positive
- each accompanied by changes in water type, copepod biomass and biodiversity.

The title of this talk asks if the present state is something old or something new? That is, "does the 1999-2002 cold period resemble the pre-1977 cold period?".

- The answer appears to be "**NO**". Many talks and posters have shown basin scale differences in temperature and winds, and regional (Northeast Pacific) changes in circulation and transport. What about local ecosystem response in the northern California Current?
 - 1. **Hydrography** along Newport Line
 - 2. Copepod **biomass**
 - 3. Copepod species (cold water vs warm water species groups)
 - 4. Copepod biodiversity
- Mechanisms?



<u>NH-Line Hydrographic and</u> <u>Zooplankton</u> <u>Time Series</u>

Bi-weekly Sampling:

- 1969 1973 (Miller, Pearcy, Peterson)
- 1983 (Miller, Batchelder, Pearcy, Brodeur)
- 1990-1992 (Fessenden and Cowles)
- 1996 present (Peterson et al.)



Sampling methods

- Water sampling with CTD, Niskin Bottles, and buckets for hydrography, chl-a and nutrients
- Mesozooplankton with ¹/₂ m 200 um net towed vertically
- Euphausiids with 70 cm 505 um net towed obliquely





Winds and current structure off coastal Oregon:

•Winter:

Winds from the South Downwelling Poleward-flowing Davidson Current Uniform cross-shelf hydrography

•Spring Transition in April/May

•Summer:

- Strong winds from the North Coastal upwelling Equatorward alongshore transport Strong cross-shelf physical gradients
- Upwelling-favorable winds cease in September/October





Bottom water hydrography at 50 m depth, mid-shelf station

1. Note: Seasonal cycle of temperature and salinity

2. Note:
98 = warm winter
00-03 = cool winter
04 = somewhat
warm winter



Abrupt shift in bottom water hydrography in 1998 and 2003

The winters and summers were cooler in 1999-2003; bottom waters saltier in summer 1999-2002 but freshened in 2003, becoming "minty" (Whitney, 2004).

> Average Salinity at 50 m at NH 05 May-September Upwelling Season







Copepod biomass increased dramatically in 2000 and 2001







Past work (in the sub-arctic Pacific and southern California current) has suggested that PDO changes are accompanied by sudden changes in copepod biomass



However, off Newport, • the PDO and copepod biomass appear to be unrelated: although in **1999 copepod biomass** did double with change in sign of PDO to negative, biomass has remained high through 2004 even though PDO turned positive in 2002.

If we examine changes in species composition, the picture becomes a bit more clear: here we group species by water-type affinities

- "Cold-water" copepod species (boreal / neritic); dominant in Bering Sea, coastal GOA, coastal NCC
 - Pseudocalanus mimus, Calanus marshallae, Acartia longiremis
- "Warm-water" copepod species (subtropical); common in SCC neritic and offshore NCC waters
 - Clausocalanus spp., Ctenocalanus vanus, Paracalanus parvus, Mesocalanus tenuicornis, Calocalanus styliremis

Based on Peterson and Keister (2003)

Zooplankton species assemblage anomalies as indicators of ecosystem and climate change

- Species-specific within-season (spring, summer, fall, winter) climatological means were calculated from log transformed biomass values.
- Mean anomaly values were calculated for each taxa for each season, then summed over the upwelling season (May-September) of each year sampled;
- Calculate average anomaly value for:
 - the three dominant boreal taxa ("*Cold-water*"), and
 - the five dominant sub-tropical taxa ("Warm-water")



PDO vs. Northern and Southern Copepod Species Anomalies Now a pattern is evident...

When PDO is negative, ("cool phase") cold water or northern species have high biomass whereas the warm water southern species have low biomass

and vice versa...

The changes are rapid and approach order of magnitude differences among years.



N and S Copepod biomass anomalies are significantly correlated with the Pacific Decadal Oscillation



If we delete the 1998 El Nino data point (circle),the coefficient of variation is nearly doubled.



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With respect to food chain interactions, are there implications for consumers of this variable mix of species? Perhaps...

Comparisons in size and chemical composition

- Warm-water taxa (from offshore OR) are small in size and have limited high energy wax ester lipid depots
- Cold-water taxa (boreal coastal species) store wax esters as an over-wintering strategy

Comparisons in size and chemical composition

- Warm-water taxa (from offshore OR) are small in size and have limited high energy wax ester lipid depots, whereas...
- Cold-water taxa (boreal coastal species) are larger and store wax esters as an over-wintering strategy thus move high-energy lipids into the food chain.



Adult Female Carbon Weight [ln (ug)]



Which type of food particle would you prefer if you were a sardine, salmon or sablefish?

Ample evidence has been presented at this meeting as well as in publications, that a fat fish is a fish that will almost certainly survive the winter whereas a slim fish is threatened.

Northern (boreal) copepod species package up those lipids needed for successful overwintering not only for themselves (if they survive) but for fishes.

This lipid hypothesis may be that which gives definition to the meaning of a negative or positive value of the PDO.

To this point we have shown the following:

• PDO is **not** correlated with copepod biomass, but....

• PDO is correlated with biomass of copepod species: warm water species do well if PDO is positive; cold water species if PDO is negative.

• What about biodiversity....is the total number of species in a sample related to the PDO?

Canonical Pattern: Low species diversity in summer; high diversity in winter. This pattern is due to seasonally-varying source waters: sub-arctic water in summer vs. sub-tropical in



The 1997-1998 El Nino event resulted in high copepod biodiversity during both winter 97-98 and summer of 1998



The past several years have seen dramatic changes in copepod biodiversity



More species are seen now than during the 1997/98 "El Nino of the Century"!



Looking retrospectively, the number of species ranged from 5-10 species per sample in 1970's, 1983 and early 1990's. Thus recent increases in biodiversity may be unprecedented.



What can this possibly mean?

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•For our analysis, we removed the seasonal differences by taking monthly averages, then calculated monthly anomalies

•Next figure shows that biodiversity appears to be related to both the PDO and ENSO



What mechanisms might account for recent increases in biodiversity and for the correlation of copepod species with the Pacific Decadal Oscillation and the Multivariate ENSO index

- Upwelling weaker or stronger?
- Transport?
- Source waters to NCC and location of bifurcation associated with westerly winds?
- Atmospheric teleconnections affecting wind patterns off Oregon during past two years?

Don't have the answers yet but our hypothesis is that variations in transport are driving biodiversity rather than any changes in local productivity.

•Curiously, increased biodiversity over the past two years is due to increased numbers of both warm water and cold water species. In fact, this summer (2004) was the first time that both the warm water and cold water had positive anomalies.

What changes are occurring today? 2003/2004 observations include:

- PDO changed sign to positive in August 2002
- 0.5° C temperature increase and salinity decrease in bottom waters of OR coastal shelf
- Total copepod biomass remained above average, due in part to high biomass of both "northern" and "southern" copepods)
- Increase in biodiversity
- Altimetry and current meter observations reveal a shift toward anomalous pole-ward transport beginning in January 2003; current meter observations confirm that pole-ward transport continued through at least July 2004.

Tentative conclusions

- Biomass of all copepod species combined is not correlated with PDO or other environmental indices, especially over the past two years;
- Partitioning biomass into "northern species" and "southern species" seems to have more explanatory power;
- Transport may be more important than local upwelling in determining zooplankton biomass, species composition and biodiversity.

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<u>A working hypothesis</u>: source waters...

> ↑ Transport of boreal coastal copepods into NCC from Gulf of Alaska

↑ Transport of subtropical copepods into NCC from Transition Zone offshore





Summer PDONS0.290.51 all data0.420.76 w/o 1998

Winter PDONS0.240.46 all data0.380.76 w/o 1998

= similar results

Coastal Upwelling Index



Ekman Transport Anomaly (monthly)



Altimetry: Alongshore Transport Anomalies (Seasonal; 45N-53N)



Adapted from Stub & James (2003)

Dec 9 03

"Anomalous transports were southward in the 300 km next to the PNW coast from 2000-2002, strongest in 2001 and the first half of 2002" - Strub and James (GRL, 2003)

Ecosystem differences in the N. California

Current that are correlated with the phase of PDO

COOL PHASE

- Temperatures cool
- Upwelling early
- Zooplankton ++
- Euphausiids ++
- Salmon ++
- Anchovies ++
- Whiting in deep water

WARM PHASE

- Temperature warm
- Upwelling late
- Zooplankton biomass ?
- Euphausiids down
- Salmon down
- Sardines + Anchovies?
- Whiting in shelf waters



In the northern California Current, the PDO and salmon survival are correlated



Pacific Decadal Oscillation and CalCOFI zooplankton volumes are correlated:

>> cool phase = higher zooplankton biomass

Implications for higher trophic levels

Relating zooplankton biomass to fish recruitment:

The stronger the northern copepod anomaly, the greater the Coho performance.

(Peterson & Schwing 2003)





Data Courtesy of R. Emmett (NMFS)