Climate change scenarios for the Northern California Current: a talk mostly about the PDO

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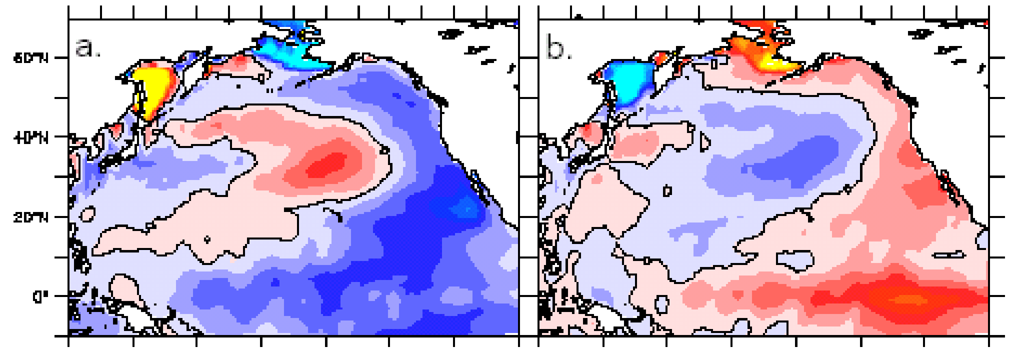
W6 – Climate scenarios for ecosystem modeling
Friday 26 Oct, King and Foreman

- PDO appears in many of the global climate models out to at least the years 2040;
- Difficult to evaluate effects of other scenarios such as changes in upwelling, stratification or seasonal cycles of production because models are not quite yet ready for regional downscaling;
- A new index, the North Pacific Gyre Oscillation index, was presented at W6 and in Science Board. This index seems to capture well variability in the California Current south of 38°N whereas the PDO continues to capture variability to the north.

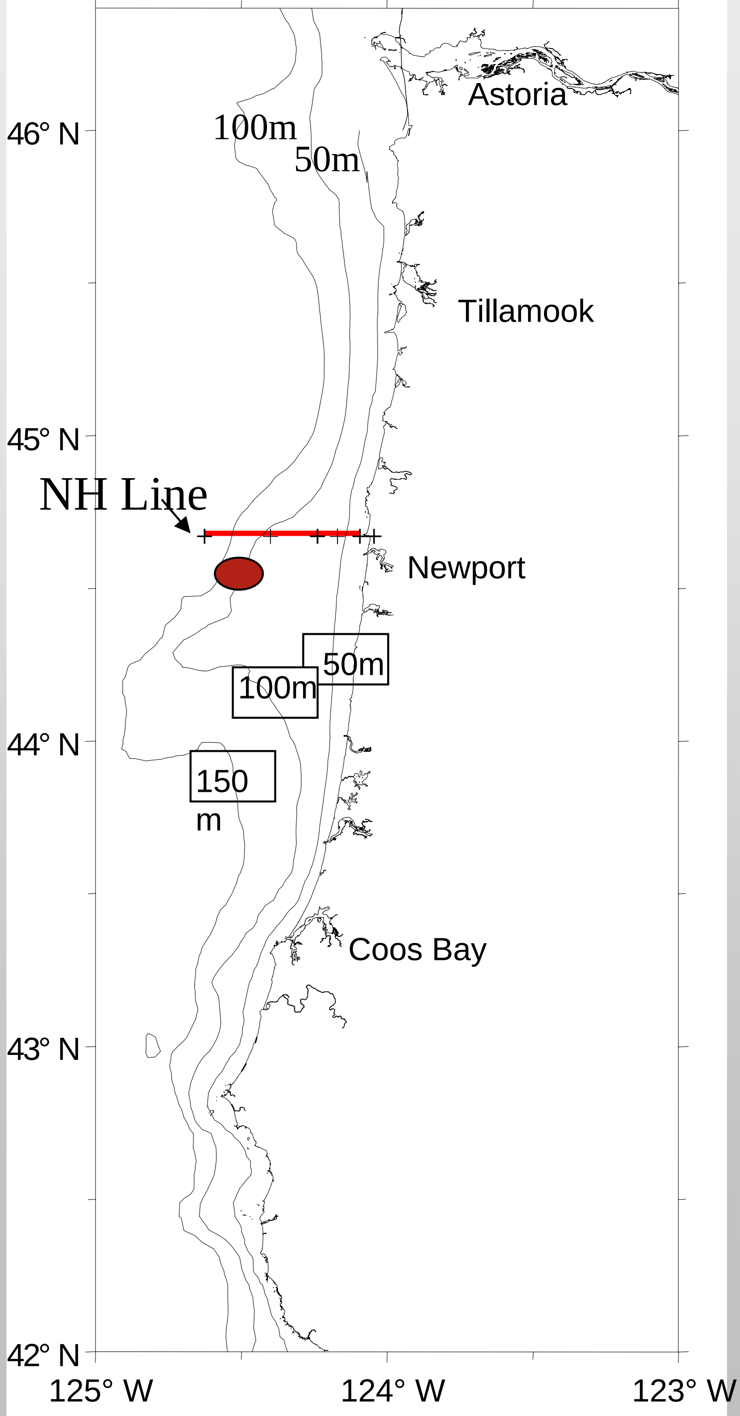
PDO has two phases, resulting from the direction of winds in winter. The SST patterns [shown on the right] result from Westeries and NWesterlies [negative phase] and SWesterlies [positive phase]

Westerlies are dominating this winter.

PDO & SST



Negative Phase	Positive Phase
1947-1976	1977-1998
1999-2002	2003-2006
2007-	

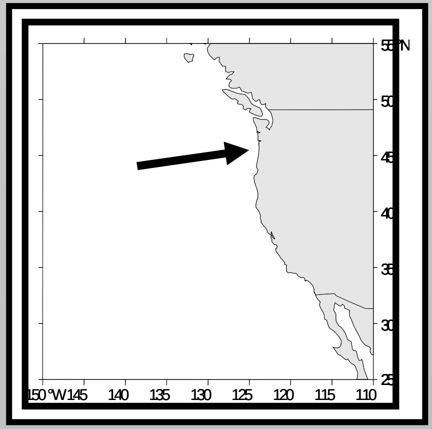


NH-Line Hydrographic and Zooplankton Time Series

Sample every two weeks:

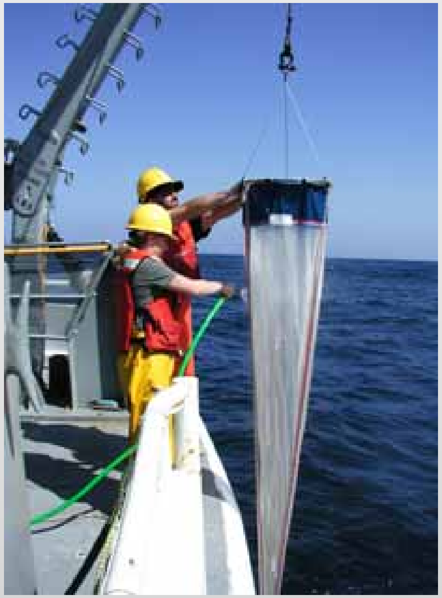
- **1969 – 1973** (Miller, Pearcy, Peterson)
- **1978** (Peterson)
- **1983** (Miller, Batchelder)
- **1990-1992** (Fessenden and Cowles)
- **1996 – present** (Peterson et al.)

Weather Buoy 46050

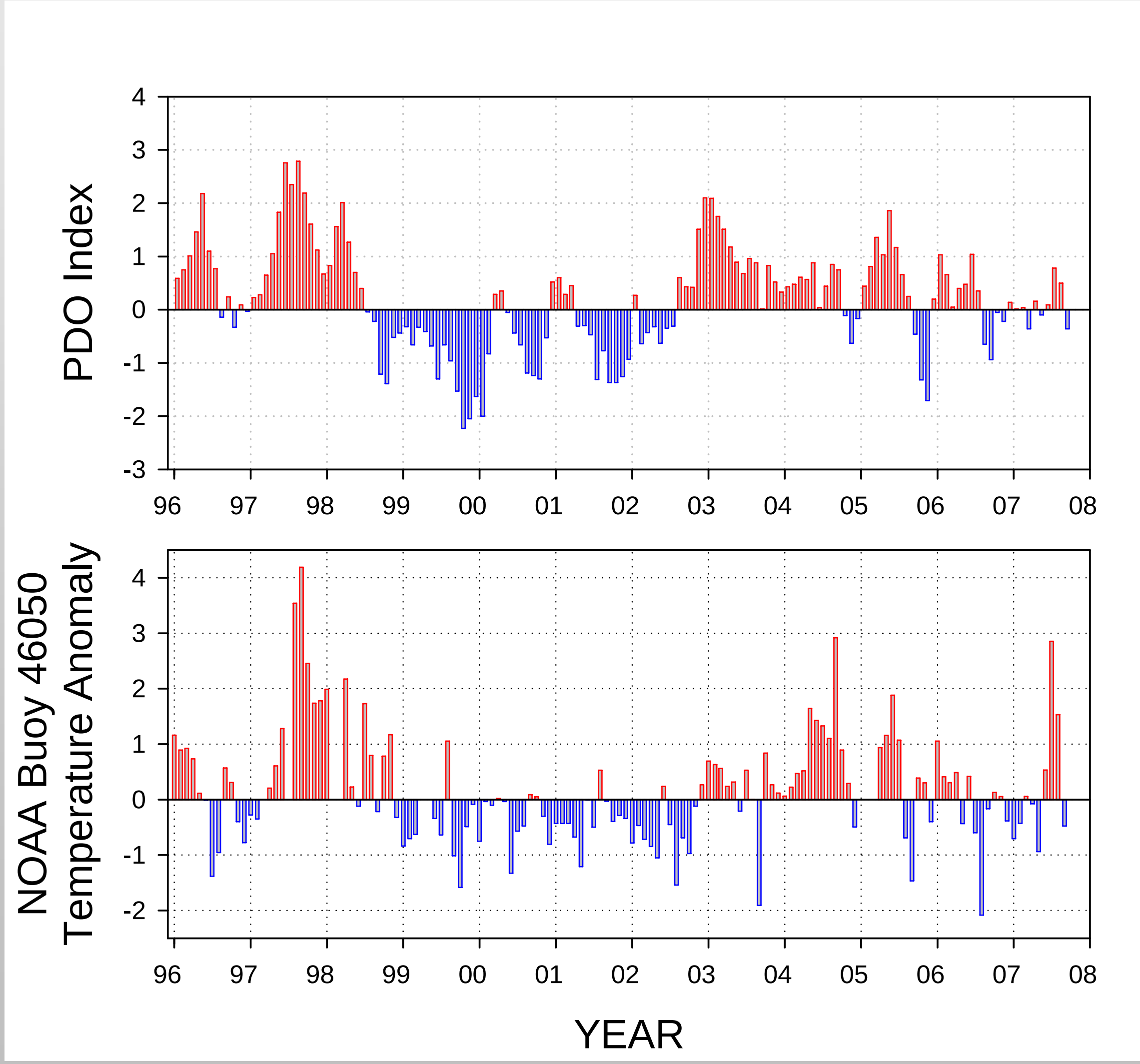


Sampling methods

- Water sampling with CTD, Niskin Bottles, and buckets for hydrography, chl-a and nutrients
- Mesozooplankton with ½ m 200 µm mesh net towed vertically
- Euphausiids with 70 cm 505 µm mesh net towed obliquely

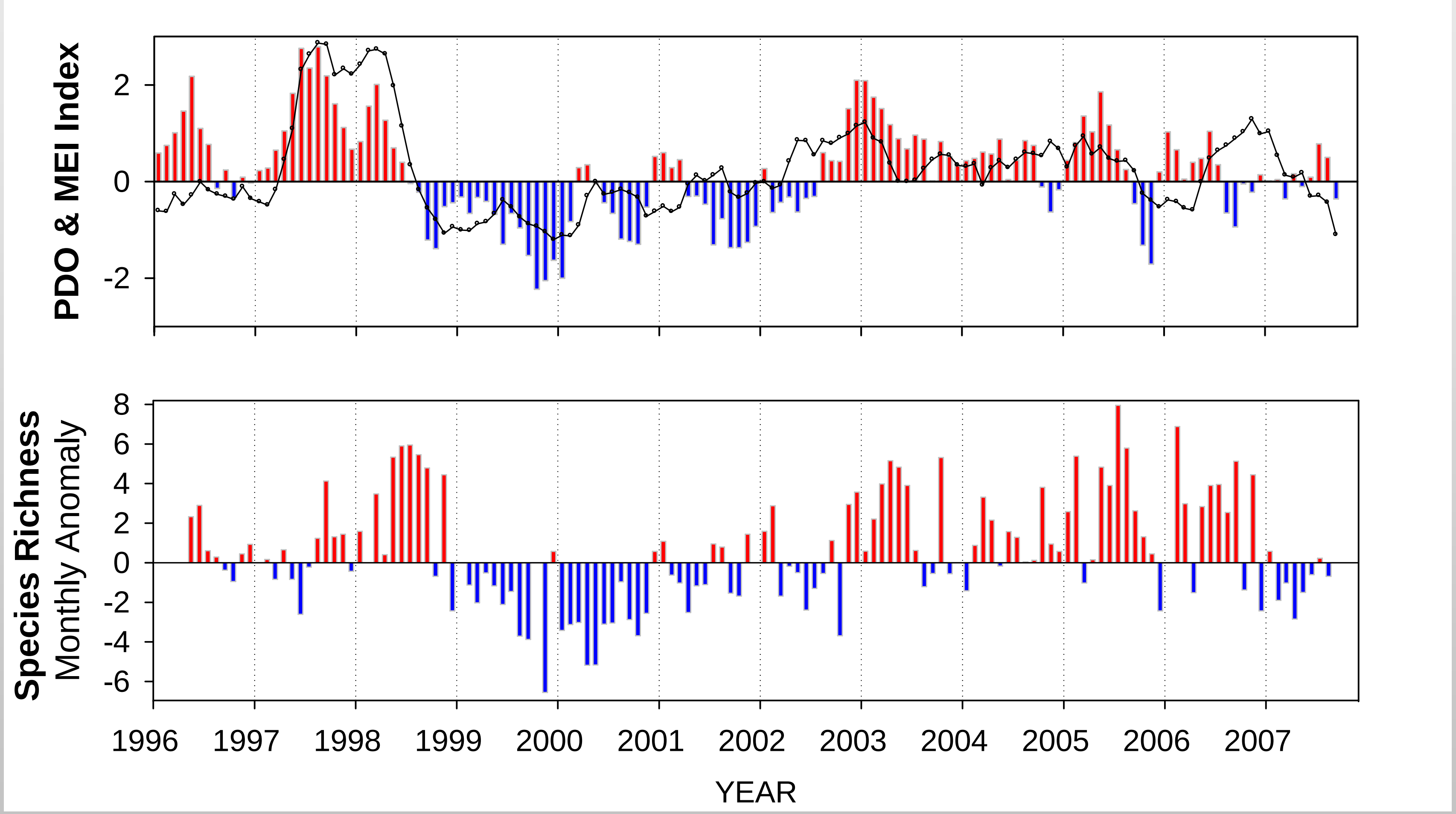


12 year time series of SST off Newport shows that PDO downscales to local SST



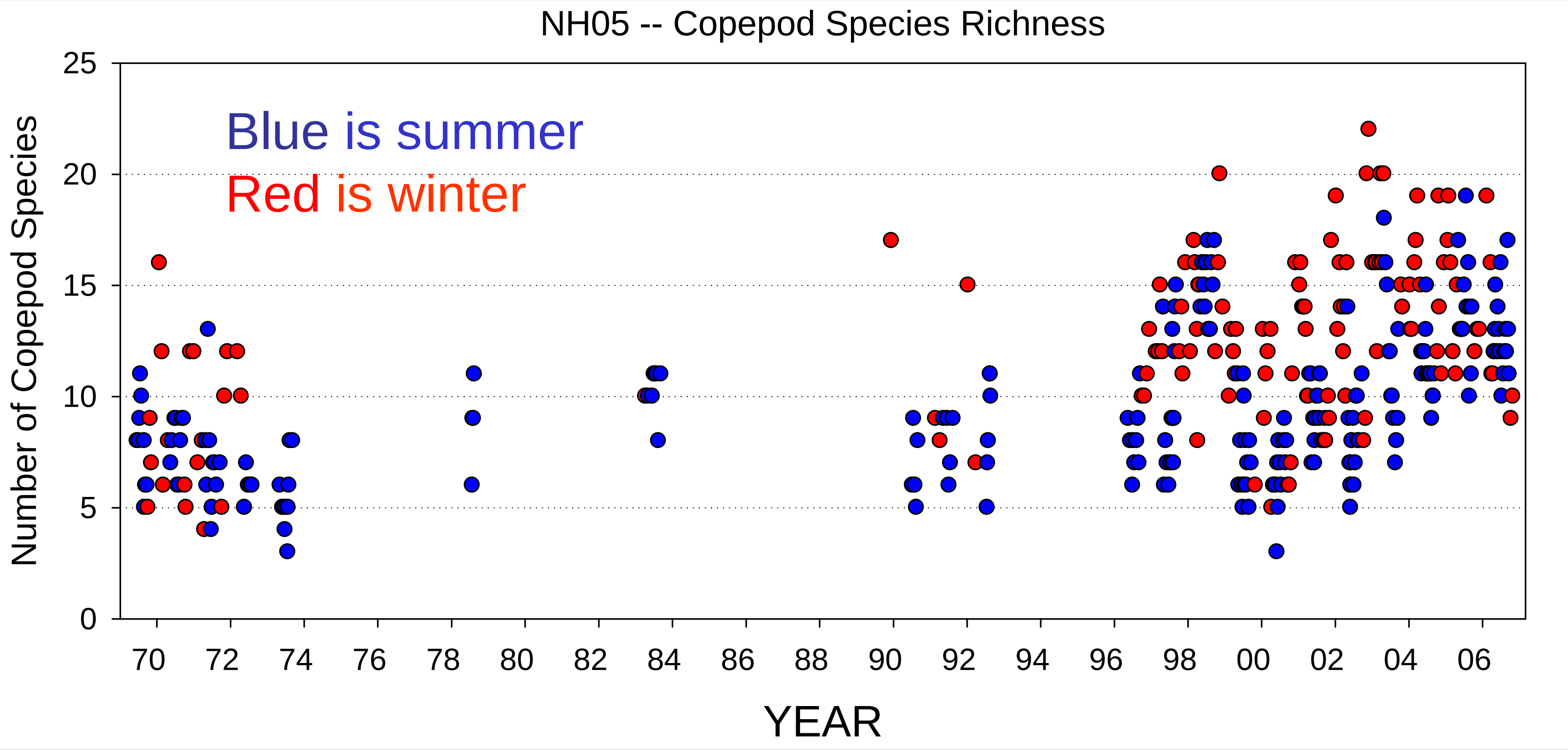
- PDO and SST correlated, as they should be.
- However there are time lags between PDO sign change and SST response of 3-5 months.
- Suggests PDO is an advective signal along the Oregon coast

12 year time series of zooplankton sampling off Newport shows that monthly anomalies of copepod species richness are correlated with the PDO & MEI



As with SST, there are time lags of a few months between the recent 4-year "cold periods" and "warm periods". Cold periods are characterized by "cold water" copepods and vice versa.

Copepod biodiversity has increased over the past few years

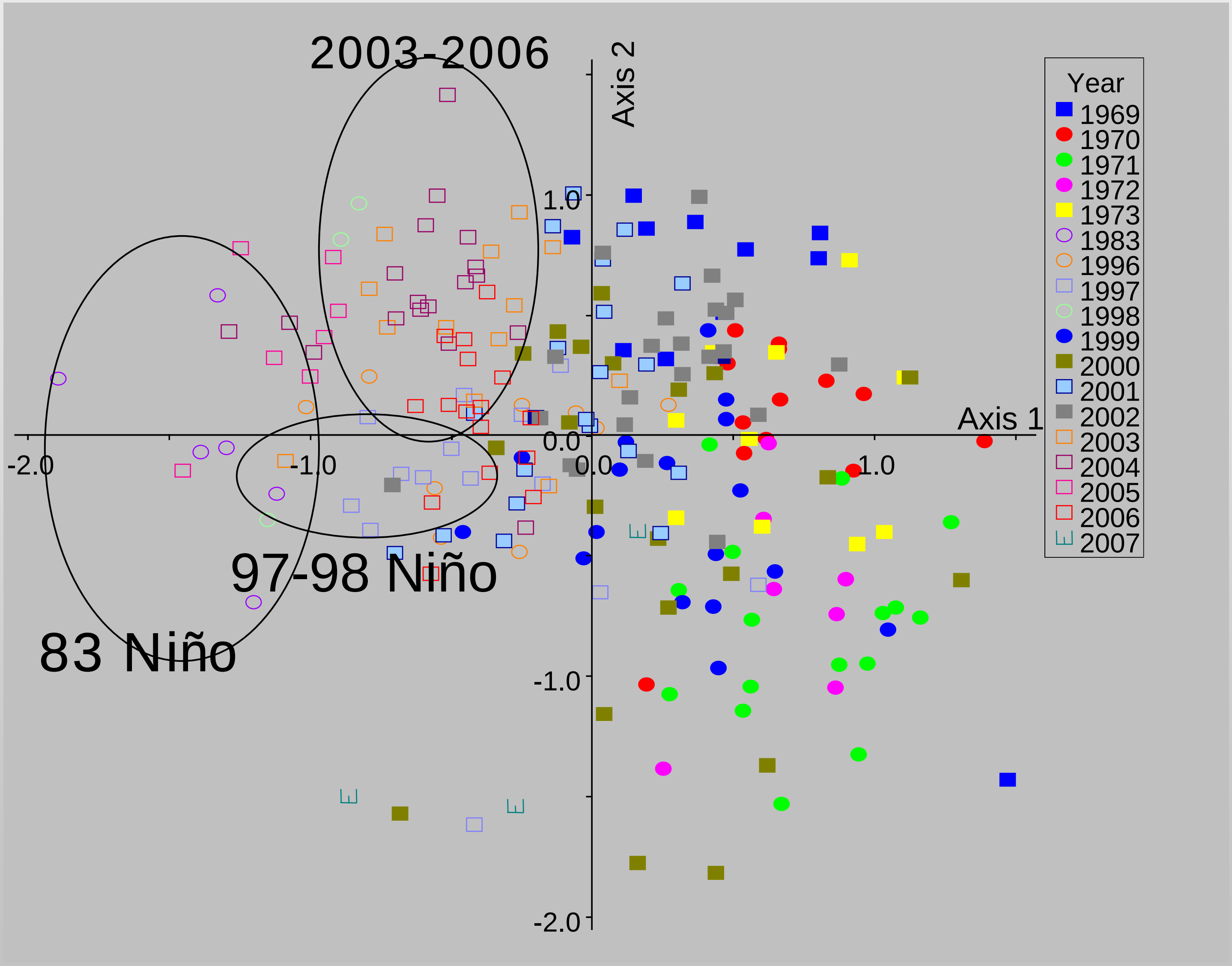


A more diverse copepod community is seen now as compared to 1970s. Thus the "cool phase" of 1999-2002 is different from the cool phase of 1947-1977, perhaps because basin-scale winds are more westerly? This may be first indication that we will find a different copepod community (and different food chain structure) in the FUTURE.

Community Composition:
Cold vs. warm water communities

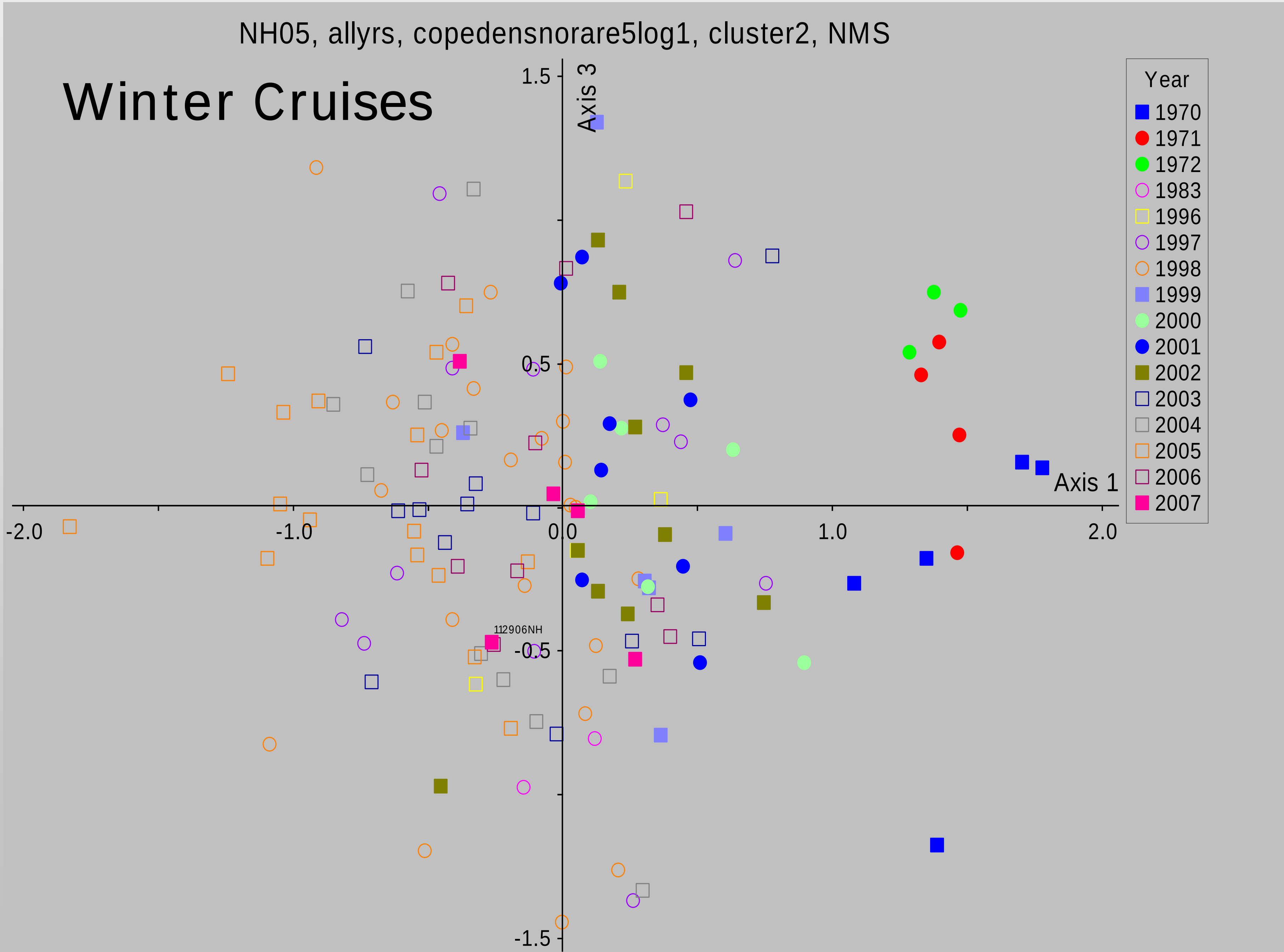
- Non-parametric multidimensional scaling (ordinations) is a technique that groups zooplankton samples using a **similarity index**; stations near to each other in MDS space have similar community structure

Ordination of 18 years of Summer Cruises

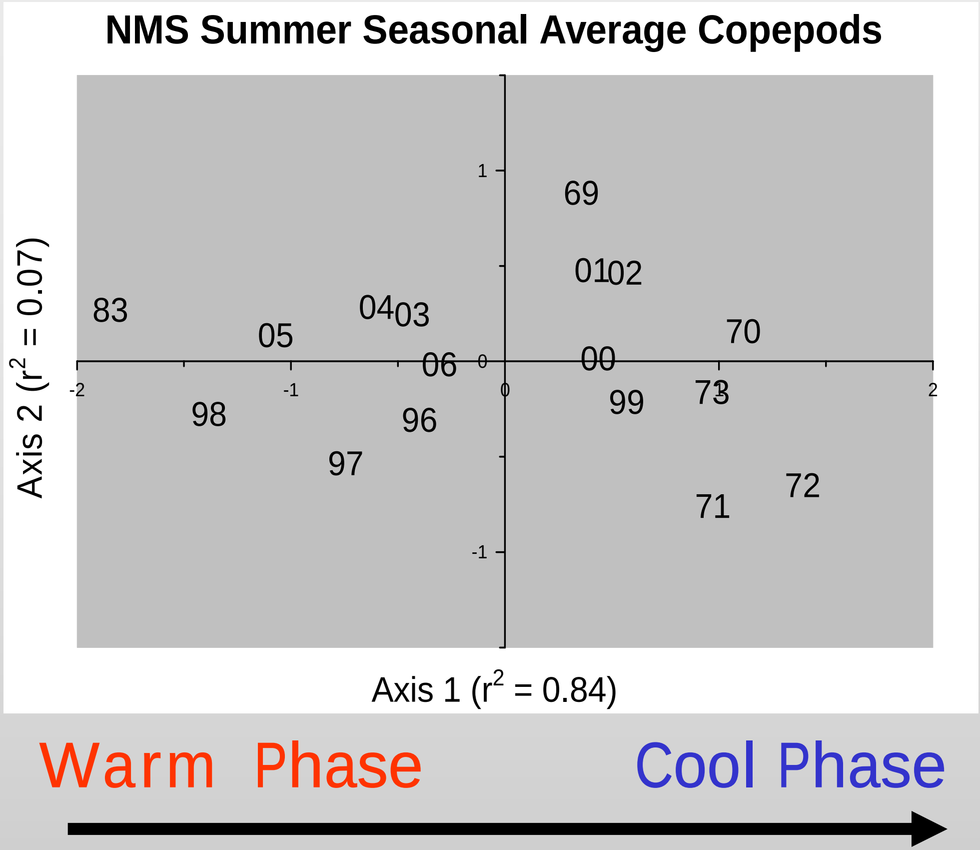


Open Symbols = warm ocean conditions & positive PDO

Closed Symbols = cold ocean conditions & negative PDO



NH05, allyrs, copedensnorare5log1, cluster2, NMS
Winter Cruises
Axis 3
Axis 1
1.5
0.5
-0.5
-1.5
-2.0
-1.0
0.0
1.0
2.0
112906NH
Year
1970
1971
1972
1983
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007

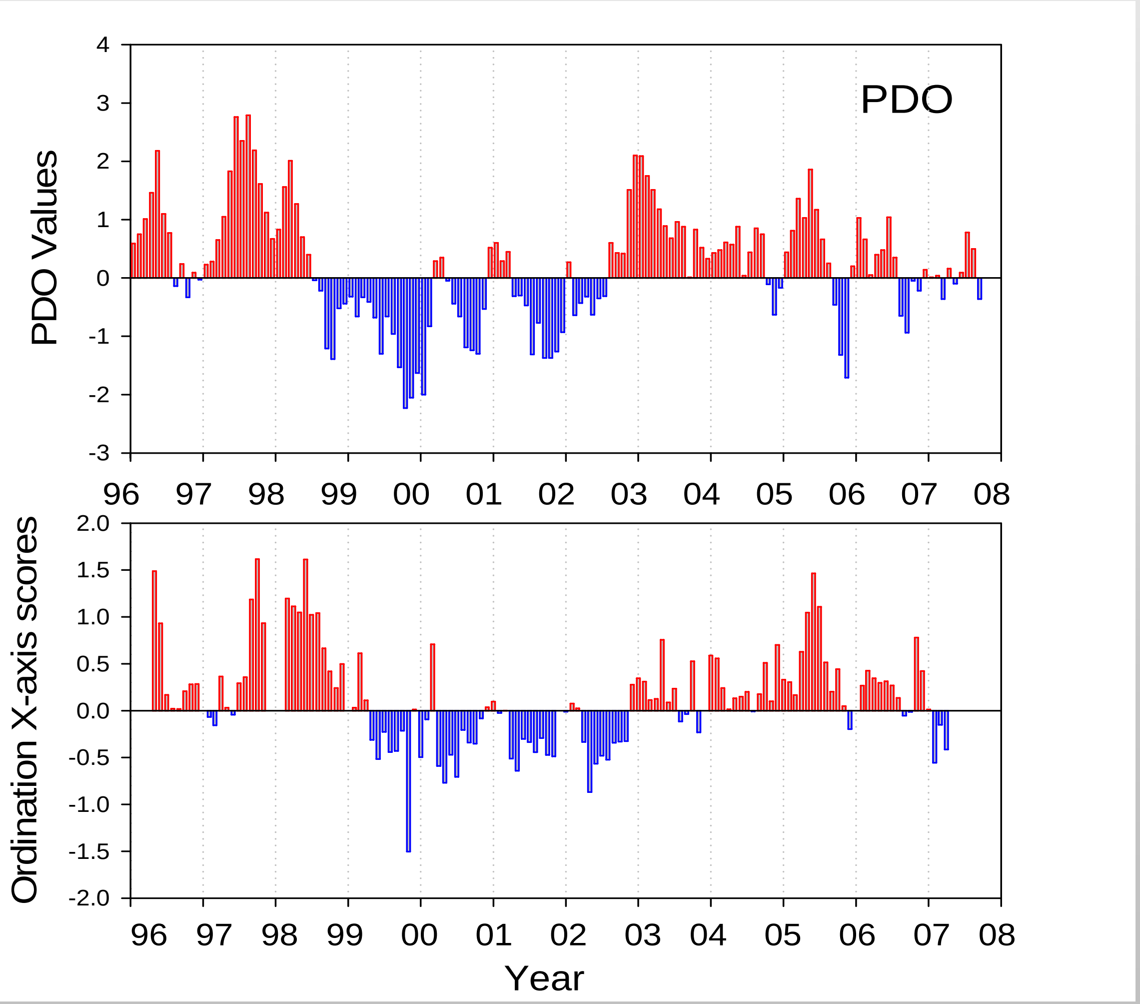


When we average the ordination scores by summers, we find similar communities in years with common patterns of PDO and SST:

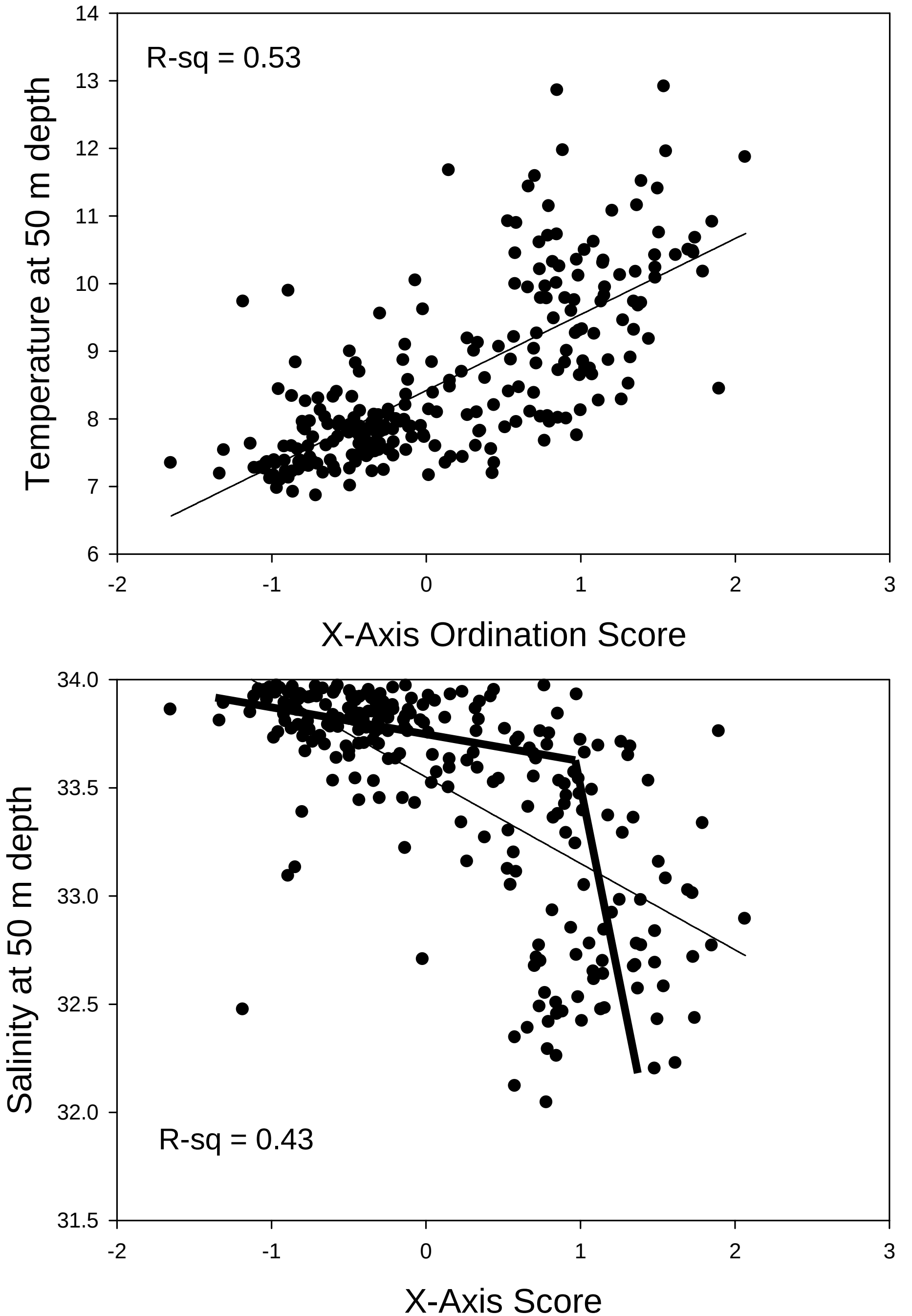
- **Cold Water** Copepod Community in 1969-1973, 1999-2002
- **Warm Water** Copepod Community in 1983, 1996-1998, 2003-2006.

Note that Axis-1 explains 84% of the variability; axis-1 is is the PDO influence on copepod community structure –
warm phase on left
cool phase on the right

PDO vs Copepod Community Structure



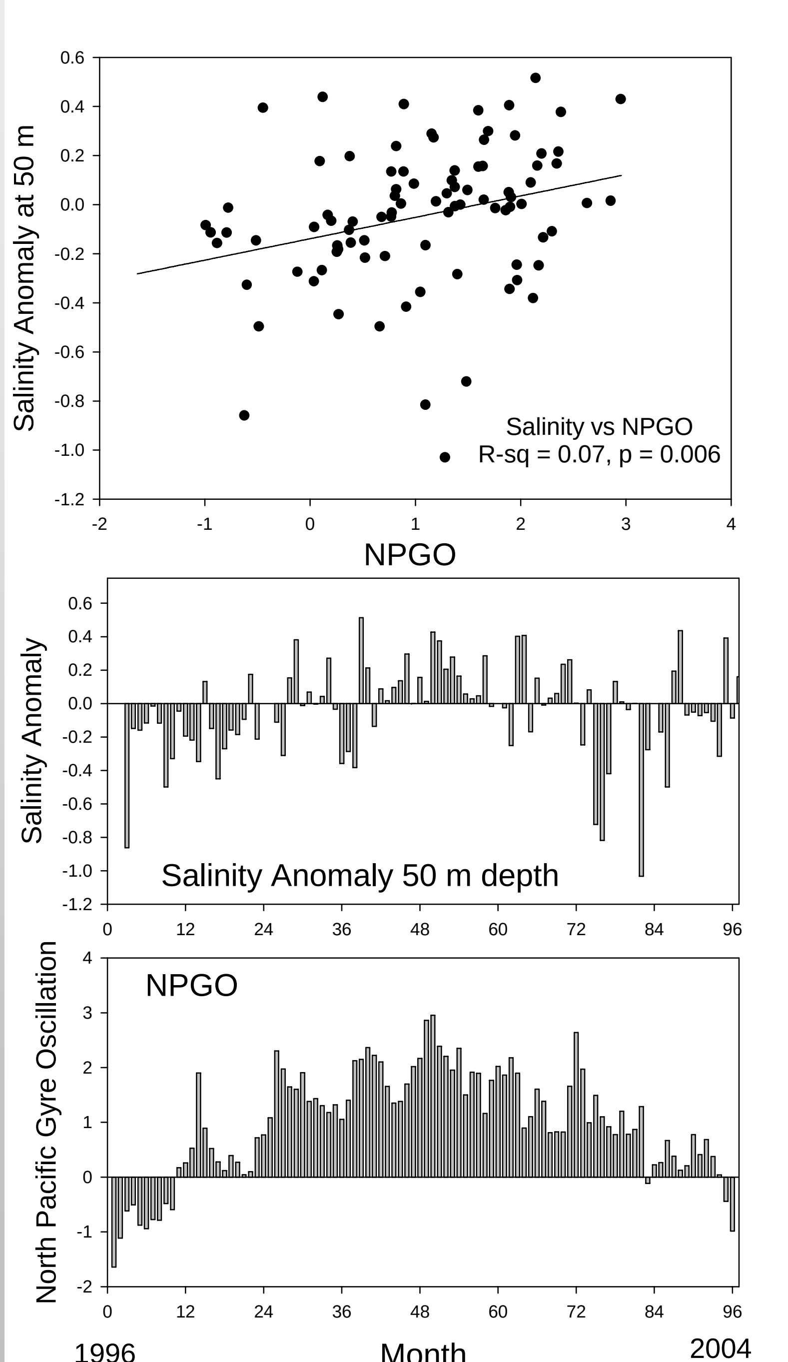
- As with SST and copepod species richness, copepod community structure also tracks the PDO



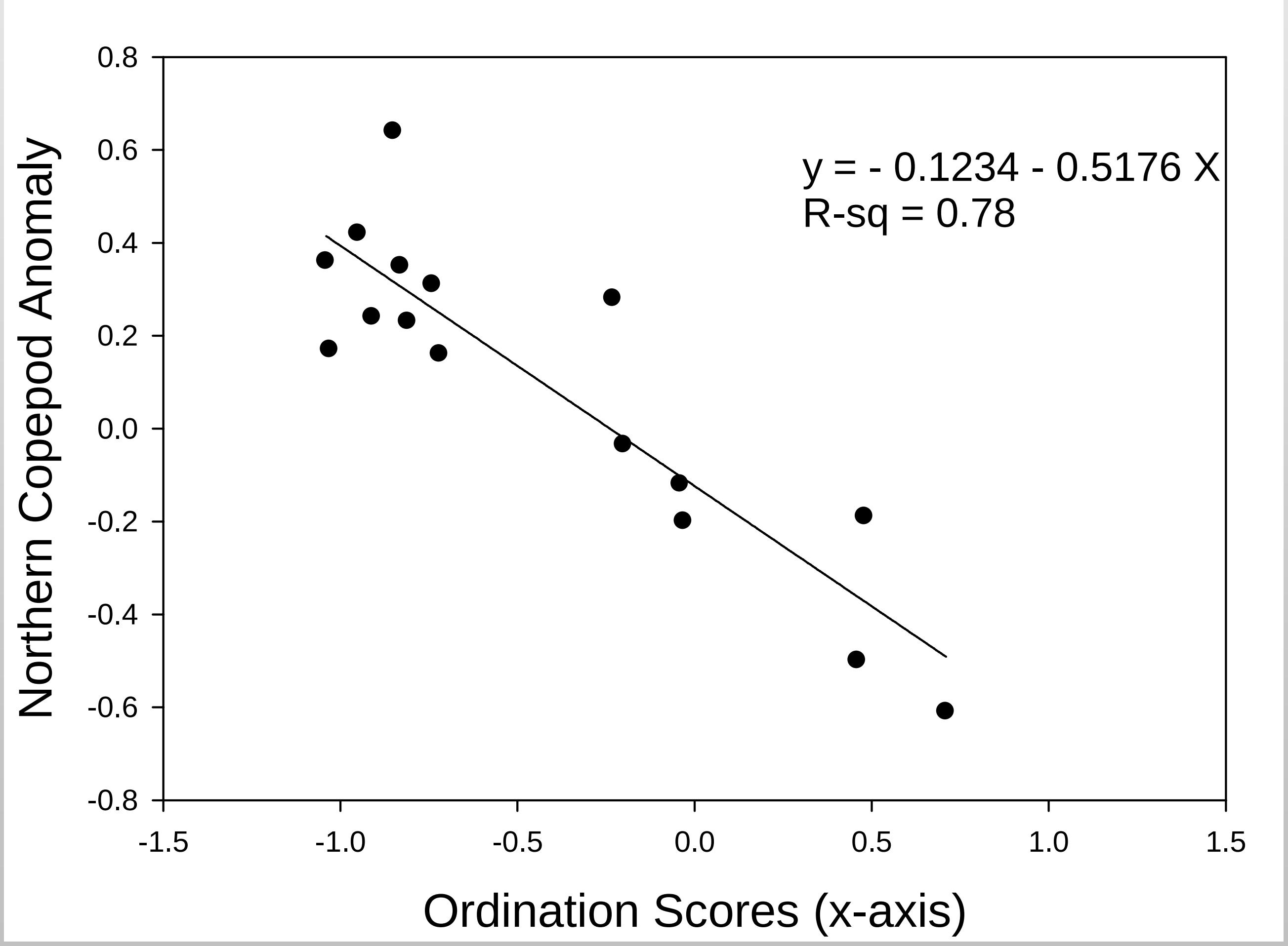
Community Structure vs. temperature and salinity measured at Newport (depth of 50 m) at the same time the plankton tows were taken

- Correlations are better with T than S
- Perhaps salinity will correlate better with the NPGO as shown for the Southern California current?

NPGO vs Salinity



Northern Copepods and Ordination Scores highly correlated



Contrasting Communities

- **Negative PDO = low diversity and "cold-water" copepod species.** These are dominants in Bering Sea, coastal GOA, coastal northern California Current
  - *Pseudocalanus mimus, Calanus marshallae, Acartia longiremis*
- **Positive PDO = high diversity and "warm-water" copepods.** These are common in the Southern California Current neritic and offshore NCC waters
  - *Clausocalanus spp., Ctenocalanus vanus, Paracalanus parvus, Mesocalanus tenuicornis, Calocalanus styliremis*

Based on Peterson and Keister (2003)

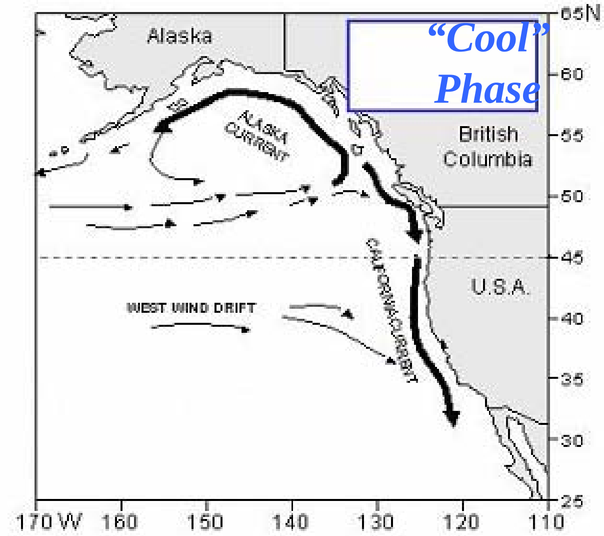
A working mechanistic hypothesis: source waters. . .

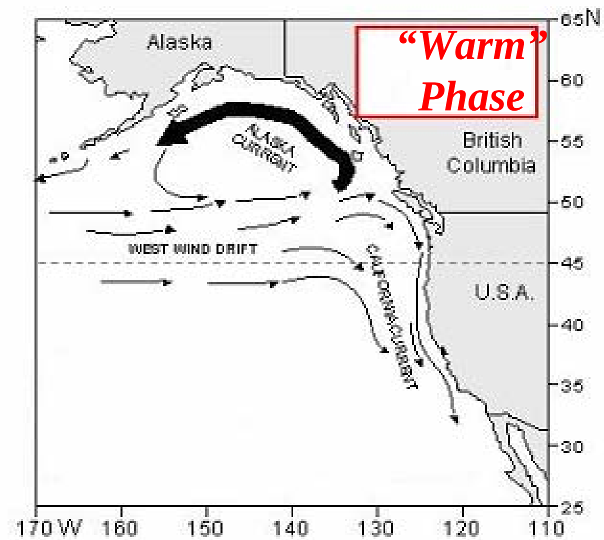
Cool Phase ➔

Transport of boreal coastal copepods into NCC from Gulf of Alaska

Warm Phase ➔

Transport of sub-tropical copepods into NCC from Transition Zone offshore





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) are **large** and store **wax esters** as an over-wintering strategy

Therefore, significantly different food chains may result from climate shifts;

But what might the FUTURE hold? In terms of food chain structure, will a cold phase PDO in the future look like a warm phase PDO now?

Wrap up

- PDO **downscales** to coastal waters of the NCC.
- **Time lags** between PDO , SST and copepod biodiversity is 3-5 months, suggesting that the PDO signal is related to transport.
- Since different water types are associated with the different PDO phases, we need to know more about how climate change will affect the **source waters** that enter the NCC.
- If we can track the **behavior** of the PDO with climate models (as suggested by Overland et al.) and if we can know if **source waters** will change, then we may be able to forecast copepod biodiversity, food chain structure and impacts on middle and higher trophic levels.
- But, even though the PDO will (apparently) persist at least until the year 2040, the ocean will be warmer. **Will warmer temperatures trump the PDO?** In the year 2040, will the kinds of copepod communities seen now with a negative PDO be similar to copepod communities seen now with a positive PDO?

Answers to these questions will be provided at PICES XLIX

= PICES 49 in the year 2040

Acknowledgements

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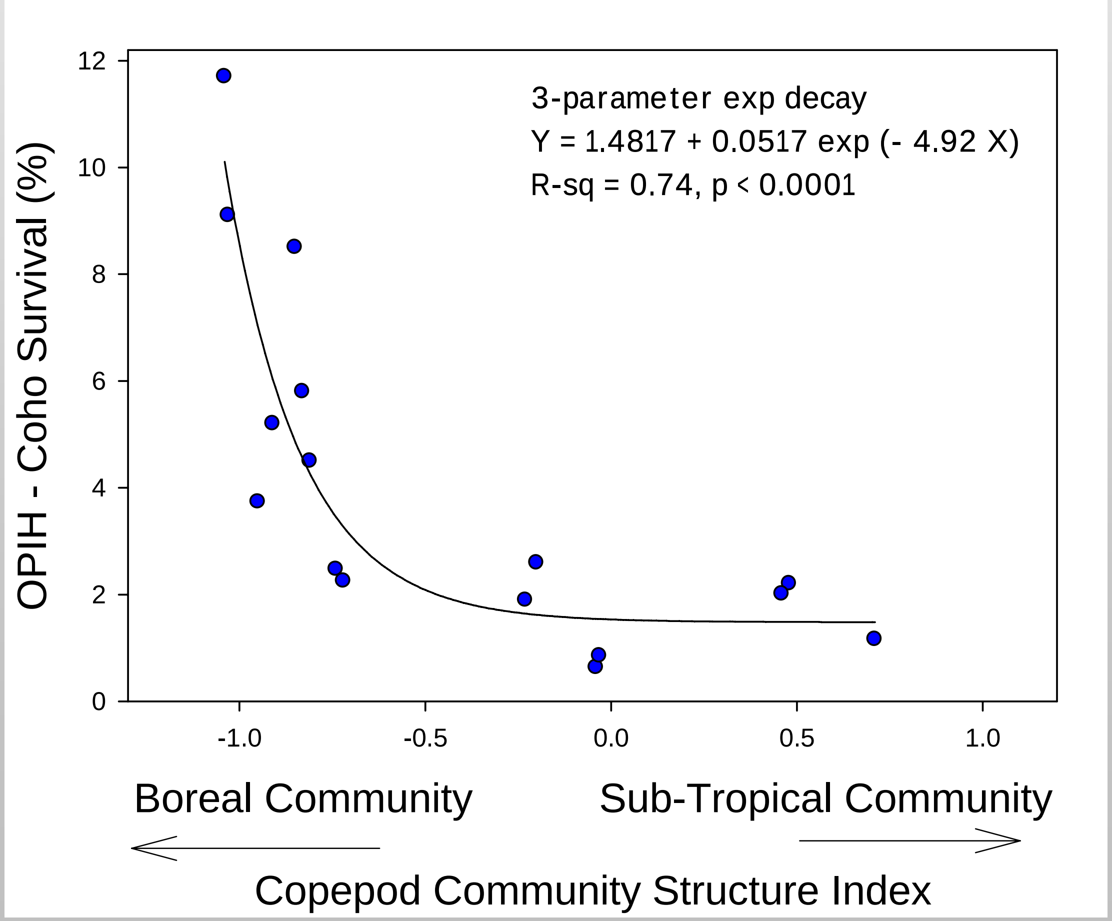
  - since 1997: Leah Feinberg, Tracy Shaw, Julie Keister, Jen Menkel, Rian Hooff, Jay Peterson, Jesse Lamb, Karen Hunter
  - in the 1970s and 1980s: Peter Rothlisberg, Greg Lough, Charlie Miller, Hal Batchelder



3-parameter exp decay
Y = 1.4817 + 0.0517 exp (- 4.92 X)
R-sq = 0.74, p < 0.0001
OPIH - Coho Survival (%)
0
2
4
6
8
10
12
-1.0
-0.5
0.0
0.5
1.0
Boreal Community
Sub-Tropical Community
Copepod Community Structure Index

Winds and current structure off coastal Oregon:

- Winter:
  - Winds from the South
  - Downwelling
  - Poleward-flowing Davidson Current

- Spring Transition in April/May
  - Upwelling-favorable winds

- Summer:
  - Strong winds from the North
  - Coastal upwelling
  - Equatorward alongshore transport

- Fall Transition in Sept or October
  - Upwelling-favorable winds cease