The influence of ~~ENSO events and~~ the PDO on copepod *biodiversity* and *community structure* in the Northern California Current: is climate change a contributing factor?

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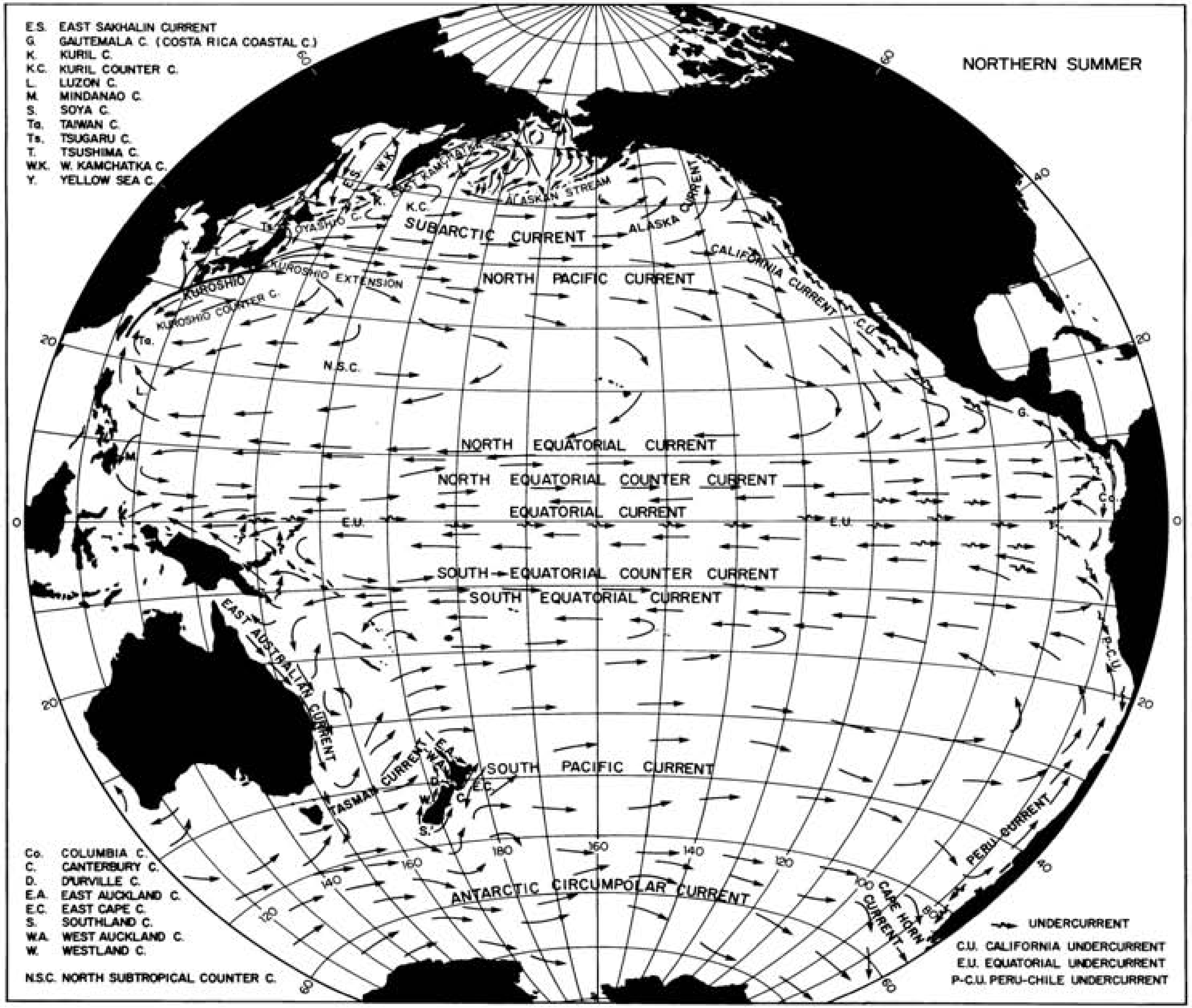
NOAA-Fisheries and Oregon State University

- McGowan, Cayan and Dorman (1998) commented that "…the biological consequences of climate variability are not well understood, largely because of the mismatch between time scales of important atmospheric and oceanographic processes and biological research programs".

We have had the good fortune of being able to assemble a hydrographic and plankton time series based on biweekly sampling off Newport OR (44°40'N), now in its 12th year, and historical plankton and hydrographic data collected off Newport from 1969-1973, and 1983.

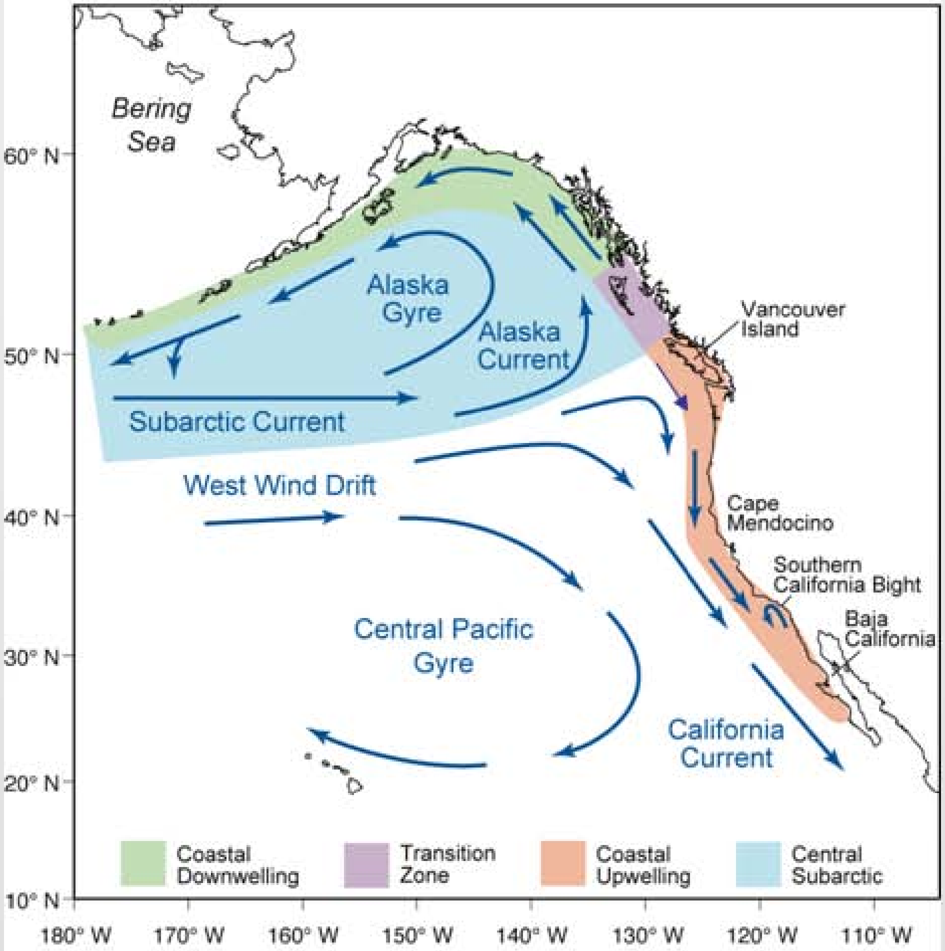


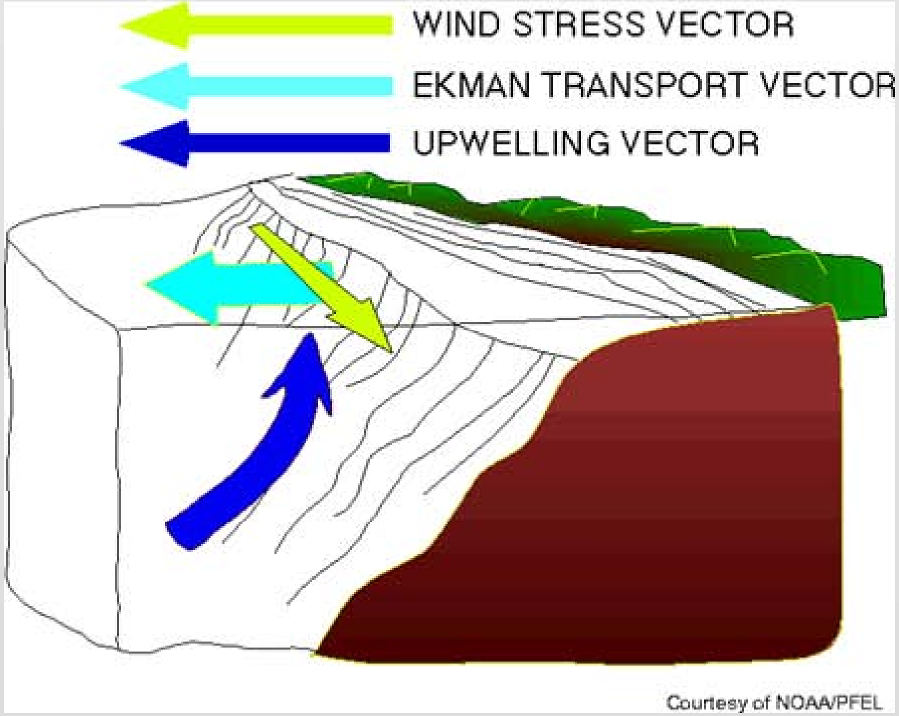
E.S. EAST SAKHALIN CURRENT
G. GAUTEMALA C. (COSTA RICA COASTAL C.)
K. KURIL C.
K.C. KURIL COUNTER C.
L. LUZON C.
M. MINDANAO C.
S. SOYA C.
Ta. TAIWAN C.
Ts. TSUGARU C.
T. TSUSHIMA C.
W.K. W. KAMCHATKA C.
Y. YELLOW SEA C.
NORTHERN SUMMER
ALASKAN STREAM
ALASKA CURRENT
SUBARCTIC CURRENT
OYASHIO C.
KUROSHIO EXTENSION
KUROSHIO
KUROSHIO COUNTER C.
NORTH PACIFIC CURRENT
CALIFORNIA CURRENT
C.U.
N.S.C.
NORTH EQUATORIAL CURRENT
NORTH EQUATORIAL COUNTER CURRENT
EQUATORIAL CURRENT
E.U.
SOUTH EQUATORIAL COUNTER CURRENT
SOUTH EQUATORIAL CURRENT
EAST AUSTRALIAN CURRENT
P.-C.U.
TASMAN CURRENT
SOUTH PACIFIC CURRENT
PERU CURRENT
ANTARCTIC CIRCUMPOLAR CURRENT
CAPE HORN CURRENT
Co. COLUMBIA C.
C. CANTERBURY C.
D. D'URVILLE C.
E.A. EAST AUCKLAND C.
E.C. EAST CAPE C.
S. SOUTHLAND C.
W.A. WEST AUCKLAND C.
W. WESTLAND C.
N.S.C. NORTH SUBTROPICAL COUNTER C.
UNDERCURRENT
C.U. CALIFORNIA UNDERCURRENT
E.U. EQUATORIAL UNDERCURRENT
P-C.U. PERU-CHILE UNDERCURRENT

Tabata (1975)

Circulation off the Pacific Northwest

Note: CC begins at ~ N end of Vancouver Island



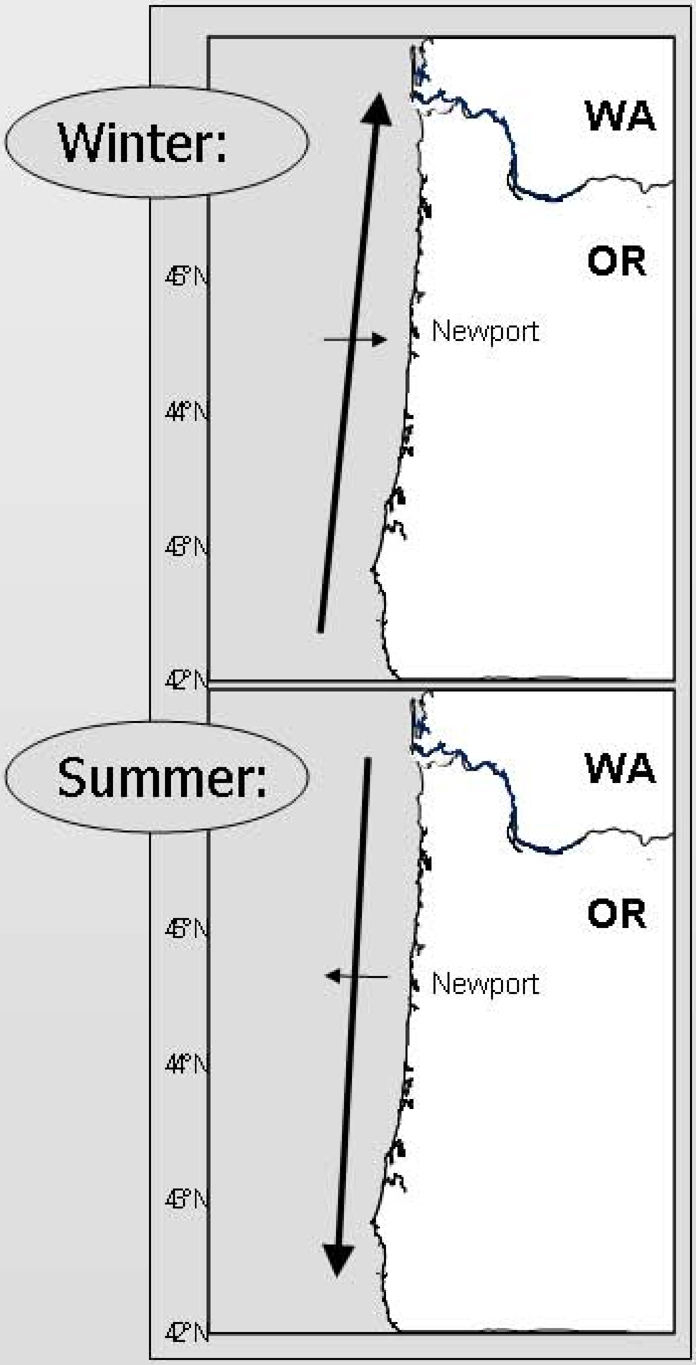


Three factors affect zooplankton species composition and community structure in the northern California Current off Oregon

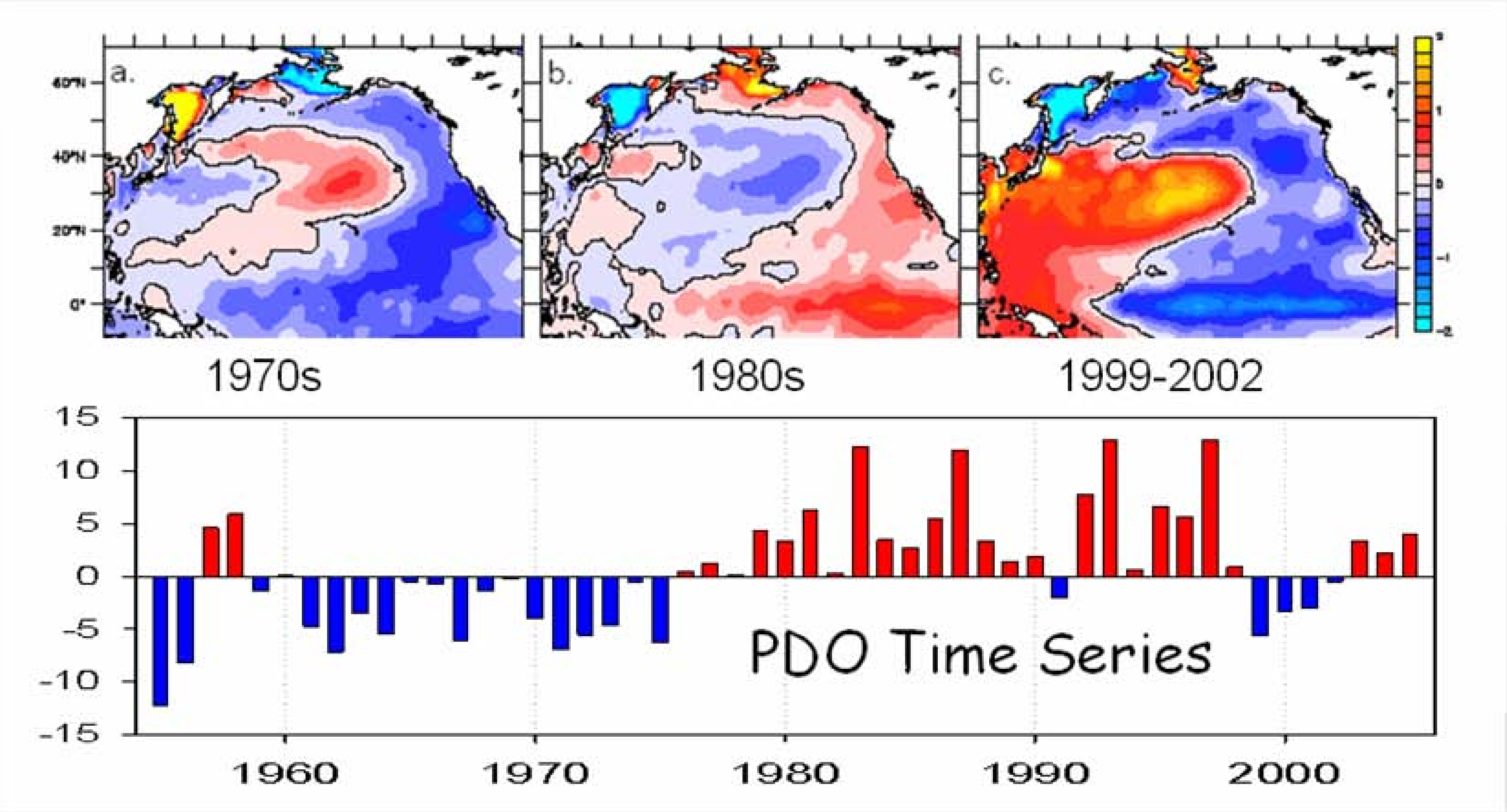
- Strength of coastal upwelling and cross-shelf transport
- Seasonal reversal of coastal currents: southward in summer – northward in winter
- Phase of the Pacific Decadal Oscillation (PDO)

Winds and current structure off coastal Oregon:

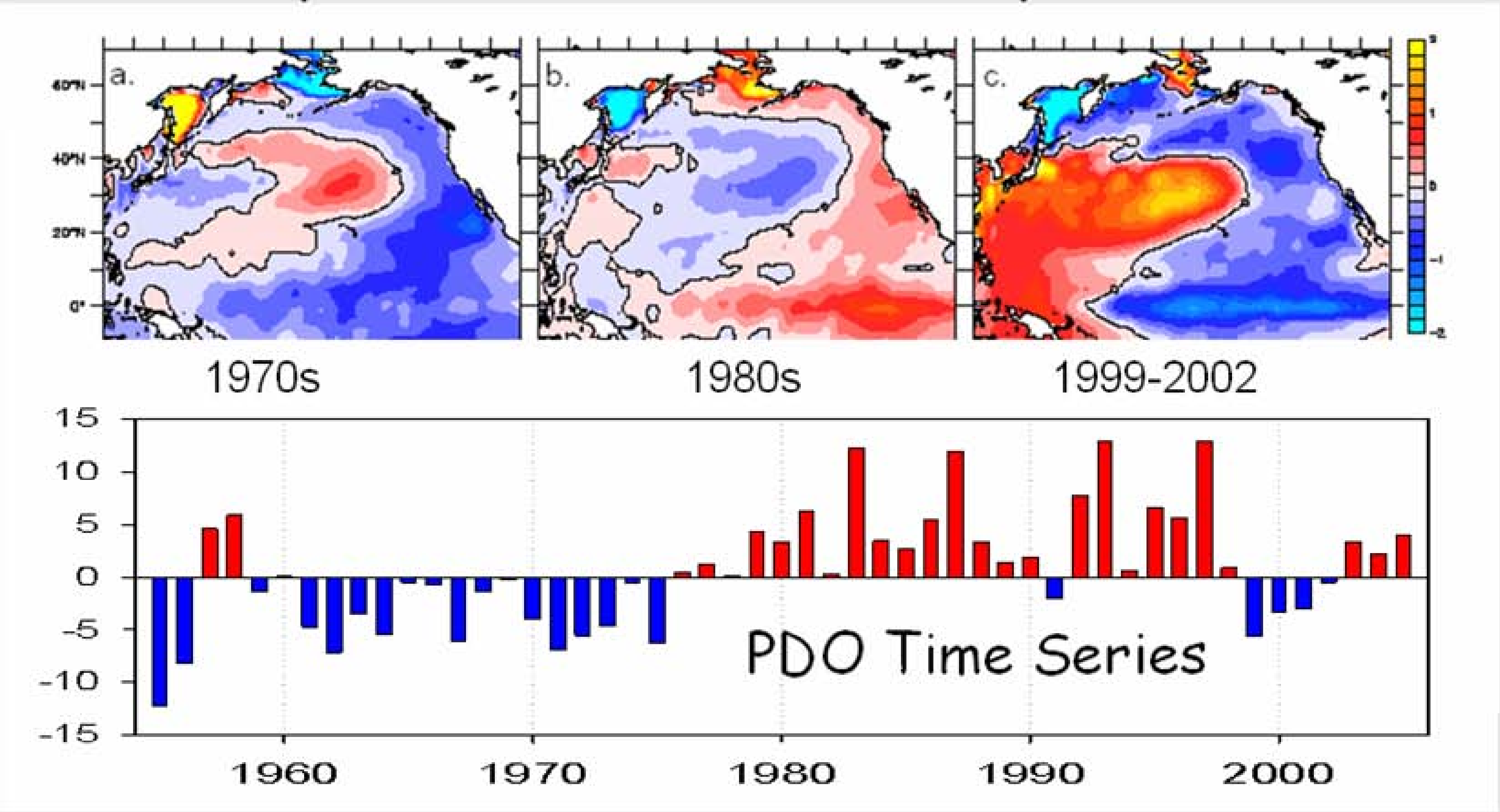
- Winter:
  - Winds from the South
  - Downwelling
  - Poleward-flowing Davidson Current
  - Subtropical/southern species transported northward & onshore
- **Spring Transition in April/May**
- Summer:
  - Strong winds from the North
  - Coastal upwelling
  - Equatorward alongshore transport
  - Boreal/northern species transported southward
- **Fall Transition in October**



NORTH PACIFIC SST



Phase shifts are tracked by the Pacific Decadal Oscillation (PDO): negative values = cool phase; positive values = warm phase.



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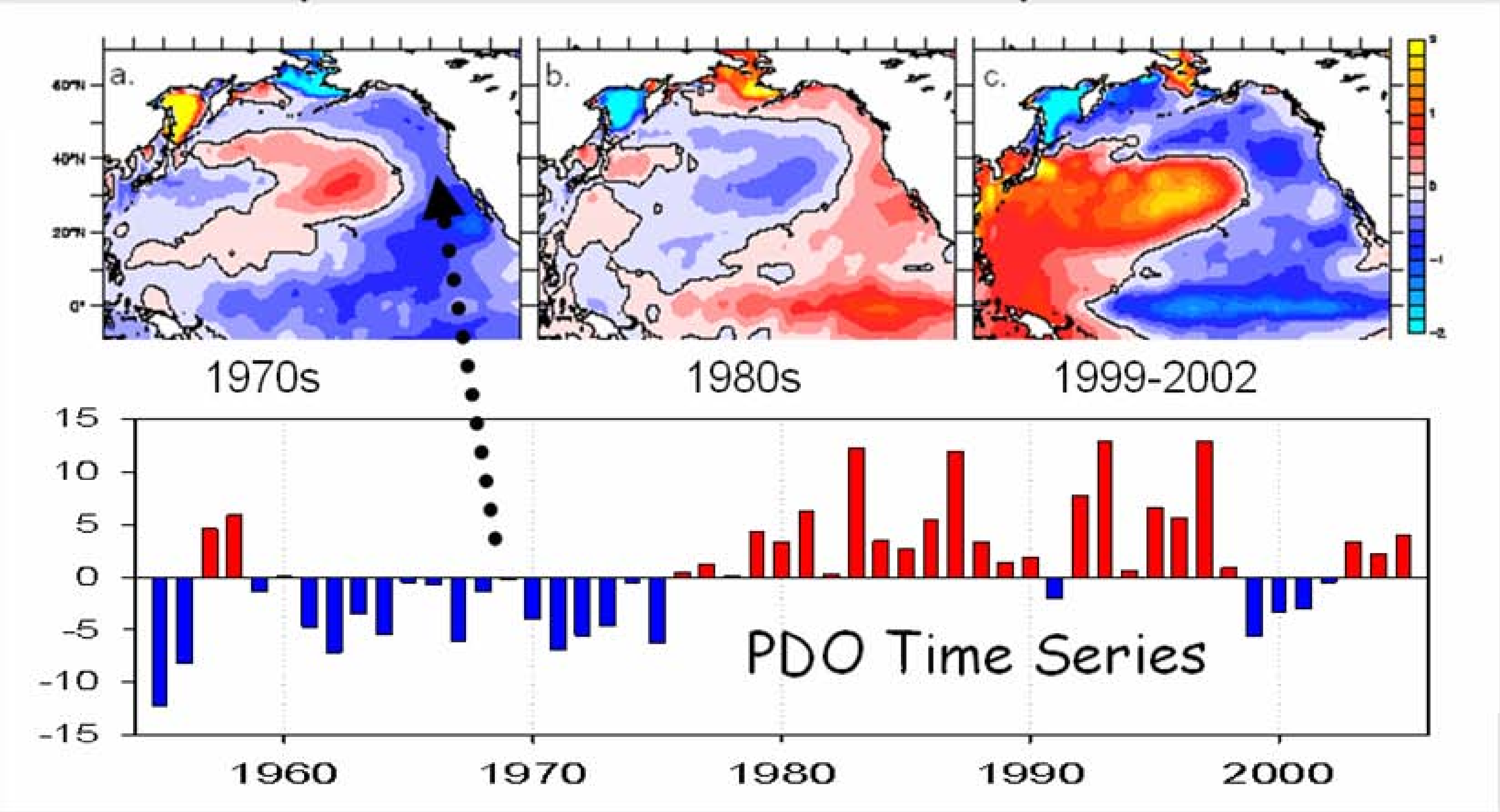
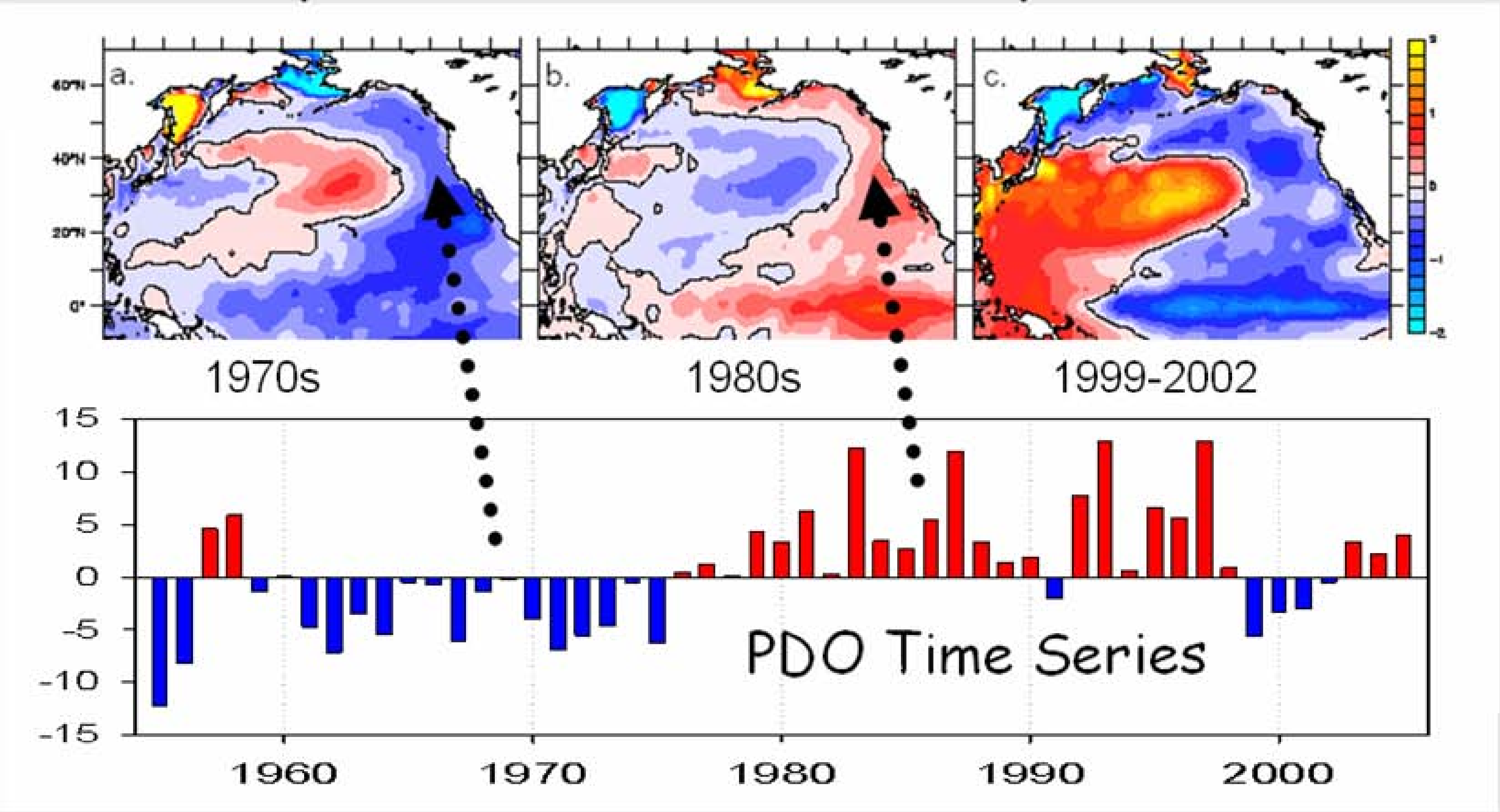


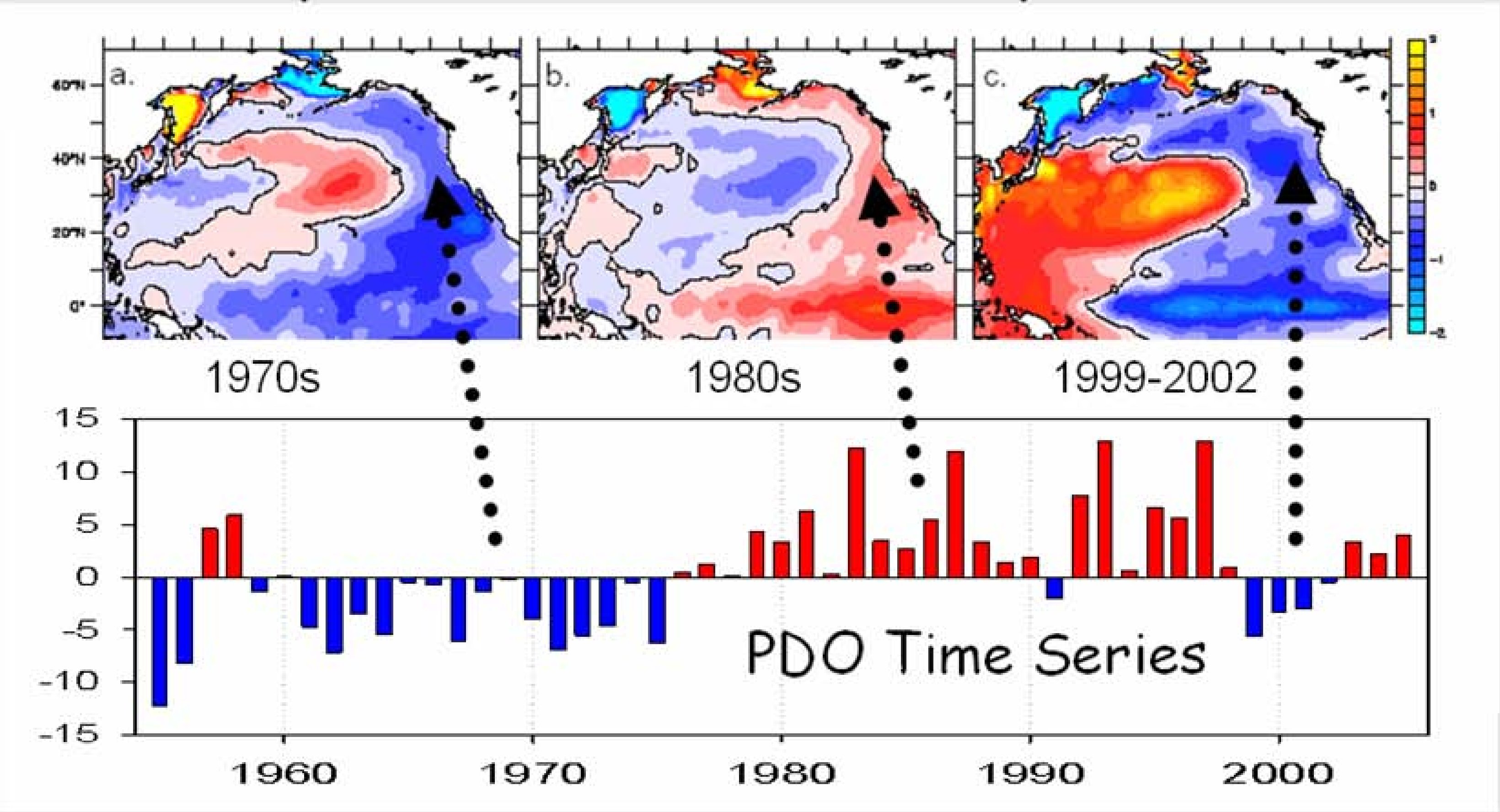
- Cool phase 1947-1976

Phase shifts are tracked by the Pacific Decadal Oscillation (PDO): negative values = cool phase; positive values = warm phase.



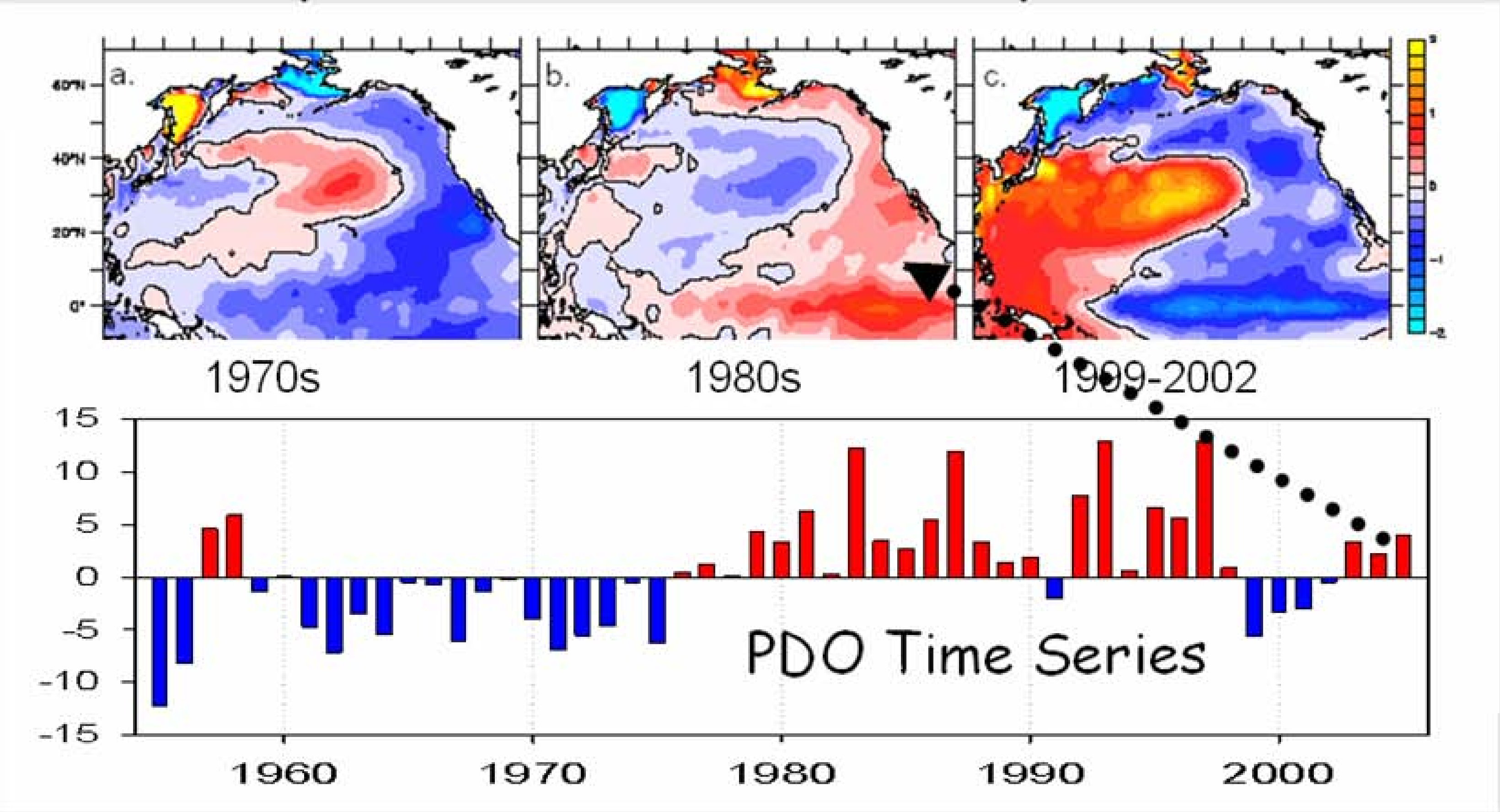
- Cool phase 1947-1976
- Warm phase 1977-1998

Phase shifts are tracked by the Pacific Decadal Oscillation (PDO): negative values = cool phase; positive values = warm phase.



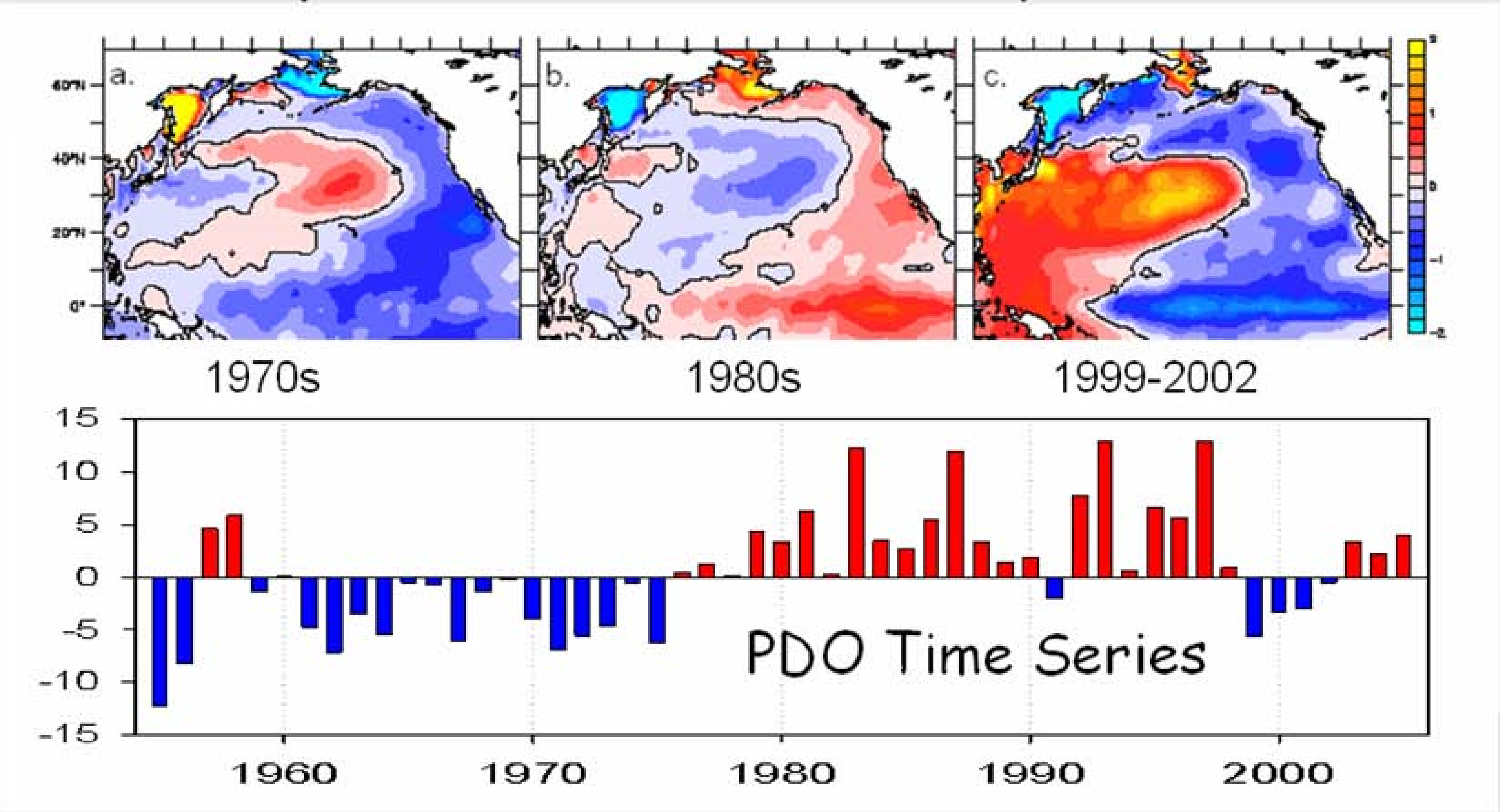
- Cool phase 1947-1976
- Cool phase 1999-2002
- Warm phase 1977-1998

Phase shifts are tracked by the Pacific Decadal Oscillation (PDO): negative values = cool phase; positive values = warm phase.



- Cool phase 1947-1976
- Cool phase 1999-2002
- Warm phase 1977-1998
- Warm phase 2002-2006

Phase shifts are tracked by the Pacific Decadal Oscillation (PDO): negative values = cool phase; positive values = warm phase.

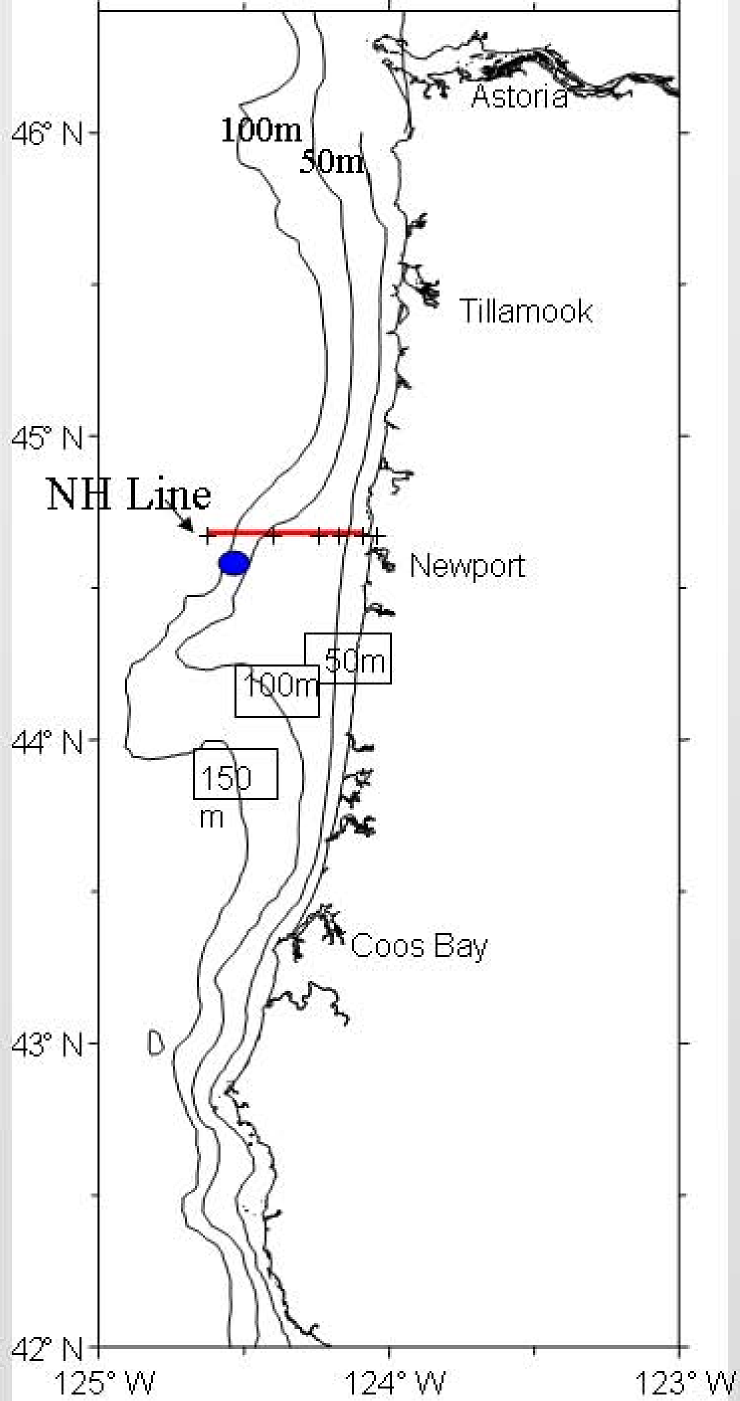


- Cool phase 1947-1976
- Cool phase 1999-2002
- Cool phase 2007-

- Warm phase 1977-1998
- Warm phase 2002-2006

An opportunity

- With the recent 4-year cycling of the PDO, nature has handed us a grand experiment that allows us determine in what ways and how quickly organisms respond to short term climate variability.
- Use information on changes in hydrography, zooplankton and pelagic fish biomass and species composition to try to understand mechanisms by which sign changes in the PDO changes result in changes in ecosystem dynamics in the northern California Current. (Similar to attempts to unravel role of NAO in controlling ecosystem dynamics).
- Using information on PDO, SST, hydrography and zooplankton to forecast salmon returns to the Columbia River (but this is not part of this today).

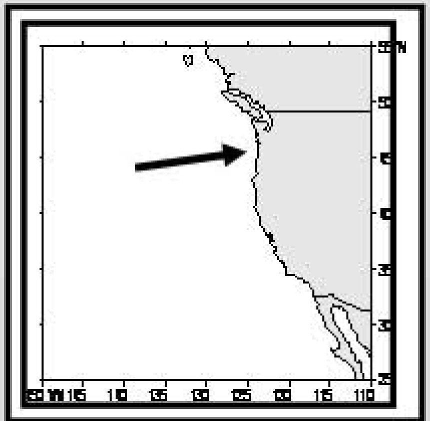


NH-Line Hydrographic and Zooplankton Time Series

Bi-weekly Sampling:

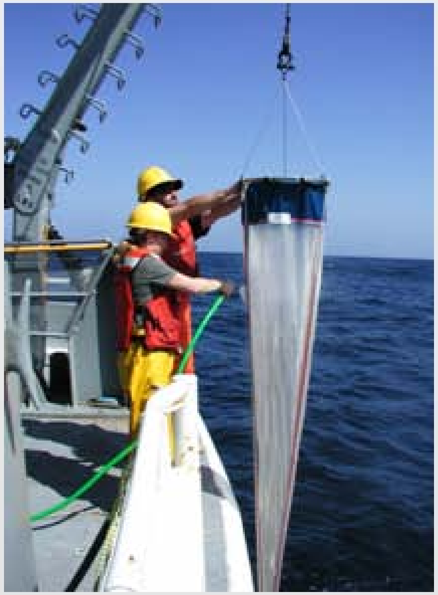
- **1969 – 1973** (Miller, Pearcy, Peterson)
- **1977, 1978** (Miller, Peterson)
- **1983** (Miller, Batchelder, Pearcy, Brodeur)
- **1990-1992** (Fessenden and Cowles)
- **1996 – present** (Peterson et al.)

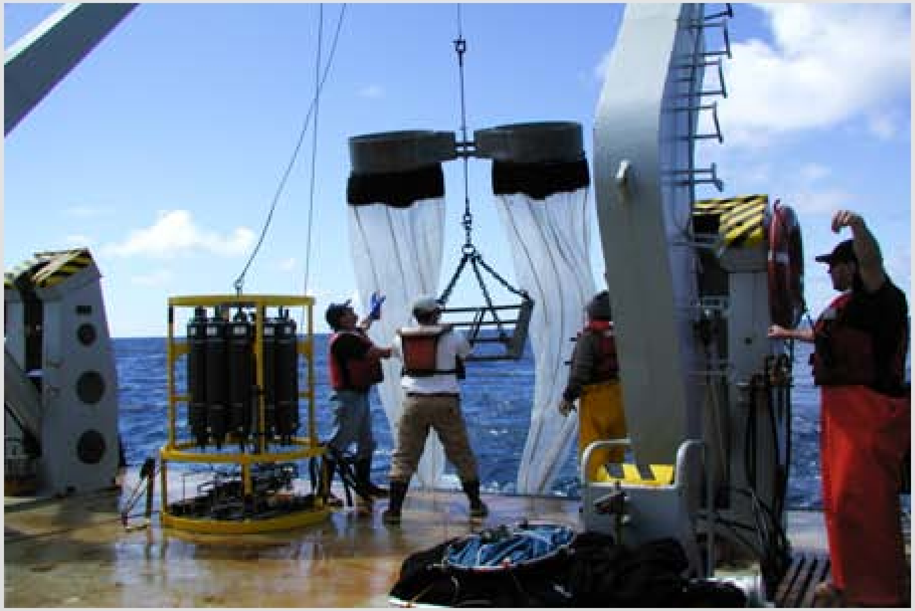
N = 368 visits to NH 05



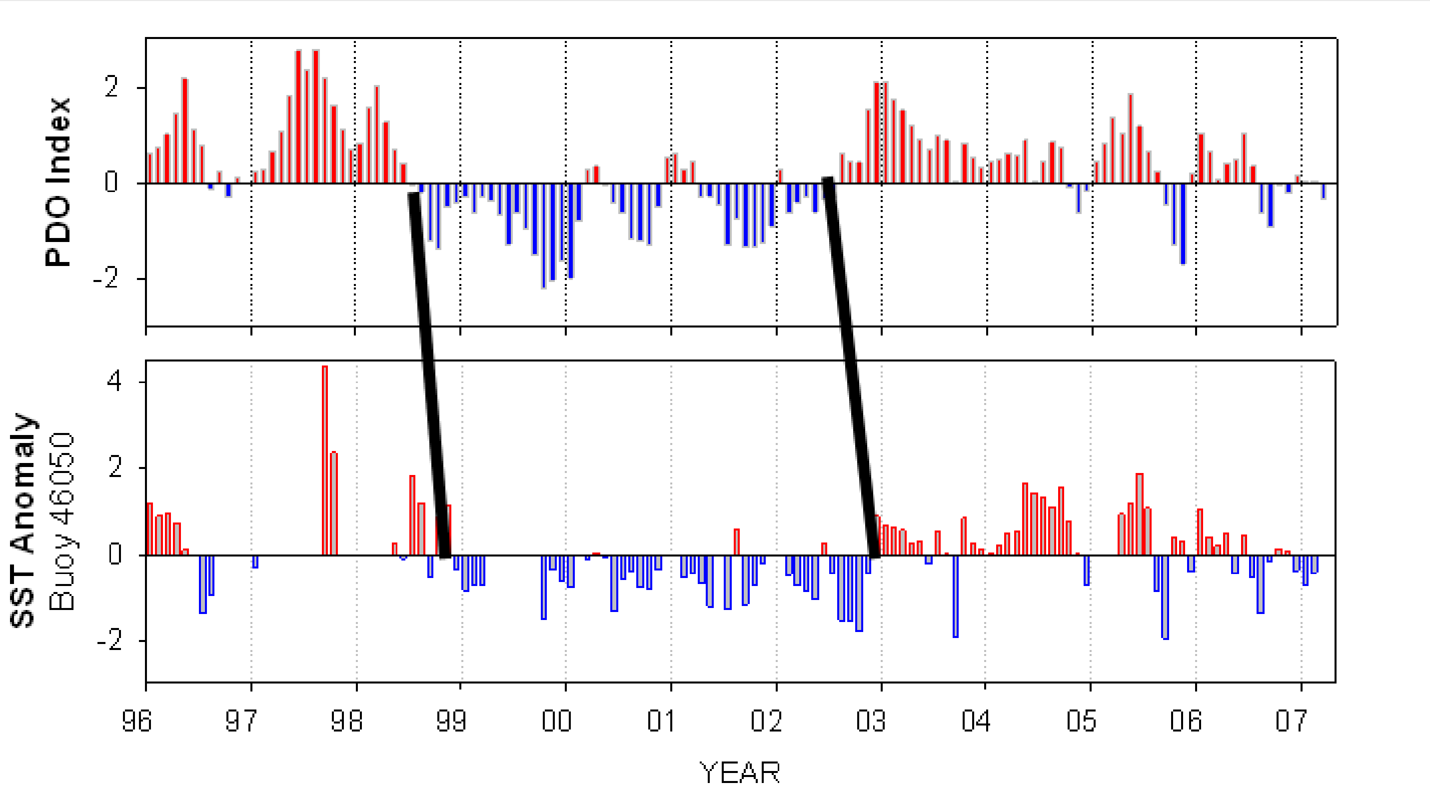
Sampling methods

- Water sampling with CTD, Niskin Bottles, and buckets for hydrography, chl-a and nutrients
- Mesozooplankton with ½ m diameter 200 μm mesh net towed vertically from 100 m
- Euphausiids with 70 cm 333 μm mesh net towed obliquely





Sea surface temperature (SST) data from weather buoy off Newport shows that SST is related to the PDO = downscaling



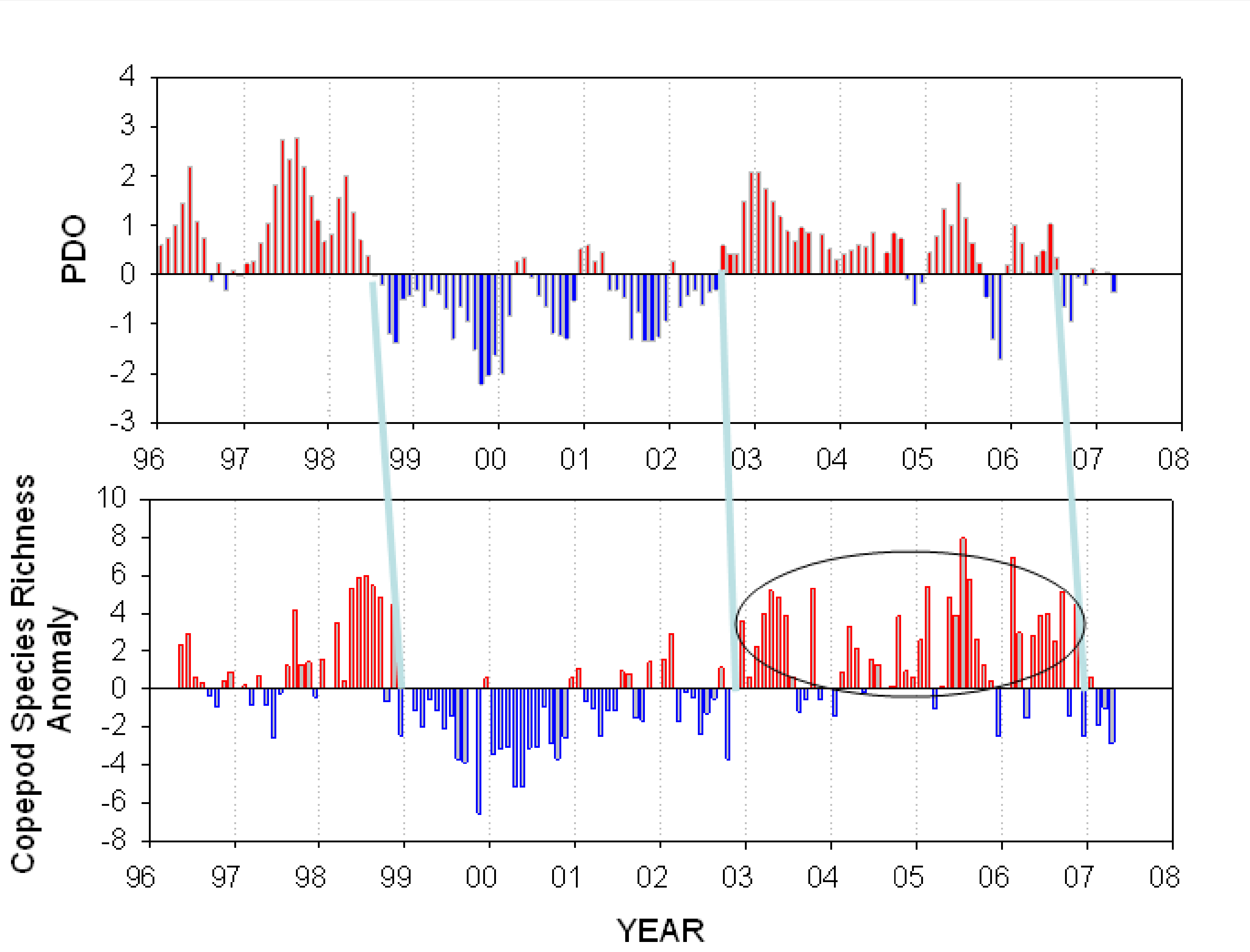
Cooler water in late 1998 associated with PDO change.

Warmer water in late 2002 associated with PDO change.

Most months now cooler, since late 2005

Note: time lags between PDO and SST change, associated with advection of different water types to Oregon.

Copepod species richness anomaly and the PDO



Species richness reflects origins of the animals. Low = subarctic; high = subtropical

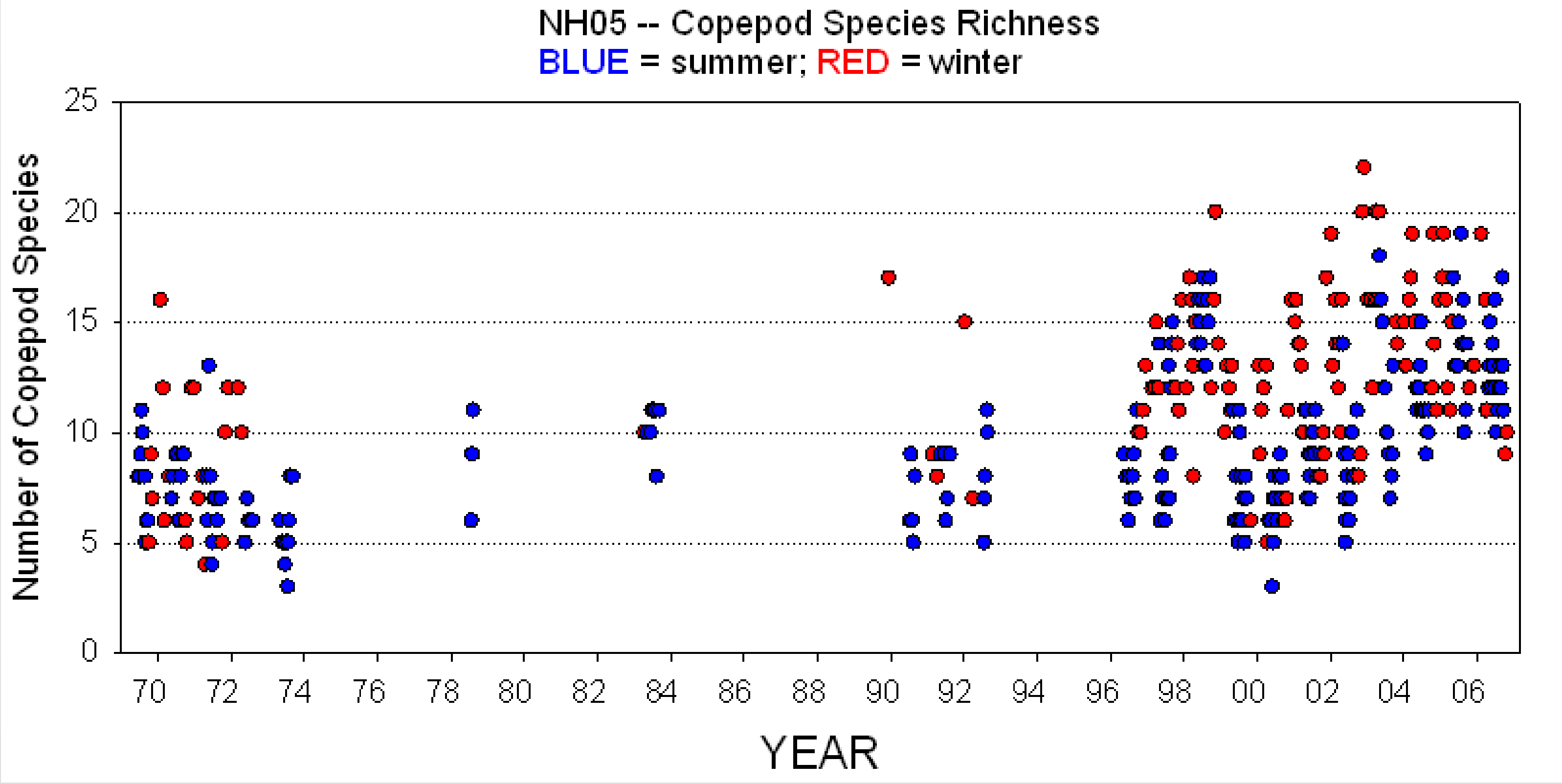
Species richness declined in fall 1998 but began to increase in Nov 02 due to phase shift of PDO

Richness in 2003, 2005 and 2006 similar to the 1997-98 El Niño event

As with SST, 3-5 months following PDO change, copepod species richness switches.

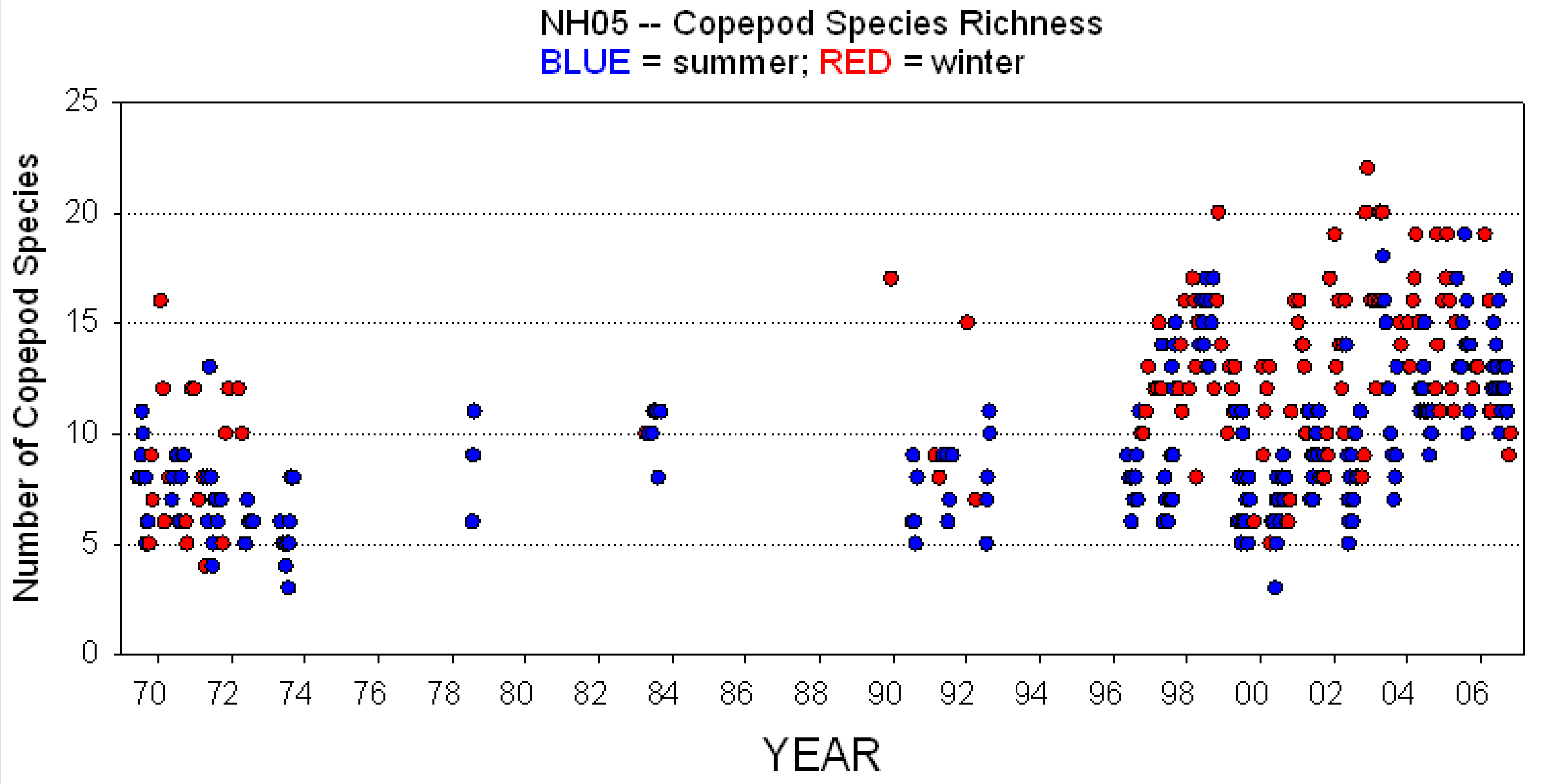
- Suggests different water types appear off Oregon with persistent changes in PDO.
- Now, changing again,

Copepod Biodiversity since 1969



Winter usually more diverse due to northward transport of sub-tropical species in the Davidson Current. Summers usually less diverse due to southward transport of boreal species from the coastal Gulf of Alaska.

Copepod biodiversity is much higher now than in 1970s



Winter usually more diverse due to northward transport of sub-tropical species in the Davidson Current. Summers usually less diverse due to southward transport of boreal species from the coastal Gulf of Alaska.

Is increased biodiversity a problem?

- Perhaps….
  - A very different mix of copepods dominate during cold vs warm water conditions

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)

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, it is possible that significantly different food chains may result from climate shifts

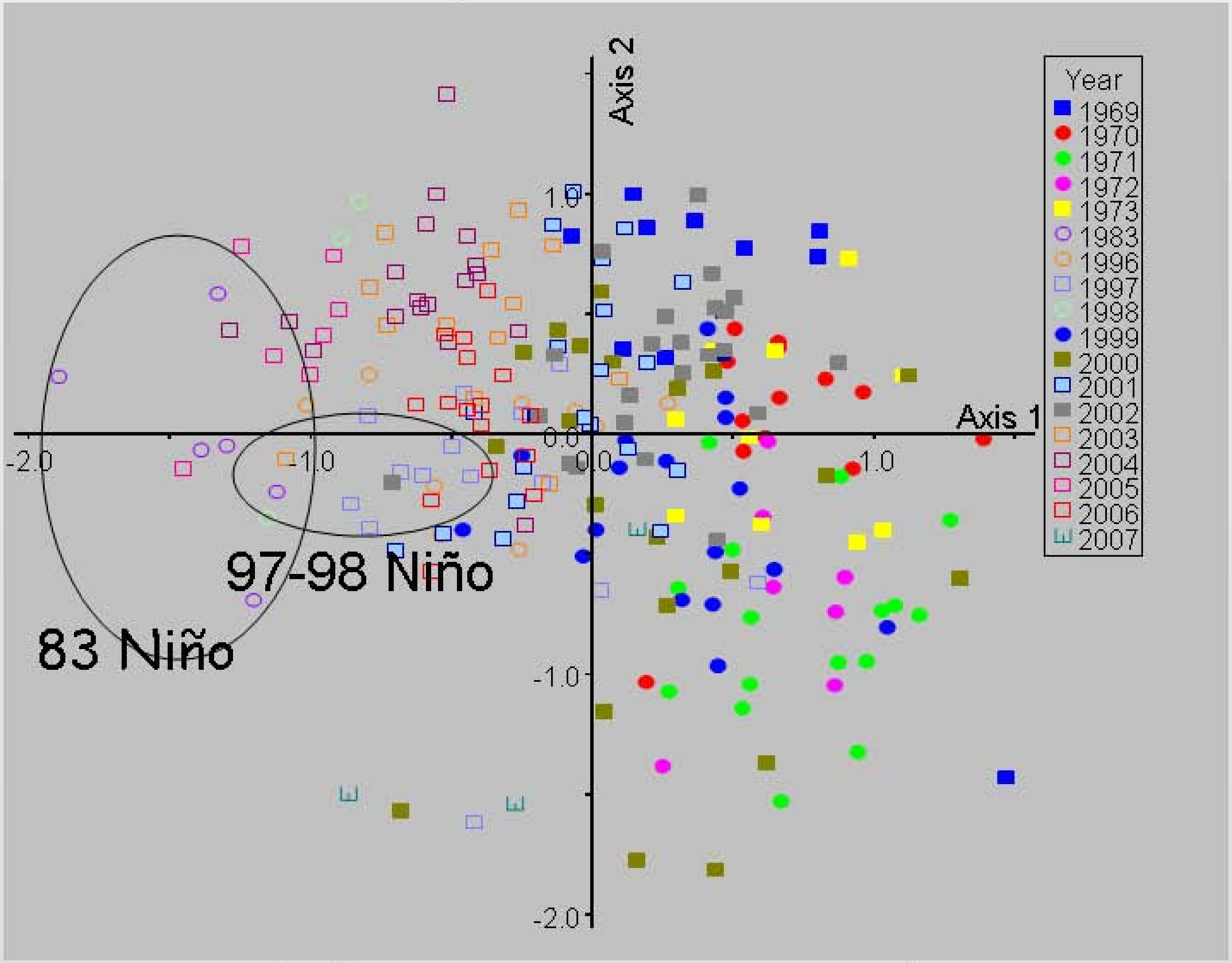
Which food chain would you prefer if you were a salmon or sardine?

Community Composition:
Cold vs. warm water communities

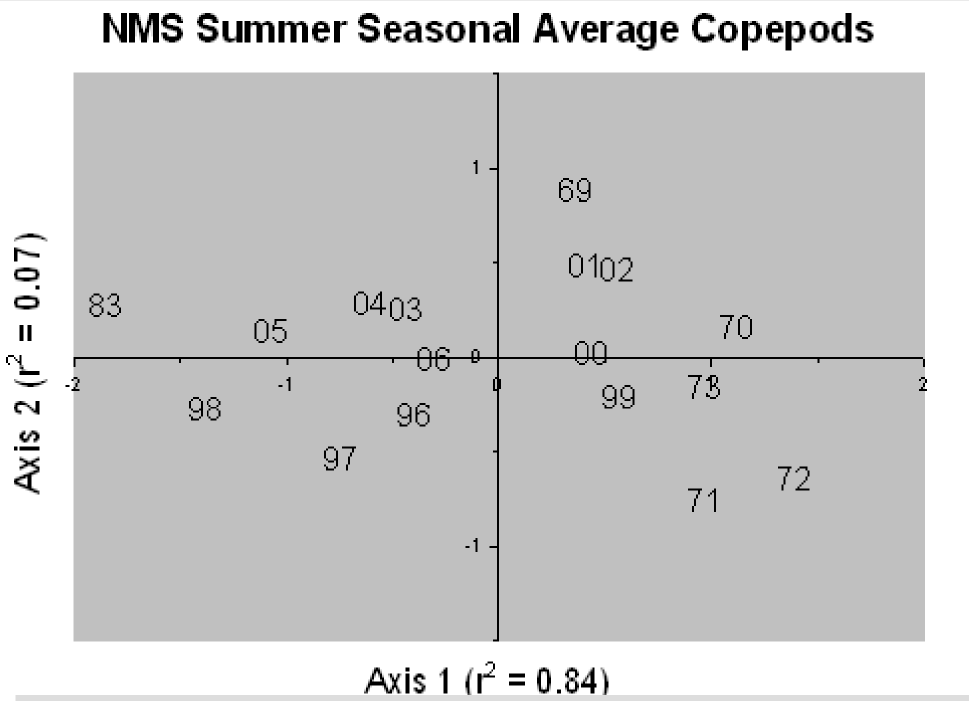
- Non-parametric multidimensional scaling (ordinations) groups stations using a similarity index; stations near to each other in MDS space have similar community structure

- Cluster Analysis: arranges similar community types into a dendogram structure

Ordination of 18 years of Summer Cruises)



Open Symbols = warm ocean conditions
Closed Symbols = cold ocean conditions



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.

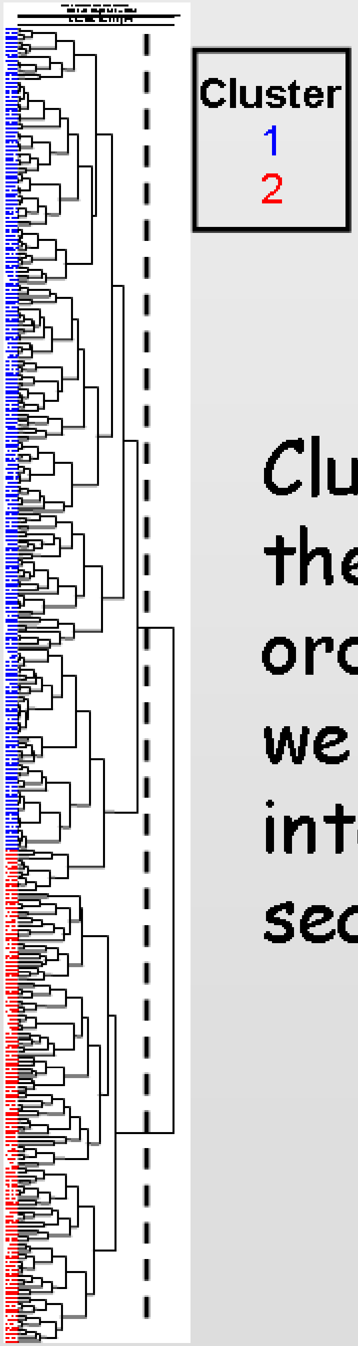
Cluster analysis

Results of processing of 368 samples not easy to illustrate.

Two patterns:

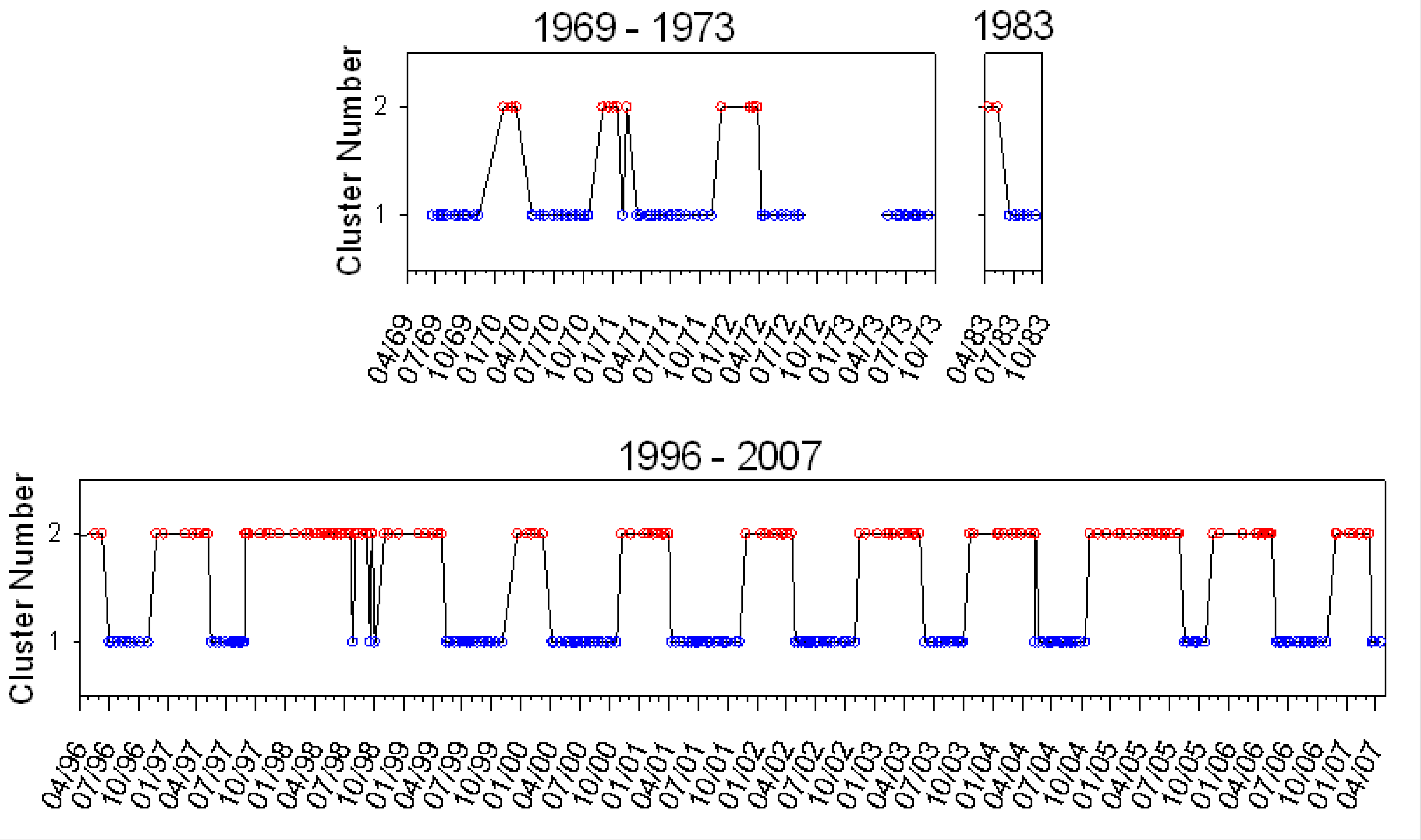
- Clusters 1 and 2 capture seasonal variations.

- Clusters 3-5 capture warm vs. cold ocean and El Niño events.



Cluster analysis shows the same result as the ordinations….but what we found most interesting were the seasonal changes

Summer and Winter Clusters



Apart from the 1998 El Niño, cluster fidelity was stunning!

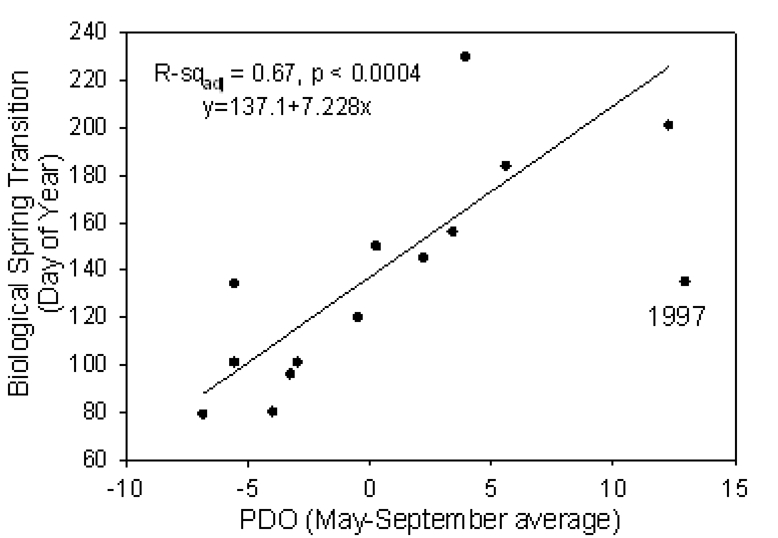
Phenology changes with PDO?

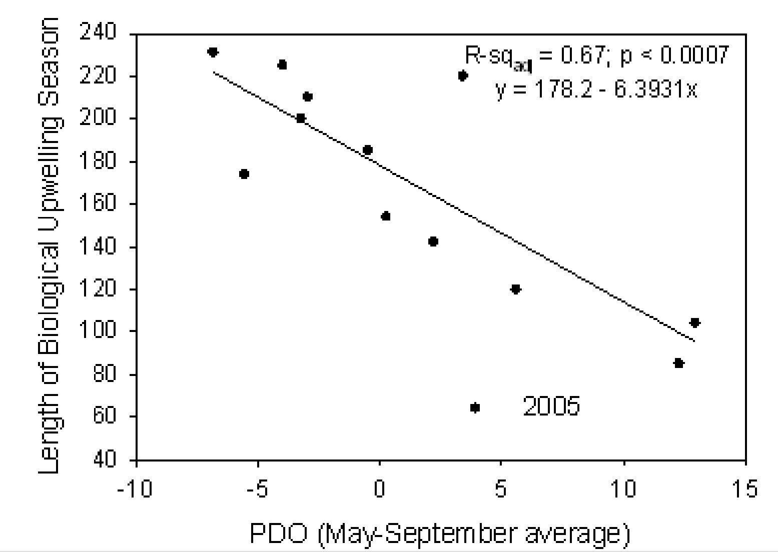
- Date of first appearance of summer community
- Length of upwelling season 174-231 d if PDO neg

  64-154 d if PDO pos

	Upwelling Season Start Date	End Date	Length of the upwelling season Days	PDO
1970	~ 20 Mar	20 Oct	225	neg
1971	20 Mar	6 Nov	231	neg
1983	20 Jun	13 Sep	85	pos
1996	3 Jul	31 Oct	120	pos
1997	15 May	27 Aug	104	pos
1998	never	never	0	pos
1999	14 May	4 Nov	174	neg
2000	6 Apr	23 Oct	200	neg
2001	11 Apr	7 Nov	210	neg
2002	30 Apr	1 Nov	185	neg
2003	5 June	3 Oct	220	pos
2004	25 May	14 Oct	142	pos
2005	18 Aug	21 Oct	64	pos
2006	30 May	31 Oct	154	pos
2007	22 Mar			neg

PDO vs date of 'biological spring transition (UPPER) and number of days that a cold water community persisted in a given year (LOWER)



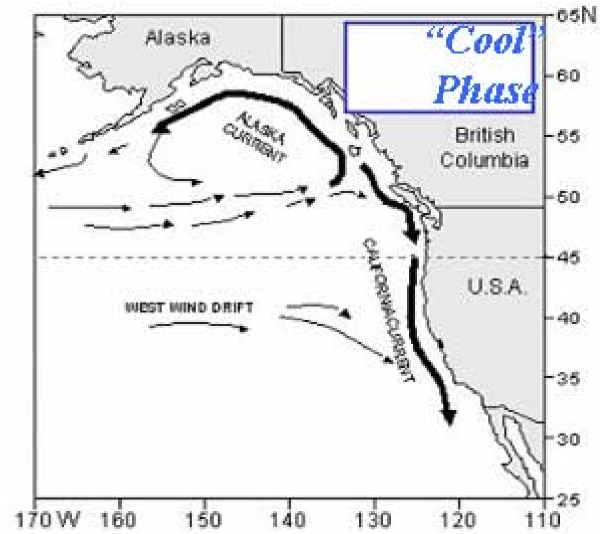


- The more negative the PDO, the **earlier** the date of "biological spring"
  - 'Zero' point is day 10 April
- The more negative the PDO the **longer** a cold water community persists.
  - 64-154 d when PDO **positive**
  - 174-231 d when PDO **negative**

A working mechanistic hypothesis: source waters. . .

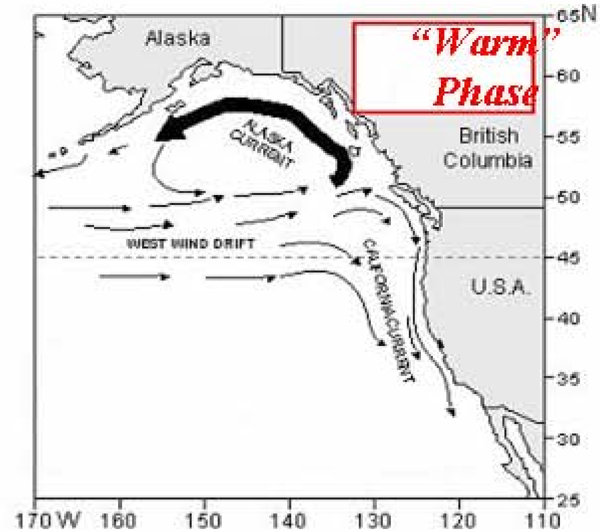
Cool Phase →

Transport of boreal coastal copepods into NCC from Gulf of Alaska



Warm Phase →

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



Wrap up

- PDO **downscales** to coastal waters of the NC C
- **Time lags** between PDO sign change and change in SST and copepod biodiversity is 3-5 months
- Changes in community structure track PDO, with cold water lipid rich copepods during negative phase and warm water lipid-poor animals in positive phase (Hooff and Peterson 2006)
- Community structure changes show length of the **growth season:** LONGER WHEN PDO NEGATIVE
- Therefore if we can track the **behavior** of the PDO with climate models (as suggested by Overland et al.) then we may be able to forecast copepod biodiversity, food chain structure and returns of salmon to Columbia River (A DIFFERENT TALK)
- Climate change may result in a warm water community made up of similar congeners but with different life histories. Jessd Lamb talk, S5, Zooplankton functional groups in ecosystems

Acknowledgements

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  - in the 1970s and 1980s: Peter Rothlisberg, Greg Lough, Charlie Miller, Hal Batchelder