Variations in source waters which feed the California Current may be the mechanism which links the PDO and climate change with ecosystem response

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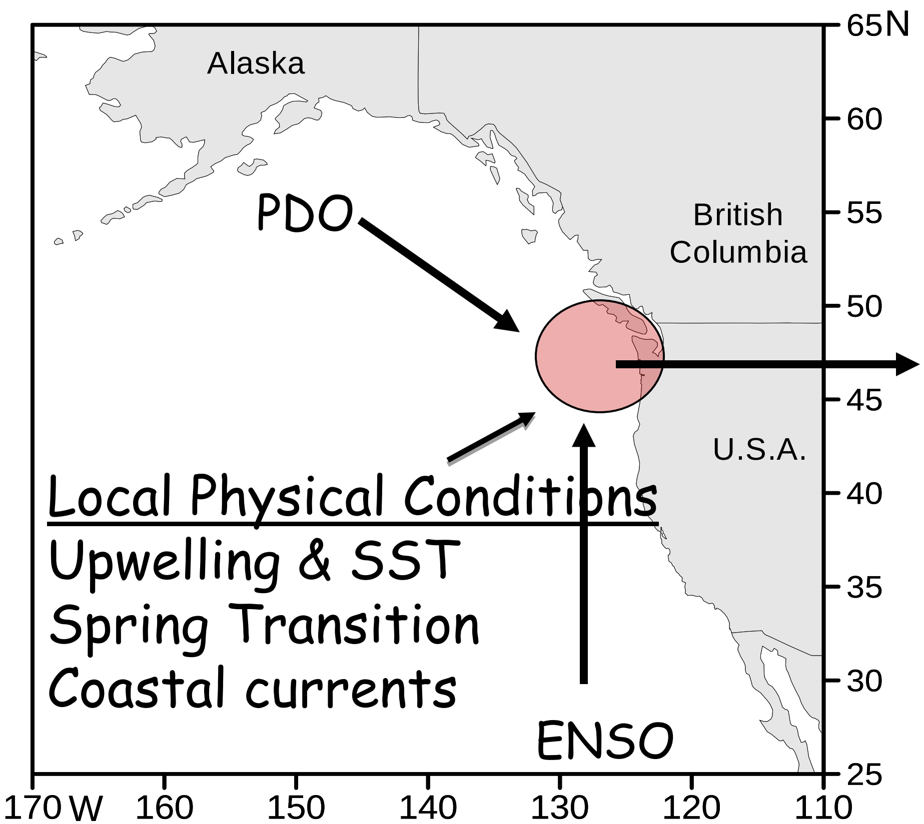
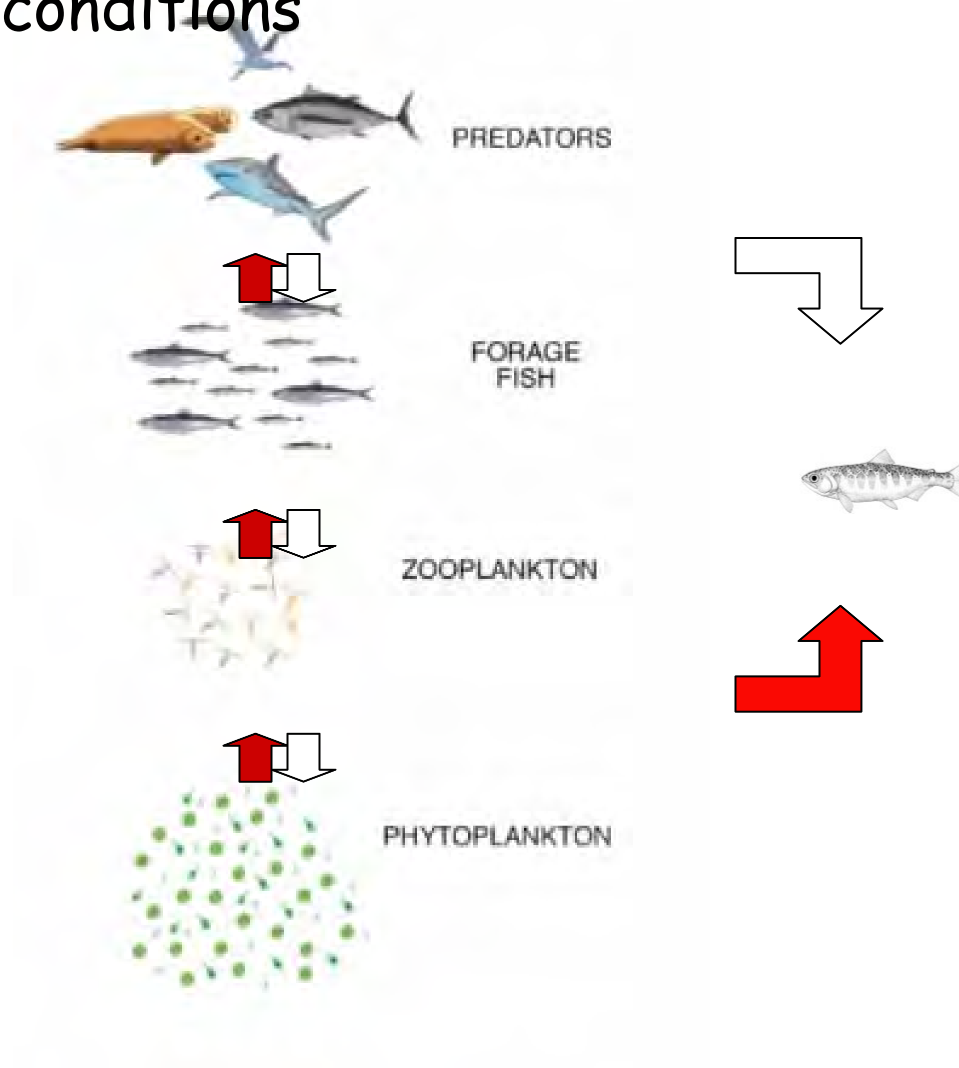
<www.nwfsc.noaa.gov> "Ocean Conditions and Salmon Forecasting"

We are developing management advice for salmon managers based on a suite of physical, biological and ecological indicators of ocean conditions

Today I will speak about the PDO and bottom-up forcing

Large scale physical forces acting on the local scale can influence biological process important for salmon





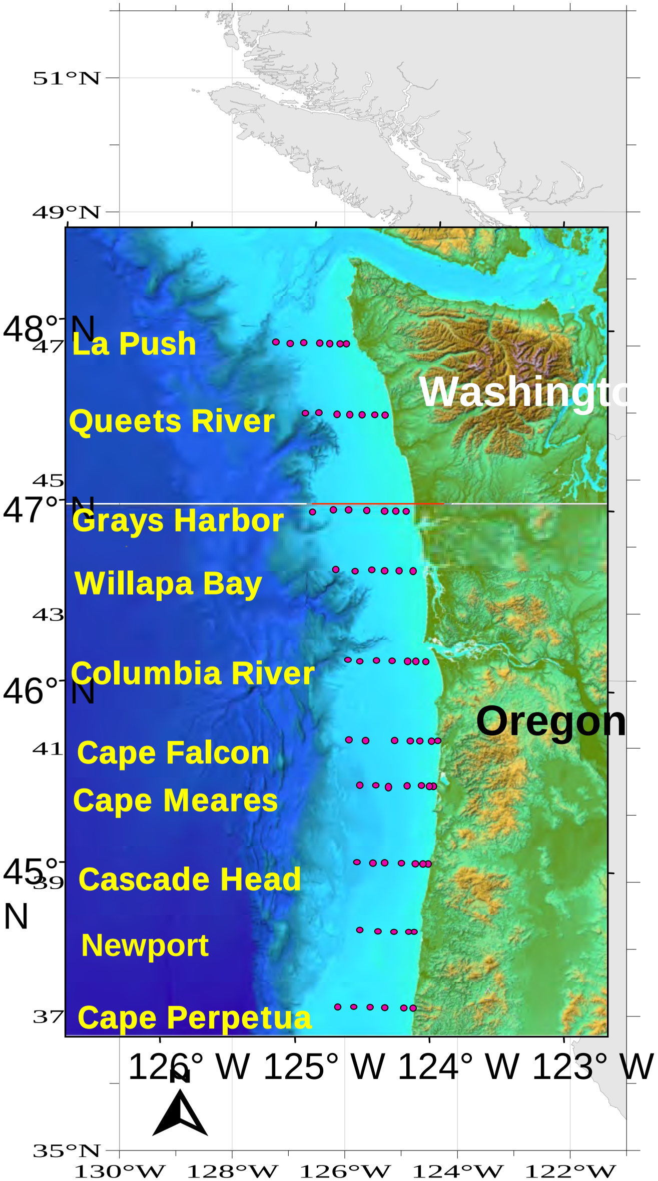
Local Biological Conditions

Observations

- Newport Line biweekly sampling since 1996 (16th year)

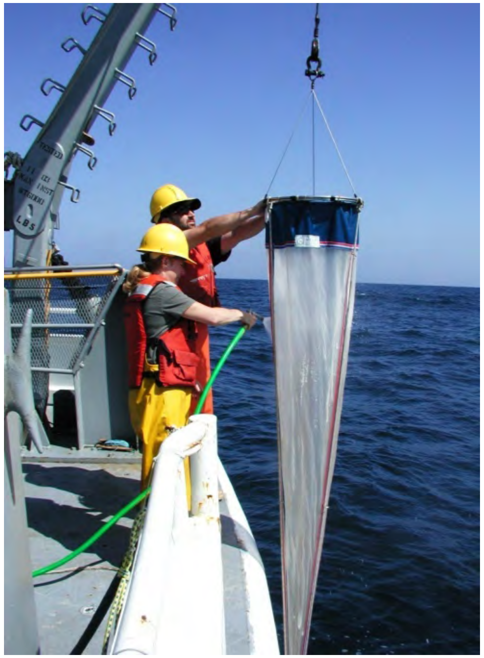
- Juvenile salmon sampling in June and September since 1998 (14th year)

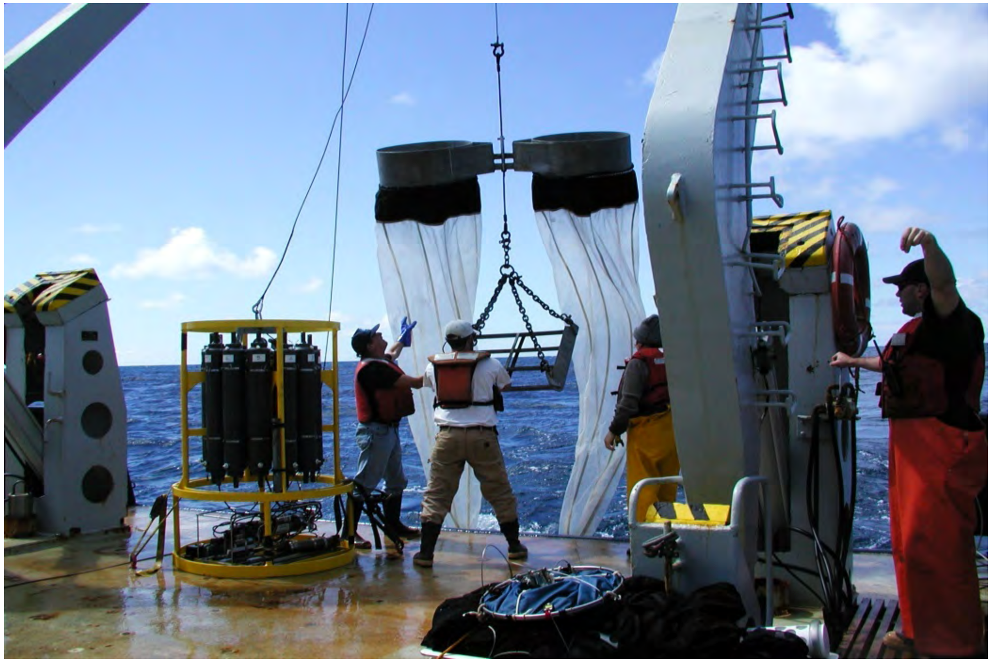
•Historical data:
  hydrography, 1960s;
  plankton, 1969-1973;
      1983, 1990-1992
  juvenile salmon, 1981- 1985



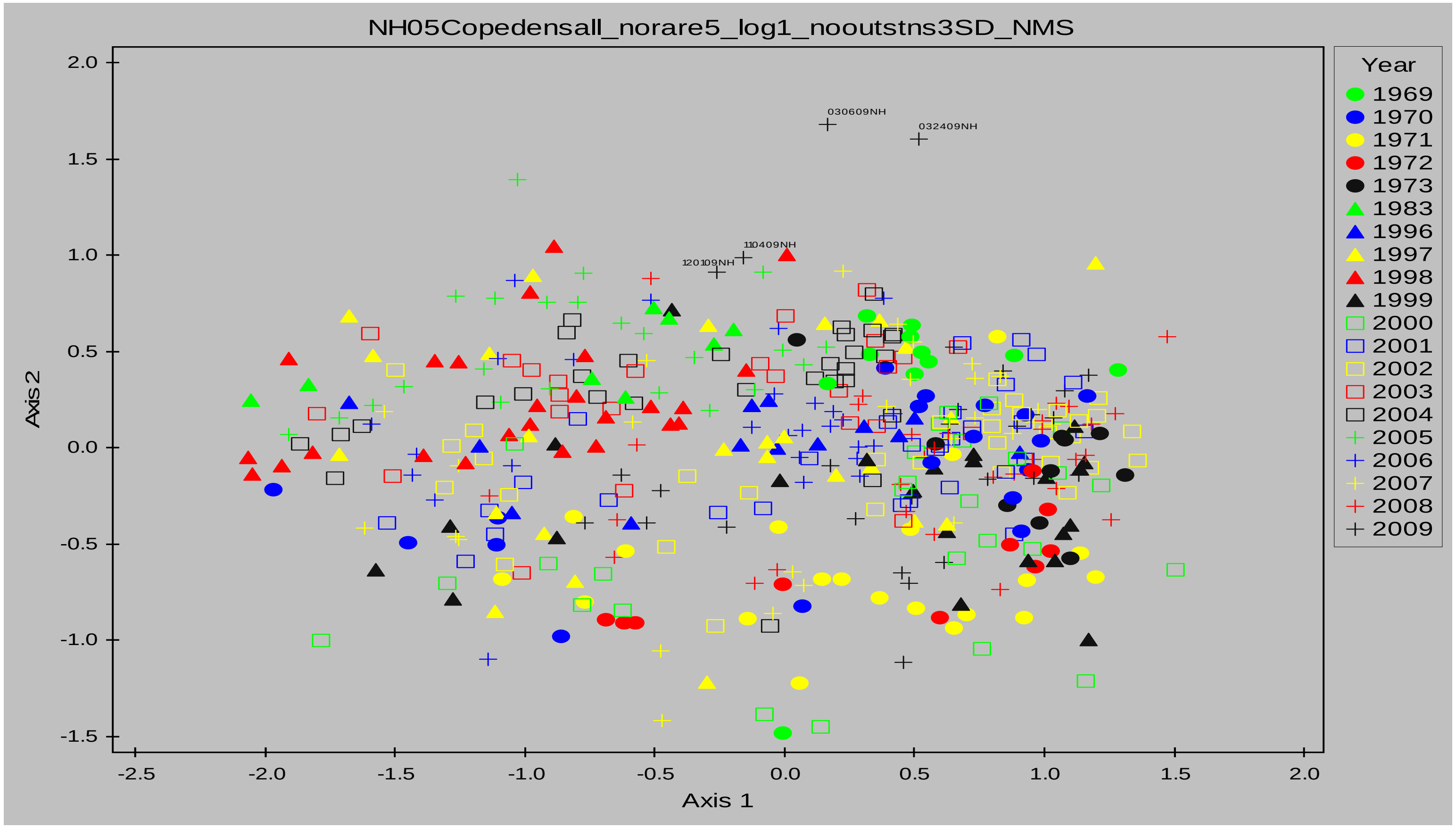
Methods

- Hydrography from CTD profiles
- Copepods with $\frac{1}{2}$ m diameter 200 μm mesh net towed vertically from 100 m
- Krill, fish eggs and fish larvae with 70 cm 333 μm mesh Bongo net towed obliquely
- DATA: Ordination analysis of ~ 400 copepod samples collected at the station NH 05 produces a Copepod Community Index (CCI)





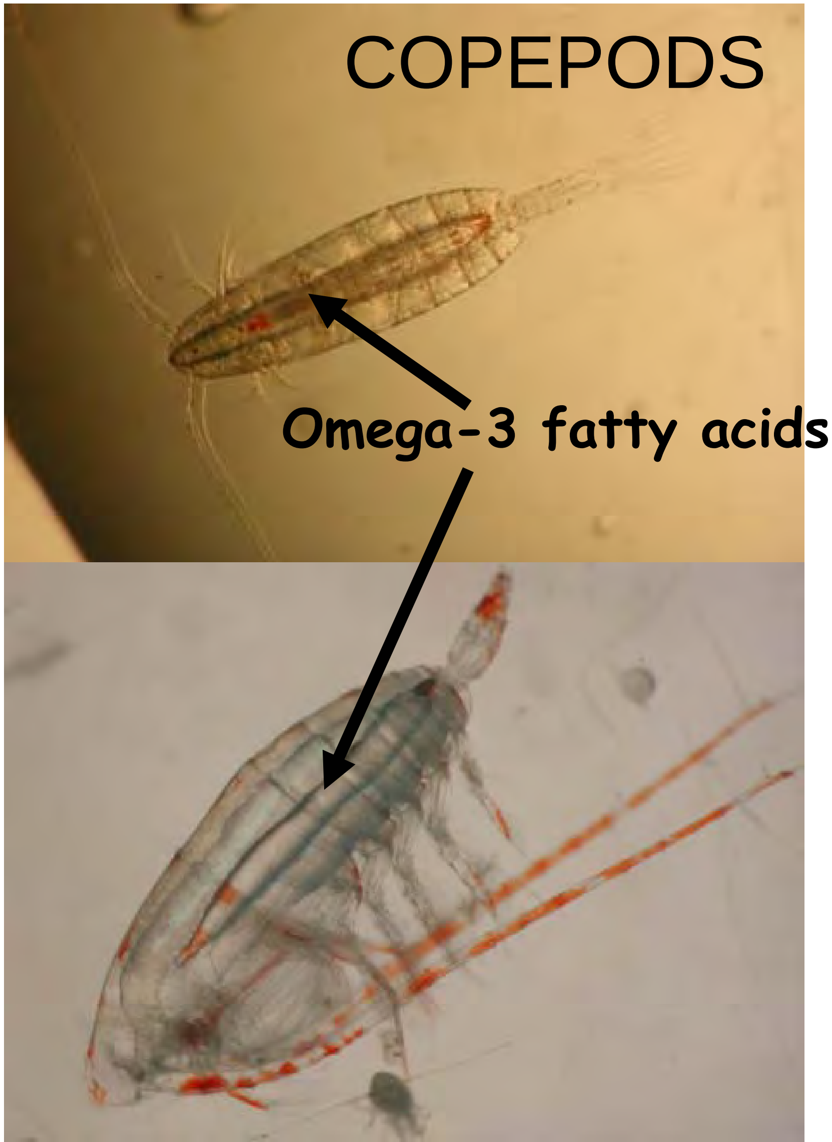
Ordination using NMDS (Non-Metric Multidimensional Scaling)
Copepod Community Structure over 21 years



X-axis explains about 70% of the variance

X-axis scores are the Copepod Community Index

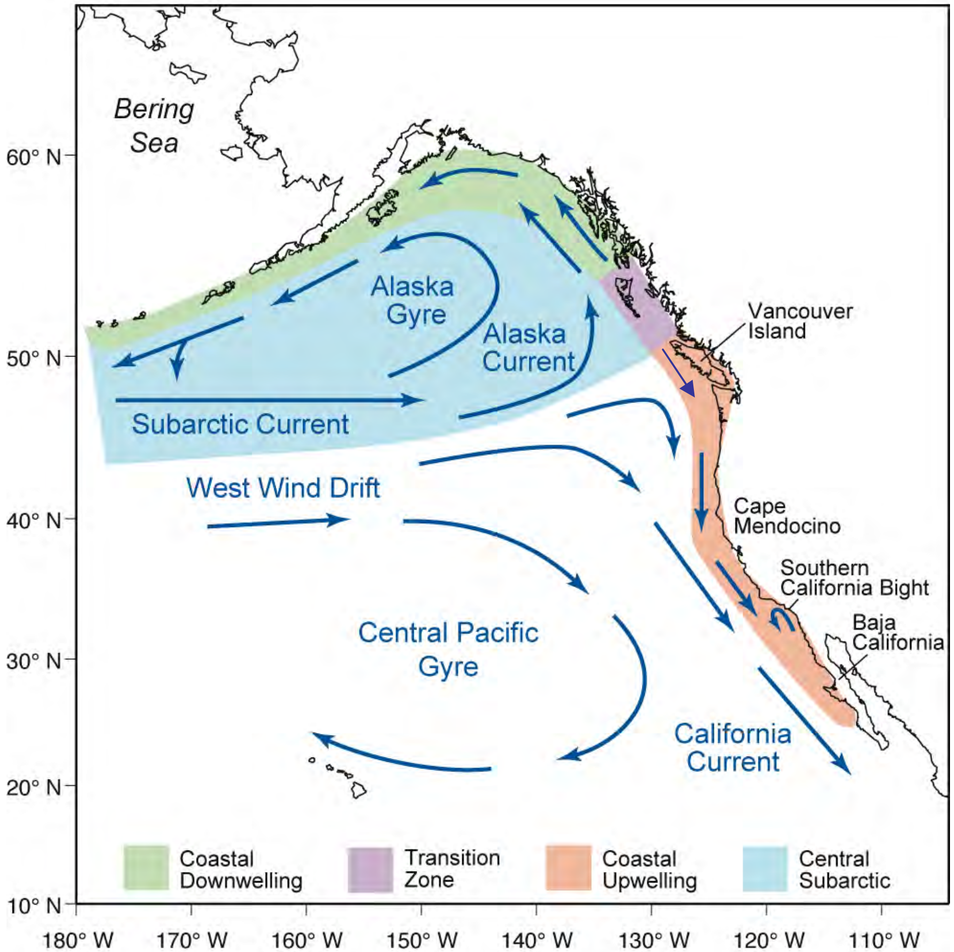
Here are two types of plankton that play key roles in a salmon's food chain: copepods and krill,



We know from past research (in part by Mantua, Francis, Hare and others) that changes in the sign of the PDO (a basin scale indicator) translate into changes in salmon returns (a local response) in the northeast Pacific Ocean, from Alaska south to California

I will show that the sign of the PDO is correlated with changes in
food chain structure and lipid content as indexed by
copepod species composition

Circulation off the Pacific Northwest



Subarctic Current brings cold water and northern species to the N. California Current;

The West Wind Drift brings subtropical water and subtropical species to the N. California Current

Therefore, ecosystem structure is affected by the source waters which feed the California Current.

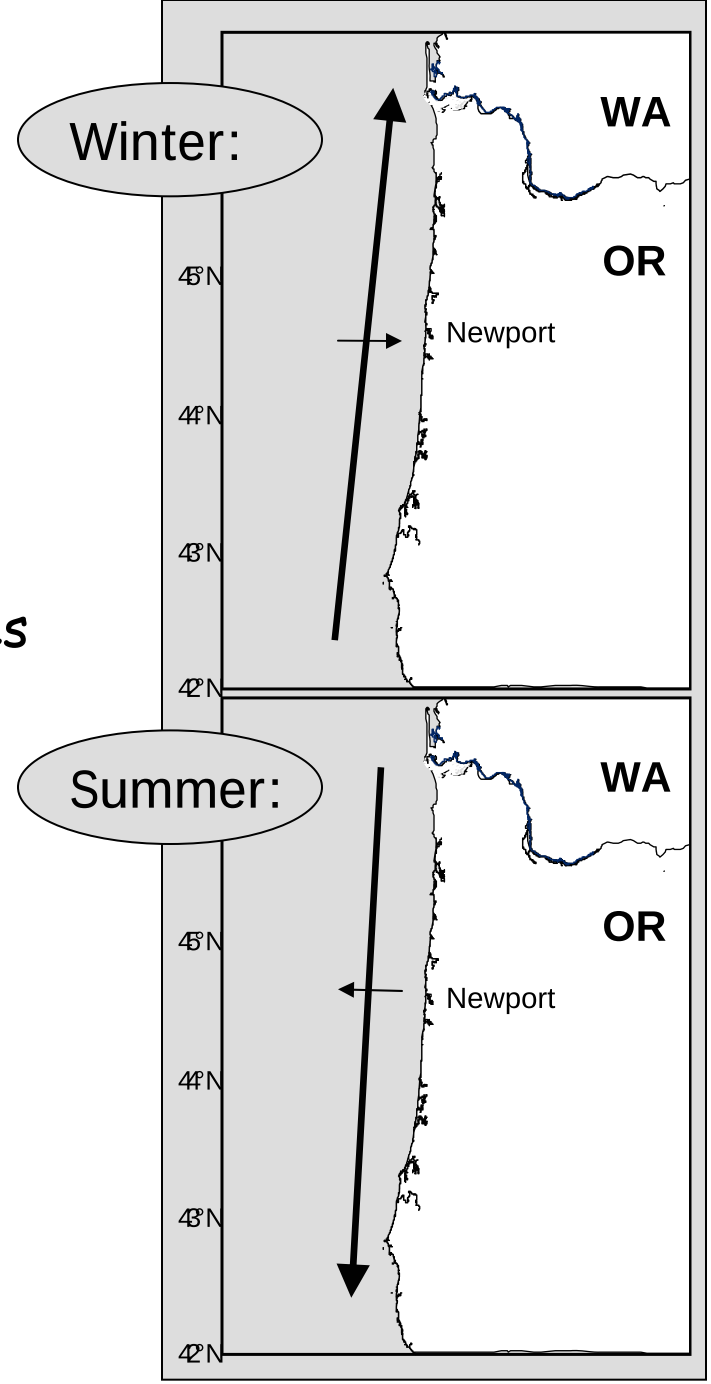
The source waters have strong seasonality over the continental shelf:

Winter:
- Winds from the South
- Downwelling
- Poleward-flowing Davidson Current
- Subtropical and southern plankton species transported northward & onshore
- Many fish spawn at this time

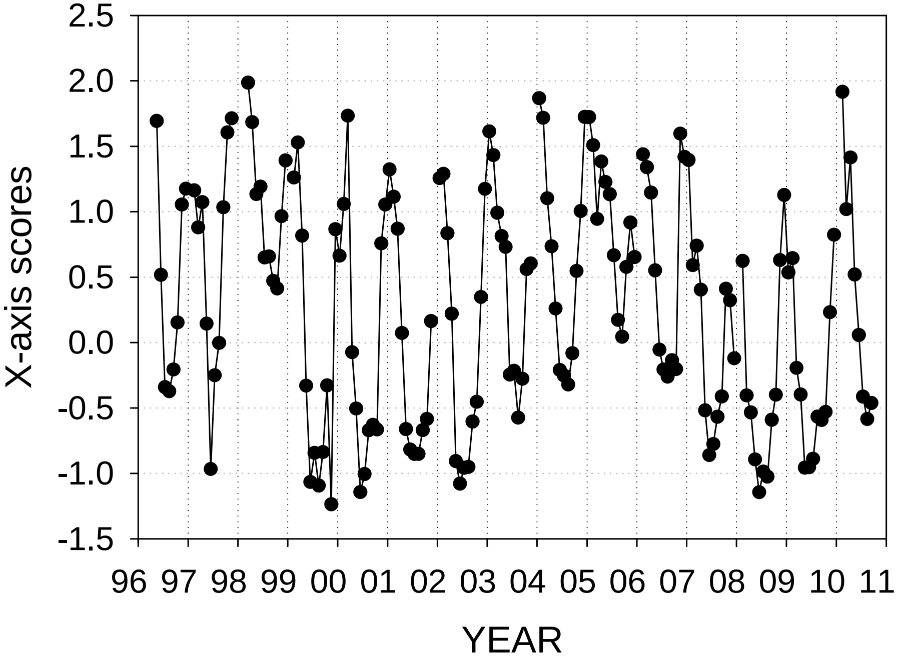
•**Spring Transition in April/May**

•**Summer**:
- Strong winds from the North
- Coastal upwelling
- Equatorward alongshore transport
- Boreal/northern species transported southward

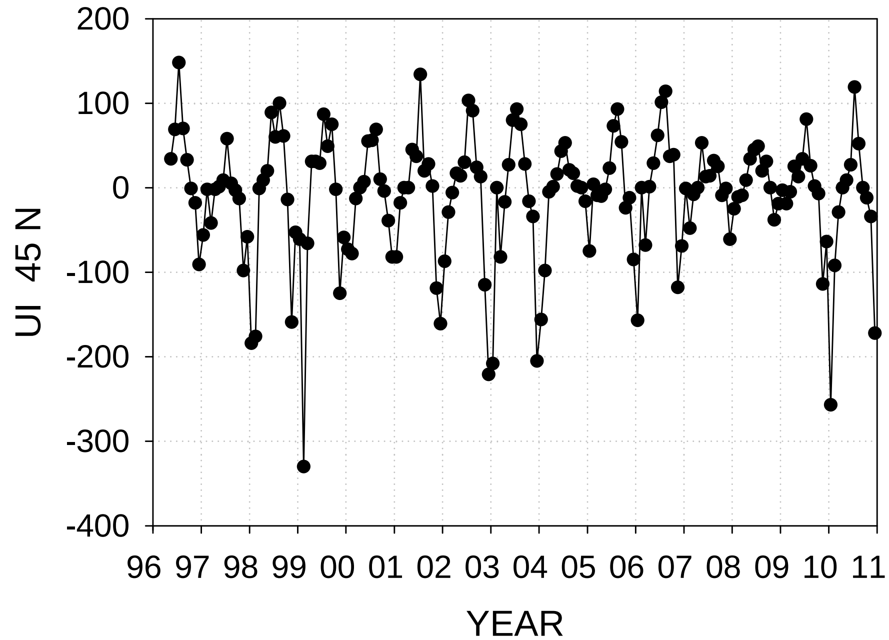
•**Fall Transition in October**

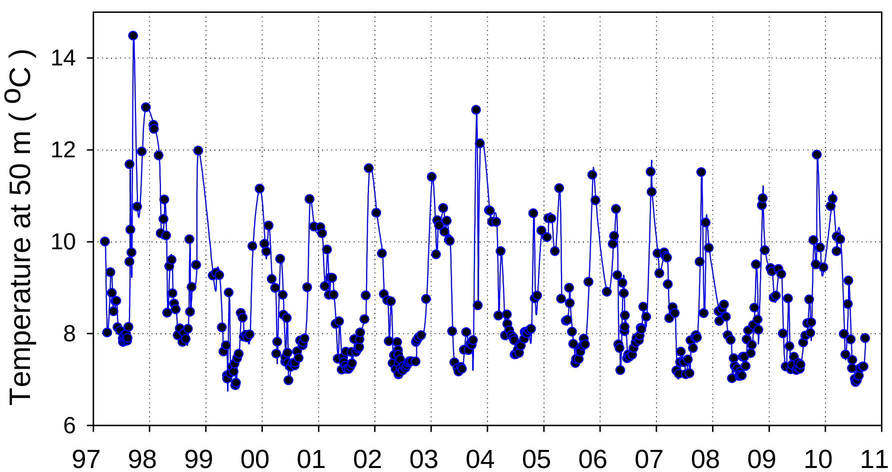


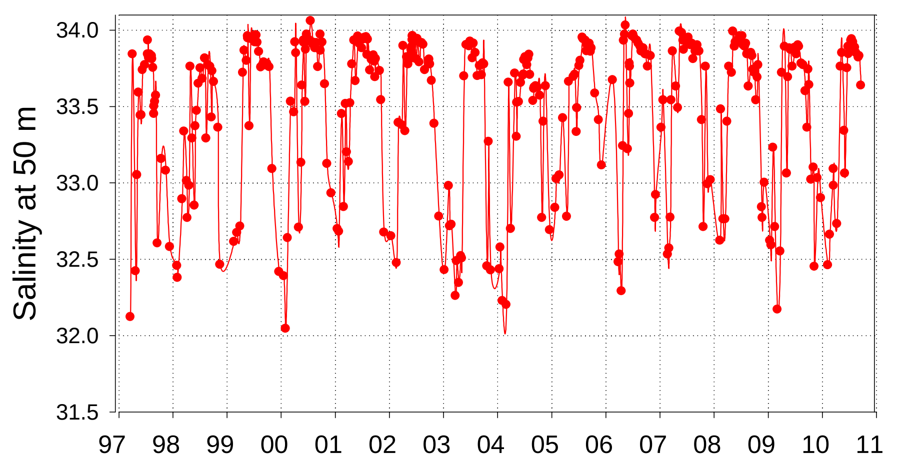
X-axis SCORES



UPWELLING INDEX AT 45 N



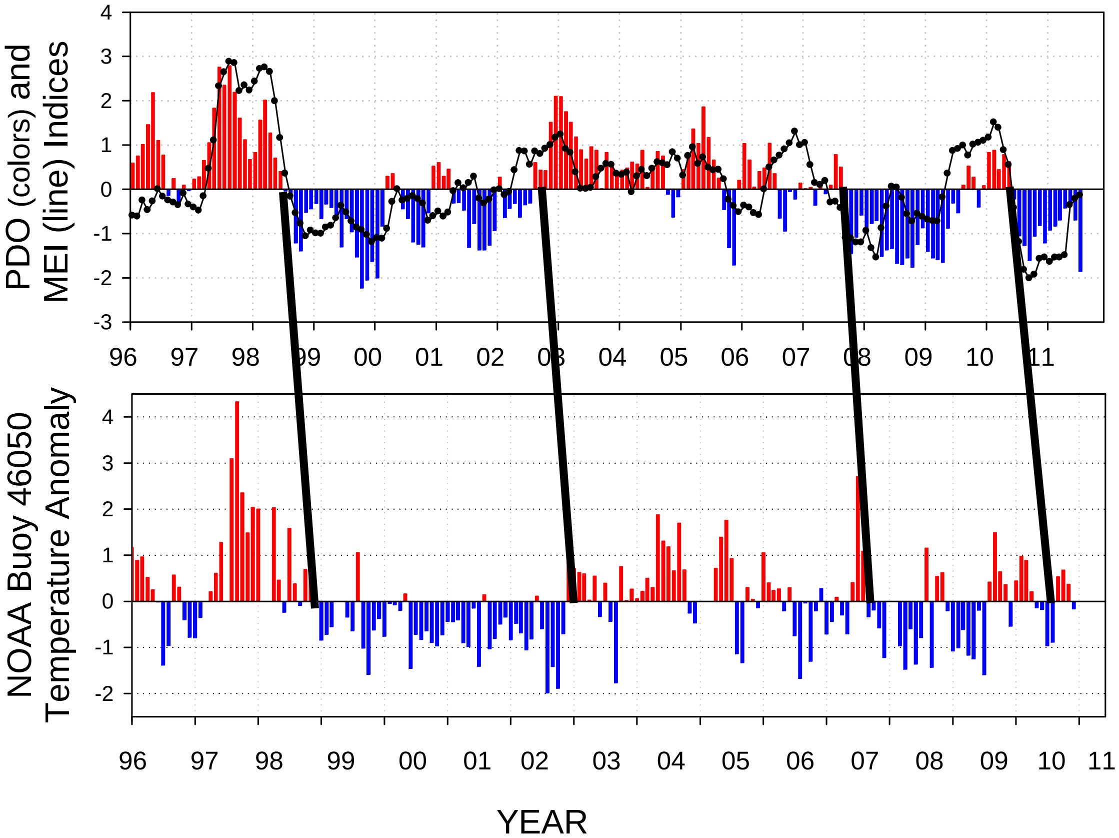




TEMPERATURE AT NH 05 AT 50 m

SALINITY AT NH 05 at 50 m

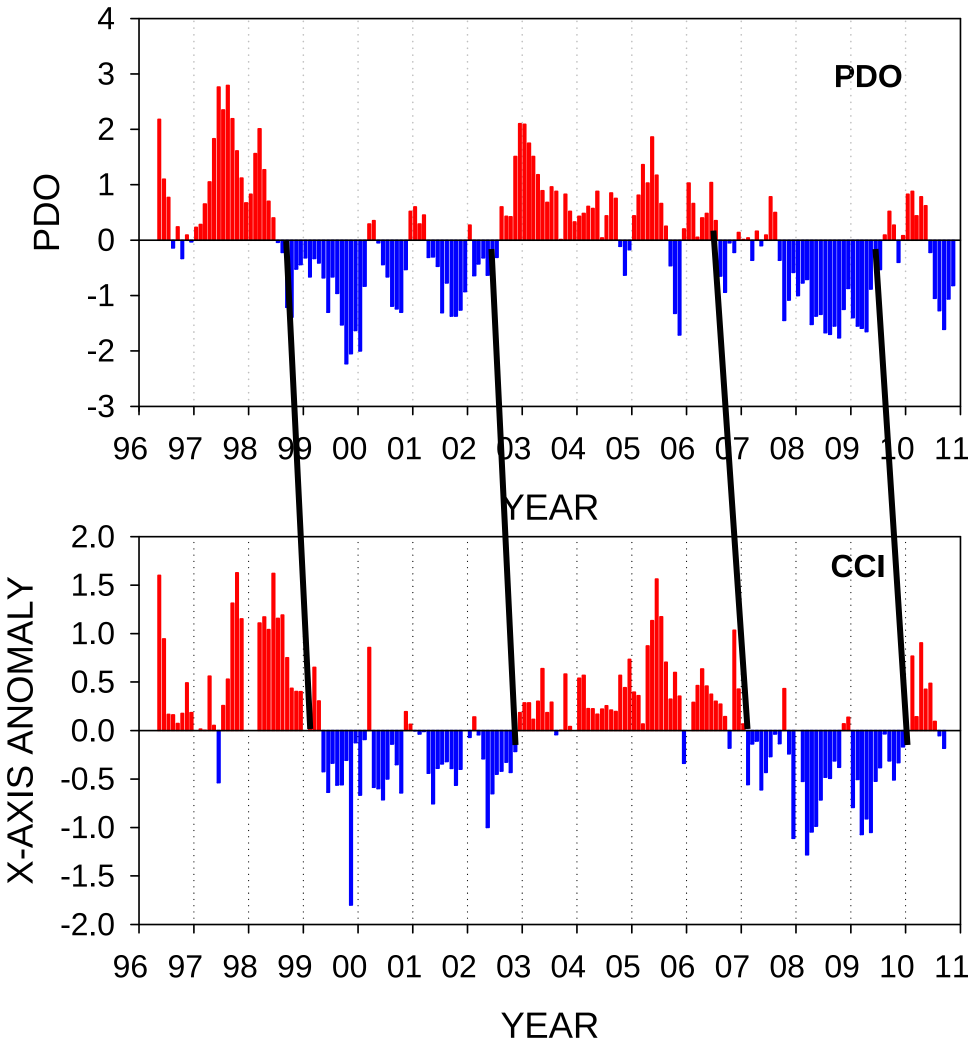
15 year time series of monthly SST anomalies off Newport shows that PDO (and MEI) downscale to local SST



Temperature differences usually ± 1°C

- PDO and SST correlated, (as they should be.
- Note the four recent periods of persistent sign changes: mid-1999, mid-2003, mid-2007, mid-2009
- However there are time lags between PDO sign change and SST response of ~ 3-5 months, suggesting perhaps that the PDO is an advective signal along the Oregon coast

PDO and zooplankton: monthly anomalies of the copepod community index



The sign of the PDO is associated with either warm or cold water being advected to the coast

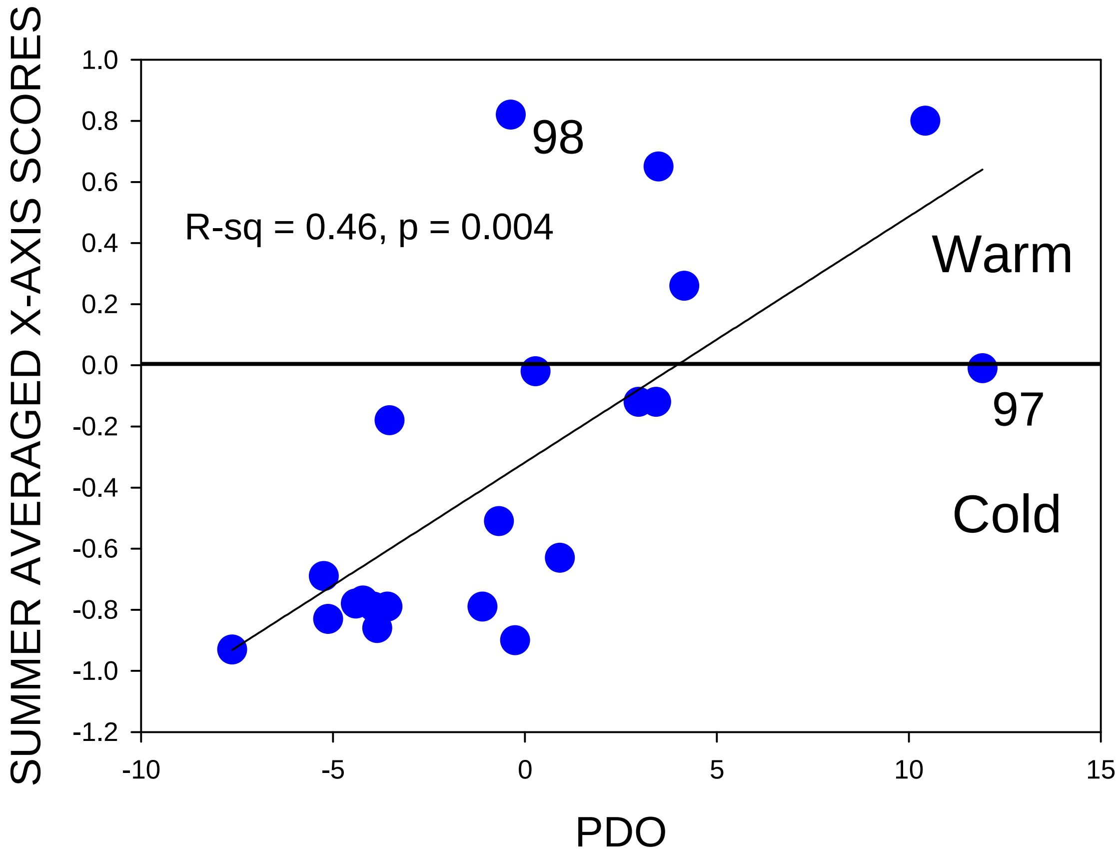
As a consequence you get "warm" and "cold" water zooplankton communities in association with positive or negative phase of the PDO.

Warm water community

Cold water community

As with SST, there are lags of a few months duration

Summer-averaged PDO vs summer averaged X-axis scores: 1969-1973, 1983, 1996-2010 (n = 21 years)



Contrasting Communities

- **Negative PDO = "cold-water" copepod community**
  Dominated by species which also dominate the eastern Bering Sea, coastal GOA, coastal northern California Current
  - *Pseudocalanus mimus, Calanus marshallae, Acartia longiremis*

- **Positive PDO = "warm-water" copepod community**
  Dominated by copepod species that are common in neritic waters of the coastal southern California Current and/or offshore waters of the NCC: *Clausocalanus spp., Ctenocalanus vanus, Paracalanus parvus, Mesocalanus tenuicornis, Calocalanus styliremis, Corycaeus anglicus*

Based on Peterson and Keister (2003)

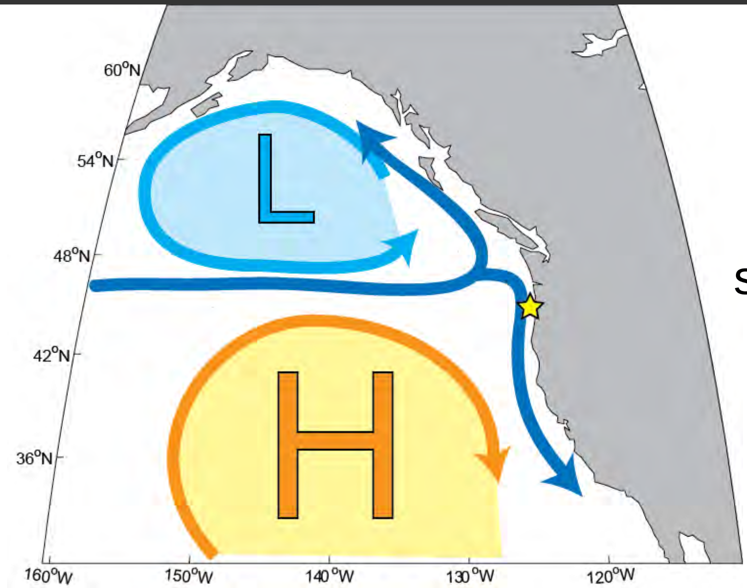
Comparisons in size and chemical composition

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

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

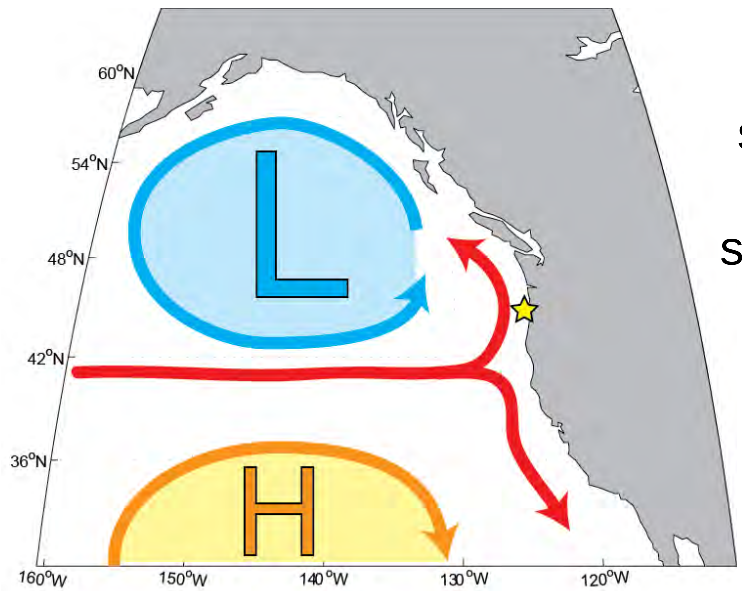
Relationship between gyre size and local ecosystem properties (from Ryan Rykaczewski)

Cool Coastal Phase
➔
Weaker Aleutian low pressure; but more southerly flow along the coast; rich, boreal zooplankton at Newport



Smaller subpolar gyre; Larger subtropical gyre

Warm Coastal Phase
➔
Stronger Aleutian low pressure; but more northerly flow along the coast; smaller, subtropical zooplankton at Newport



Larger subpolar gyre; Smaller subtropical gyre

What problems lie ahead for salmon and other fishes off the Pacific Northwest?

- Will coastal upwelling become weaker, stronger or stay the same?
- Will warming of the ocean lead to greater stratification thus reducing the effectiveness of coastal upwelling?
- Will the Pacific “Decadal” Oscillation return to “Decadal”?
- Will the north Pacific High and central North Pacific Gyre expand northward and make the coastal waters off Oregon more sub-arctic in character?
- Of great concern in coastal upwelling systems is the trend toward decreased oxygen concentration and of decreased pH in waters which upwell at the coast.

Acknowledgements

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- NASA

See Keister et al. (2011) GCB and Bi et al. (2011) GRL for details.