The Northern California Current Ecosystem: variability, indicator development, and ocean condition indices for fishery management

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Background

- In 1998, our laboratory formed the Estuarine and Ocean Ecology Program recognizing the importance of ocean productivity to the ecology of salmon and other marine organisms.

- We have developed some simple, easily understood forecast tools that provide a <u>one-year forecast</u> of salmon returns for those who manage salmon and the Columbia River hydropower system.

- We take an empirical approach by using observations of physical and biological oceanographic conditions in local waters made on frequent oceanographic cruises to make inferences as to how variability in "ocean conditions" affects ocean productivity

- Translate this information into a form usable to managers who have little knowledge of oceanography.

- We in turn are learning what products the managers might need, and how information on "ocean conditions" may result in actions taken by managers

Background

- Salmon spawn in freshwater but 90-95% of their growth takes place in the ocean.
- Coho salmon migrate to the sea at an age of 1.5 years (in May, anticipating upwelling), return to rivers at age 3.0 (in October) when winter rains begin.
- Spring Chinook salmon migrate to the sea at an age of 1.5 years (in May, anticipating upwelling) but do not return to rivers until age 4 or 5 (in October).
- Columbia River has many hydroelectric dams; most have fish ladders. For dams without fish ladders, fish are transported via barges and tanker trucks.
- Bonneville Power Administration invests in freshwater habitat improvements and need to know ocean conditions to evaluate success of freshwater programs.
- Need forecasts to plan how to balance hydropower needs against use of water for irrigation and fish passage.

Attributes of salmon ecology that are important for analysis of relationships between ocean conditions and salmon survival

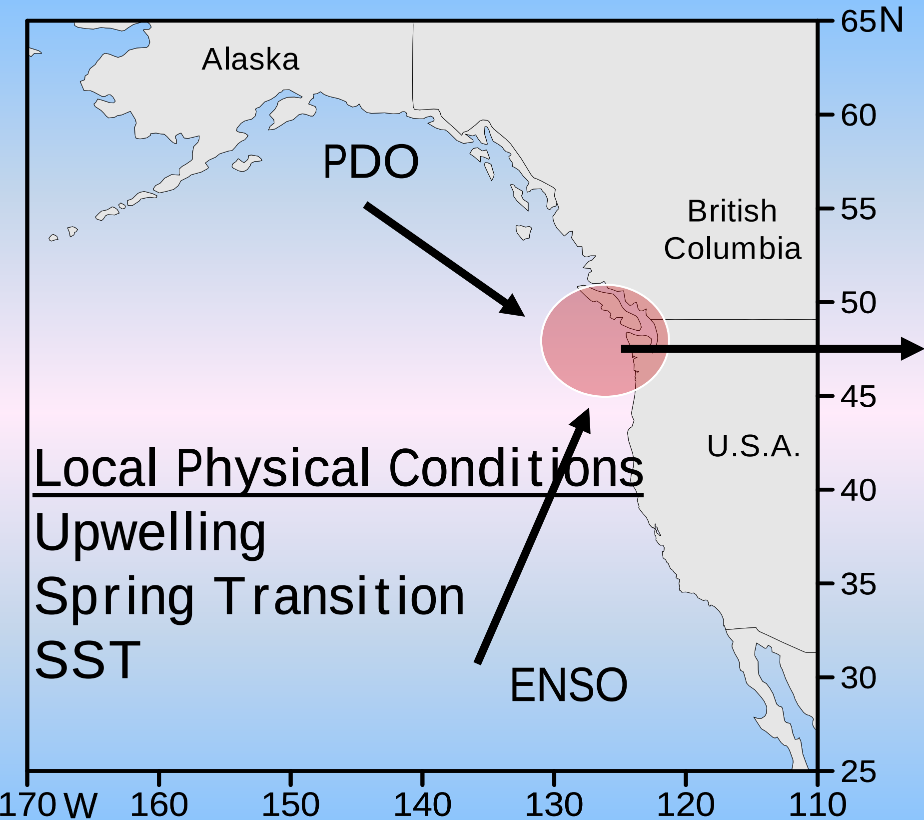
- Live in continental shelf waters during first summer at sea; coho mid-to-outer shelf, Spring Chinook mid-to-inner shelf. Fall Chinook chiefly inner shelf -> surf zone.
- Coho salmon: number of juvenile fishes released by hatcheries is known, and most are marked. The number of fish caught in the fishery + the number that return to rivers and hatcheries is also known.
- Spring Chinook: number of juvenile fish passing by Bonneville dam are counted as are the number of jack salmon returning 12 months later, and adult salmon returning 2-3 year later.
- These data sets yield estimates of survival

Indicators of Ocean Conditions and Salmon Survival

- Large Scale Oceanic Indicators
  - PDO, MEI
- Local physical and biological indicators of ocean conditions
  - SST, Upwelling, T-S characteristics of upwelled water, date of transition from winter conditions → summer conditions (= spring transition) following Logerwell et al. 2003
  - Copepod biodiversity, cold water copepod species biomass anomalies, date of biological spring transition.
- Response variables
  - Catches of juvenile salmon during surveys,
  - Forage fish abundance
  - Predators (hake and pelagic birds)
- Use 2005 as an example

We are taking a holistic approach to index development and management advice by considering both physical and biological factors

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



Local Physical Conditions

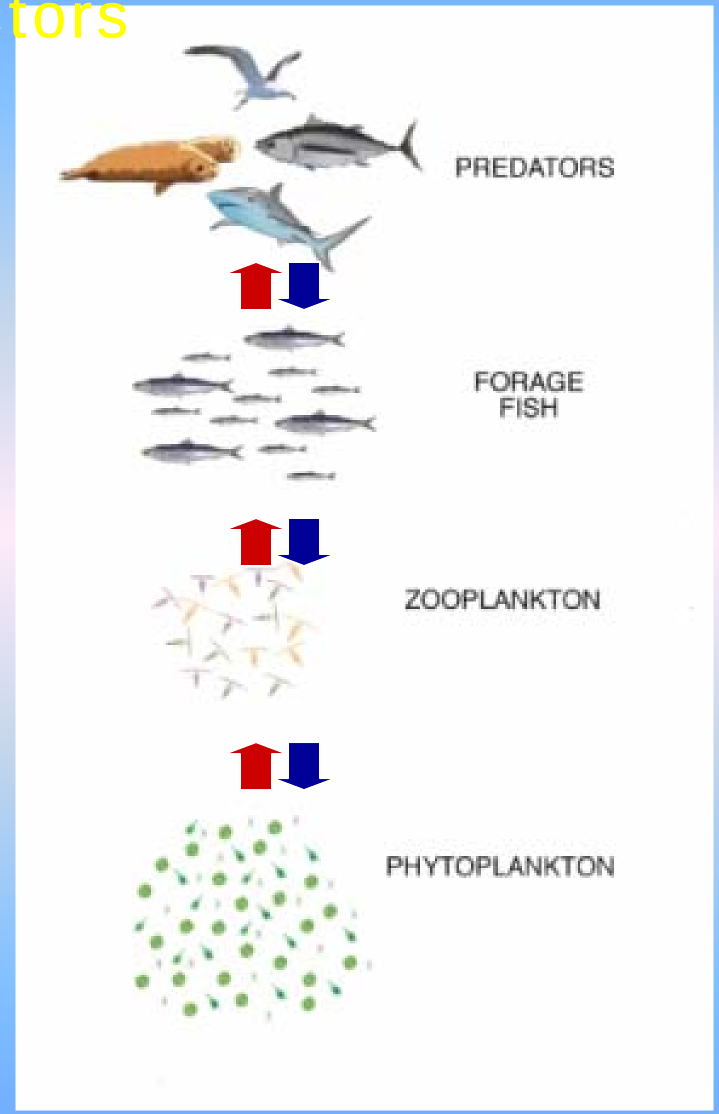
Upwelling

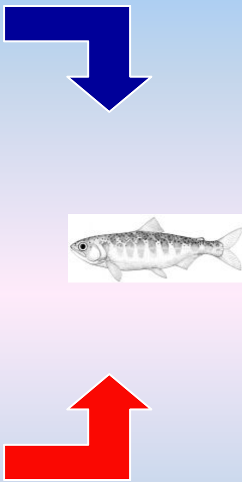
Spring Transition

SST

Approach

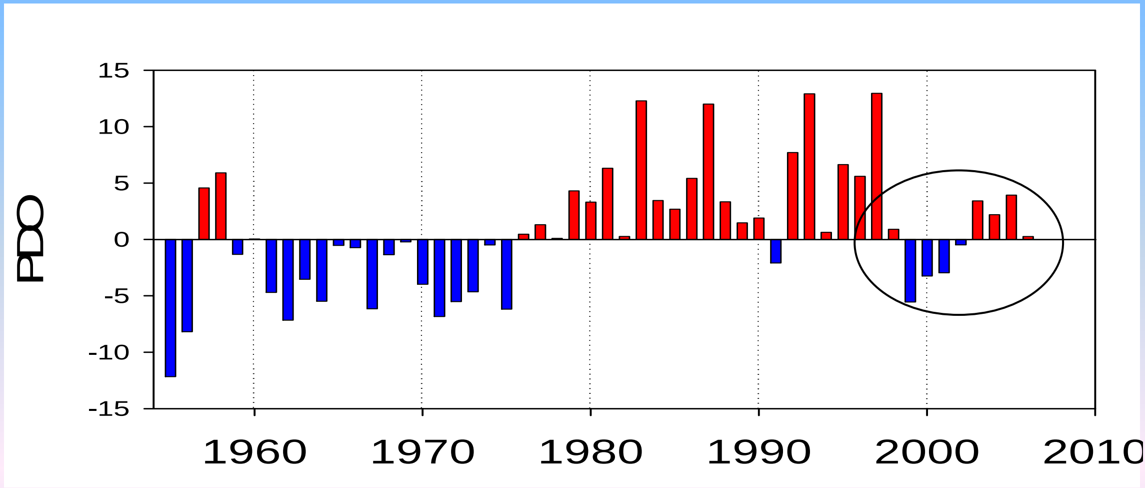
1. Develop time series
2. Relate to salmon through simple bivariate analyses





Local Biological Conditions

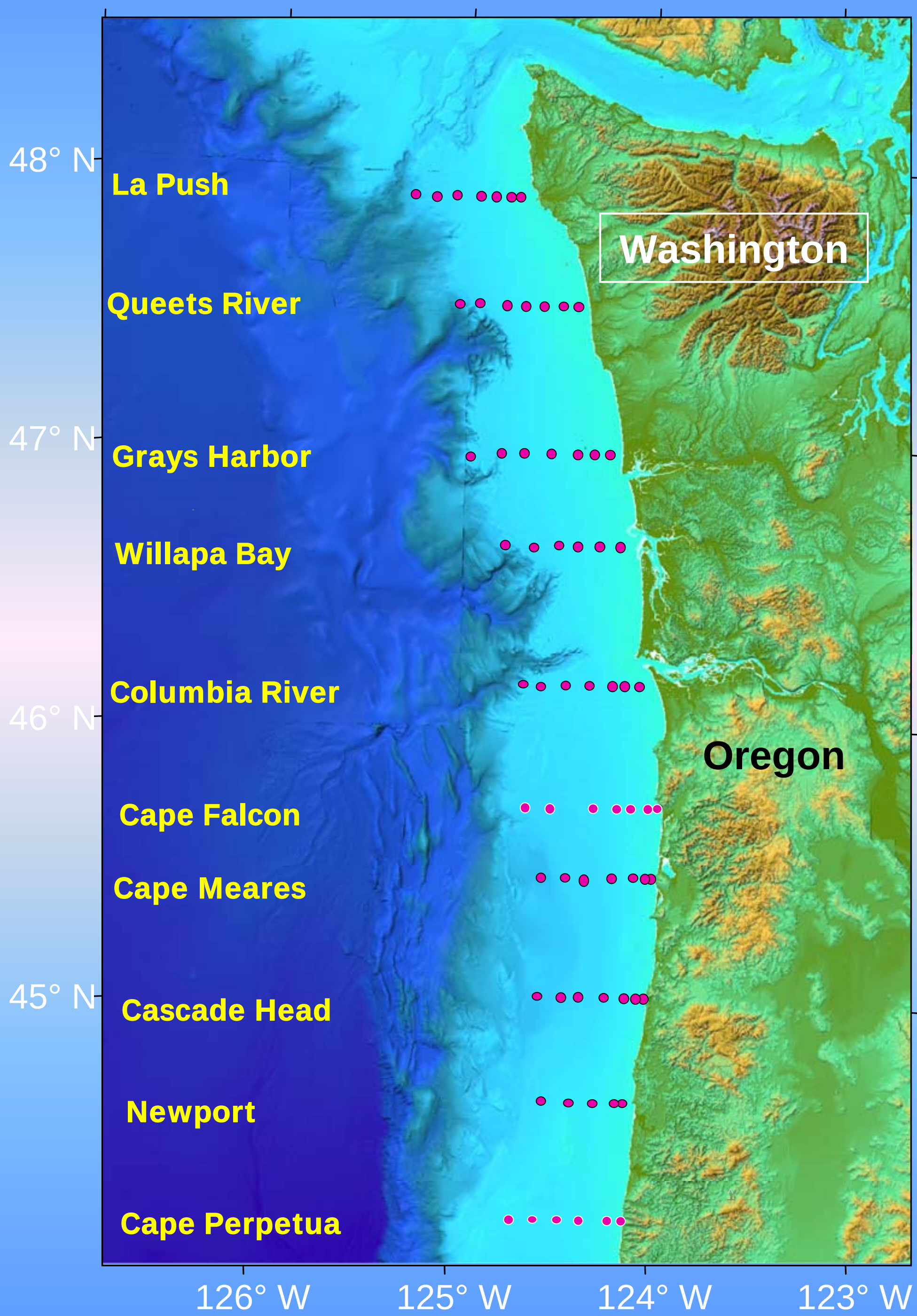
An opportunity…



- The high frequency changes and strong contrasts in the PDO (and ENSO) since 1996 have provided us with a grand experiment that allows us to study in what ways and how quickly organisms respond to short term climate variability;

- Use information on changes in SST, water properties, spring transition, zooplankton biomass and species composition, salmon, baitfish and predatory fish to try to understand mechanisms by which the PDO (and ENSO) affect ecosystem dynamics (and salmon) in northern California Current.

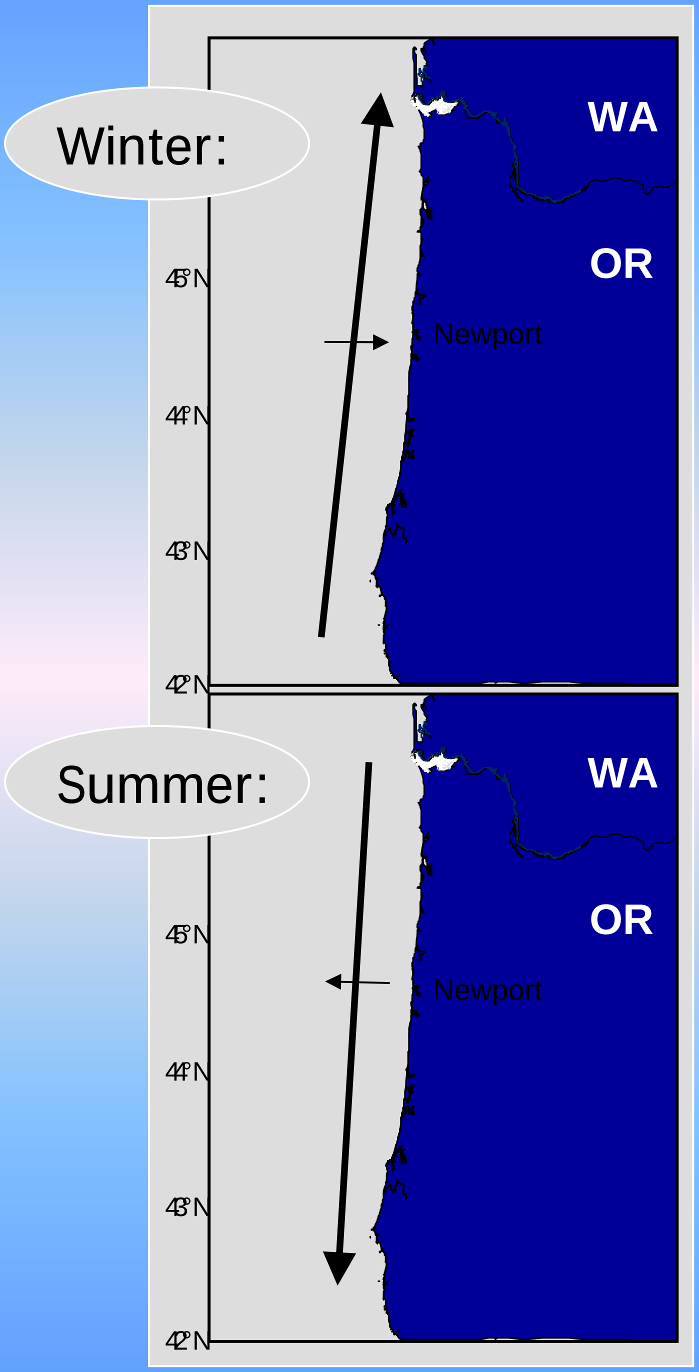
Plankton, Salmon and Pelagic Fish Sampling



- Sample in May, June and September (50 stations) since 1998
- Sample Columbia River and Willapa Bay every 10 days from April through July (AT NIGHT) at ~ 10 stations; since 1998
- Sample off Newport every two weeks, since 1996
- Have historical data on hydrography and zooplankton from 1970s and 1983; salmon abundance data from 1981-1985 but these data are not part of this talk

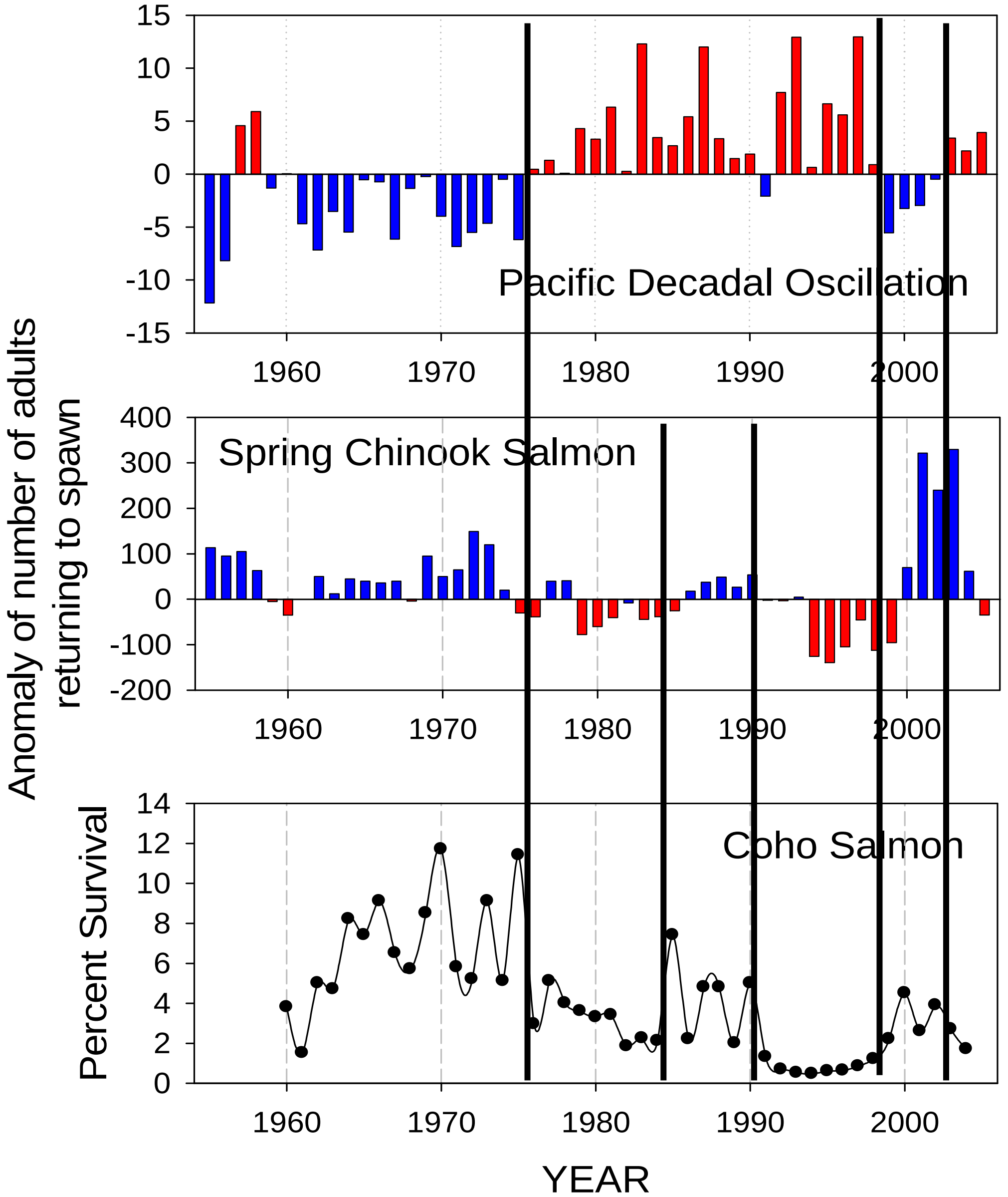
Winds and current structure off Oregon and Washington:

- Winter:
  - Winds from the south/southwest
  - Downwelling
  - Poleward-flowing Davidson Current
  - Uniform cross-shelf hydrography
- Spring Transition in April/May
- Summer:
  - Strong winds from the north/northwest
  - Coastal upwelling
  - Equatorward alongshore transport
  - Strong cross-shelf physical gradients
- Upwelling-favorable winds cease in September/October



Results

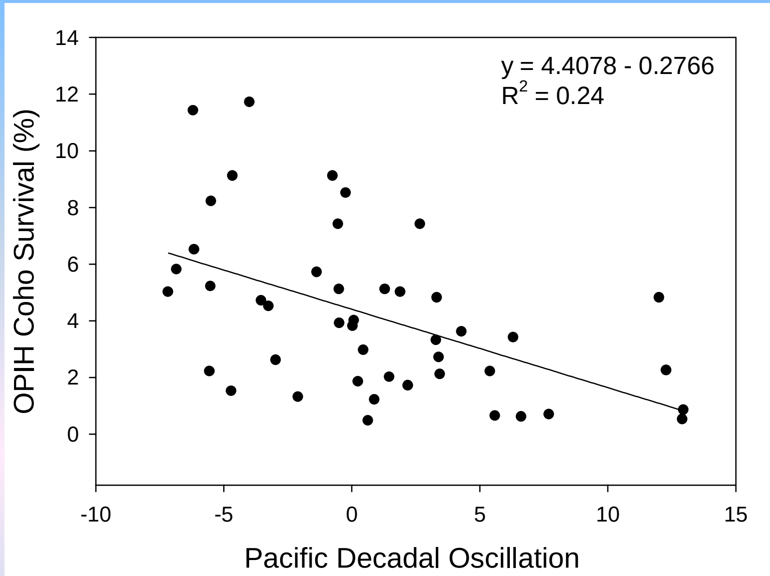
- PDO
- WATER TYPES
- DATE OF SPRING TRANSITION
- COPEPOD COMMUNITY COMPOSITION
- CATCHES OF JUVENILE SALMONIDS
- SUMMARY OF NEXT STEPS

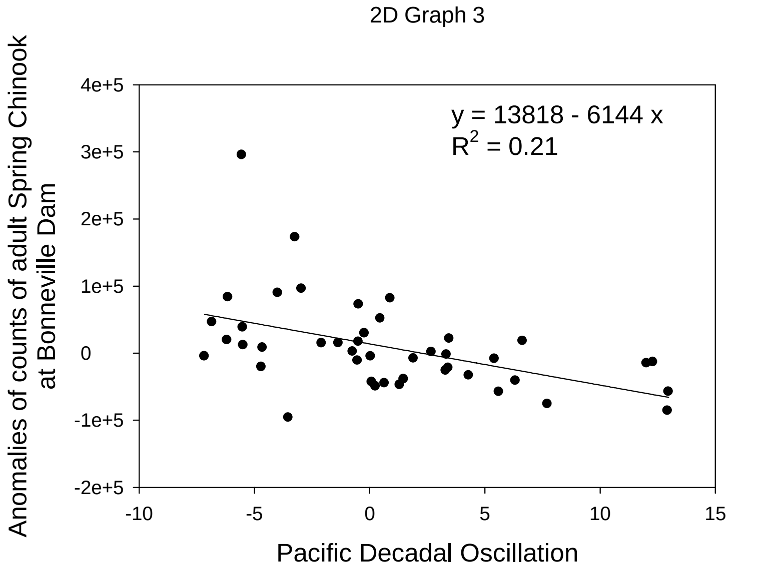


Large Scale Physical indicator: PDO

Coho and Spring Chinook respond similarly

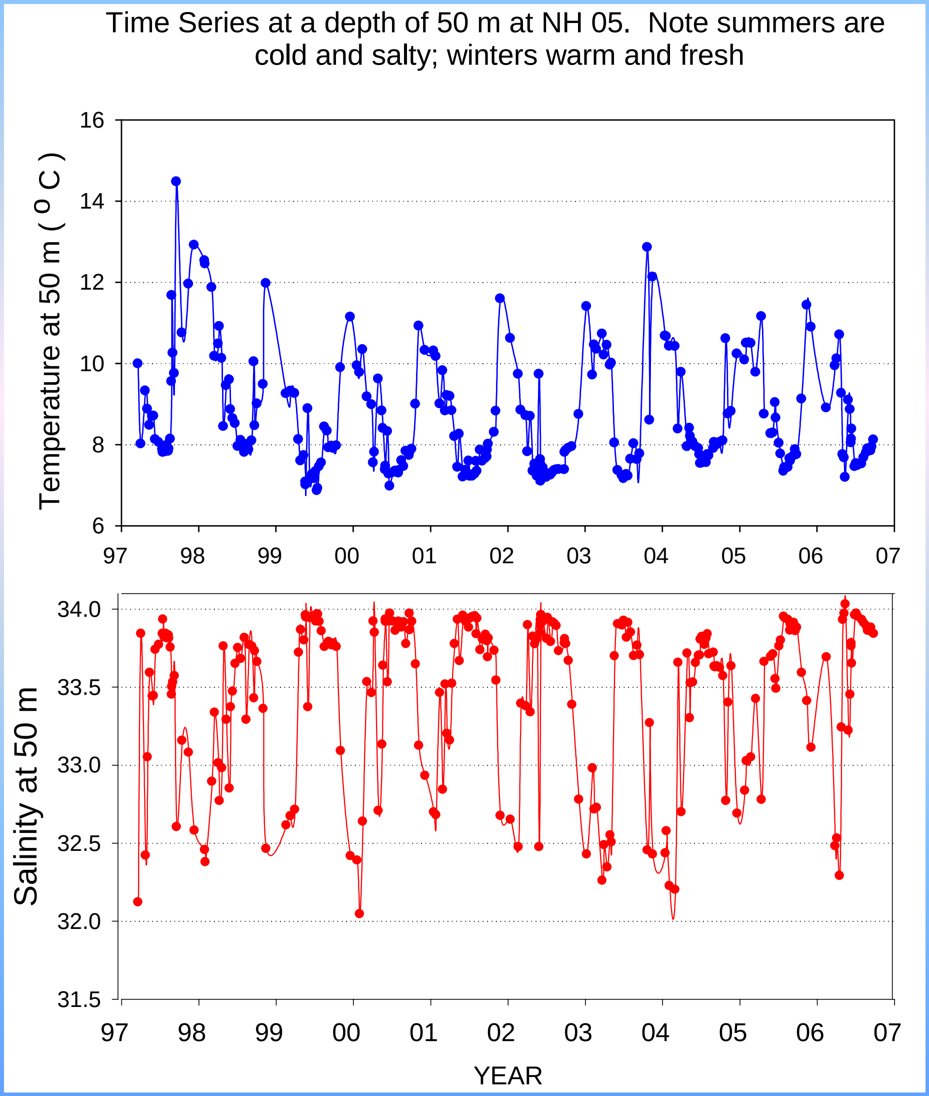
Pacific Decadal Oscillation



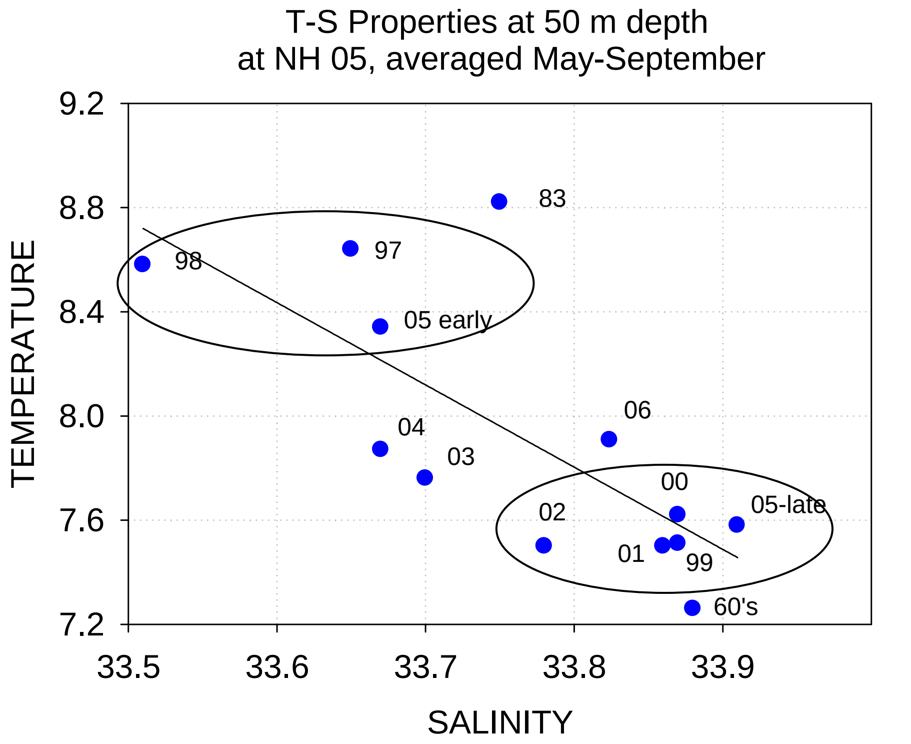


- Scattergrams show a relationship between PDO and survival of coho and Chinook but very little of the variance is explained

T-S properties of deep water on shelf during upwelling season

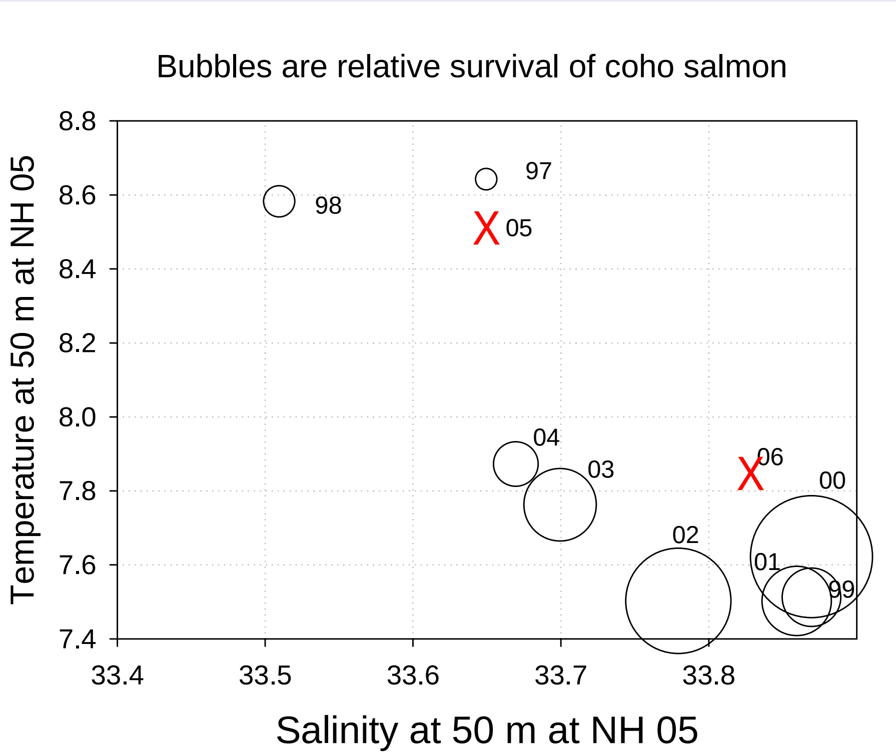


- Warm and fresh in winter (Davidson Current, runoff)
- Cold and salty in summer (upwelling)
- Trends in T and S seen in the time series (cool 1999-2002 when PDO was negative, warm in other years when PDO was positive).



Average temperature (T) and salinity (S) at a mid-shelf station during the summer upwelling season showing different water types: cold and salty vs. warm and fresh.

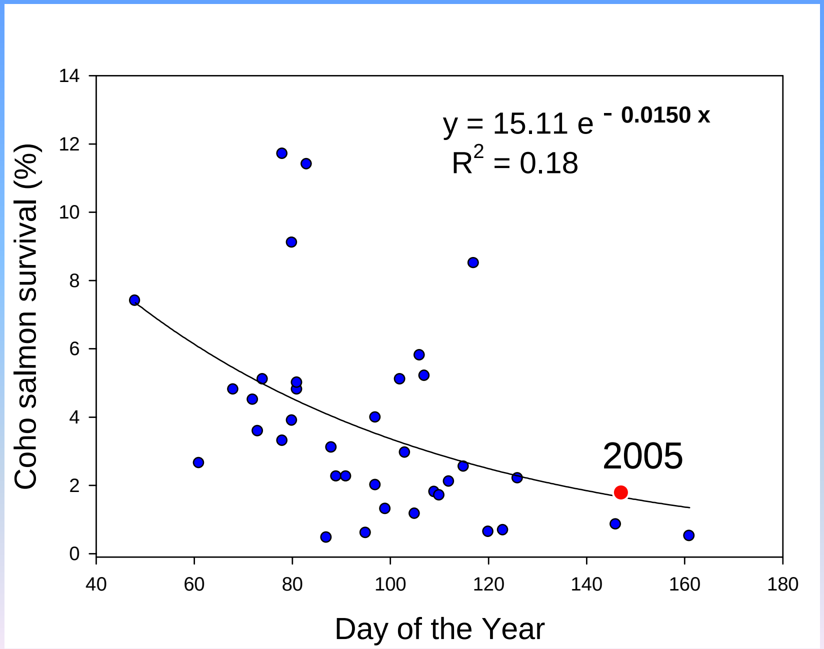
Related to PDO: negative PDO associated with upwelling of colder waters. Positive PDO associated with onshore transport of warmer waters. NOTE: 2005 similar to El Niño event of 1997-98

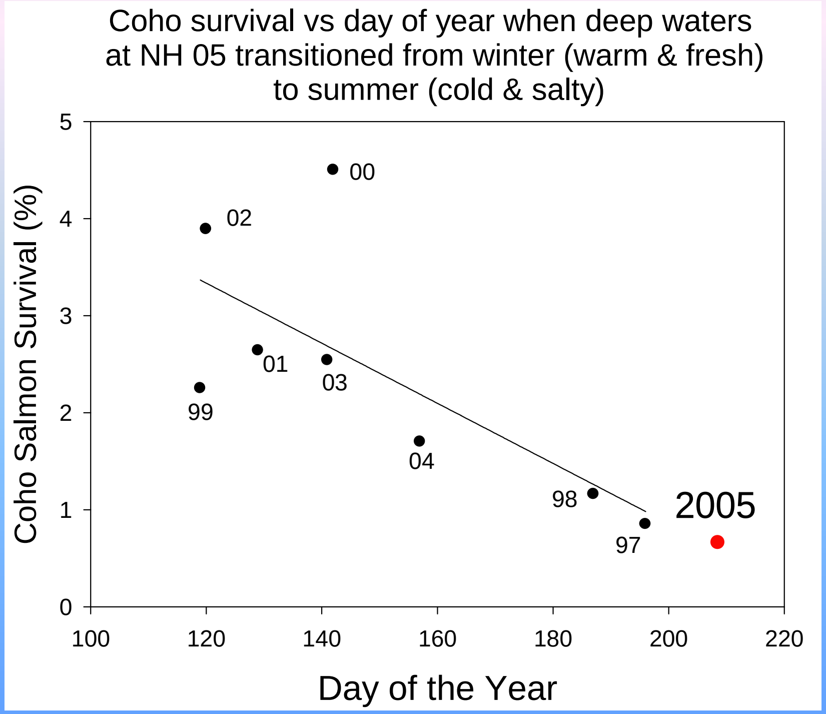


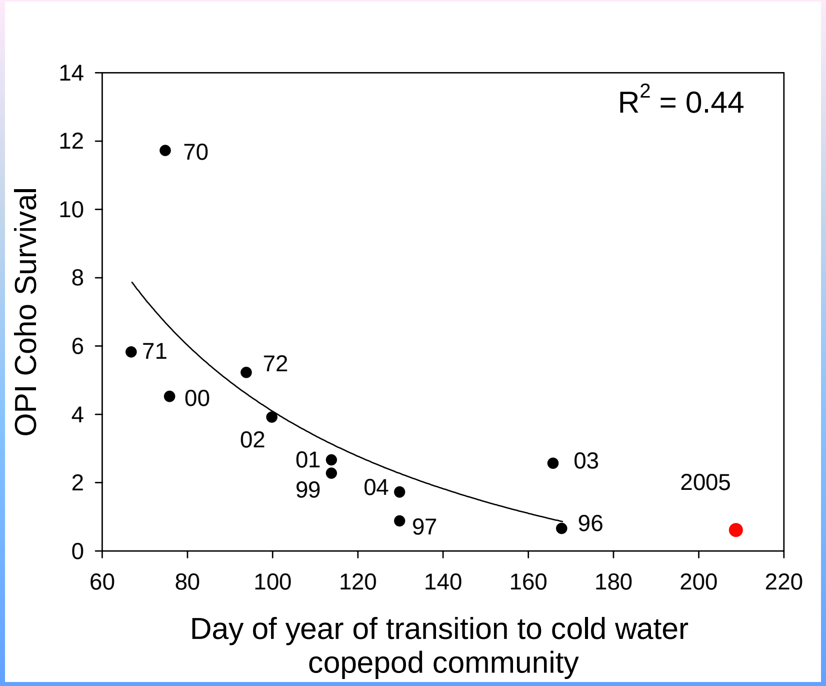
Spring Transition

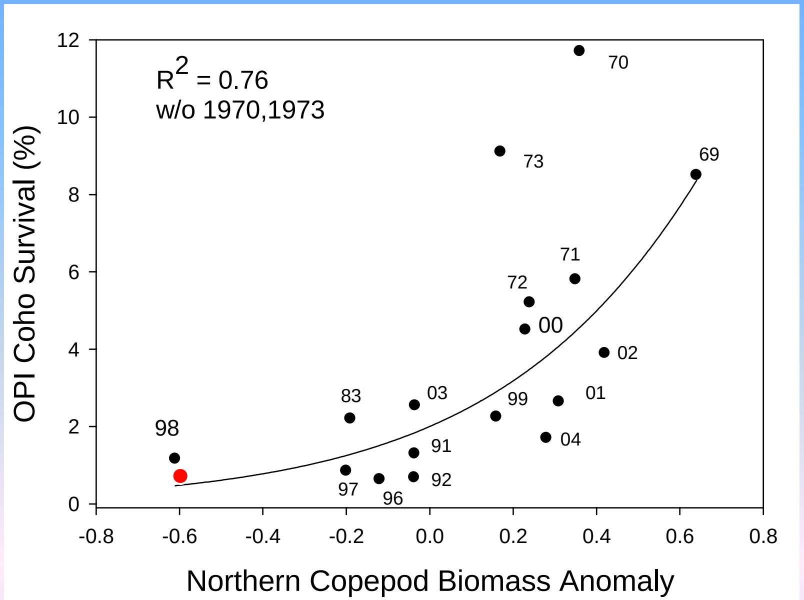
- Upper chart is date based on change in sea level (from Logerwell et al.)

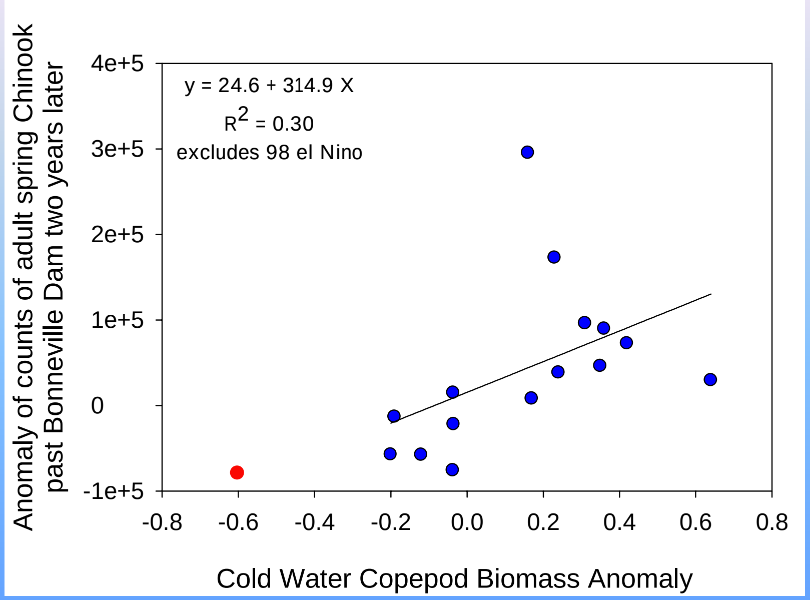
When we look at the date when the copepods transitioned to a summer community, a somewhat different result is seen











Coho (upper panel) and Spring Chinook Salmon (lower) returns correlated with a “food chain” indicator: cold water copepod species biomass anomalies

The copepod indicators suggests lower returns of coho this fall and lower returns of Chinook in 2007 than do the physical indicators.

Comparisons in copepod size and chemical composition

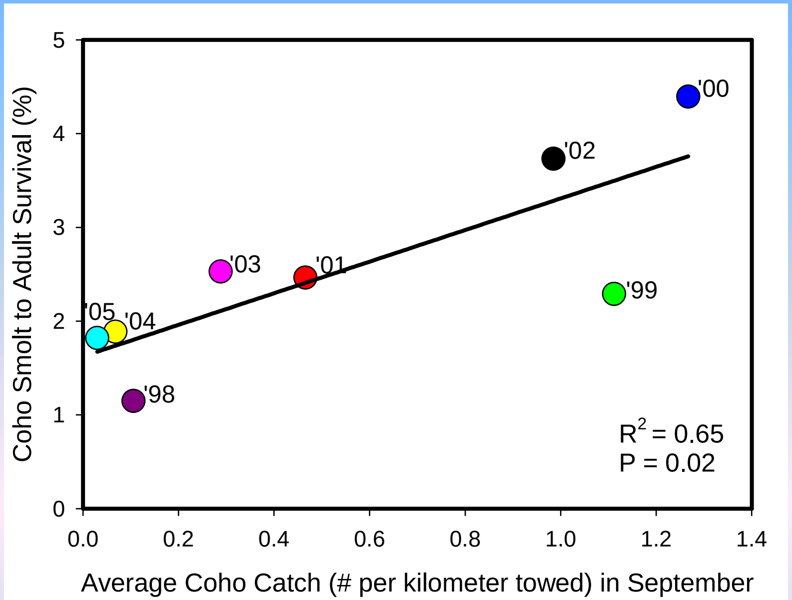
- **Warm water taxa are associated with positive PDO-** taxa are from offshore OR, are **small** in size and have limited high energy wax ester lipid depots

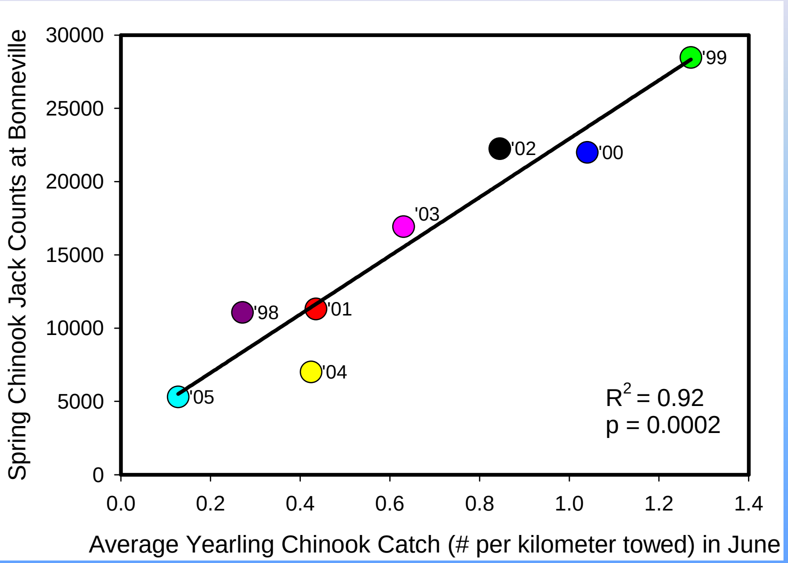
- **Cold water taxa are associated negative PDO-** taxa are boreal coastal GOA species, are **large** in size and store **wax esters** as an over-wintering strategy

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

Might differences in species composition of lower trophic level organisms be the mechanism that links PDO changes with salmon production?

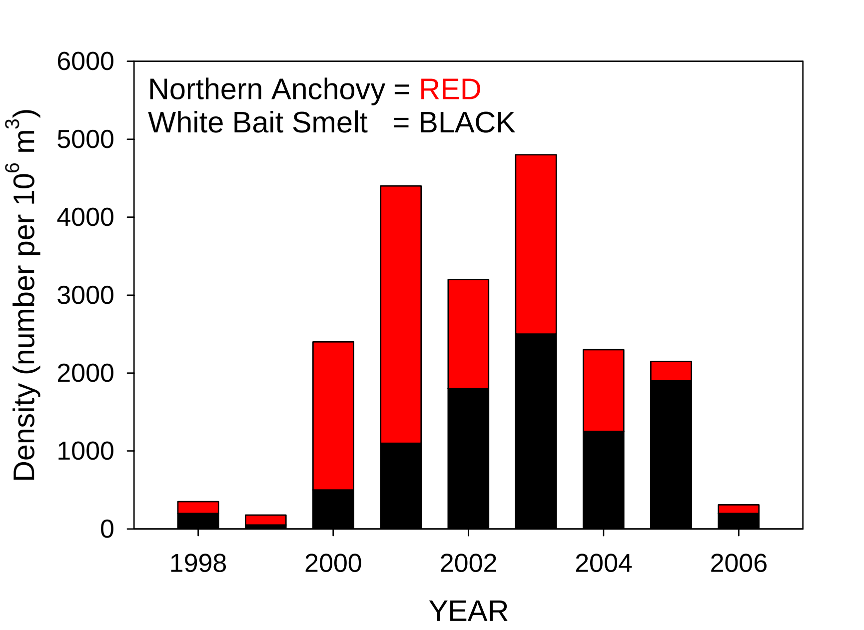
Catches of juvenile salmon on mesoscale surveys



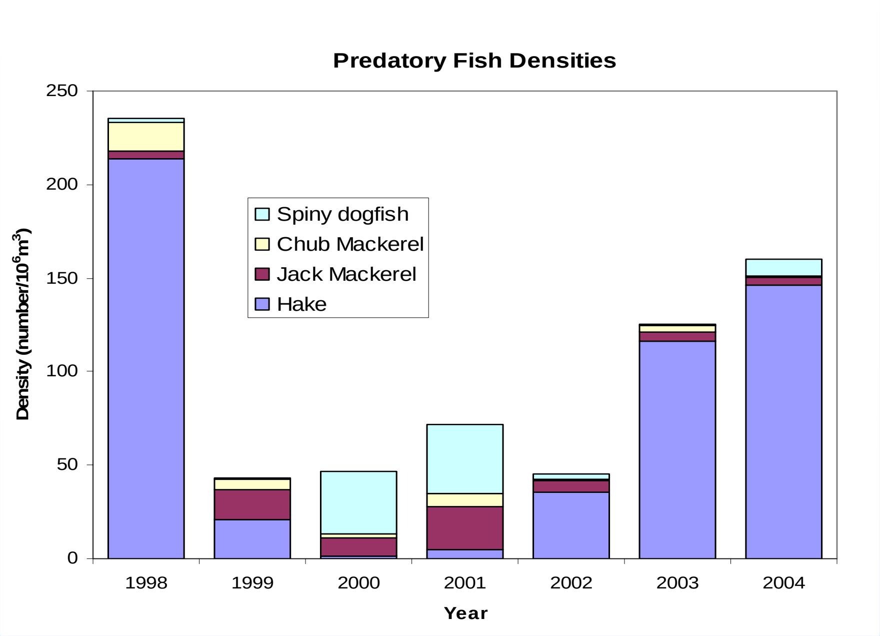


- Coho catches in September a good predictor of returns one year later
- Spring chinook catches in June a good predictor of returns of jack salmon one year later

Forage Fish and Predatory Fish



Anchovies, smelt and hake all track changes in ocean conditions but with variable lags



Anchovies and smelt provide juvenile fish in salmon diets; hake may be a key predator on juvenile salmonids

Product: Early assessment of salmon returns 1 or 2 years from now

We produce an assessment based on **physical ocean indicators by June** of each year (related to date of spring transition and water types present when salmon first enter the sea)

We produce an assessment of overall ocean conditions based on **physical and biological ocean indicators by October** of each year (based on copepod community structure, copepod biodiversity, juvenile salmonid catches on surveys, forage fish numbers and predator numbers

http://www.nwfsc.noaa.gov/research/divisions/fed/climatechange.cfm

	Juvenile migration year				Forecast of adult returns	
	2000	2004	2005	2006 (to June)	Coho 2006	Chinook 2007
Large-scale ocean and atmospheric indicators						
PDO	green ■	red ■	red ■	yellow ■	red ●	red ●
MEI	green ■	red ■	red ■	yellow ■	red ●	red ●
Local and regional physical indicators						
Sea surface temperature	green ■	red ■	red ■	green ■	red ●	red ●
Coastal upwelling	green ■	red ■	red ■	green ■	red ●	red ●
Physical spring transition	green ■	red ■	red ■	green ■	red ●	red ●
Deep water temp. & salinity	green ■	red ■	red ■	green ■		
Local biological indicators						
Copepod biodiversity	green ■	red ■	red ■	red ■	red ●	red ●
Northern copepod anomalies	green ■	green ■	red ■	green ■	red ●	red ●
Biological spring transition	green ■	red ■	red ■	yellow ■	red ●	red ●
Spring Chinook--June	green ■	yellow ■	red ■	yellow ■	red ●	red ●
Coho--September	green ■	yellow ■	red ■	red ■	red ●	red ●

Key

- green ■ good conditions for salmon marine survival
- yellow ■ intermediate conditions for salmon marine survival
- red ■ poor conditions for salmon marine survival
- green ● good returns expected
- red ● poor returns expected

A chain of events

	Negative	Positive
Changes in basin-scale winds lead to sign changes in PDO	Negative	Positive
SST changes as do water types off Oregon	Negative Cold/salty	Positive Warm/fresh
Spring transition	Early	Late
Upwelling season	Long	Short
Zooplankton production	Cold species	Warm species
Forage Fish	Many	Few
Juvenile salmonids	Many	Few
Predatory fish (hake)	Few	Many

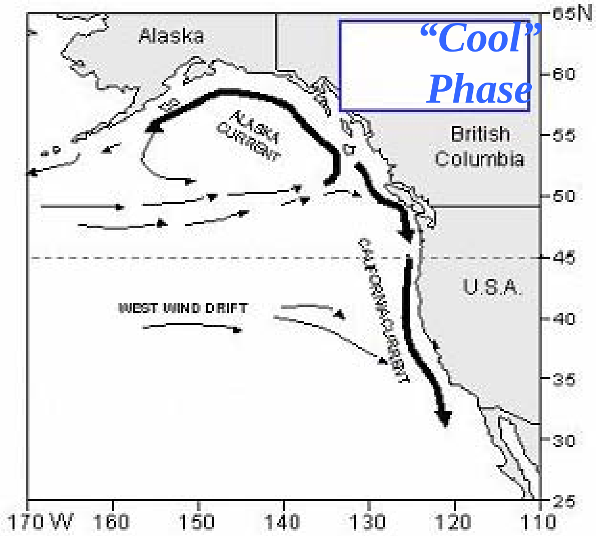
But time lags complicate interpretations!

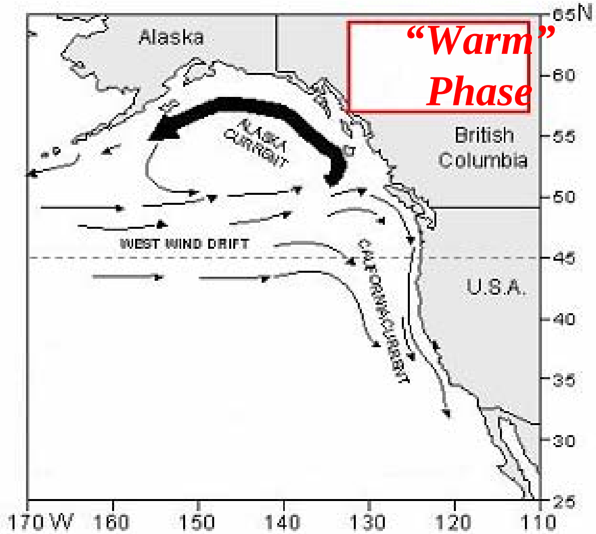
Peterson talk on Friday

A working mechanistic hypothesis: source waters. . .

⇑ Transport of boreal coastal copepods into NCC from Gulf of Alaska

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





Future Efforts:

- Multivariate analyses (WAINWRIGHT)
- NPZ (NEMURO MODELING)
- Ecosystem Modeling (Ruzicka & Wainwright)
- Phytoplankton biomass
- Euphausiid egg and adult biomass
- Euphausiid recruitment rates
- Secondary production (copepod egg production)
- Salmon Growth
- Columbia River flow rates and structure of the Plume
- Interannual variation in habitat area
- Biophysical model development
- Predators (hake and seabirds)

Thank you for your attention

Acknowledgements

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- Endangered Species Act - NOAA Fisheries
- Fisheries Management – NOAA Fisheries
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