Forecasting returns of coho and Chinook salmon to rivers in the n. California Current: A role for high-frequency long term observations

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See www.nwfsc.noaa.gov, "Ocean Index Tools"

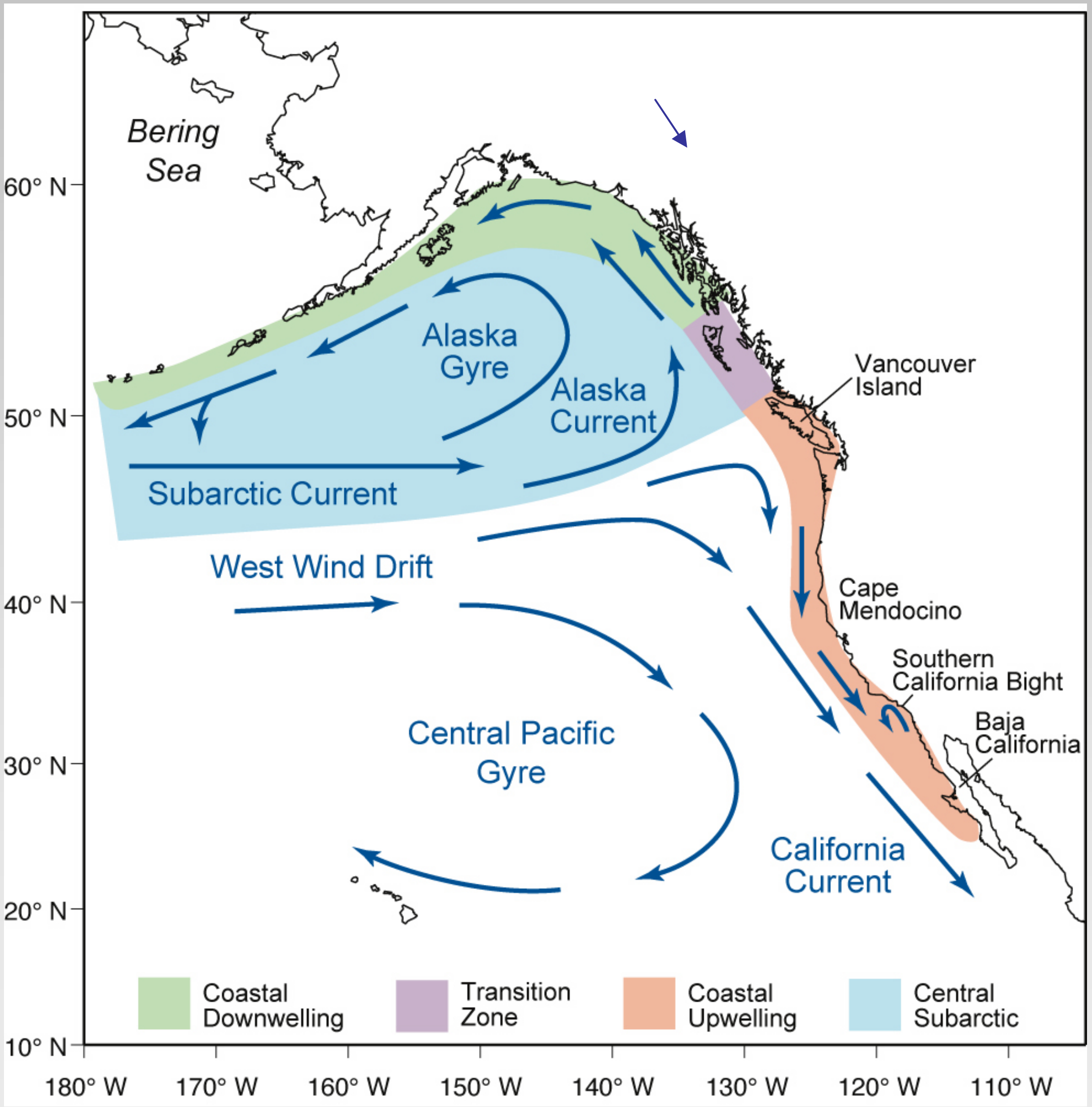
- Successful weather forecasting is based on a basic understanding of the underlying physics and physical mechanisms that determine the weather.

- Similarly, forecasting of ecological phenomena in ocean will require a basic understanding of the physical and ecological mechanisms that determine the outcomes which one hopes to predict.

- Successful prediction of fishery yields will require a modicum of knowledge of where the given species/population lives in the ocean, and of processes that determine the key recruitment bottlenecks.

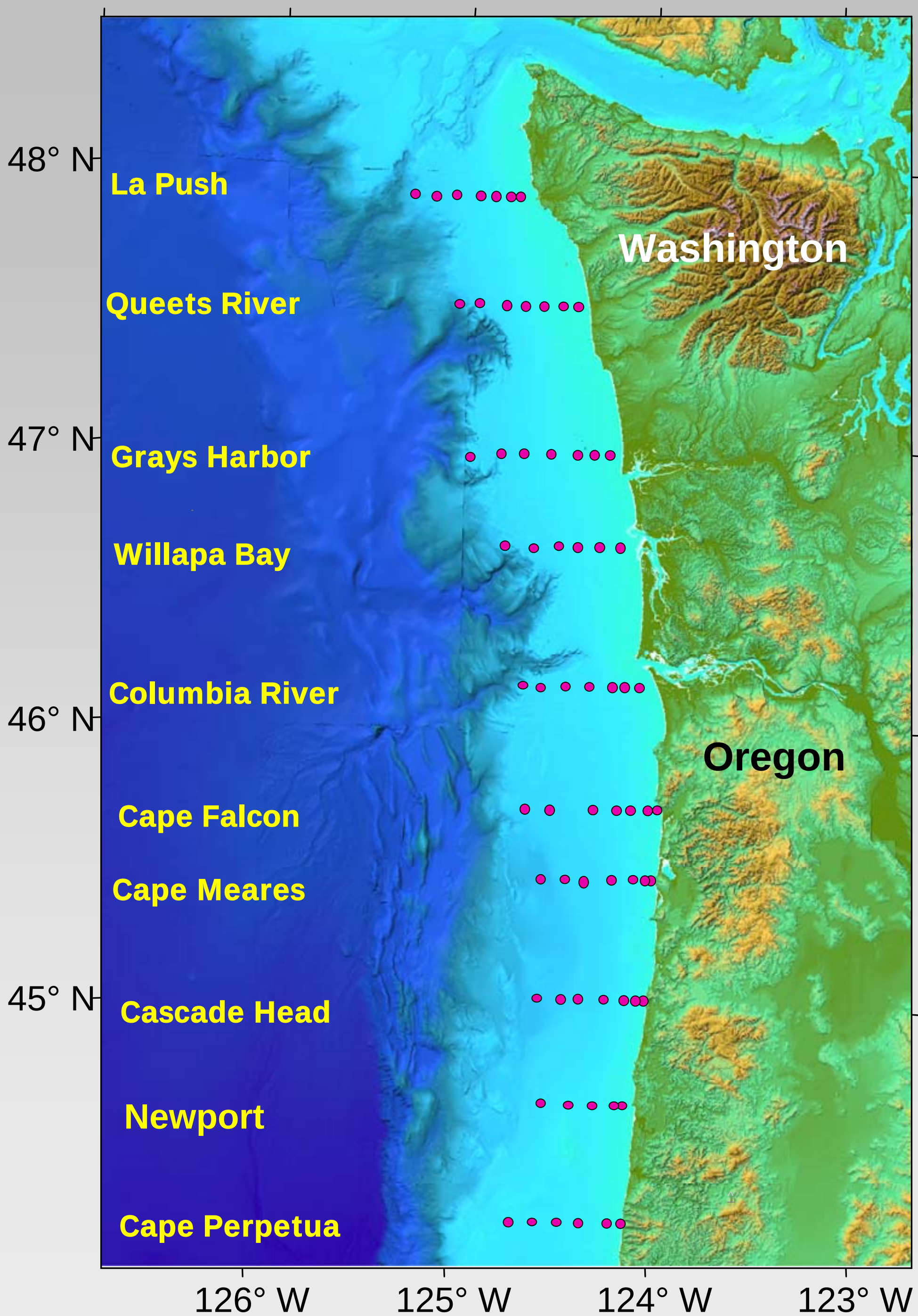
- Through long-term observations of several trophic levels, we have now begun to attempt forecasts of salmon abundances based on analysis of basin-scale and local scale forcing and ecosystem response.

Circulation in the Northeast Pacific



- Shelf circulation is wind-driven and is southward during the spring-summer upwelling season and northward during fall-winter.
- Transition in spring = spring transition

Observations



- Newport Line biweekly sampling since 1996 (13 years)
- Juvenile salmon sampling in June and September since 1998 (11 years)
- Historical data:
  - hydrography, 1960s;
  - plankton, 1969-1973; 1983, 1990-1992
  - juvenile salmon, 1981-1985

Hydrography and Zooplankton Studies

- Biweekly sampling with CTD profiles (C, T, fluroesence, oxygen), surface chlorophyll and nutrients, ½ m diameter 200 μm mesh towed vertically from 100 m to the sea surface or from just above to sea floor to the sea surface when in shallow waters for copepods and other zooplankton, and 60 or 70 cm diameter 333 μm bongos at night for euphausiids

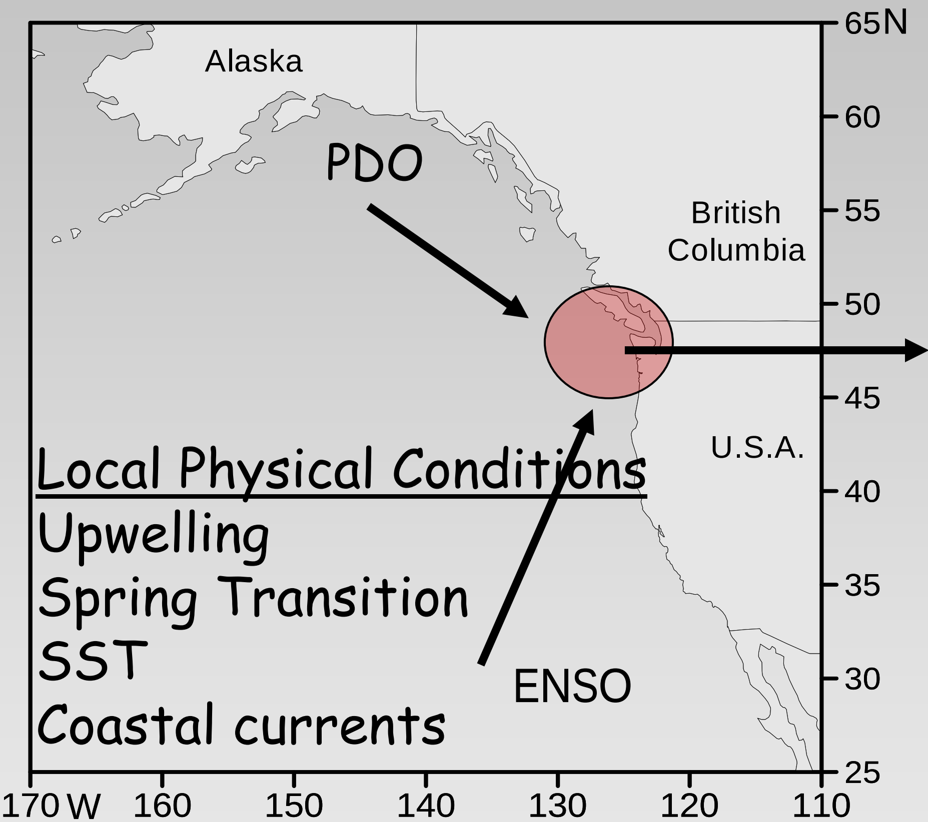
- Interannual variations in biomass, abundance, species composition, species richness and biodiversity, and community structure in relation to interannual variations in the PDO and length of the upwelling season

Juvenile Salmon Studies

- Distribution and abundance with a Nordic 264 rope trawl (20 m height x 30 m width x 100 m length)
- Habitat modeling (logistic regression; zero-inflated Poisson); interannual variations in habitat area
- Growth (IGF, scales, length-frequency)
- Gut contents and prey availability (krill and small fish)
- Predators (fish, birds)
- Genetics (stock origin)
- Coded Wire tags (stock origin; migration)
- Diseases
- Parasites

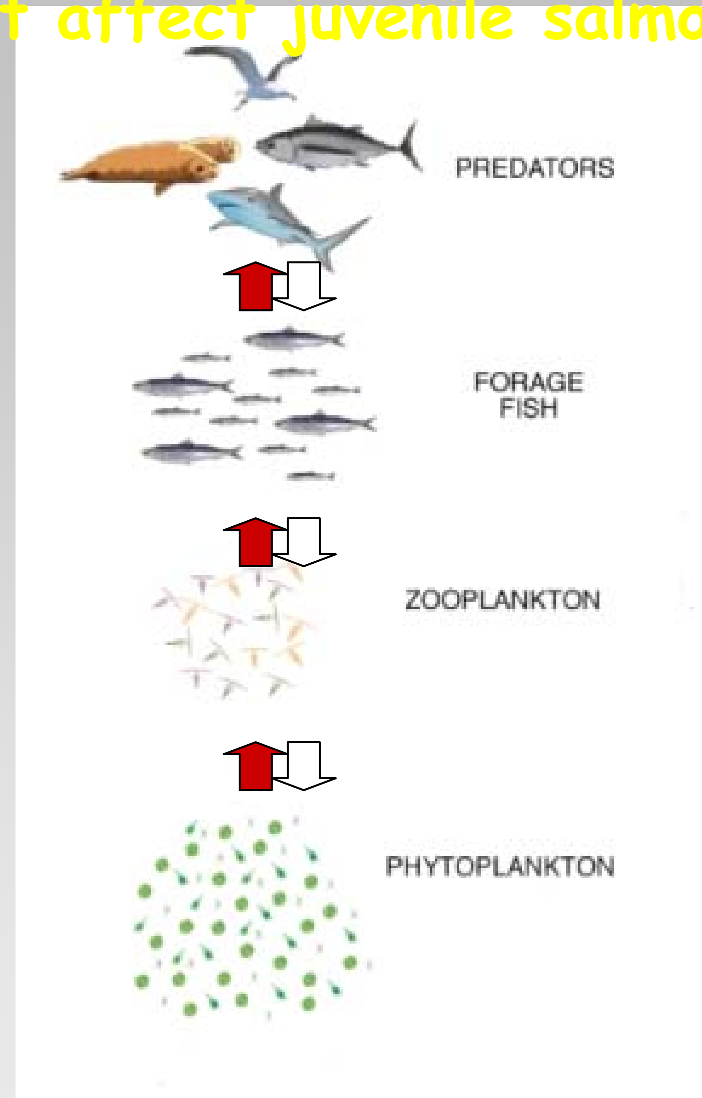
We are taking a holistic approach to development of indices and management advice by considering a suite of physical and biological factors that affect juvenile salmonids

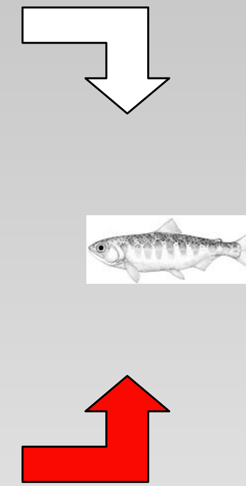
Large scale forces acting at the local scale can influence biological process important for salmon



Local Physical Conditions
Upwelling
Spring Transition
SST
Coastal currents

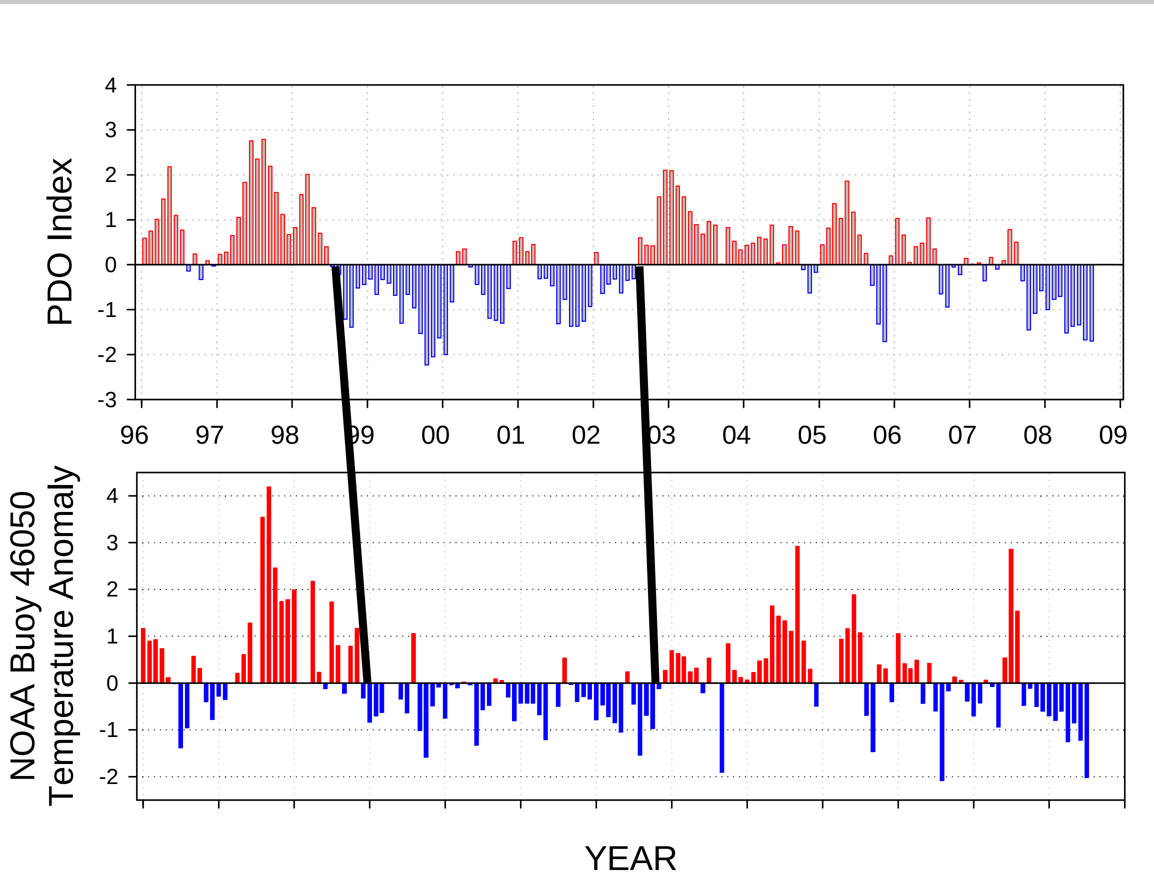
Approach
1. Develop time series
2. Relate to salmon through simple bivariate analyses





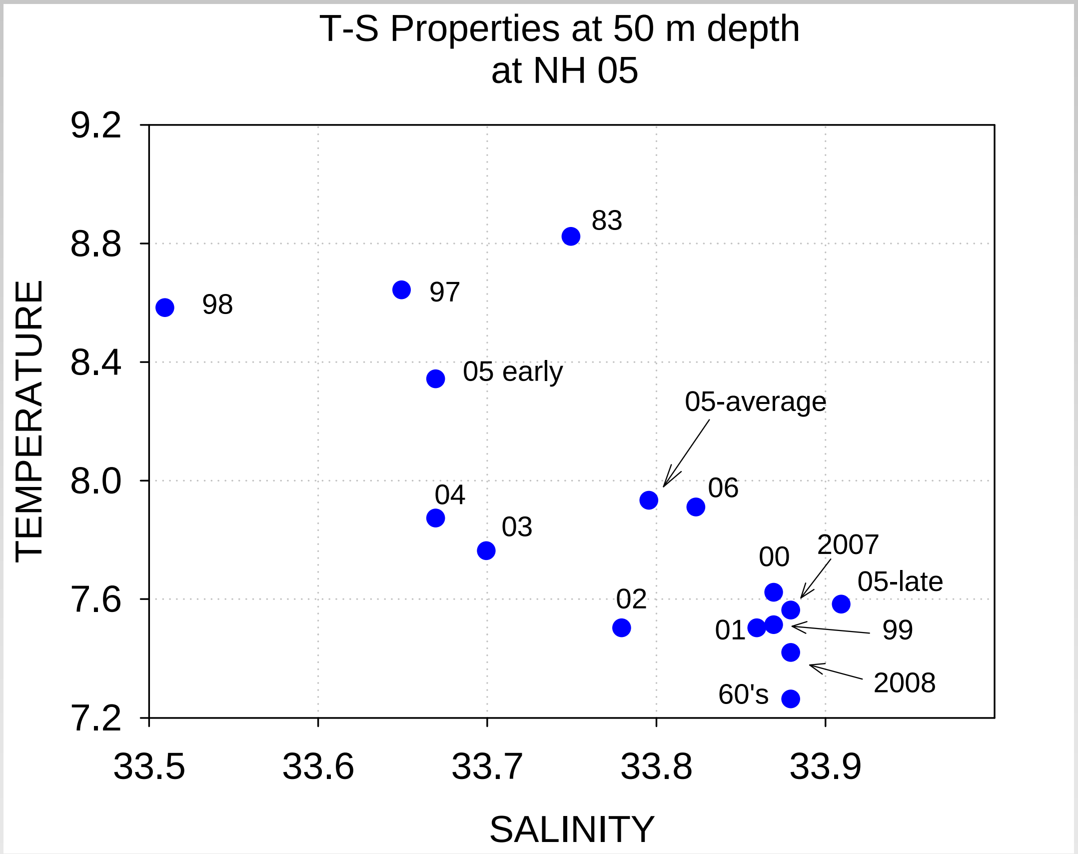
Local Biological Conditions

13 year time series of SST at Buoy 46050 off Newport shows that PDO downscales to local SST



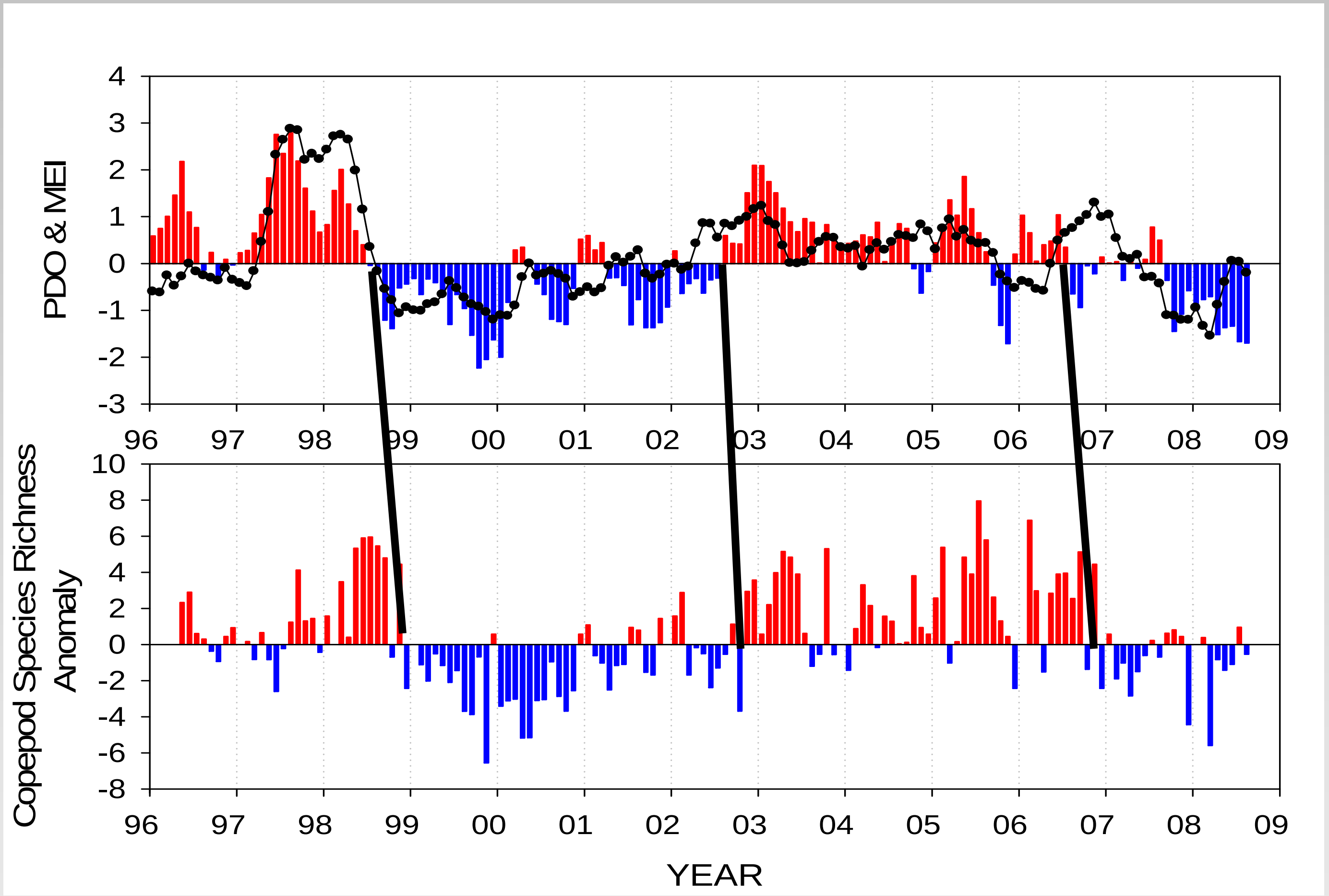
- PDO and SST correlated, as they should be.
- However there are time lags between PDO sign change and SST response of 3-5 months
- PDO began to change in 2007 (neutral state) then turned strongly negative in 2008

T-S Properties at 50 m depth; mid-shelf off Newport, averaged over May-Sept.



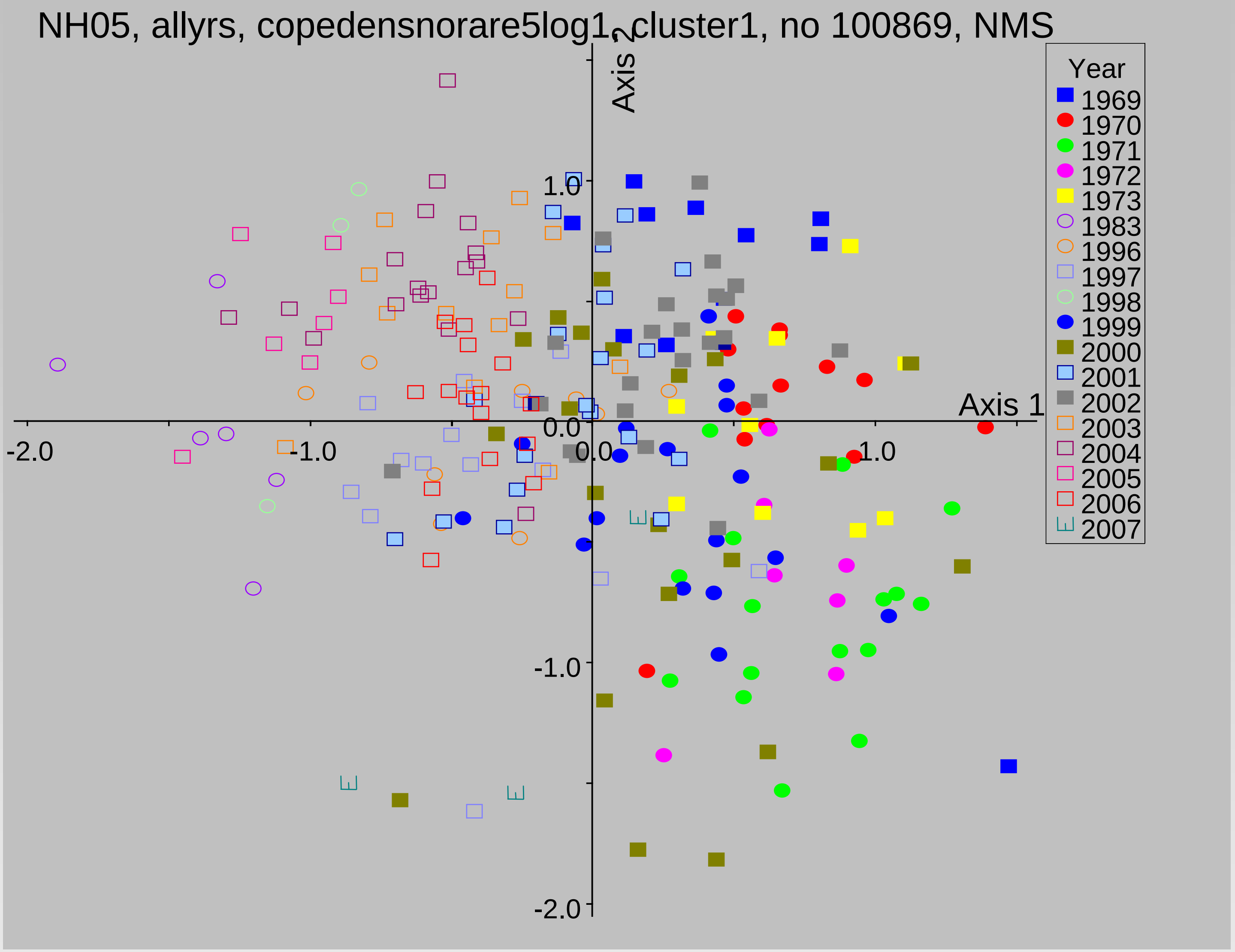
- Cold and salty during negative PDO (the 1960s, 1999-2002, 2007-)
- Warm and relatively fresh during El Niño events (1997-98) as well as early 2005 (May-July 2005)
- Average for 1960s ~ 0.25°C cooler
- 2008 the coldest summer since at least the mid-1980s

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



As with SST, there are time lags of a few months before "PDO phase shift" appears as a "copepod shift". Cold periods are characterized by "cold water" copepods and warm periods by "warm water" copepods

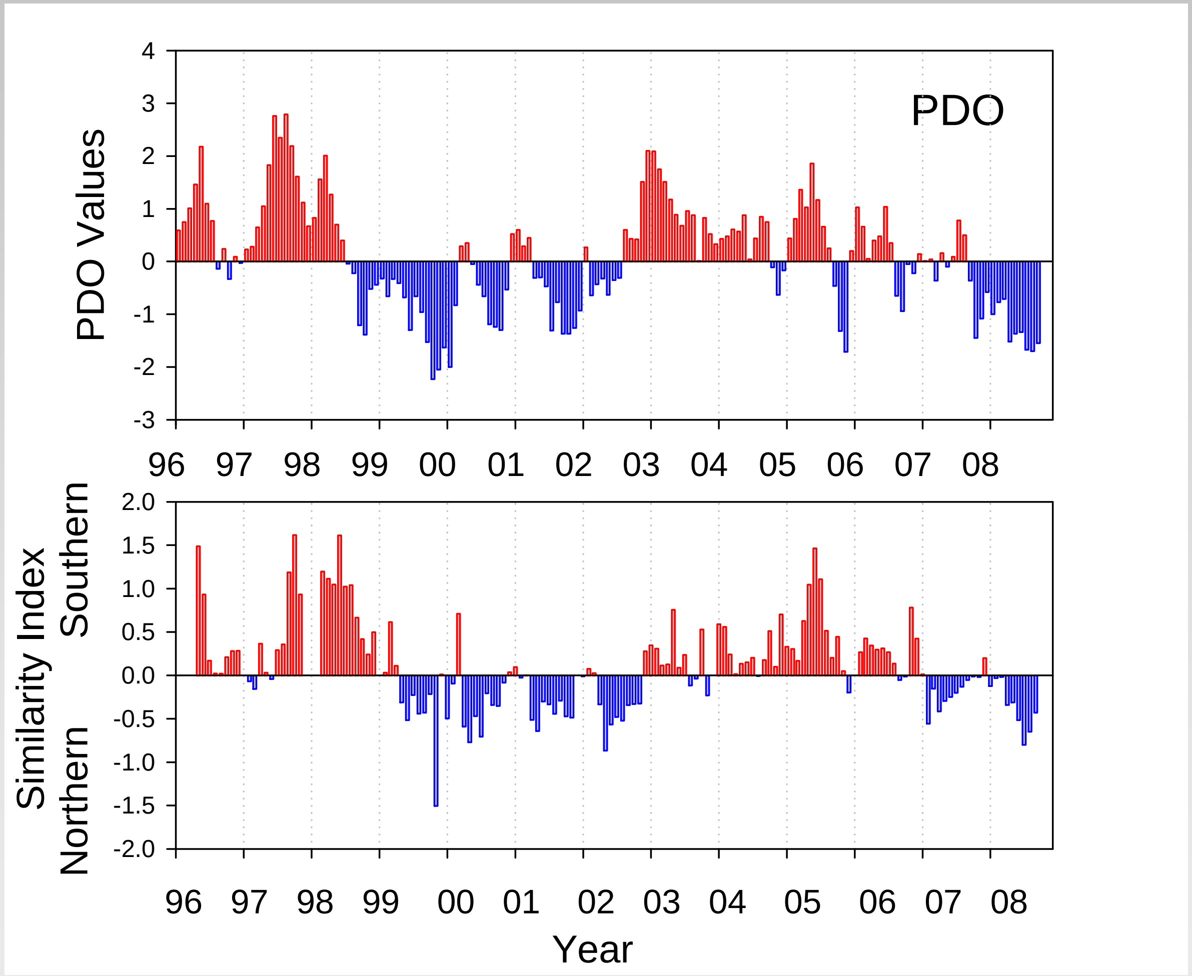
Ordination of 18 years of data (368 samples)



Open Symbols = warm ocean conditions

Closed Symbols = cold ocean conditions

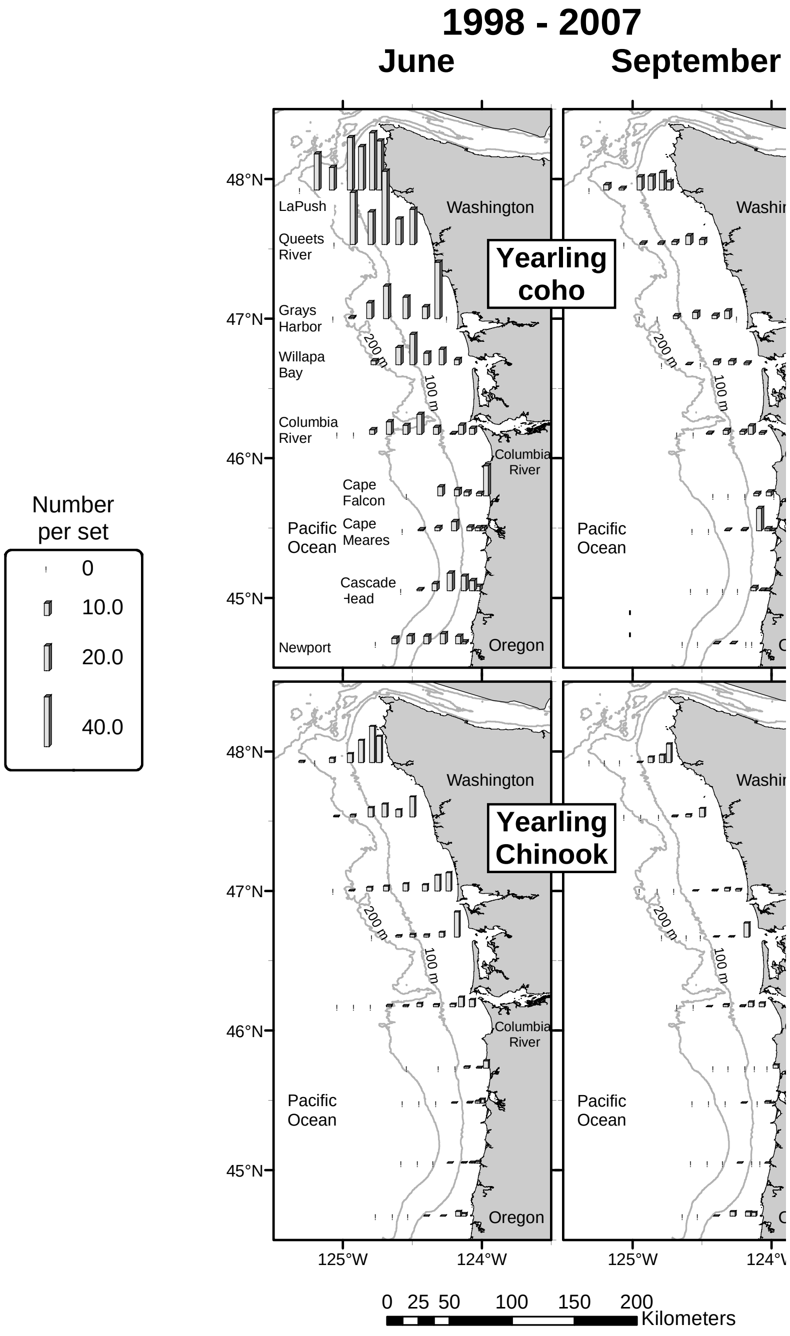
Ordinations: x-axis score vs. PDO



- Ordination of copepod community structure shows that ~ 75% of the variance is explained by the x-axis
- Positve values are "warm water community"
- Negative values are "cold water community"

Salmon Forecasting

- In order to forecast returns of various salmon life history types, we must first establish where they live in the ocean.

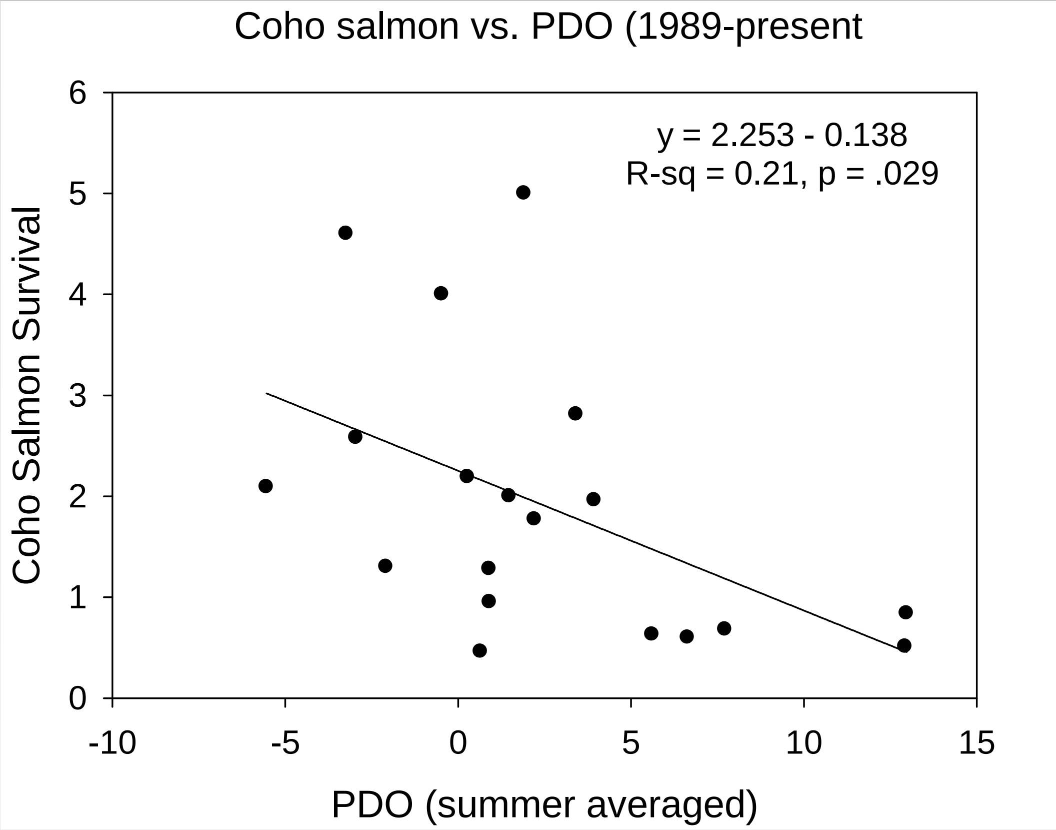


- Juvenile coho are most abundant off the Washington coast and have been collected at most stations in shelf waters; lesser numbers in September and nearer to shore
- Juvenile Chinook also more abundant off Washington but closer to shore than coho; lesser numbers in September and mostly very close to shore
- ➔ These are shelf species that are mostly likely influence by shelf processes

Forecasting –- since juvenile salmonids live in continental shelf waters, we use indices relevant to shelf waters

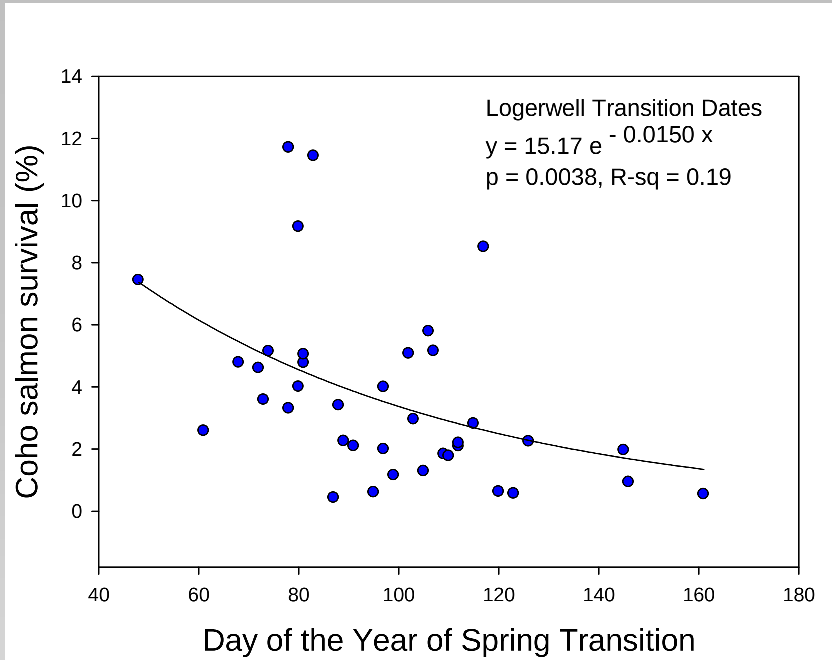
- Basin scale indicators
  - PDO
  - MEI
- Local indicators
  - SST
  - Upwelling
  - Date of spring transition
- Biological indicators
  - Copepod biodiversity
  - N. copepod biomass anomaly
  - Copepod Community Structure
  - Catches of spring Chinook in June
  - Catches of coho in September

Coho salmon vs PDO



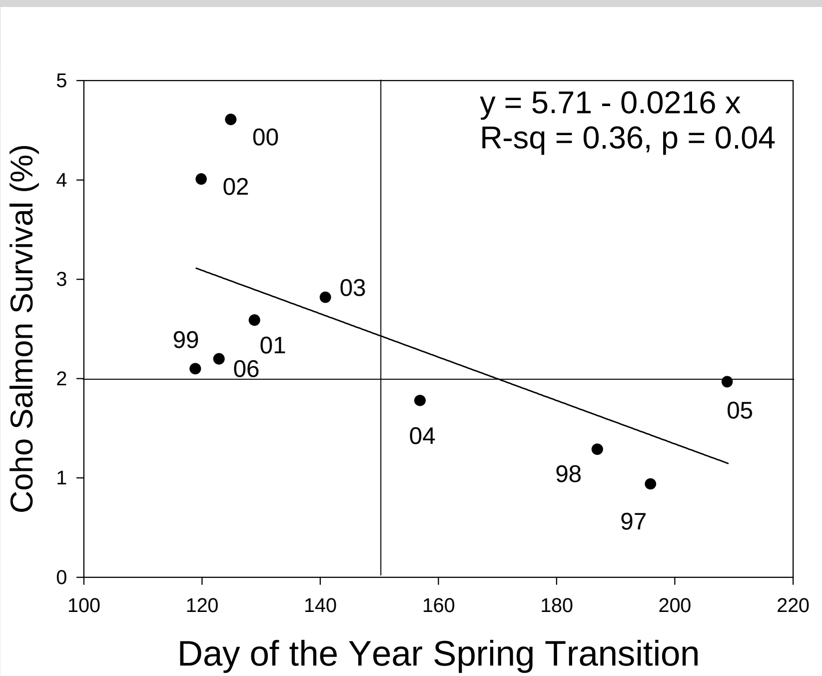
- 1989 to present

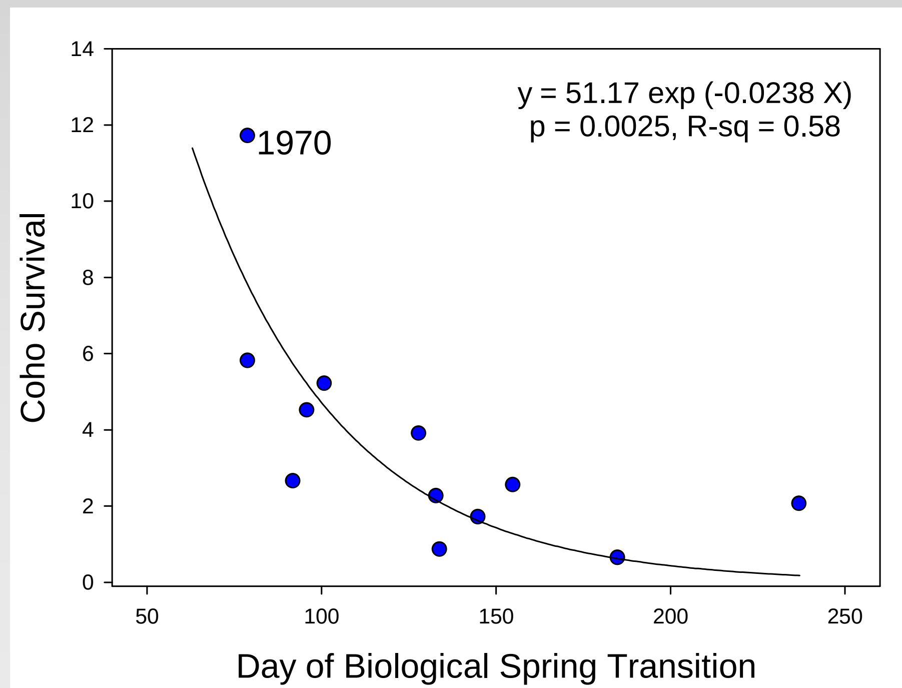
Spring Transition



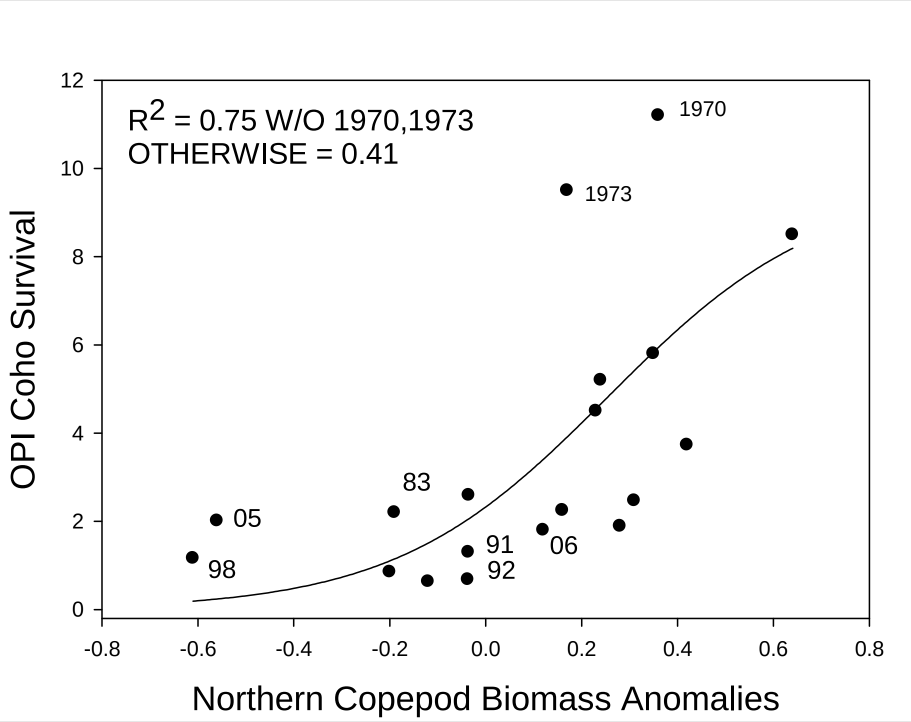
- Upper chart is date based on change in sea level and start of upwelling season (Bakun upwelling index – Bograd POC and Logerwell et al. 2003)

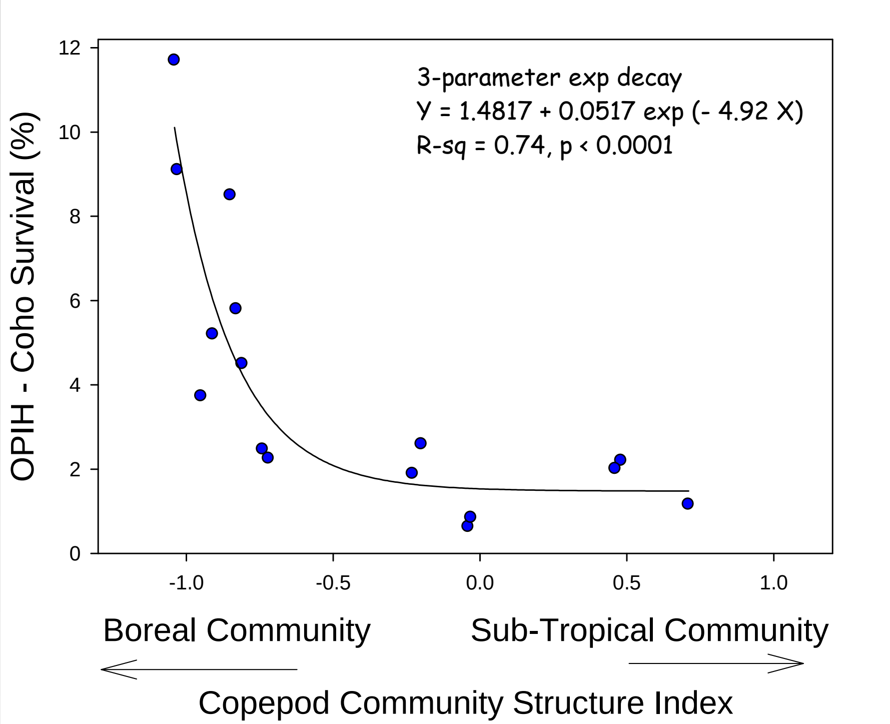
When we look at the date when the copepods transitioned to a summer community, a somewhat different result is seen



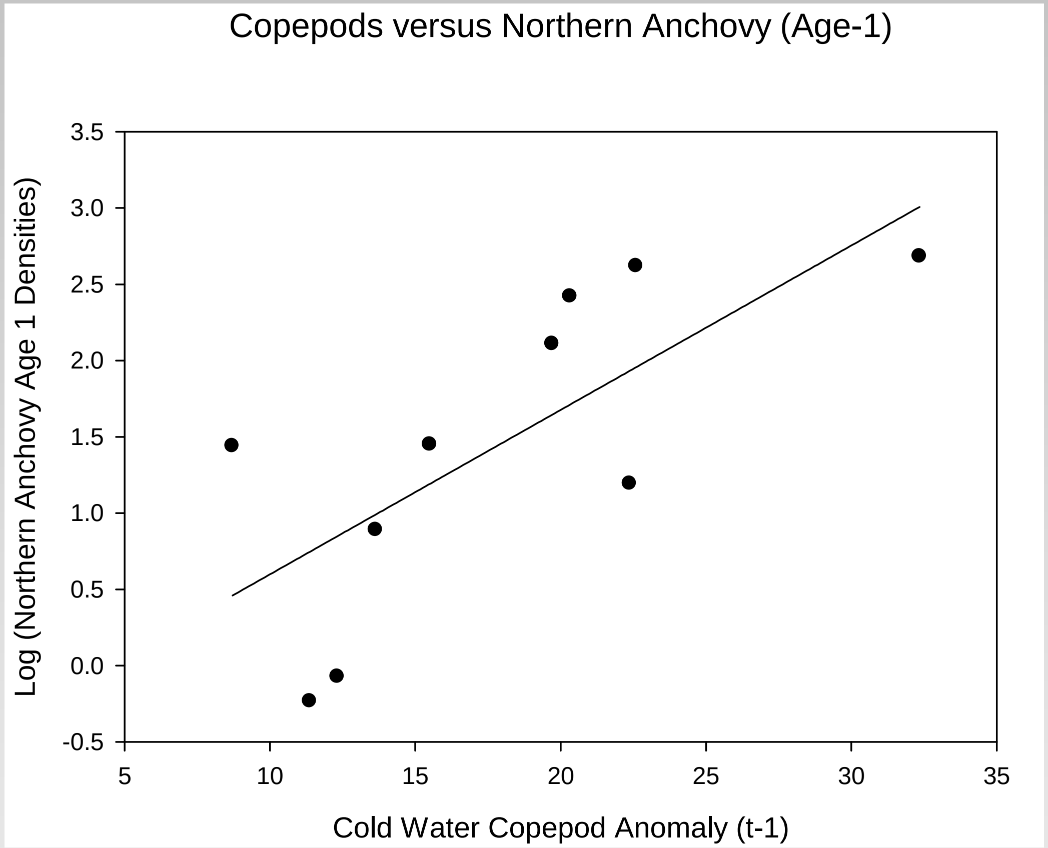


Copepod indices: integrative measures



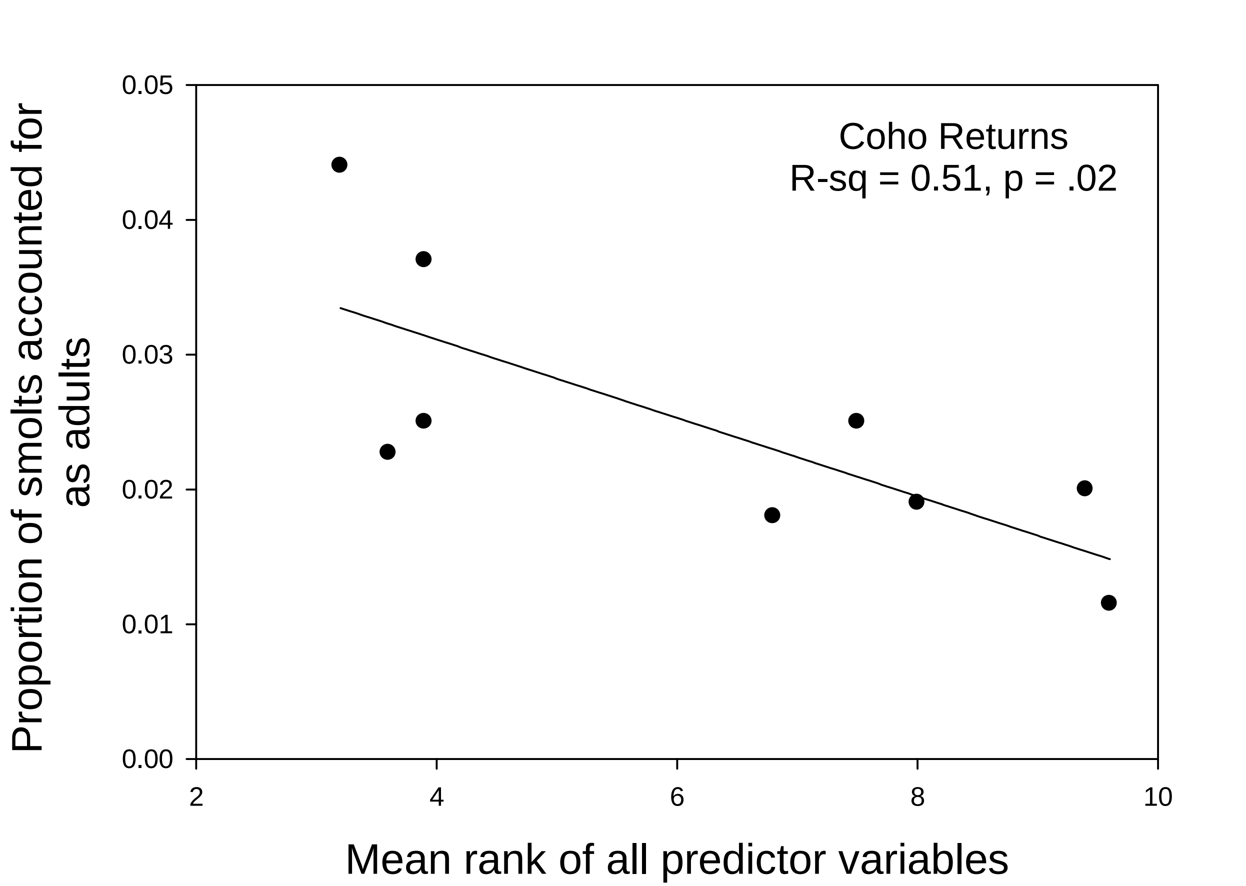


Copepods➔ Anchovies ➔ Salmon



- Anchovy data from pelagic trawl surveys carried out by Bob Emmett
- Age-1 Anchovy catches lag cold water copepod anomalies by one year.
- Anchovy abundance may be the direct food chain link between copepods and salmon

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
PDO (December-March)	10	4	1	7	3	11	6	9	8	5	2
PDO (May-September)	8	2	3	4	5	10	9	11	7	6	1
MEI Jan-June	11	2	3	5	7	9	6	10	4	8	1
SST at 46050 (May-Sept)	9	2	4	5	1	7	11	8	6	10	2
SST at NH 05 (May-Sept)	8	2	1	4	7	6	11	10	5	9	3
SST winter before going to sea	11	6	4	5	3	7	10	9	8	2	1
Physical Spring Trans (Logerwell)	9	5	2	1	4	7	6	10	7	3	***
Upwelling (Apr-May)	6	1	10	3	5	9	8	11	6	2	4
Deep Temperature	11	4	6	2	2	7	8	10	9	5	1
Deep Salinity	11	3	3	5	8	9	10	7	6	1	1
Length of upwelling season	10	2	4	2	1	7	8	9	6	5	***
Copepod richness	11	2	1	5	3	8	7	10	9	6	4
N.Copepod Anomaly	10	7	2	4	1	8	5	9	6	3	***
Biological Transition	11	6	3	2	5	9	7	10	8	4	1
Baitfish Abundance	9	10	4	1	3	2	5	6	8	7	***
June-Chinook Catches	10	2	3	8	5	7	9	11	6	4	1
Sept-Coho Catches	8	2	1	4	3	5	10	9	6	7	***
Coho Salmon Returns (ocn entry)	9	3	1	4	2	5	7	6	8		
Mean of Ranks	9.6	3.6	3.2	3.9	3.9	7.5	8.0	9.4	6.8	5.1	1.8
RANK of the mean rank	11	3	2	5	4	8	9	10	7	6	1


Coho Returns
R-sq = 0.51, p = .02
Proportion of smolts accounted for as adults
0.05
0.04
0.03
0.02
0.01
0.00
2
4
6
8
10
Mean rank of all predictor variables

<http://www.nwfsc.noaa.gov>

- All indices explained in plain English; updated annually.
- Every six months a 2-3 page written “outlook” is published to the web
- All tables and written updates are archived
- Invitational oral presentations made regularly to various policy and management groups: OWEB, ODFW Advisory Panel, Oregon State Police, Watershed Councils, PFMC: Salmon Technical Committee, Pacific States Marine Fisheries Commission, Bonneville Power Administration, Northwest Power and Conservation Council, Quinault Indian Nation,Tri-State Governors, NW Shellfish Growers Assoc, general public at Hatfield Marine Science Center, University seminars, local Community College, and local grade schools.

Thoughts on mechanisms…

Comparisons in size and chemical composition

- **Warm-water taxa and warm water communities-** (from offshore OR) are **small** in size and have limited high energy wax ester lipid depots

- **Cold-water taxa and cold water communities–** (boreal coastal species) are **large** and store **wax esters** as an over-wintering strategy

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

A chain of events (in a perfect year)

	Negative	Positive
Changes in basin-scale winds lead to sign changes in PDO		
SST changes as do water types off Oregon	Cold/salty	Warm/fresh
Spring transition	Early	Late
Upwelling season	Long	Short
Zooplankton species	Cold species	Warm species
Food Chain	Lipid-rich	Lipid-deplete
Forage Fish	Many	Few
Juvenile salmonids	Many	Few

But time lags complicate interpretations!

A working mechanistic hypothesis: source waters. . .

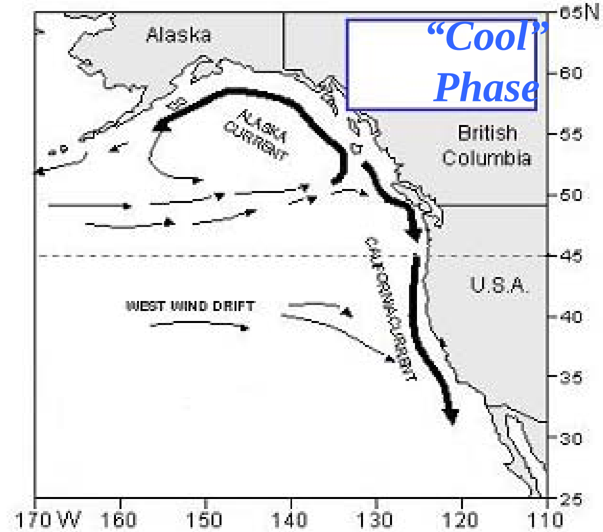
Cool Phase →

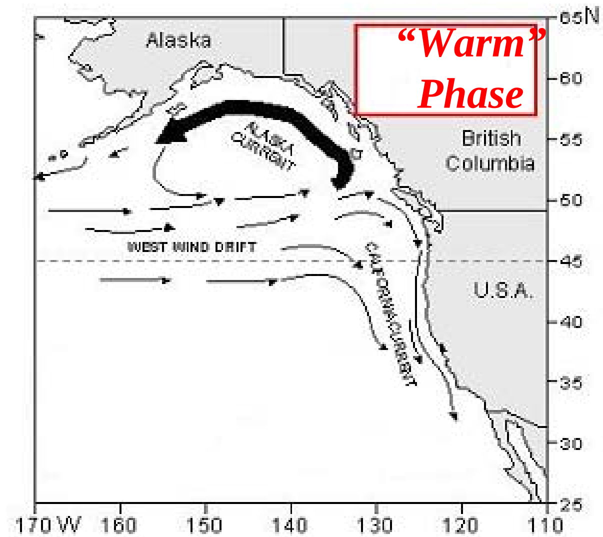
Transport of boreal coastal copepods into NCC from Gulf of Alaska

Boundary of west wind drift can move north or south as well.

Warm Phase →

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





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- National Science Foundation
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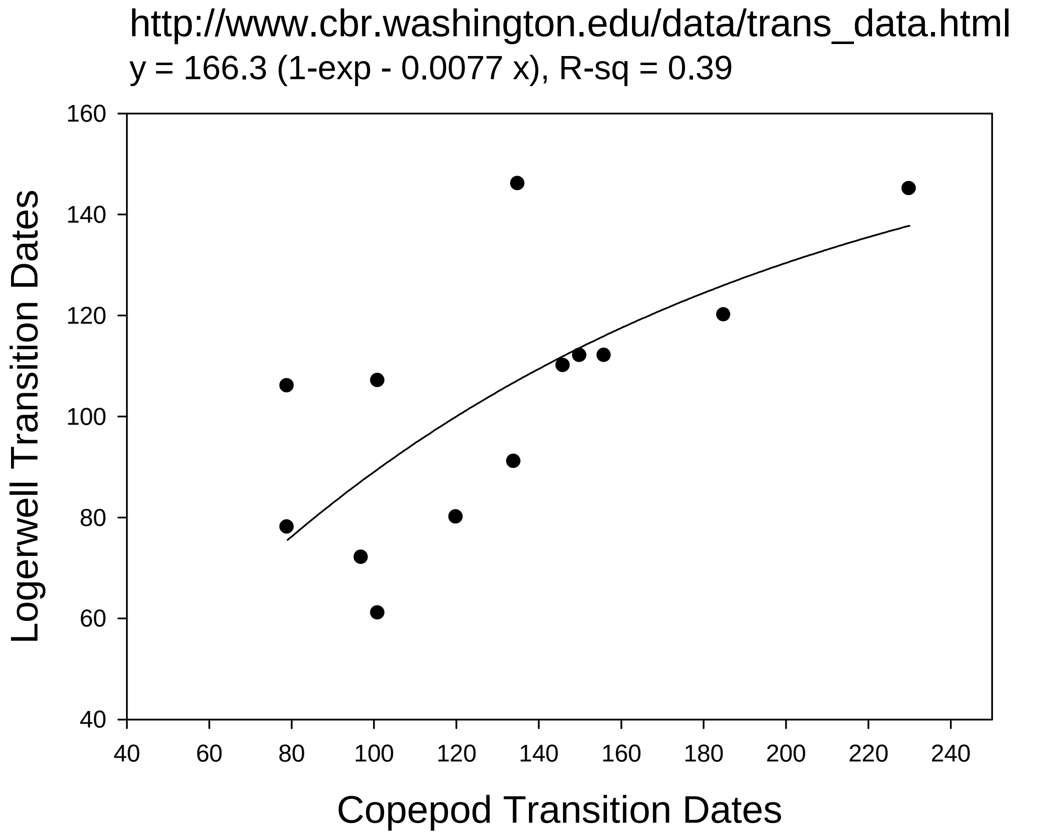
- NASA

- See www.nwfsc.noaa.gov, "Ocean Index Tools"

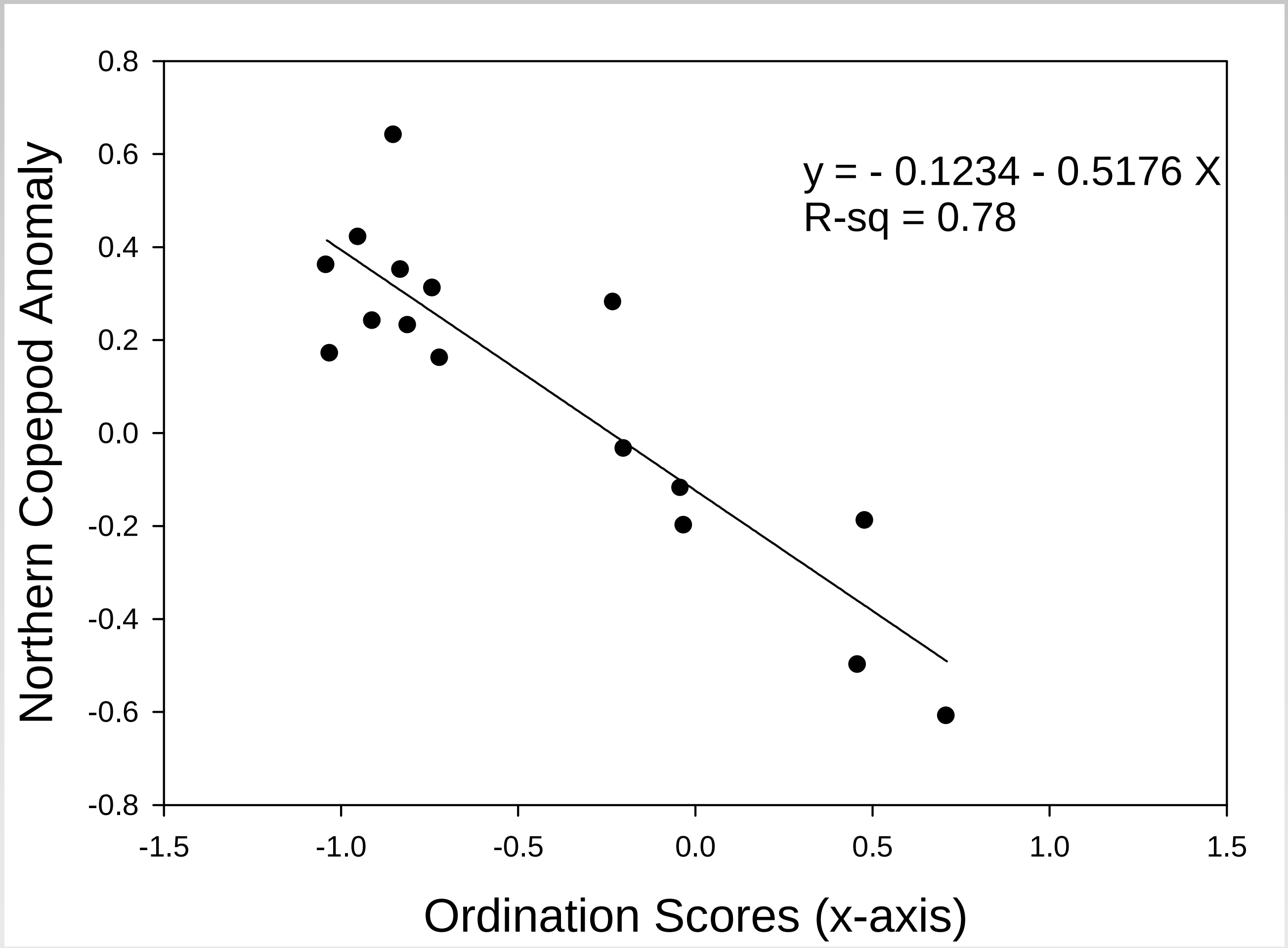
Logerwell vs Peterson Transition Dates



	Peterson	Logerwell
1996	185	120
1997	135	146
1998	---	105
1999	134	91
2000	97	72
2001	101	61
2002	120	80
2003	156	112
2004	146	110
2005	230	145
2006	150	112
2007	81	
1970	79	78
1971	79	106
1972	101	107

Mean = 128 (Copepods) v 103 (Sea Level)

Northern Copepods and Ordination Scores highly correlated



Catches of juv. salmon vs. number of returning spring Chinook jacks and OPIH coho one year later