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

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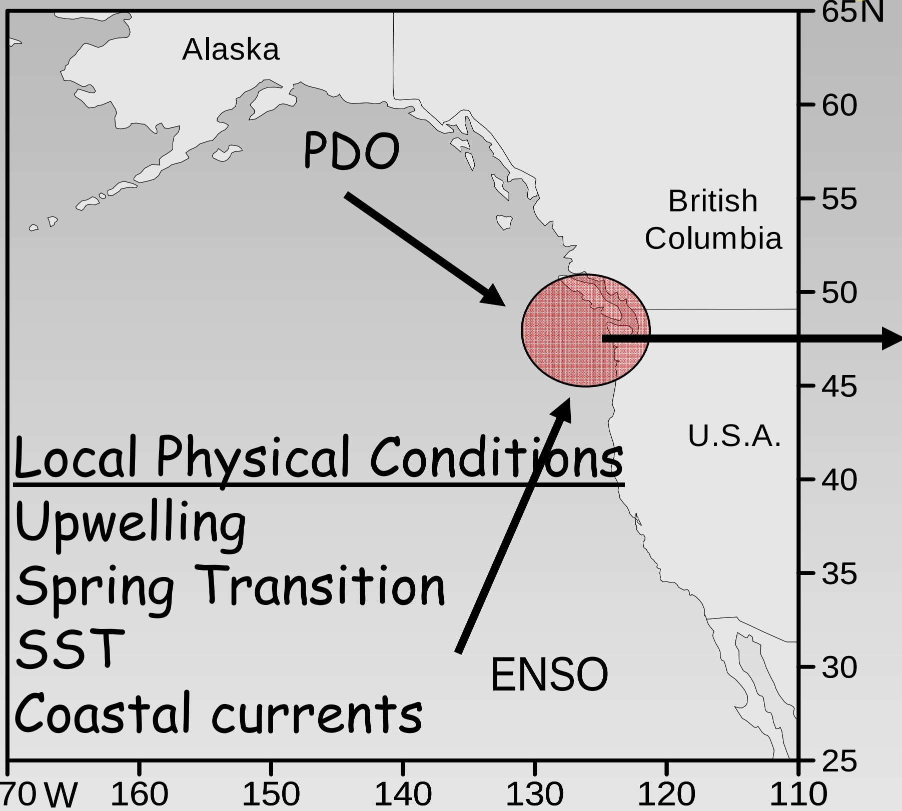
See www.nwfsc.noaa.gov, “Ocean Index Tools”

- 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.
- 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.

We are contributing to salmon management by studying the ocean phase of their life history and by developing management advice based on a suite of physical, biological and ecological indicators

Today I will speak about changes in the food chain upon which salmon depend

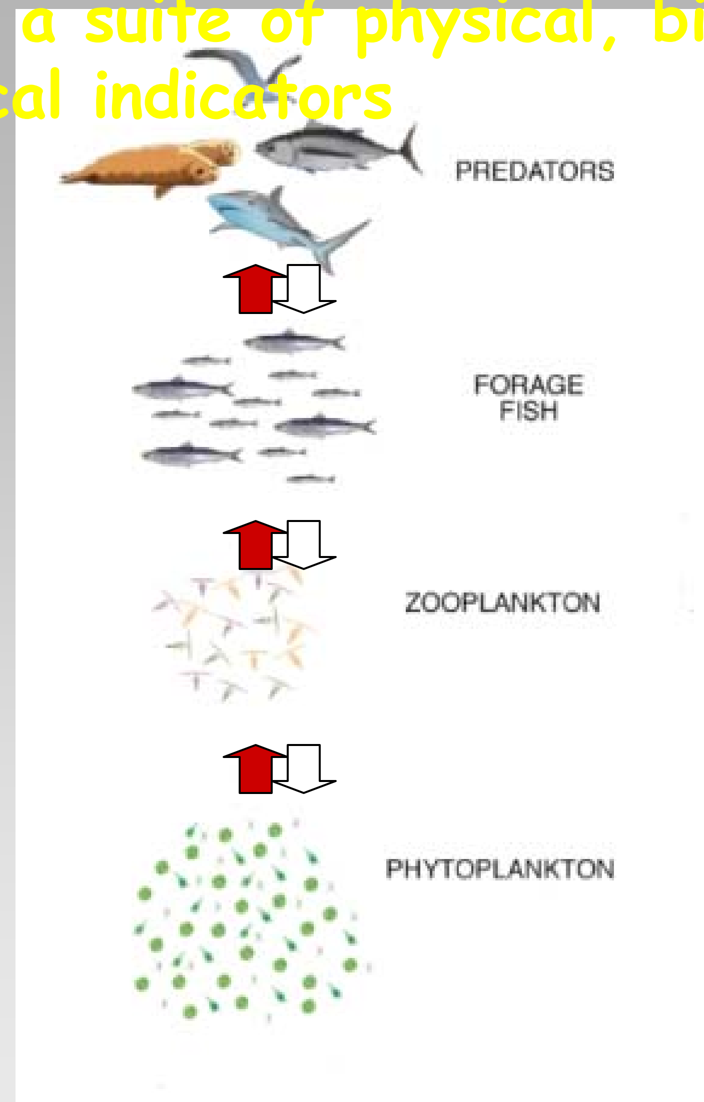


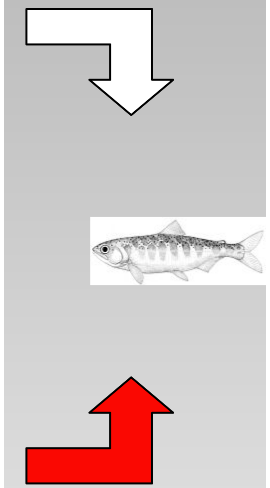
Local Physical Conditions

Upwelling
Spring Transition
SST
Coastal currents

Approach

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

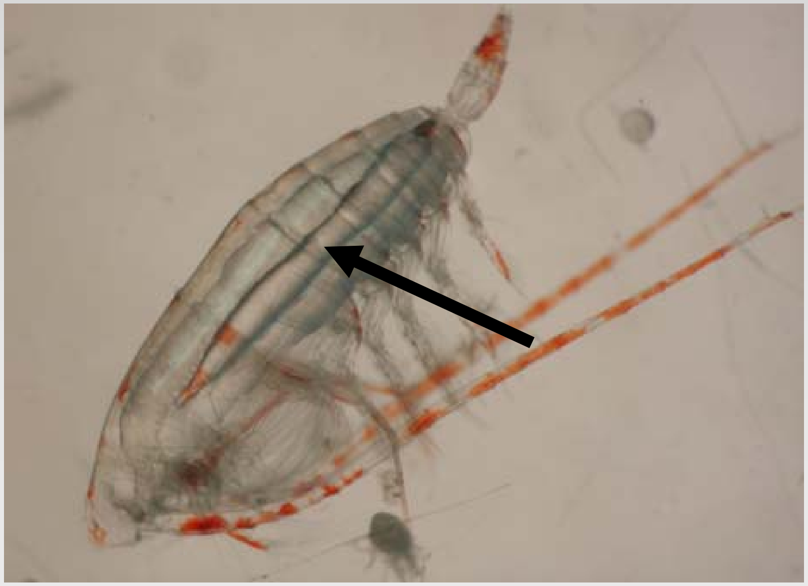




Local Biological Conditions

Here are some copepod and krill images…



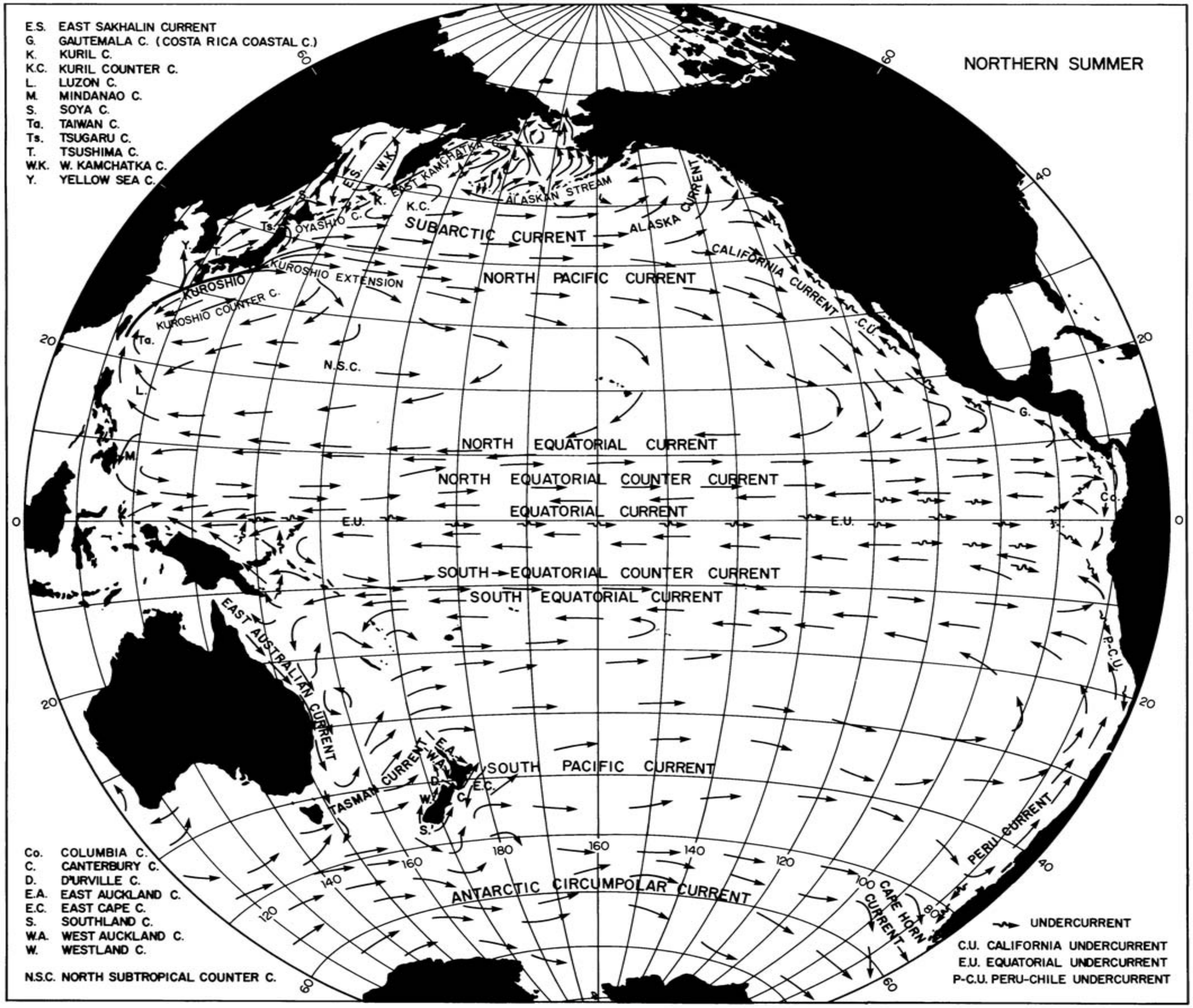



Four factors affect plankton, food chains, pelagic fish and the growth and survival of salmon in the northern California Current

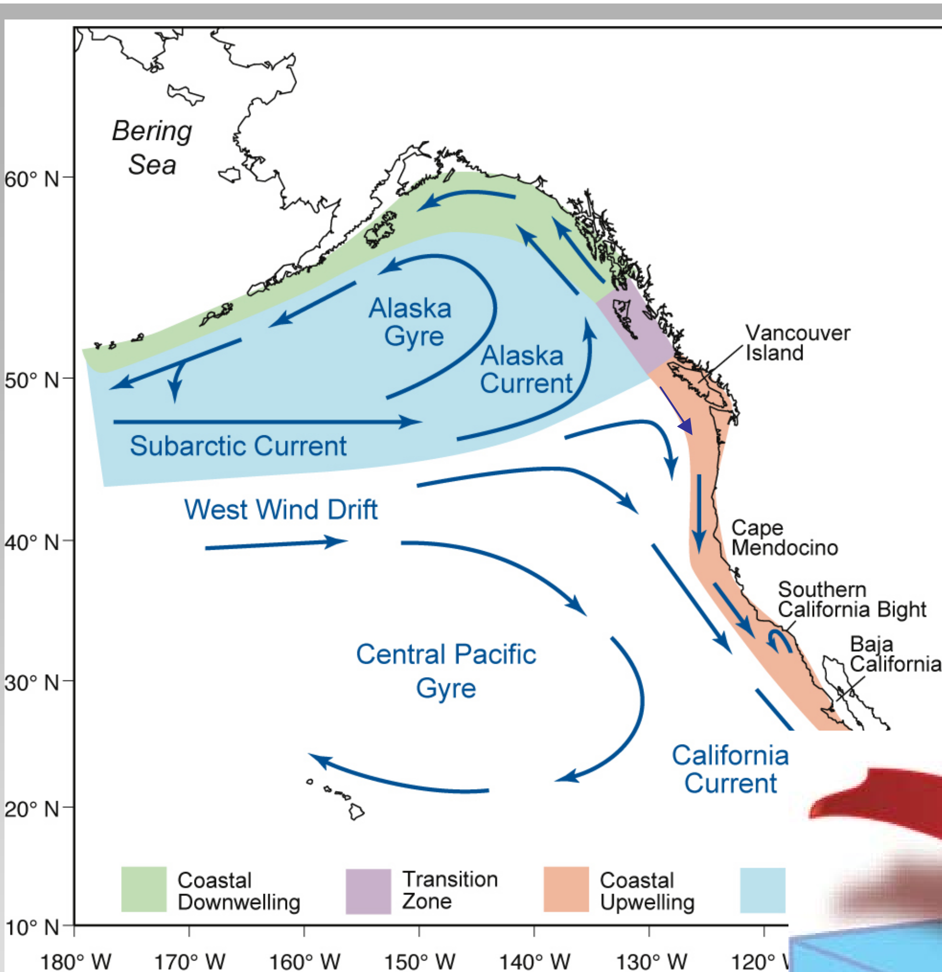
- Large-scale circulation patterns and the kinds of water that feed the California current
- Seasonal reversal of coastal currents: southward in summer – northward in winter
- Coastal Upwelling
- Phase of the Pacific Decadal Oscillation (PDO)

I will then briefly touch on our observations program, then present our forecast tools. Everything is on the web at http://www.nwfsc.noaa.gov under "Ocean Index tools".

Oceanography 101: wind-driven ocean circulation

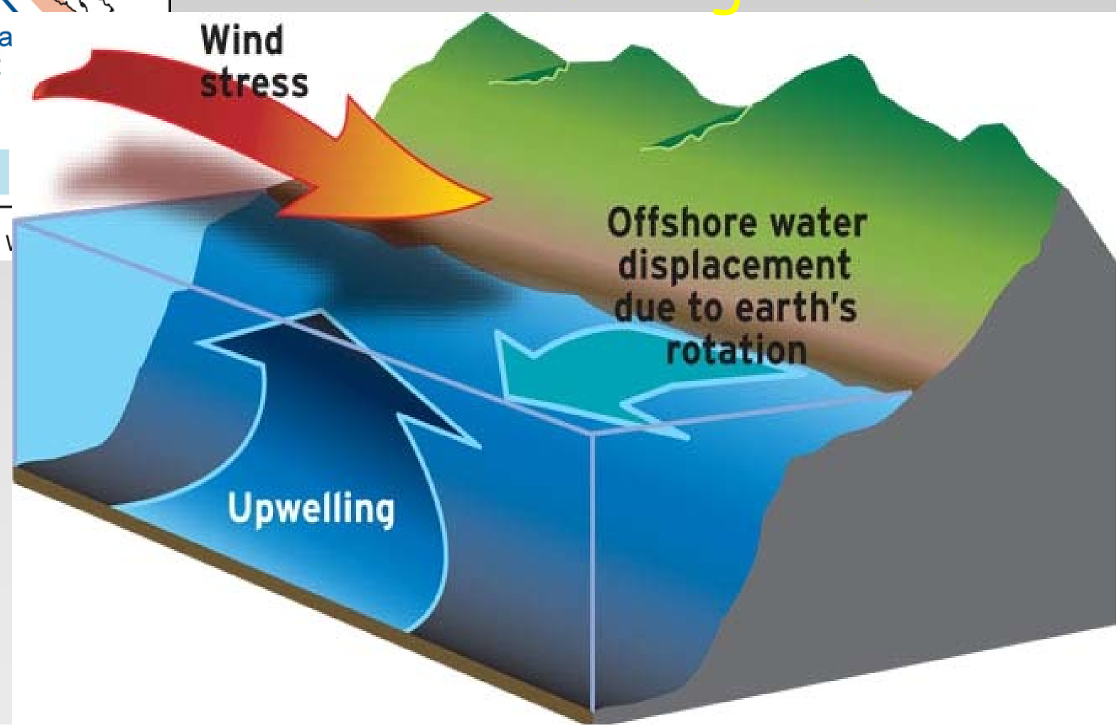


Circulation off the Pacific Northwest



Continental shelf waters reverse direction with the seasons.

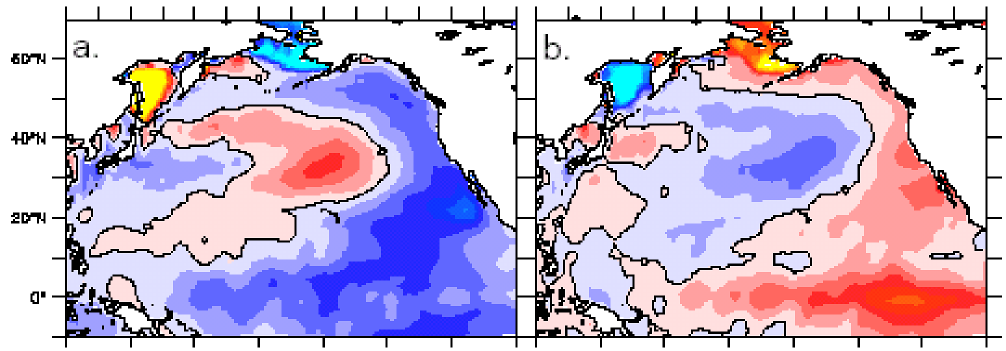
Winds drive currents and cause upwelling in summer and downwelling in winter



Salmon like it cold thus they love upwelling

PDO & SST

The PDO has two phases, resulting from the direction from which winds blow in winter.



Negative Phase

1948-1976
1998-2002
2006-

Positive Phase

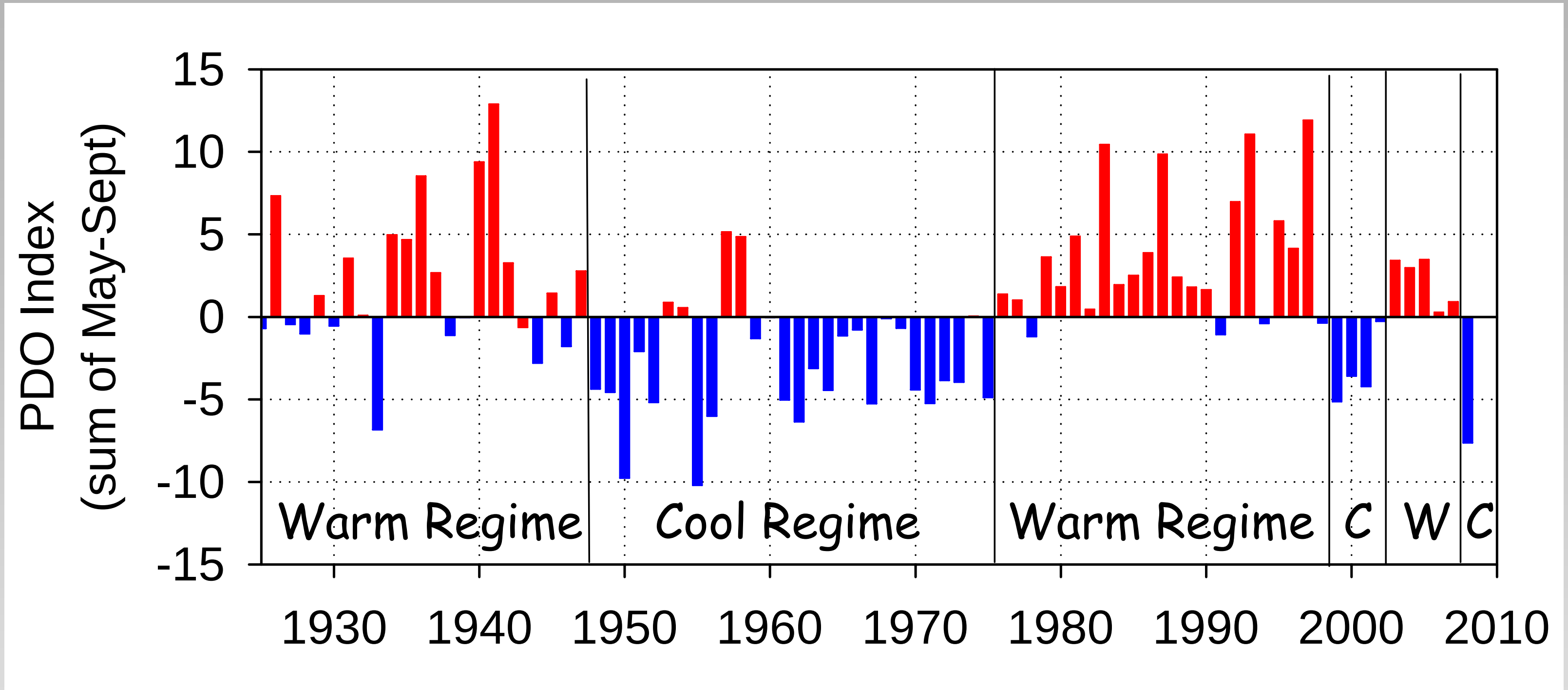
1925-1947
1976-1998
2003-2006

The SST anomaly patterns shown on the right results from basin scale winds: W'ly and NW'ly [negative phase] and SW'ly [positive phase]

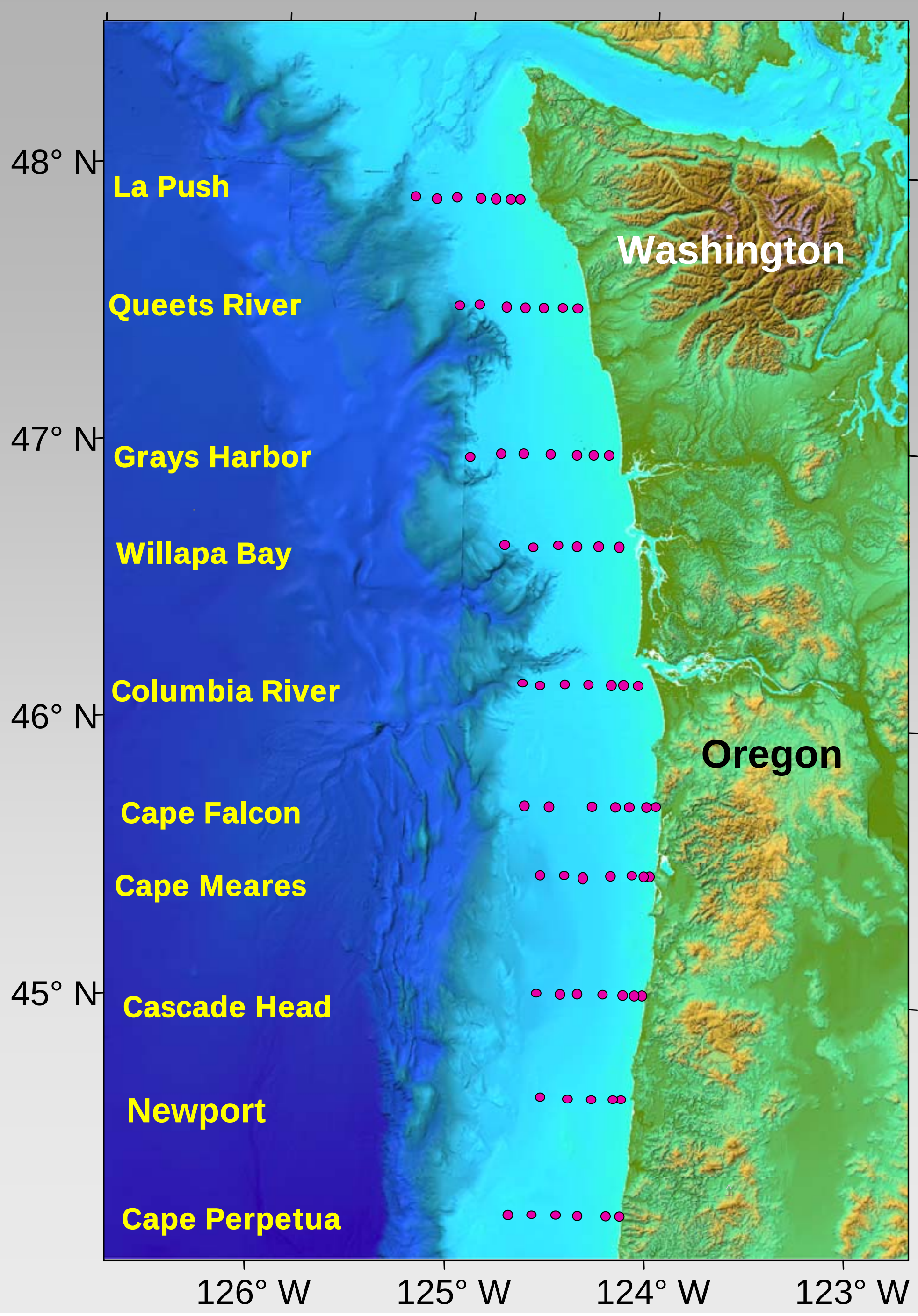
Westerlies dominated last winter (07-08) and now this winter so far.

Blue is anomalously cold
Red is anomalously warm

PDO: May-Sep Average, 1925-2007



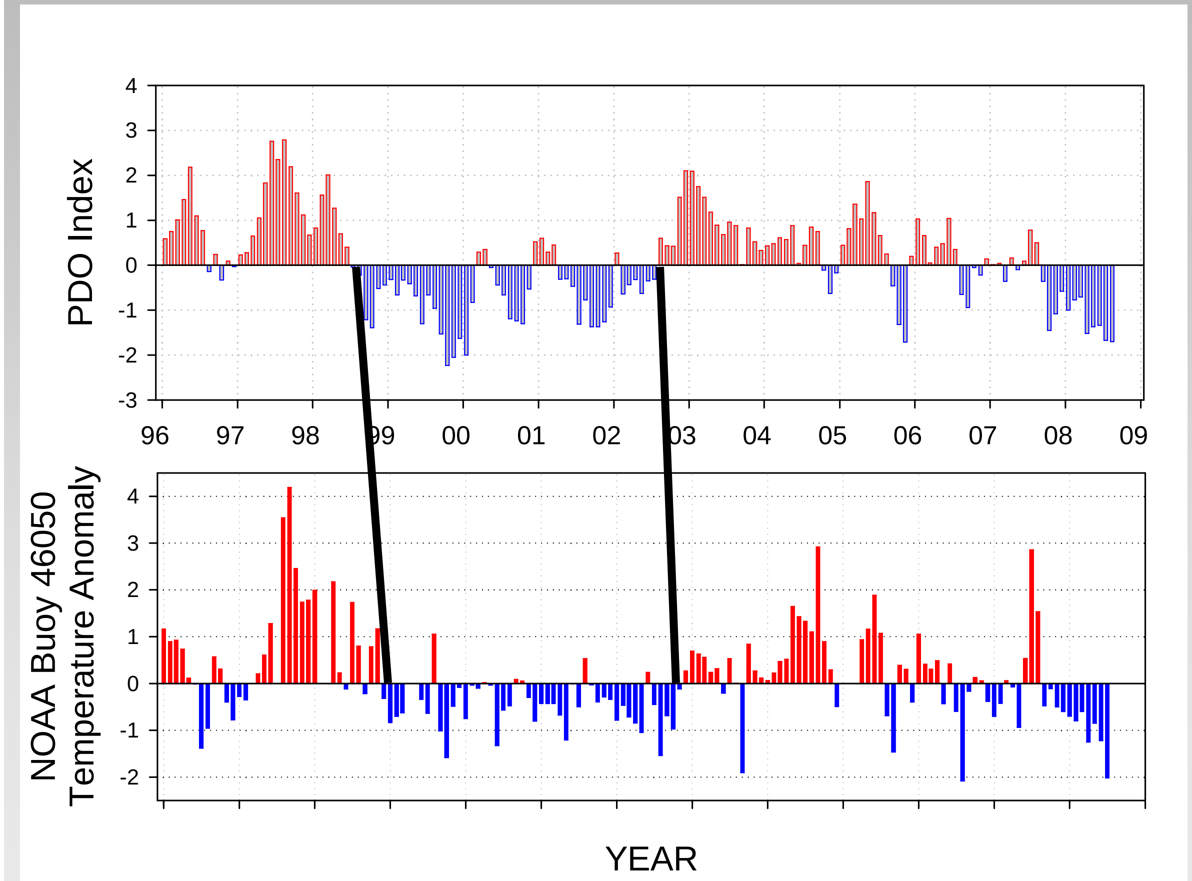
- From 1925-1998, PDO shifted every 20-30 years. Some refer to these as “salmon” regimes (cool) and “sardine” regimes (warm).
- However, we have had two shifts of four years duration recently: 1999-2002 and 2003-2006, and another shift in late 2007, thus we have a natural experiment to test the affects of PDO on marine food chains and salmon populations.
- Note 2008: most negative PDO since 1950s!!



Observations

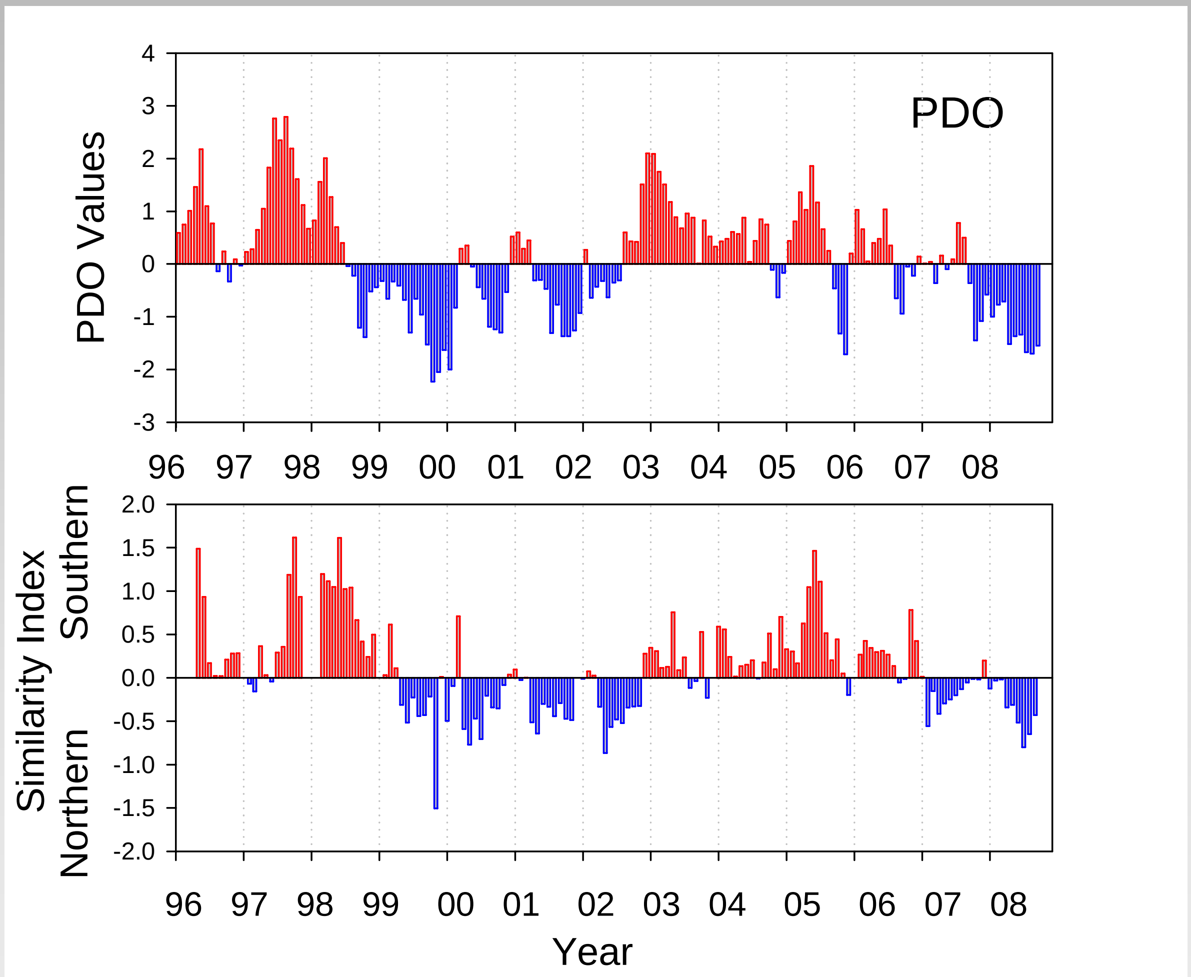
- Newport Line biweekly sampling since 1996 (13 years)
- Juvenile salmon sampling in June and September since 1998 (11 years)
- Historical data:
  hydrography, 1960s;
  plankton, 1969-1973;
  1983, 1990-1992
  juvenile salmon, 1981-1985

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

Copepod community structure vs. PDO (based on an ordination analysis)



- Positive values (red) indicate a "warm water community" and seen during PDO positive phase;
- Negative values (blue) indicate a "cold water community" and seen during PDO negative phase.

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, significantly different food chains may result from climate shifts;

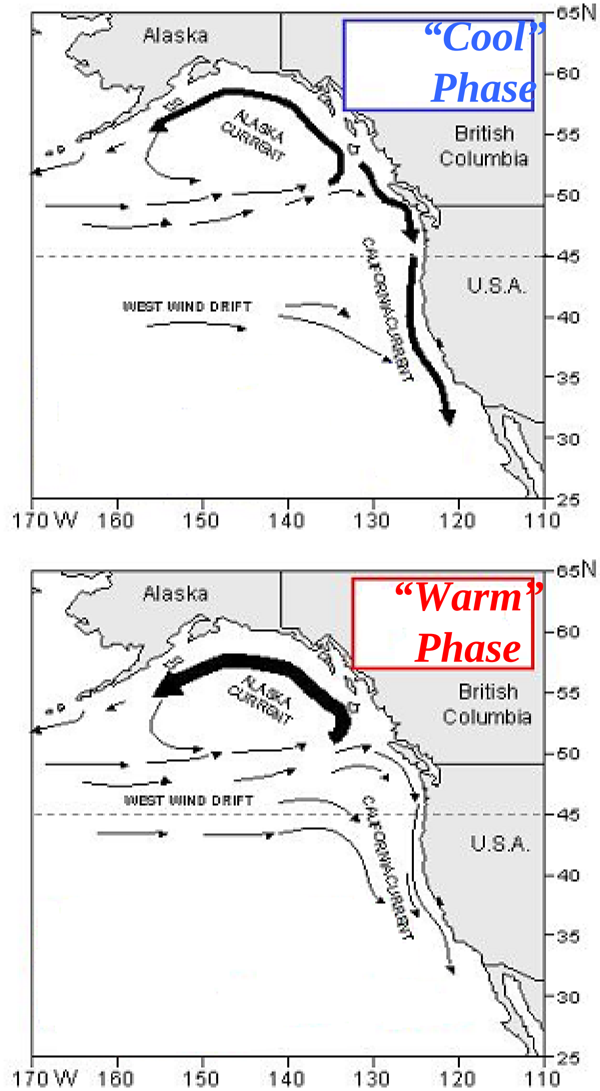
A working mechanistic hypothesis: source waters. . .

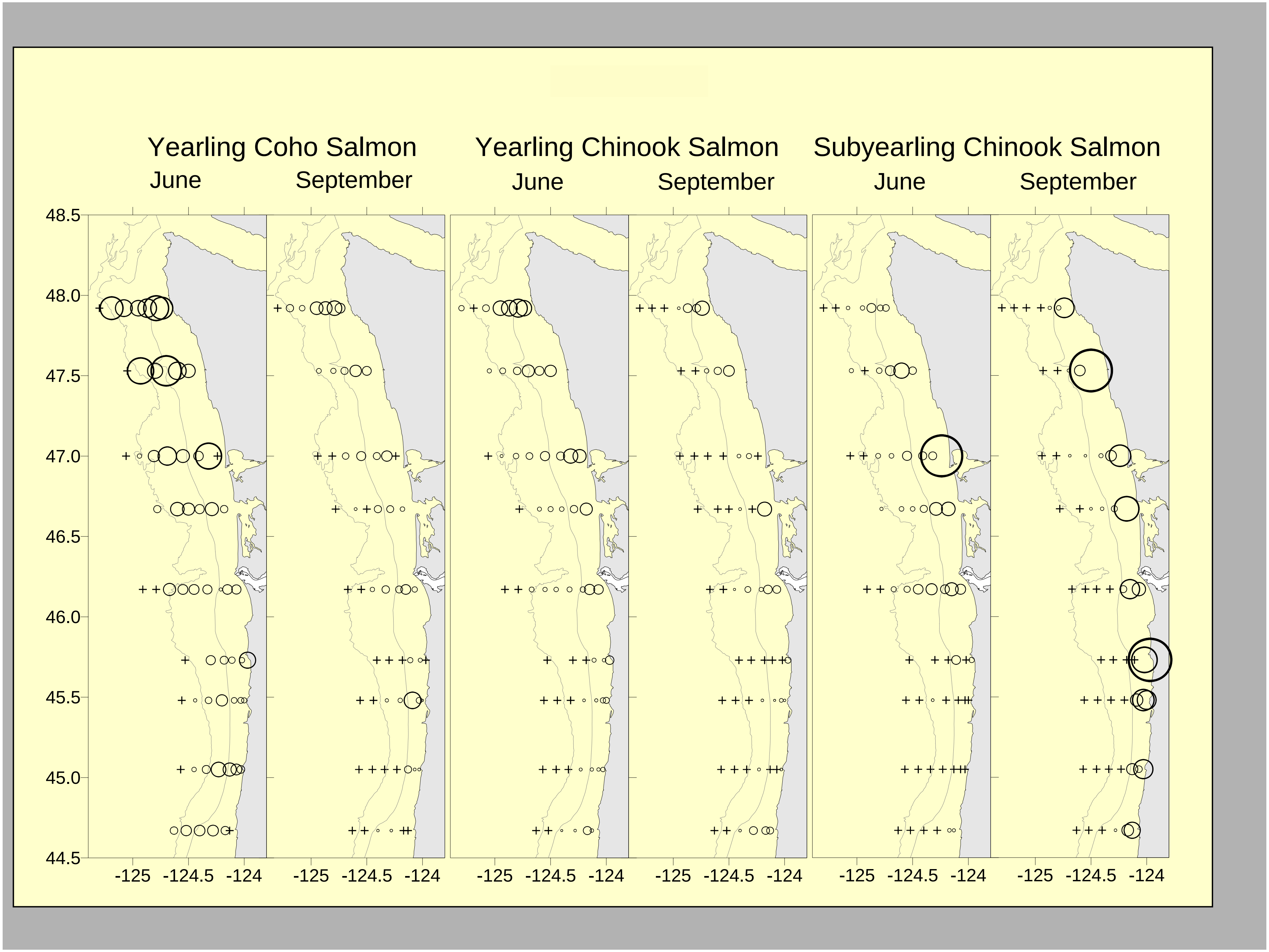
Cool Phase ➔

Transport of boreal coastal copepods into NCC from Gulf of Alaska

Warm Phase ➔

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




Yearling Coho Salmon
June
September
Yearling Chinook Salmon
June
September
Subyearling Chinook Salmon
June
September
48.5
48.0
47.5
47.0
46.5
46.0
45.5
45.0
44.5
-125
-124.5
-124

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
  - Length of upwelling season
- Biological indicators
  - Copepod biodiversity
  - N. copepod biomass anomaly
  - Copepod Community Structure
  - Catches of spring Chinook in June
  - Catches of coho in September

	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)	5	2	4	3	6	10	9	11	7	8	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)	7	6	2	1	4	9	8	11	9	3	5
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	7	4	3	9	1	10	8	11	6	5	2
Copepod richness	11	2	1	5	3	8	7	10	9	6	4
N.Copepod Anomaly	11	8	3	5	2	9	6	10	7	4	1
Biological Transition	11	6	3	5	4	9	7	10	8	2	1
June-Chinook Catches	10	2	3	8	5	7	9	11	6	4	1
Sept-Coho Catches	9	2	1	4	3	5	10	11	7	8	6
Mean of Ranks	9.3	3.6	3.4	4.8	4.1	8.5	8.3	9.9	6.9	4.9	2.0
RANK of the mean rank	11	2	3	5	4	8	9	10	7	6	1

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

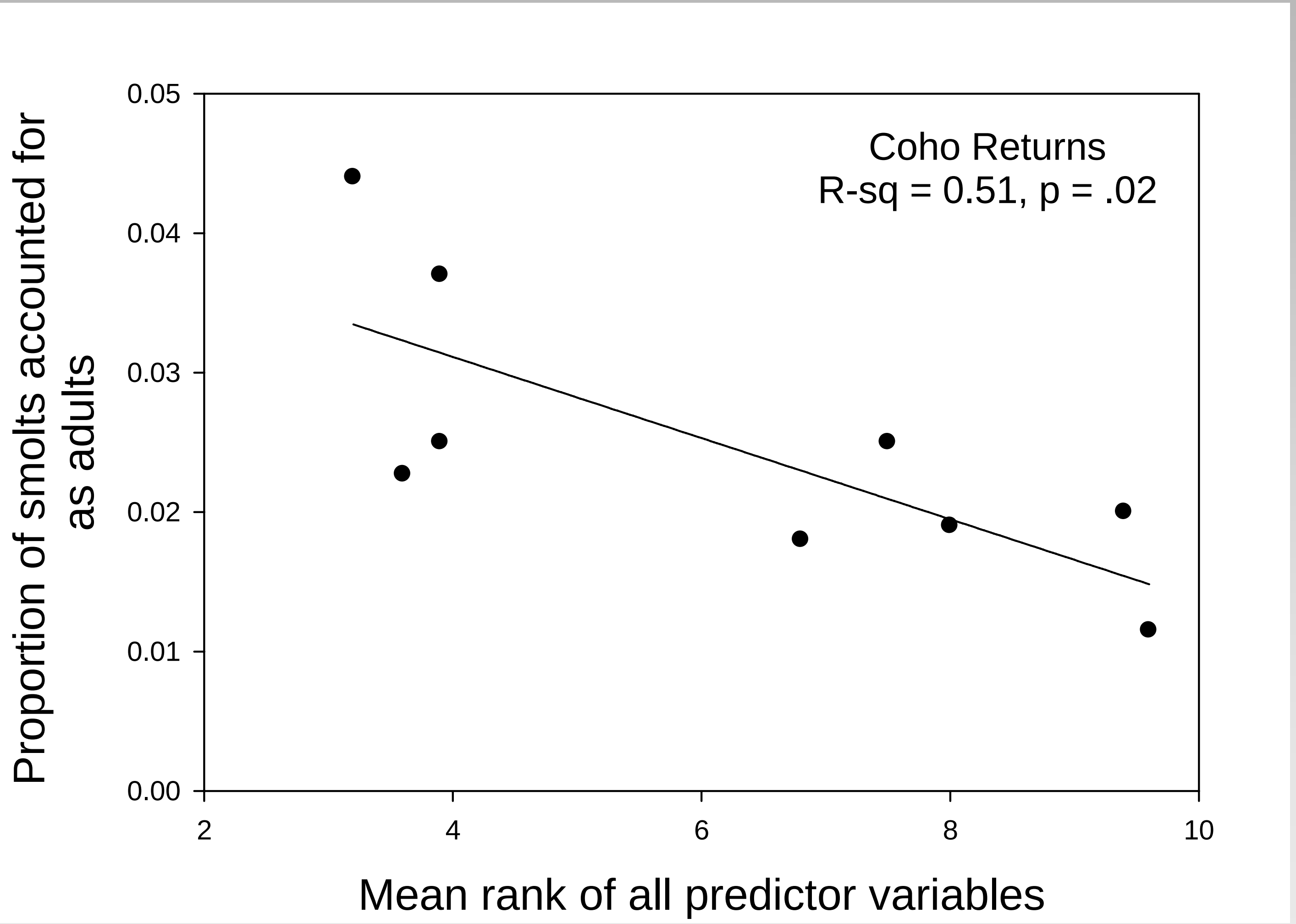
But time lags can complicate interpretations!

Acknowledgements

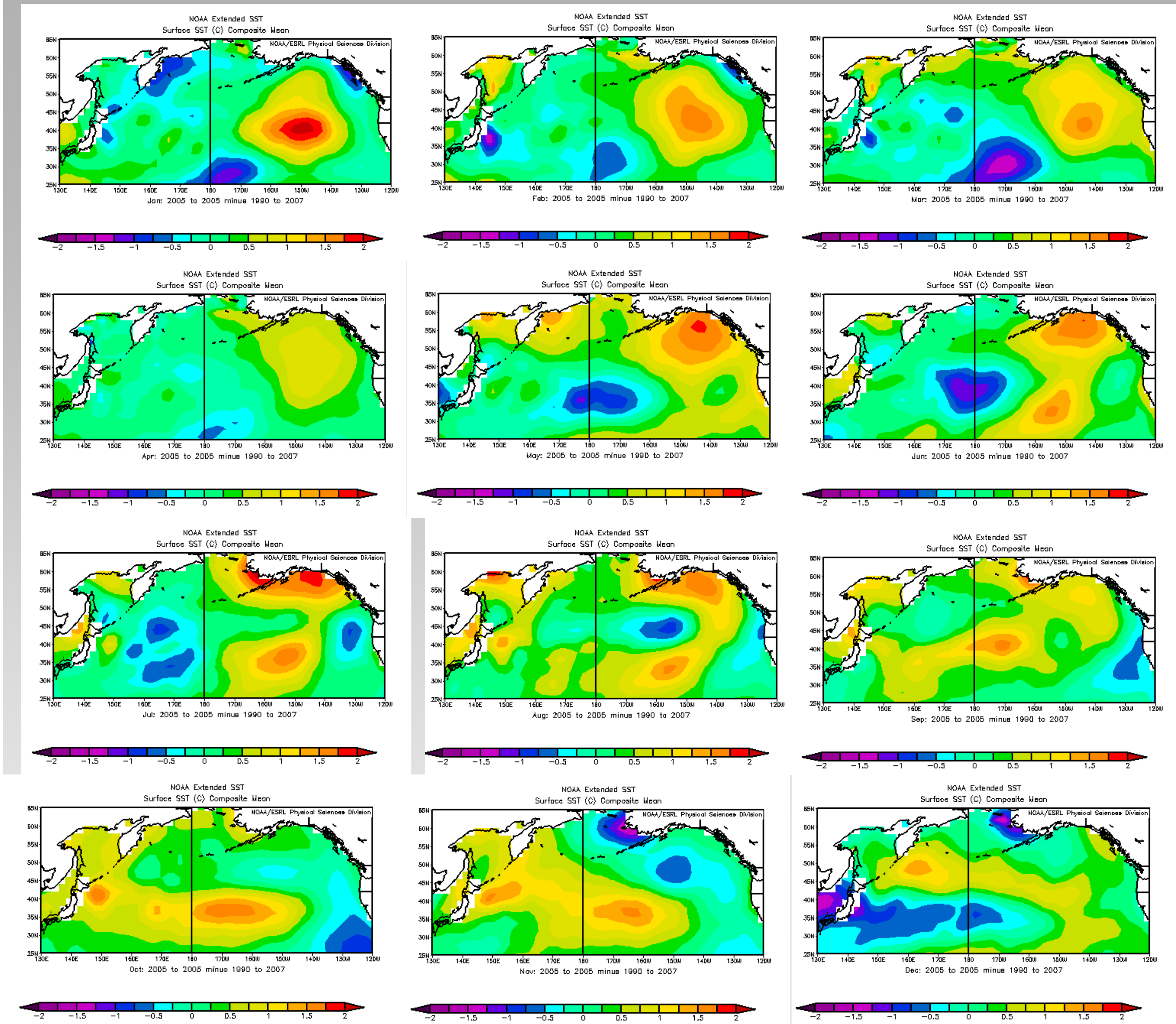
- Bonneville Power Administration
- U.S.GLOBEC Program (NOAA/NSF)
- Stock Assessment Improvement Program (SAIP-NOAA)
- Fisheries and the Environment (FATE-NOAA)
- National Science Foundation
- Office of Naval Research
- NASA

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

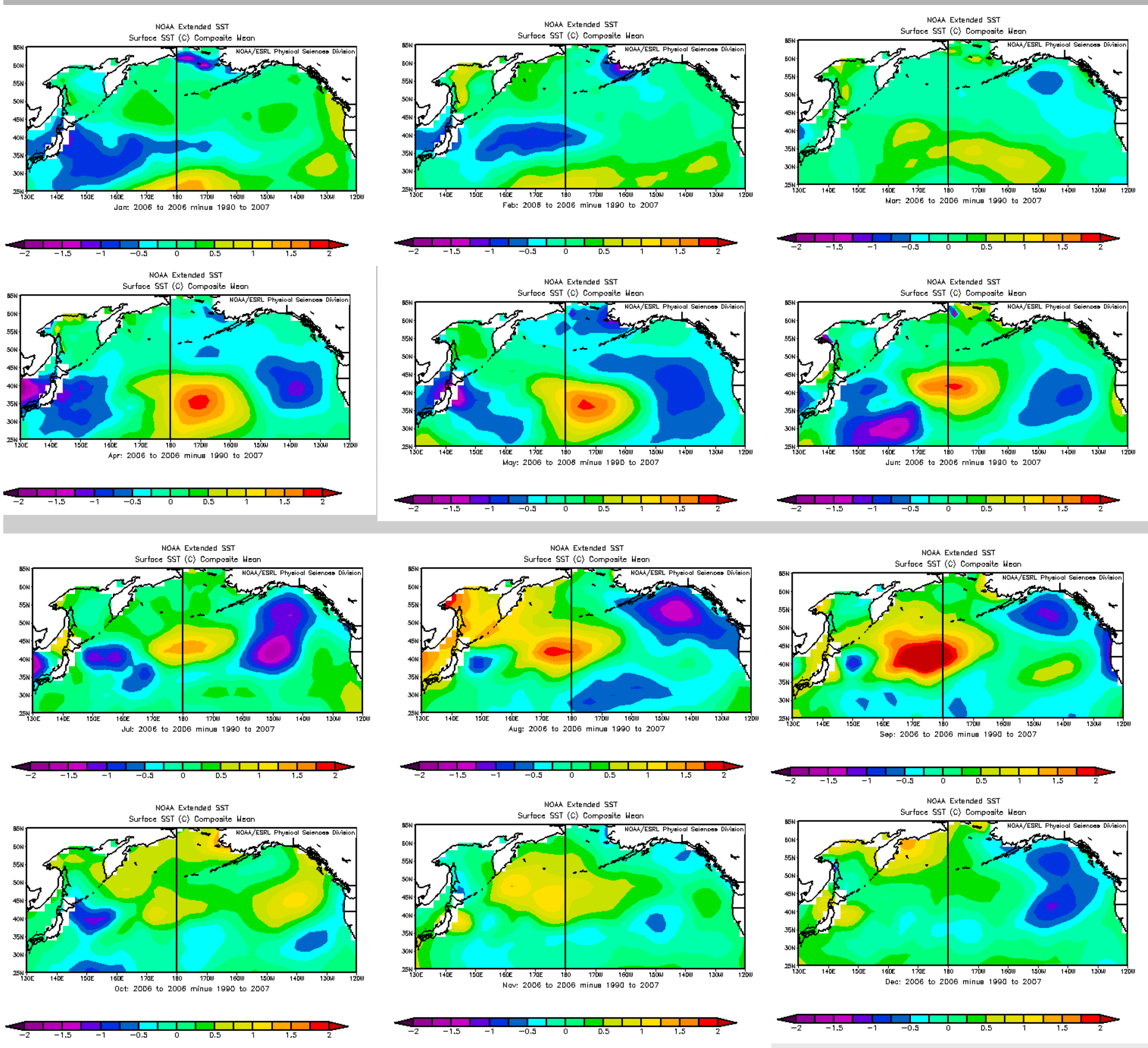
Coho returns vs. rank of all variables



2005


NOAA Extended SST
Surface SST (C) Composite Mean
NOAA/ESRL Physical Sciences Division
Jan: 2005 to 2005 minus 1990 to 2007
Feb: 2005 to 2005 minus 1990 to 2007
Mar: 2005 to 2005 minus 1990 to 2007
Apr: 2005 to 2005 minus 1990 to 2007
May: 2005 to 2005 minus 1990 to 2007
Jun: 2005 to 2005 minus 1990 to 2007
Jul: 2005 to 2005 minus 1990 to 2007
Aug: 2005 to 2005 minus 1990 to 2007
Sep: 2005 to 2005 minus 1990 to 2007
Oct: 2005 to 2005 minus 1990 to 2007
Nov: 2005 to 2005 minus 1990 to 2007
Dec: 2005 to 2005 minus 1990 to 2007
−2 −1.5 −1 −0.5 0 0.5 1 1.5 2

2006


NOAA Extended SST
Surface SST (C) Composite Mean
NOAA/ESRL Physical Sciences Division
Jan: 2006 to 2006 minus 1990 to 2007
Feb: 2006 to 2006 minus 1990 to 2007
Mar: 2006 to 2006 minus 1990 to 2007
Apr: 2006 to 2006 minus 1990 to 2007
May: 2006 to 2006 minus 1990 to 2007
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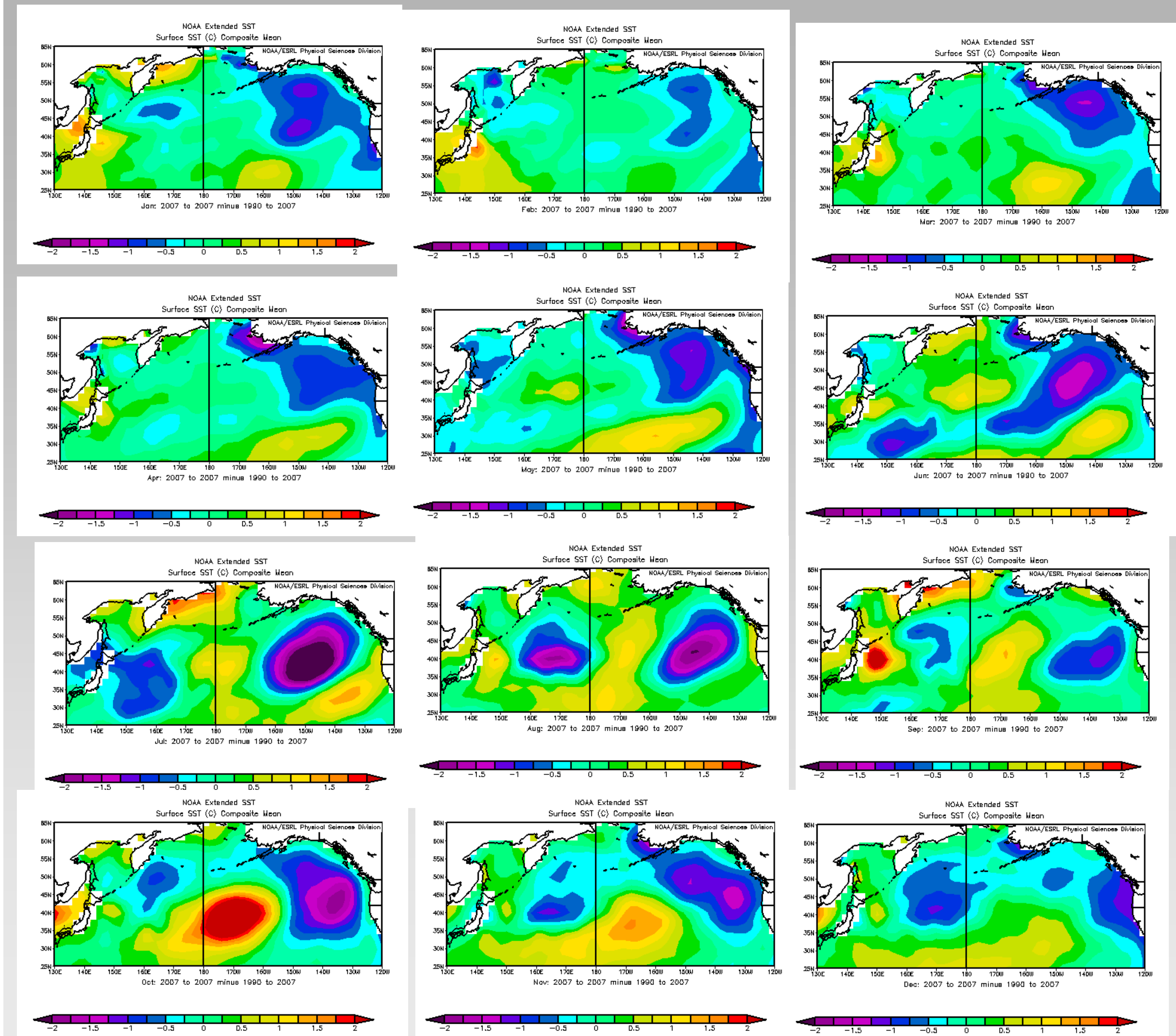
Jul: 2006 to 2006 minus 1990 to 2007
Aug: 2006 to 2006 minus 1990 to 2007
Sep: 2006 to 2006 minus 1990 to 2007
Oct: 2006 to 2006 minus 1990 to 2007
Nov: 2006 to 2006 minus 1990 to 2007
Dec: 2006 to 2006 minus 1990 to 2007

2007


NOAA Extended SST
Surface SST (C) Composite Mean
NOAA/ESRL Physical Sciences Division
Jan: 2007 to 2007 minus 1990 to 2007
Feb: 2007 to 2007 minus 1990 to 2007
Mar: 2007 to 2007 minus 1990 to 2007
Apr: 2007 to 2007 minus 1990 to 2007
May: 2007 to 2007 minus 1990 to 2007
Jun: 2007 to 2007 minus 1990 to 2007
Jul: 2007 to 2007 minus 1990 to 2007
Aug: 2007 to 2007 minus 1990 to 2007
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Nov: 2007 to 2007 minus 1990 to 2007
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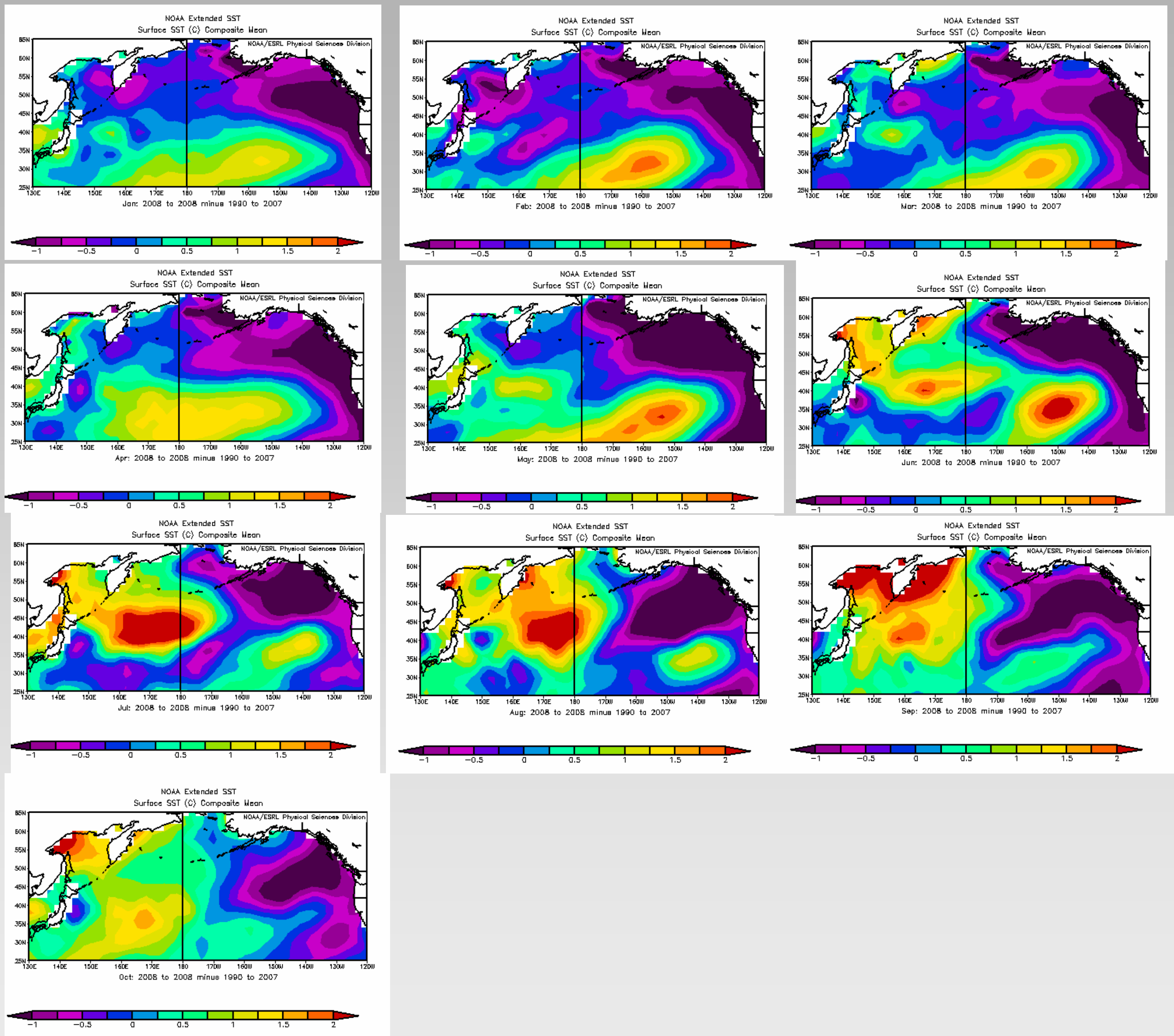
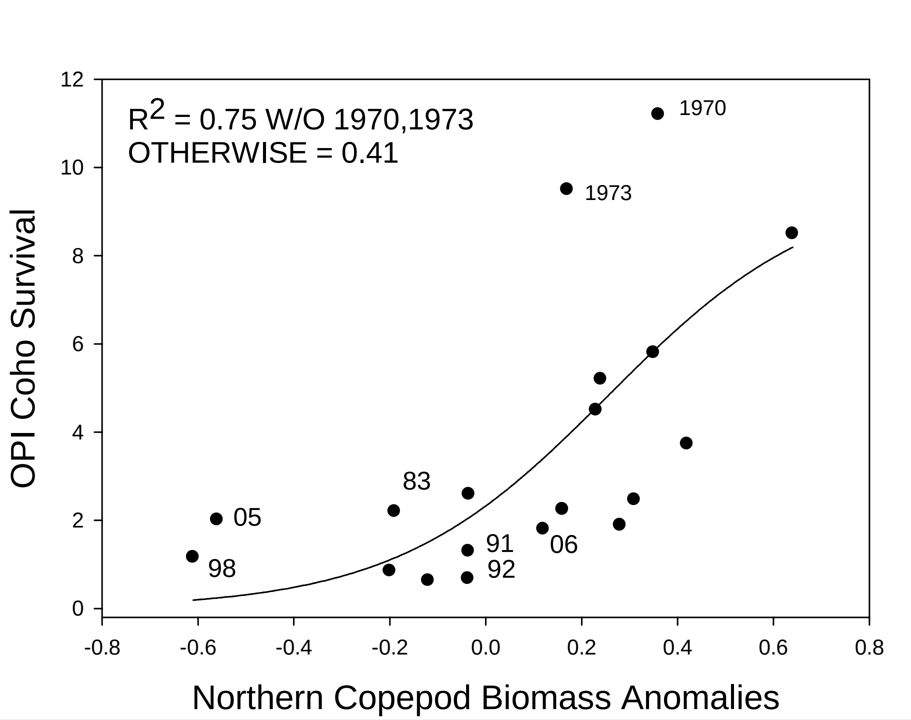
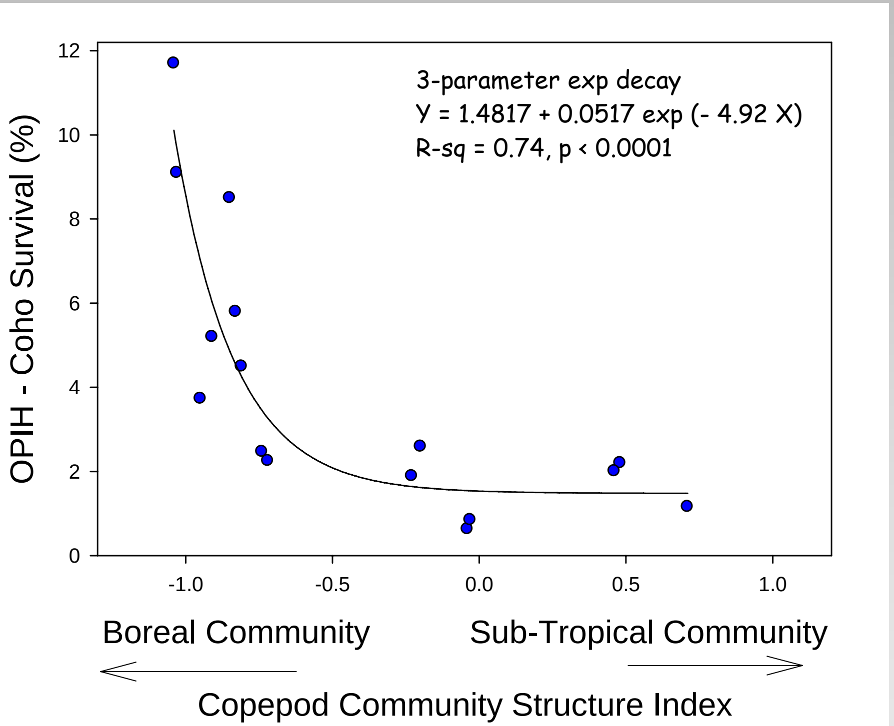
−2 −1.5 −1 −0.5 0 0.5 1 1.5 2

2008


NOAA Extended SST
Surface SST (C) Composite Mean
NOAA/ESRL Physical Sciences Division
Jan: 2008 to 2008 minus 1990 to 2007
Feb: 2008 to 2008 minus 1990 to 2007
Mar: 2008 to 2008 minus 1990 to 2007
Apr: 2008 to 2008 minus 1990 to 2007
May: 2008 to 2008 minus 1990 to 2007
Jun: 2008 to 2008 minus 1990 to 2007
Jul: 2008 to 2008 minus 1990 to 2007
Aug: 2008 to 2008 minus 1990 to 2007
Sep: 2008 to 2008 minus 1990 to 2007
Oct: 2008 to 2008 minus 1990 to 2007
−1 −0.5 0 0.5 1 1.5 2

Copepod indices: integrative measures

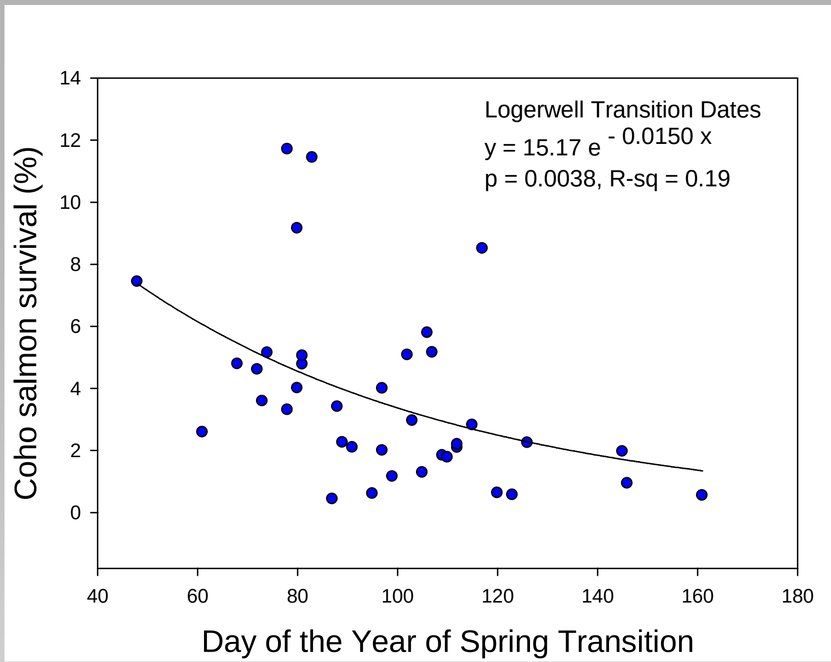


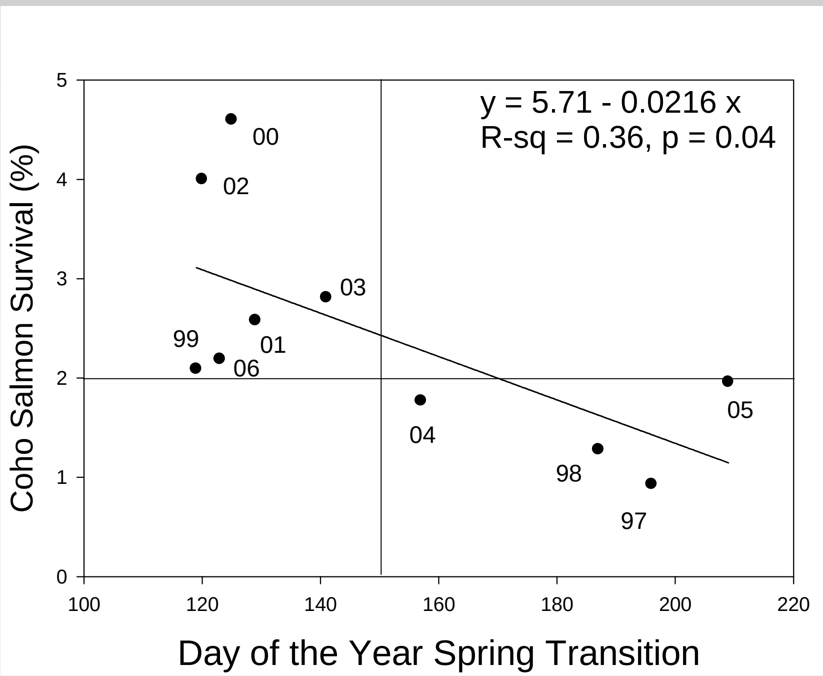


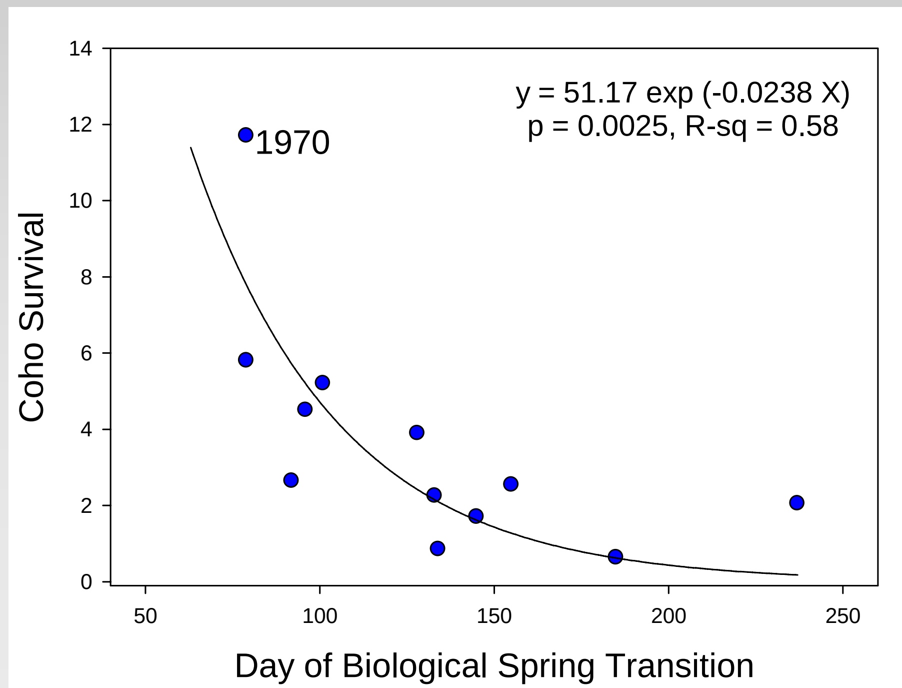
Spring Transition

- 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)

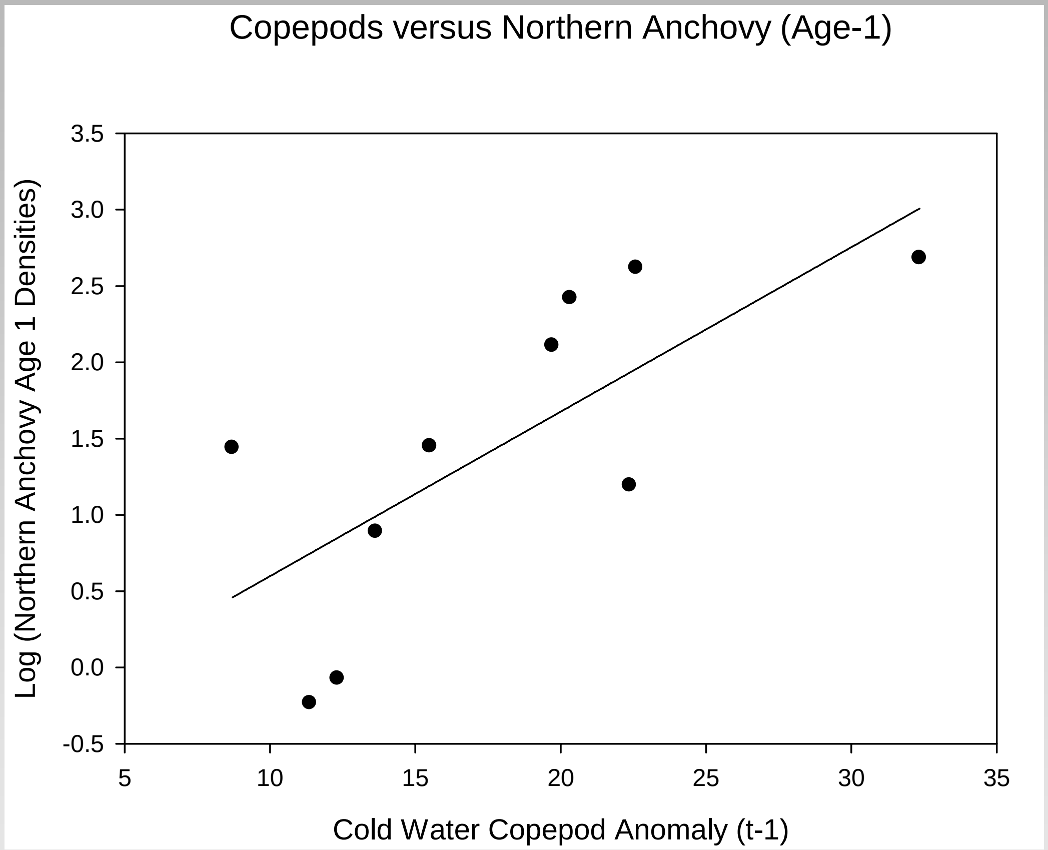
When we look at the date when the copepods transitioned to a summer community, a somewhat different result is seen







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

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