Northwest Power and Conservation Council

December 2, 2010

MEMORANDUM

TO: Council Members

FROM: Jim Ruff -- Manager, Mainstem Passage and River Operations

SUBJECT: Update by NOAA Fisheries on ocean conditions in 2010

At the December 15, 2010, Council meeting in Portland, John Ferguson and Bill Peterson from NOAA's Northwest Fisheries Science Center will present the latest information on conditions in the Pacific Ocean affecting salmon survival (Attachment). Dr. Ferguson is the Division Director of the Fish Ecology Division at NOAA's Northwest Fisheries Science Center and Dr. Peterson is a Senior Scientist and Oceanographer at NOAA's Northwest Fisheries Science Center in Newport, Oregon.

In this update, they will explain how various meteorological and oceanographic indicators interact to account for either "good" or "bad" salmon returns. They will also explain the most current 'stoplight' diagram, which summarizes current ocean conditions using 16 different indicators. Information that they will present can be found on the Northwest Fisheries Science Center's website at http://www.nwfsc.noaa.gov by clicking on "Ocean Conditions and Salmon Forecasting" in the box on the right-hand side of the page.

Attachment

w:\jr\ww\2010\12-15-10 nwfsc update on ocean conditions.docx

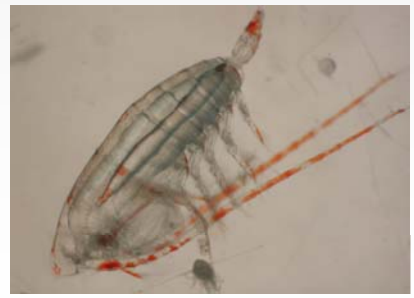
851 S.W. Sixth Avenue, Suite 1100
Portland, Oregon 97204-1348
www.nwcouncil.org

Steve Crow
Executive Director

503-222-5161
800-452-5161
Fax: 503-820-2370

Ocean Conditions and Forecasting Salmon Returns: how variability in ocean conditions affects salmon survival

Bill Peterson
Senior Scientist
NOAA Fisheries
Hatfield Marine Science Center
Newport Oregon

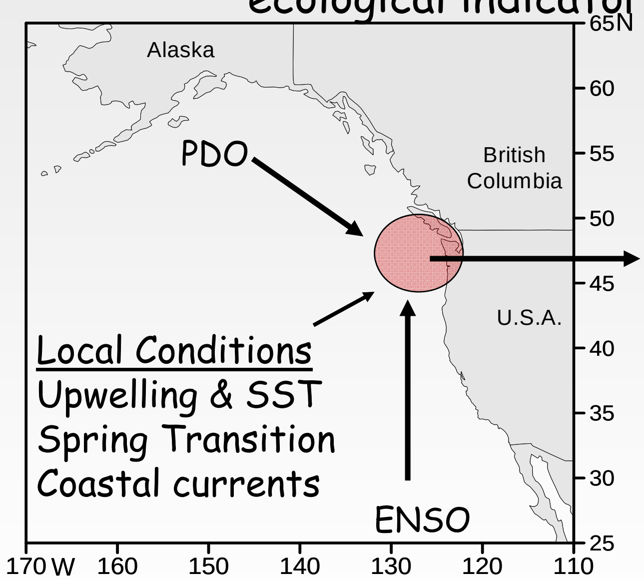


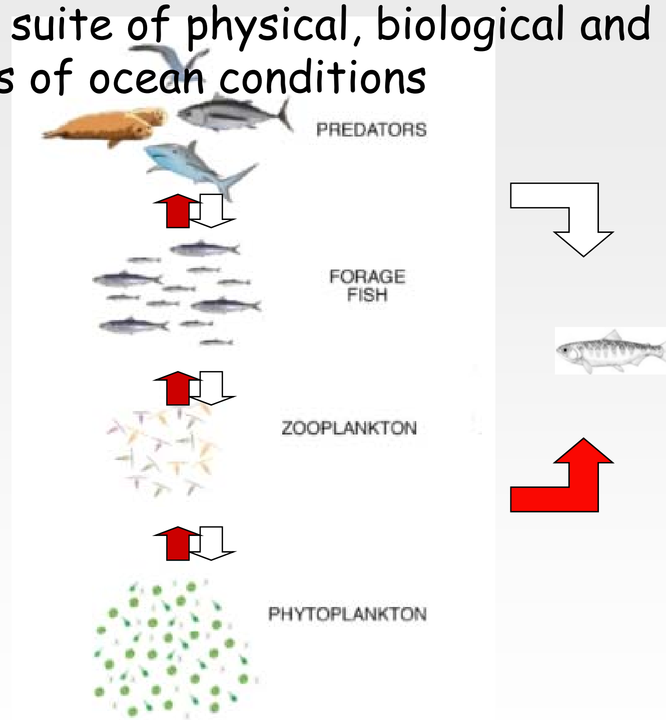
See www.nwfsc.noaa.gov, "Ocean Conditions and Salmon Forecasting"

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 of ocean conditions

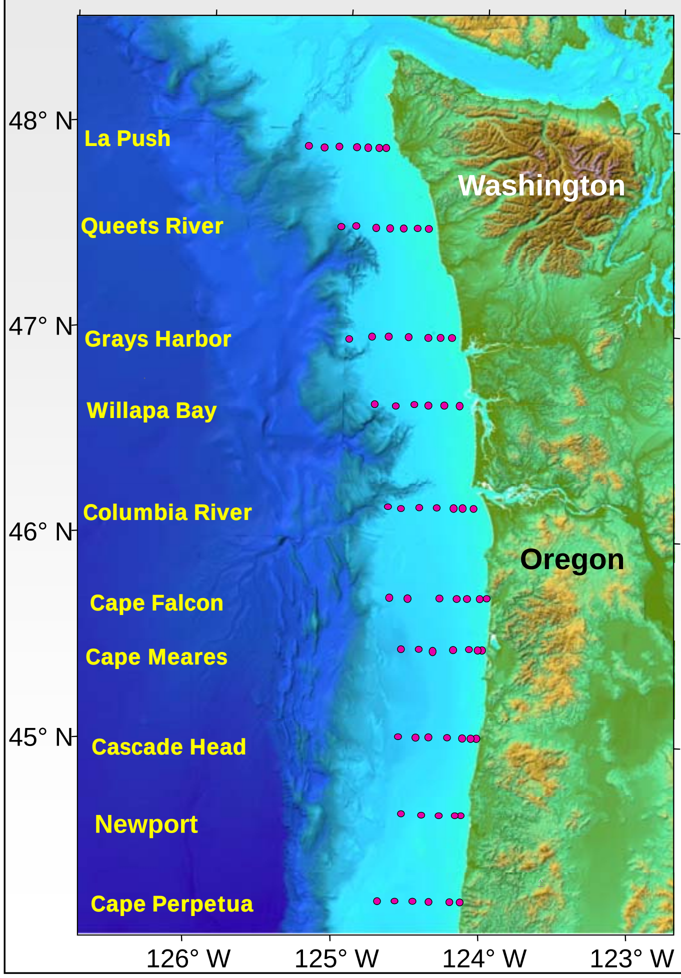
Today I will speak about each of these aspects of ocean conditions

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





Local Biological Conditions

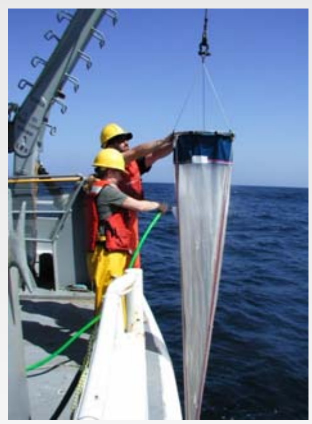


Observations

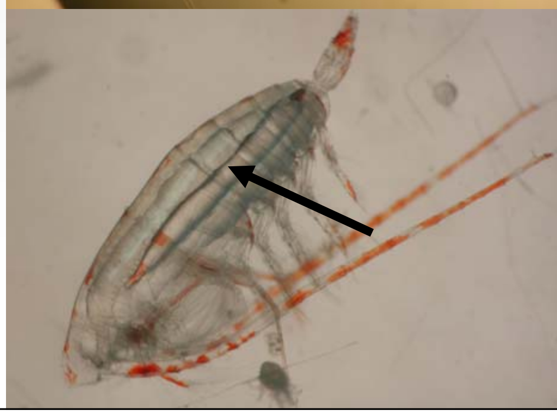
- Newport Line biweekly sampling since 1996 (15th year)
- Juvenile salmon sampling in June and September since 1998 (13th year)
- Historical data:
  hydrography, 1960s;
  plankton, 1969-1973;
  1983, 1990-1992
  juvenile salmon, 1981-1985

Sampling methods

- Copepods with ½ m diameter 200 µm mesh net towed vertically from 100 m
- Krill with 70 cm 333 µm mesh Bongo net towed obliquely
- Salmon with pelagic rope trawl, Nordic 264 from NET Systems



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

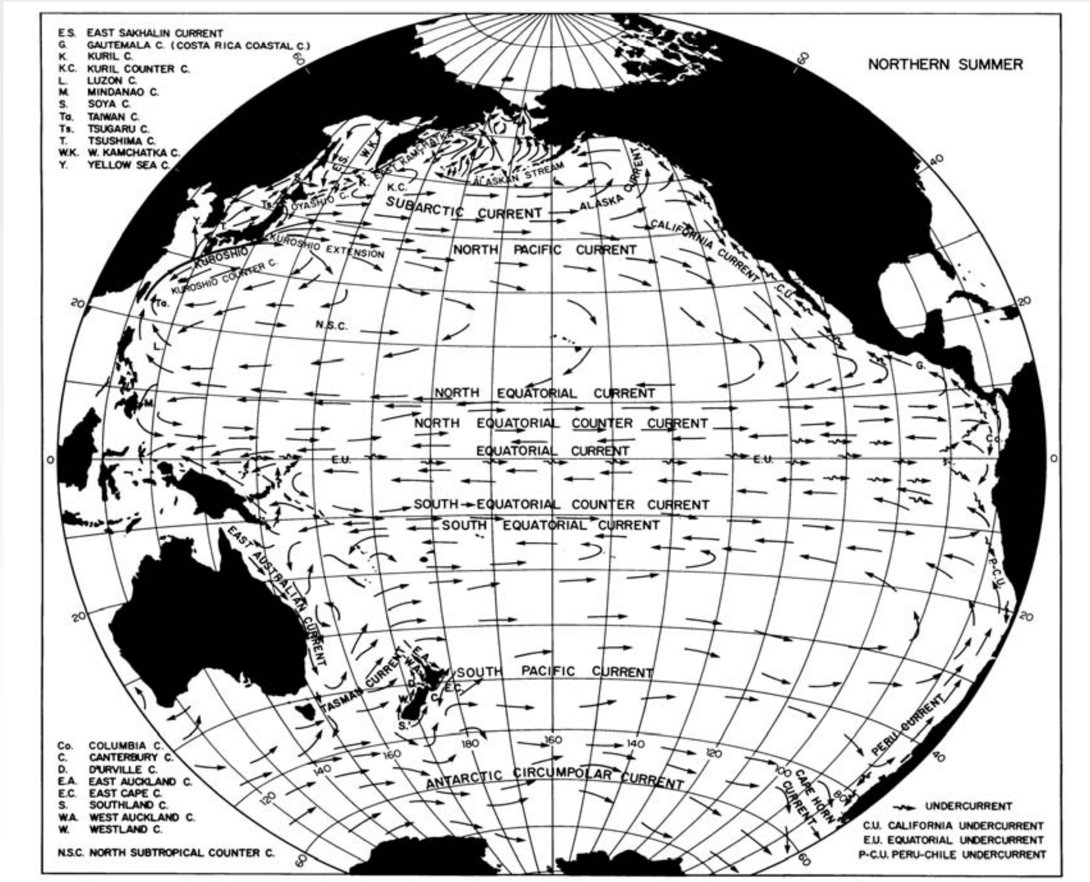


Four physical factors affect plankton, food chains, pelagic fish and the growth and survival of salmon in the northern California Current

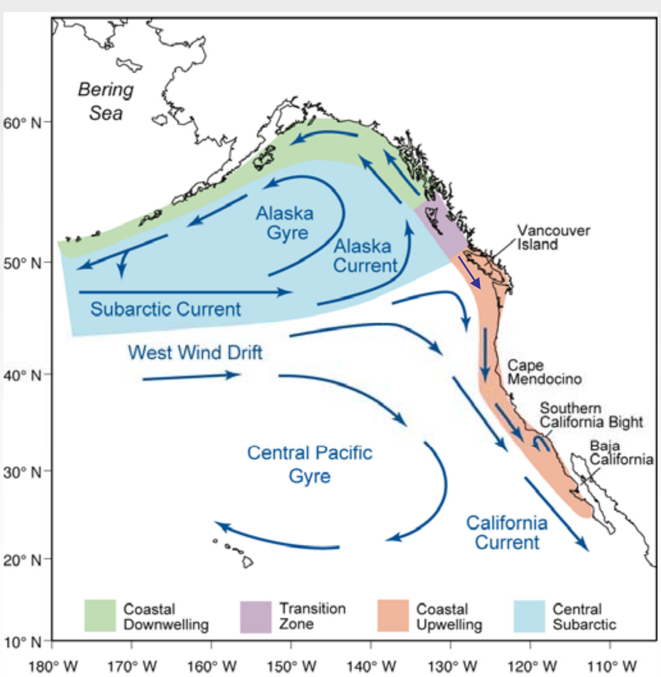
- Large-scale circulation patterns and the kinds of water that feed the California current
- Seasonal reversal of coastal currents: southward in summer – northward in winter
- Coastal Upwelling
- Phase of the Pacific Decadal Oscillation (PDO)

Everything is on the the web at: http://www.nwfsc.noaa.gov
"Ocean Conditions and Salmon Forecasting"

Oceanography 101



Circulation off the Pacific Northwest

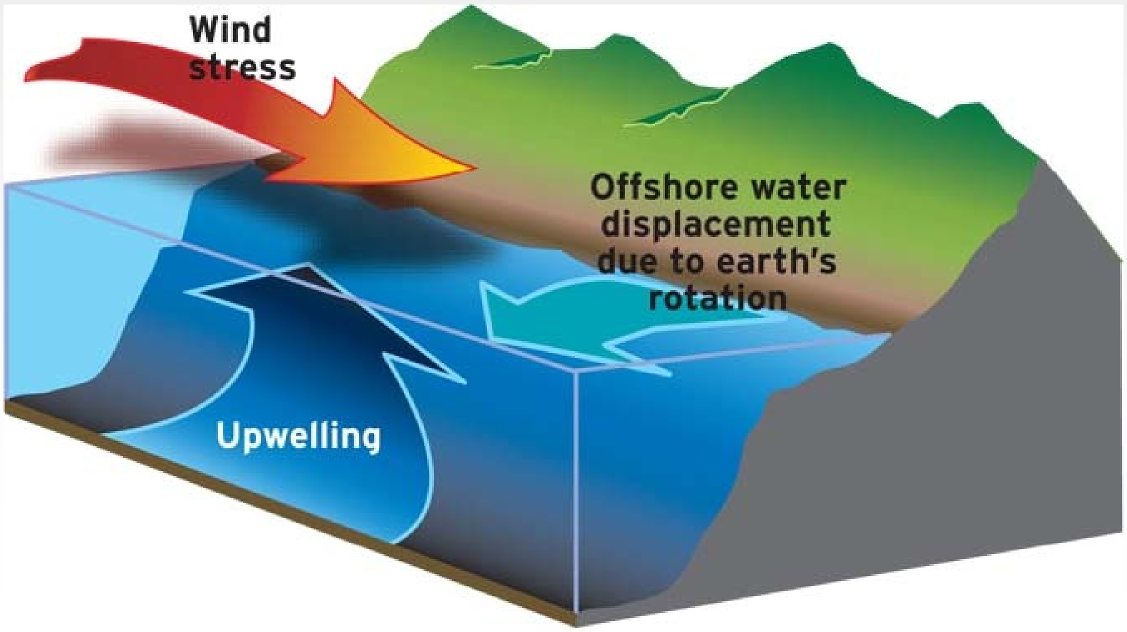


Subarctic Current brings cold water and northern species to the N. California Current;

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.

Local winds drive currents and cause upwelling along the coasts of Washington, Oregon and California



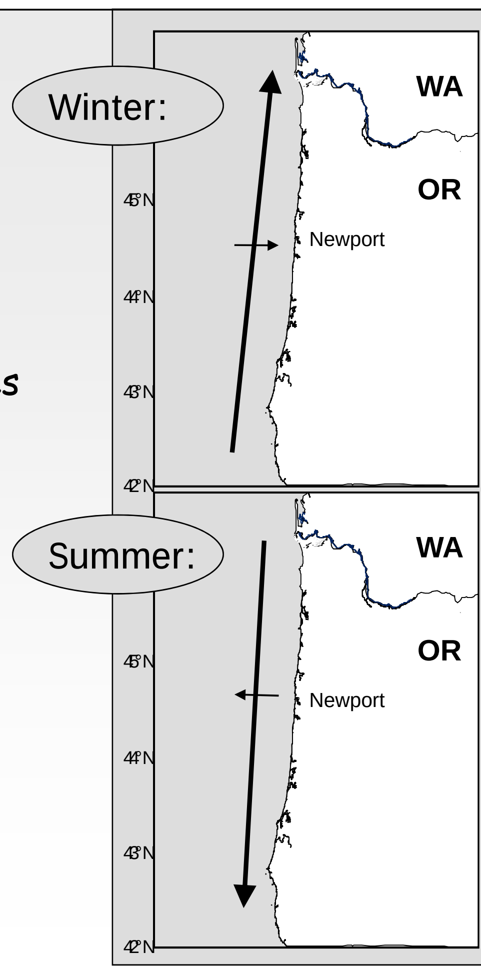
Winds and current structure off coastal Oregon:

- 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

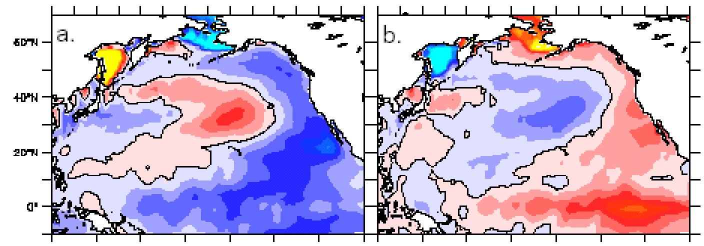


The PDO has two phases, resulting from the direction from which winds blow in winter.

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]

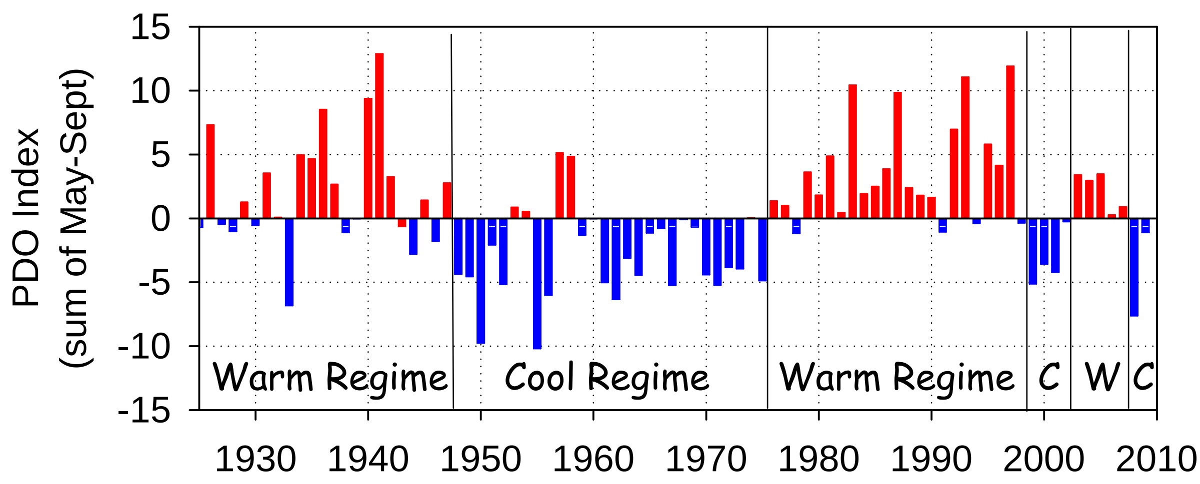
Westerlies dominated during winter 07-08; SW'ly winter 09-10.

PDO & SST



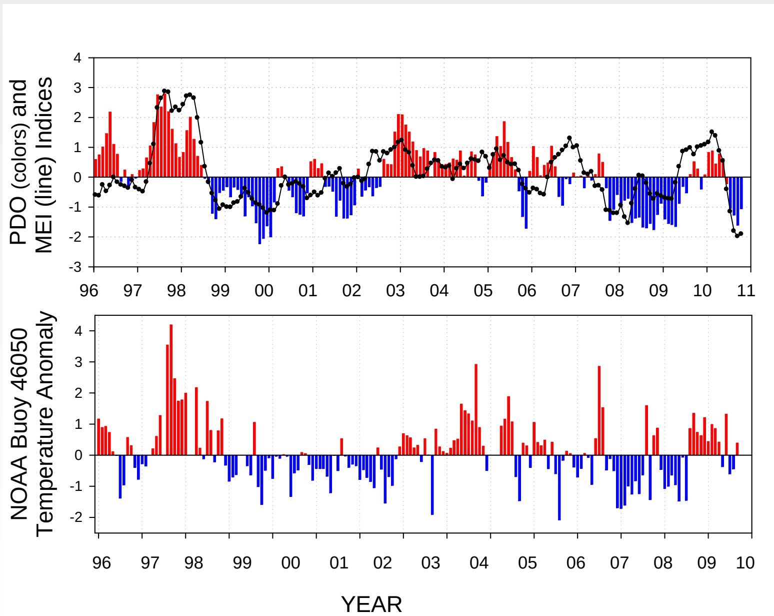
Blue is anomalously cold
Red is anomalously warm

PDO: May-Sep Average, 1925-2009



- 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!!

14 year time series of SST off Newport shows that PDO downscales to local SST



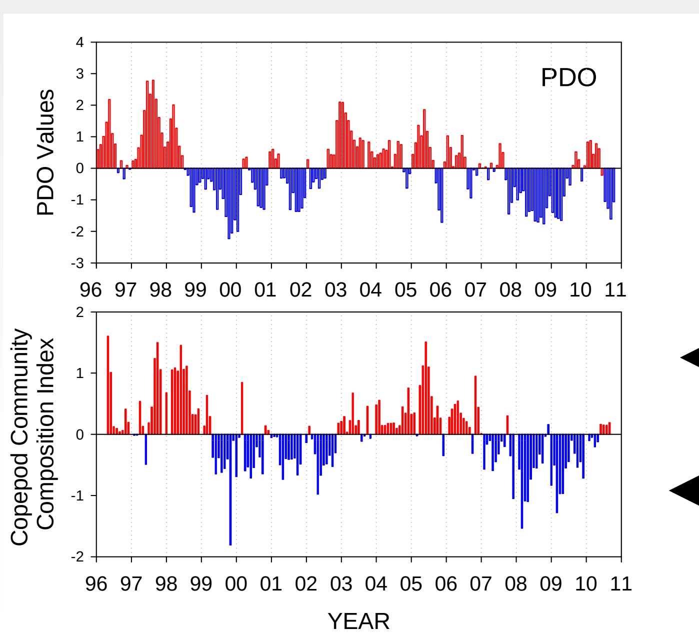
Temperature differences usually $\pm 1^{\circ}$ C

- PDO and SST correlated, as they should be.
- Note the three recent periods of persistent sign changes: mid-1999, mid-2003 and mid-2007
- 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: copepod community composition

As I said earlier, 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 coastal waters in association with positive or negative phase of the PDO, but with a few months lag



Warm water community

Cold water community

Contrasting Communities

- **Negative PDO = "cold-water" copepod species.** These are dominants in Bering Sea, coastal GOA, coastal northern California Current
  - *Pseudocalanus mimus, Calanus marshallae, Acartia longiremis*
- **Positive PDO = "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 minimal high energy wax ester lipid depots
- **Cold-water taxa** – (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;

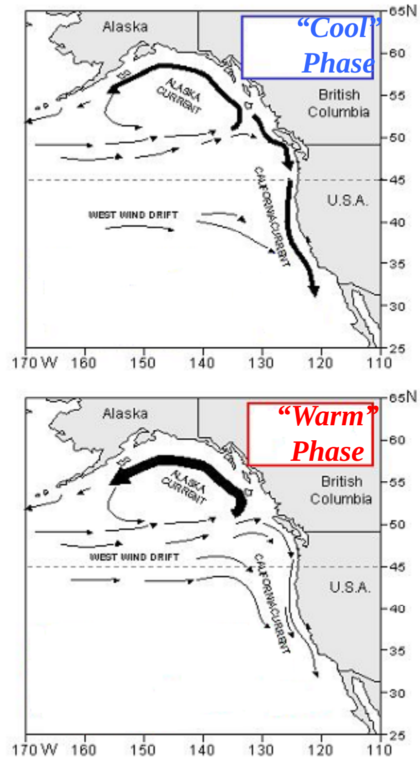
A working mechanistic hypothesis: **source waters. . .**

Cool Phase ➔

Transport of boreal coastal copepods into NCC from Gulf of Alaska

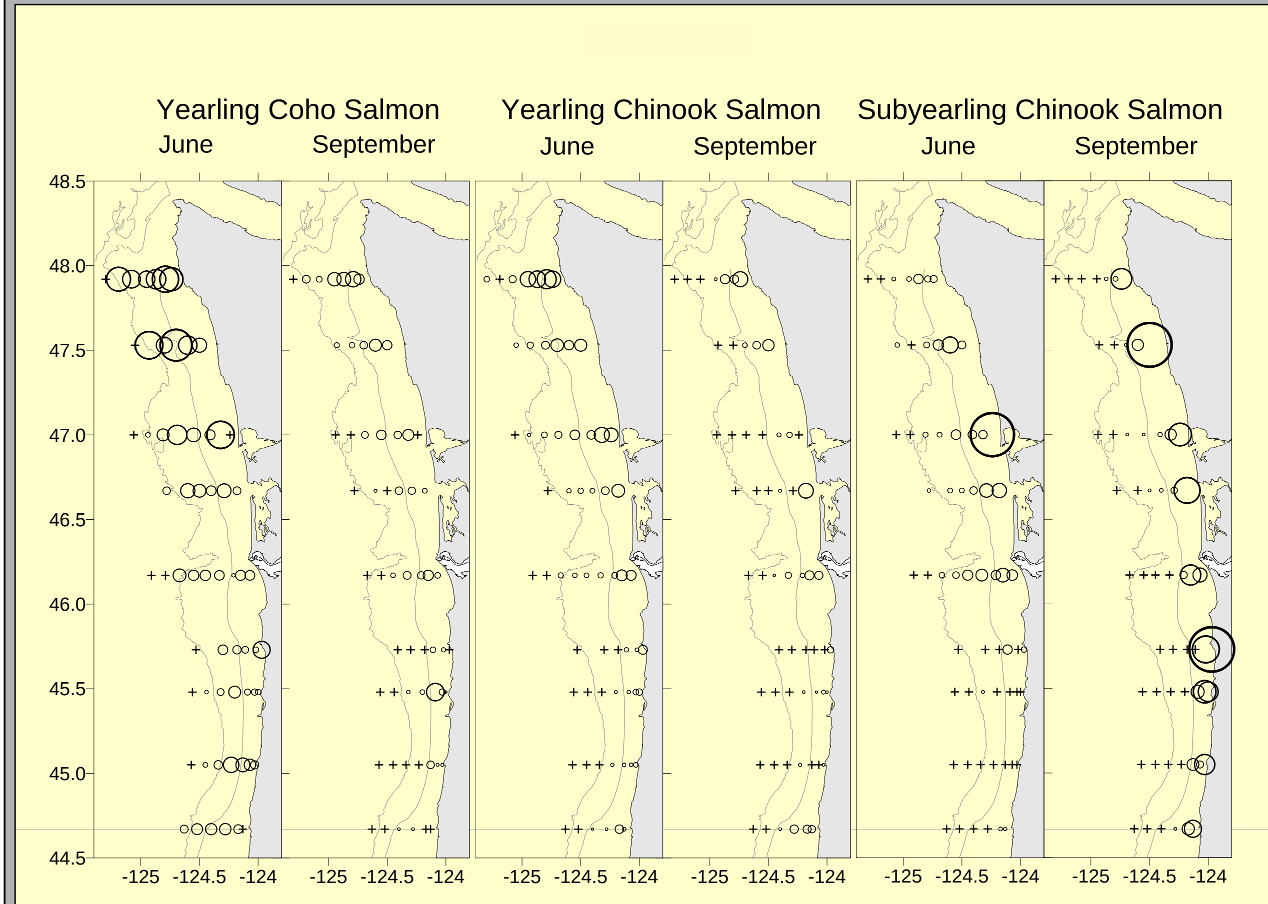
Warm Phase ➔

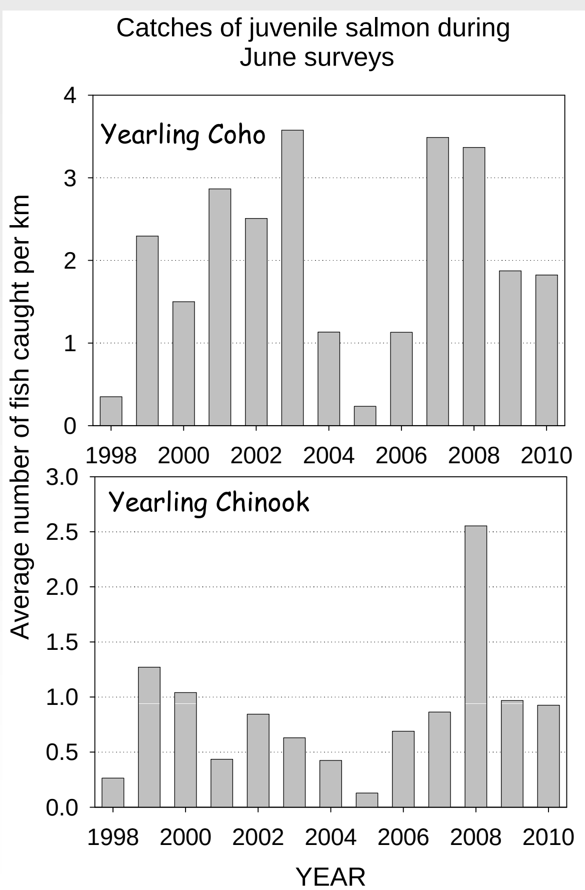
Transport of sub-tropical copepods into NCC from Transition Zone offshore



Salmon Habitat and Forecasting

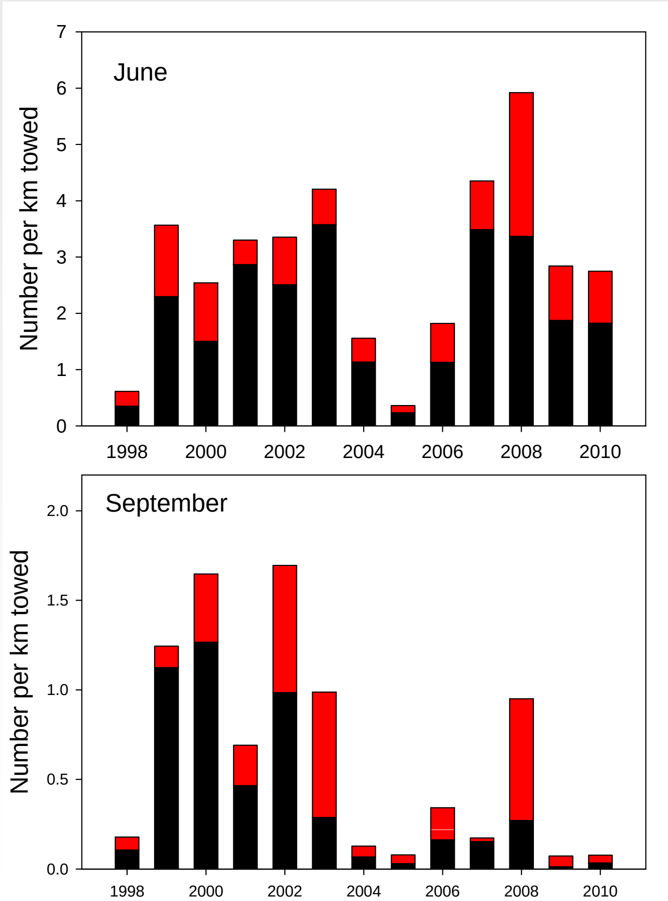
- In order to forecast returns of various salmon life history types, we must first establish where they live in the ocean.
- We have done this from our coastal surveys in May, June and September since 1998





Catches of juvenile salmon in rope trawl surveys

- High catches of coho in 2007 and 2008 but nothing special in 2009 and 2010
- Highest catches of spring Chinook in 2008, 2009 and 2010 were average



Coho and Chinook catches in pelagic trawl surveys: June & September

Coho: black
Chinook: red

Catches of coho in September of the past two year have been rather grim

Forecasting -- since we know that juvenile salmon 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

Indicator Values

		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
PDO (December-March)		5.07	-1.75	-4.17	1.86	-1.73	7.45	1.85	2.44	1.94	-0.17	-3.06	-5.41
PDO (Sum May-September)		0.9	-5.54	-3.23	-2.95	-0.47	3.42	2.21	3.94	0.28	0.18	-6.08	-1.11
MEI Annual		0.87	-0.85	-0.51	-0.18	0.59	0.46	0.38	0.40	0.22	-0.20	-0.65	0.32
MEI Jan-June		2.28	-0.80	-0.63	-0.28	0.32	0.55	0.27	0.65	-0.42	0.49	-0.84	-0.23
SST 46050	deg C	13.70	13.14	12.54	12.56	12.30	12.92	14.59	13.43	12.60	13.88	12.5	13.02
SST NH 05 Summer	deg C	11.34	10.89	10.62	10.91	11.14	11.2	12.99	12.24	11.02	11.55	10.9	12.00
SST NH 05 Winter Before	deg C	12.11	10.52	10.26	10.31	10.01	10.81	11.32	11.07	10.92	9.96	9.03	9.63
SST NH 05 Winter After E	deg C	10.52	10.26	10.31	10.01	10.81	11.32	11.07	10.92	9.96	9.03	9.63	
Physical Spring Trans Lo	Day of Year	105	91	72	61	80	112	110	145	112	74	89	82
Upwelling Anomaly (April-May)		-14	19	-36	2	-12	-34	-27	-55	-14	9	0	-5
NH 05 Deep T	deg C	8.58	7.51	7.52	7.50	7.39	7.75	7.88	7.91	7.92	7.55	7.46	7.83
NH 05 Deep S		33.51	33.87	33.83	33.87	33.87	33.7	33.66	33.79	33.82	33.88	33.9	33.68
Length of upwelling seaso	days	191	205	208	173	218	168	178	132	194	200	180	201
Copepod richness	no. of speci	5.49	-2.46	-3.03	-0.41	-0.72	1.52	0.57	5.02	3.67	-0.39	-0.53	-0.35
Northern Copepod Bioma	log biomass	-1.97	0.084	0.717	0.486	0.834	-0.08	0.262	-1.74	0.163	0.617	0.87	0.662
Biological Transition	Day of Year	187	119	96	129	120	156	131	206	150	81	63	83
Copepod Community stru	X-axis ordir	0.726	-0.82	-0.82	-0.78	-0.98	-0.18	-0.14	0.541	0.15	-0.66	-0.96	-0.8
June-Chinook Catches	fish per km	0.26	1.27	1.04	0.44	0.85	0.63	0.42	0.13	0.69	0.86	2.55	1.00
Sept-Coho Catches	fish per km	0.11	1.12	1.27	0.47	0.98	0.29	0.07	0.03	0.16	0.15	0.27	0.01

1998, 2003-2005 = warm & unproductive; poor salmon returns
1999-2002 and 2008 = cold & productive; record returns
2010 = a mixed bag—poor early, great late!

Environmental Variables	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
PDO (December-March)	12	4	2	8	5	13	7	11	9	6	3	1	11
PDO (May-September)	10	2	4	5	7	12	11	13	9	8	1	6	3
MEI Annual	13	1	3	5	12	1	9	10	7	4	2	8	6
MEI Jan-June	13	2	3	4	9	10	7	11	5	8	1	6	12
SST at 46050 (May-Sept)	11	8	3	4	1	7	13	10	5	12	2	9	6
SST at NH 05 (May-Sept)	8	4	1	6	2	5	13	10	7	12	3	11	9
SST winter before (Nov-Mar)	13	10	3	5	6	9	11	8	7	2	1	4	12
Physical Spring Trans (UI Based)	3	6	12	11	4	8	10	13	8	1	5	2	7
Upwelling Anomaly (Apr-May)	7	1	12	3	6	10	9	13	7	2	4	5	11
Length of upwelling season (UI Bas	6	2	12	9	1	10	8	13	5	3	7	3	11
Deep Temperature at NH 05	13	4	6	3	1	9	10	11	12	5	2	8	7
Deep Salinity at NH05	13	3	6	2	5	11	12	8	7	1	4	9	10
Copepod richness	13	2	1	5	3	9	8	12	10	6	4	7	11
N.Copepod Anomaly	12	9	3	6	5	10	4	12	9	7	2	6	3
Biological Transition	13	7	5	3	6	11	9	12	10	4	1	2	8
Copepod Community structure	13	3	4	6	1	8	10	12	11	7	2	5	8
Catches of salmon in surveys													
June-Chinook Catches	12	2	3	10	7	9	11	13	8	6	1	4	5
Sept-Coho Catches	9	2	1	4	3	5	10	12	7	8	6	13	11
Mean of Ranks of Environmental Da	10.8	4.0	4.7	5.5	4.7	8.7	9.6	11.3	7.9	5.7	2.8	6.1	8.4
RANK of the mean rank	12	2	4	5	3	10	11	13	8	6	1	7	9

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)
- NOAA Stock Assessment Improvement Program (SAIP)
- Fisheries and the Environment (FATE-NOAA)
- National Science Foundation
- Office of Naval Research
- NASA

- See www.nwfsc.noaa.gov, "Ocean Conditions and Salmon Forecasting"

Future directions of our Ocean Indicators

John Ferguson
NOAA Fisheries
Northwest Fisheries Science Center
Seattle, Washington

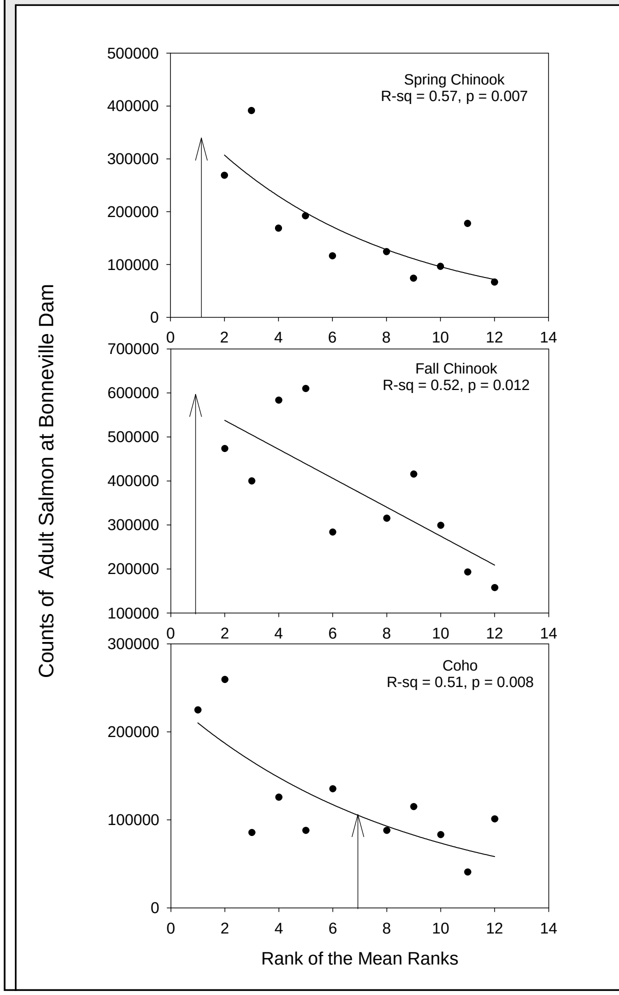
4 Points….

- Two new "composite indices": a simple one and an enhanced statistical analyses of the indicators – Brian Burke, PhD candidate

- Is variability of the California Current Large Marine Ecosystem increasing?

- NOAA's new fishery survey ships – how to best use them

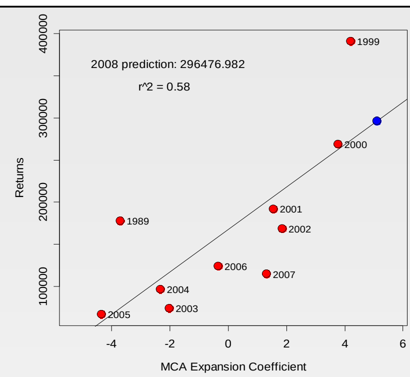
- Proposal: A coast-wide juvenile salmon recruitment initiative to NOAA Fisheries



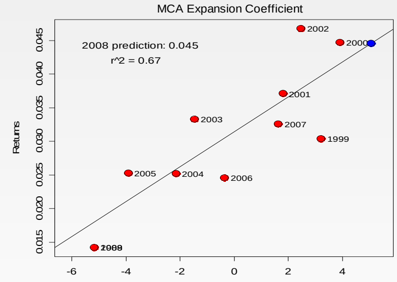
A simple approach to forecasting

Regression of salmon counts at Bonneville Dam with the rank of all variables. Arrows indicate forecast for 2010:

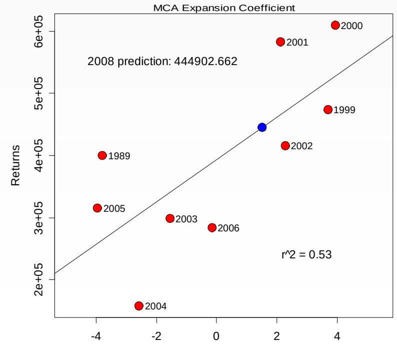
- Spring Chinook (2008 ocean entry): 278K returned in 2010, forecast was ~ 350K
- Fall Chinook (2008 ocean entry): 467K returned in 2010; forecast was ~ 550K.
- Of the coho that went to sea in 2009, 121K returned in 2010; forecast was 110K.
- Of the coho that went to sea in 2008, 225 K; forecast was 210K.



Spring Chinook Salmon



Coho Salmon

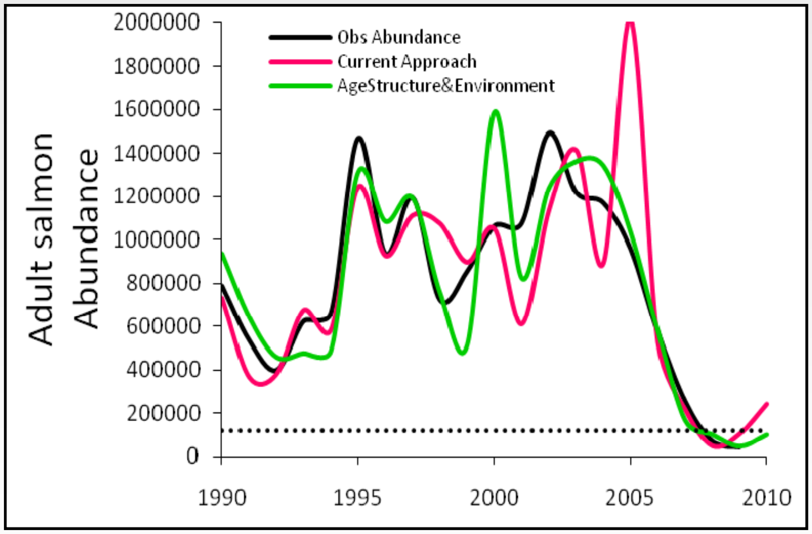


Fall Chinook Salmon

- Goal: Develop quantitative relationships between the suite of indicators and adult returns
- Using maximum covariance and partial least squares analysis
- Indicators are weighted relative to their contribution to explain the relationship
- Spring Chinook 2010:
  - TAC Forecast: 470,000
  - Index Prediction: 289,000
  - Bonneville Dam Count was 278K (through mid-June).

Central Valley Chinook Salmon Productivity and Ocean Conditions (Brian Wells, Santa Cruz Lab, SWFSC)

Abundance
(adults:
catch + escapement)

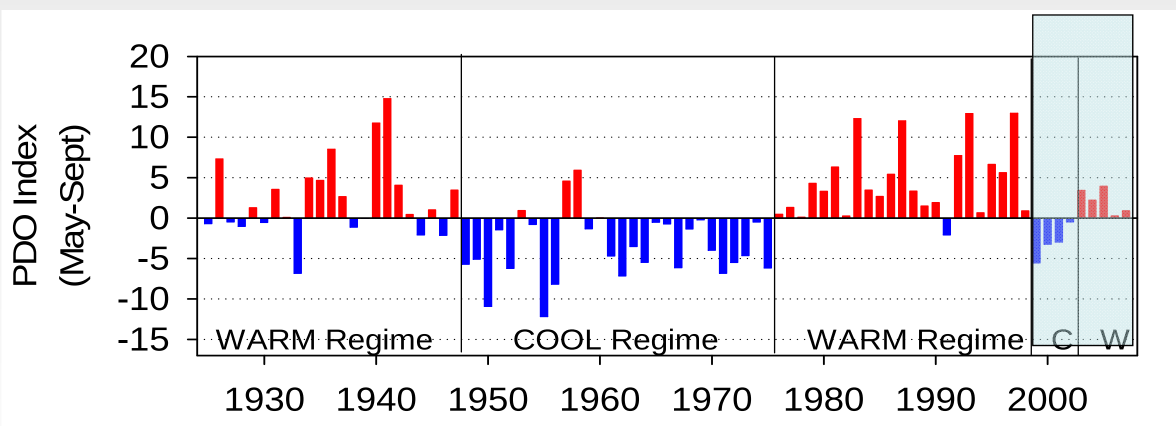


Adult Salmon Abundance = [# jacks $_{(y-1)}$ + # jacks $_{(y-2)}$] + oceanographic variables $_{(y-1)}$ **$r^2 = 0.93$**

Oceanographic variables: upwelling, sea level height, wind structure (curl), and sea surface temperature

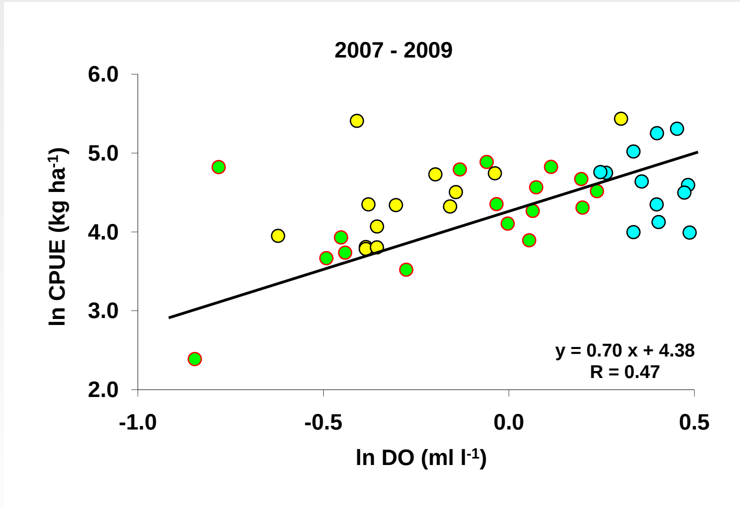
Is CCLME variability increasing? 3 examples: 1) PDO (temp)

PDO: May-Sep Average, 1925-2007



- We have had two shifts of four years duration recently: 1999-2002 and 2003-2006. Is this what the future holds?

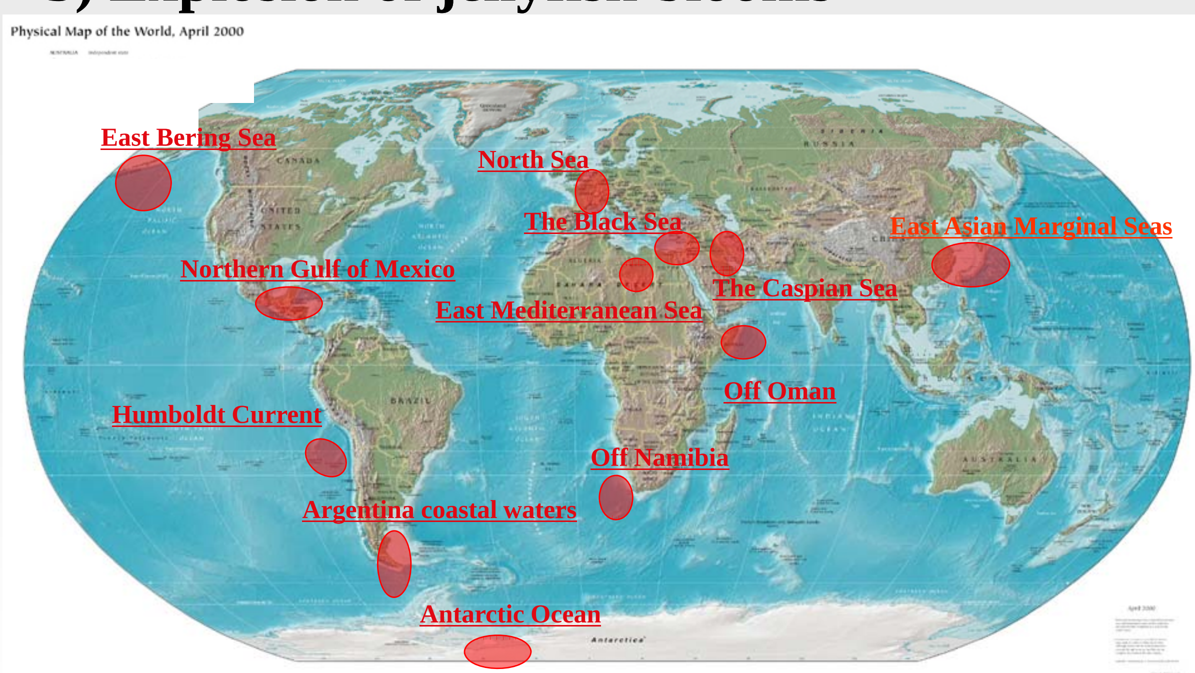
2) Hypoxia: West Coast Groundfish surveys Total CPUE versus average bottom dissolved oxygen



CPUE (kg ha^{-1}) = Catch (kg) /Area Swept (ha)

Main point: Catch (and # species) increased as DO increased

3) Explosion of jellyfish blooms



Jellyfish blooms have increased in many coastal areas of the world's ocean in the last decade but impacts on WA and OR are unclear.

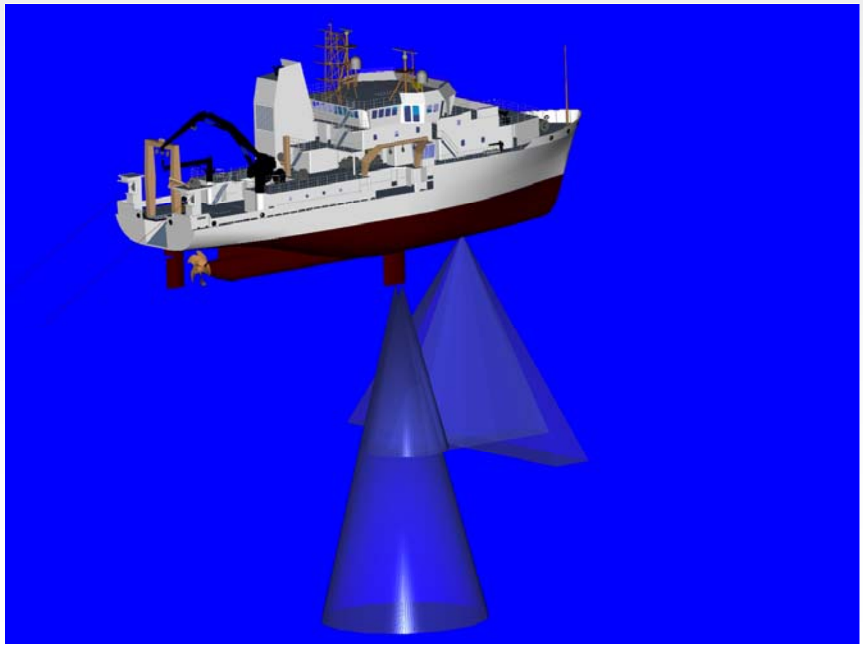
NWFSC salmon survey tow off Oregon

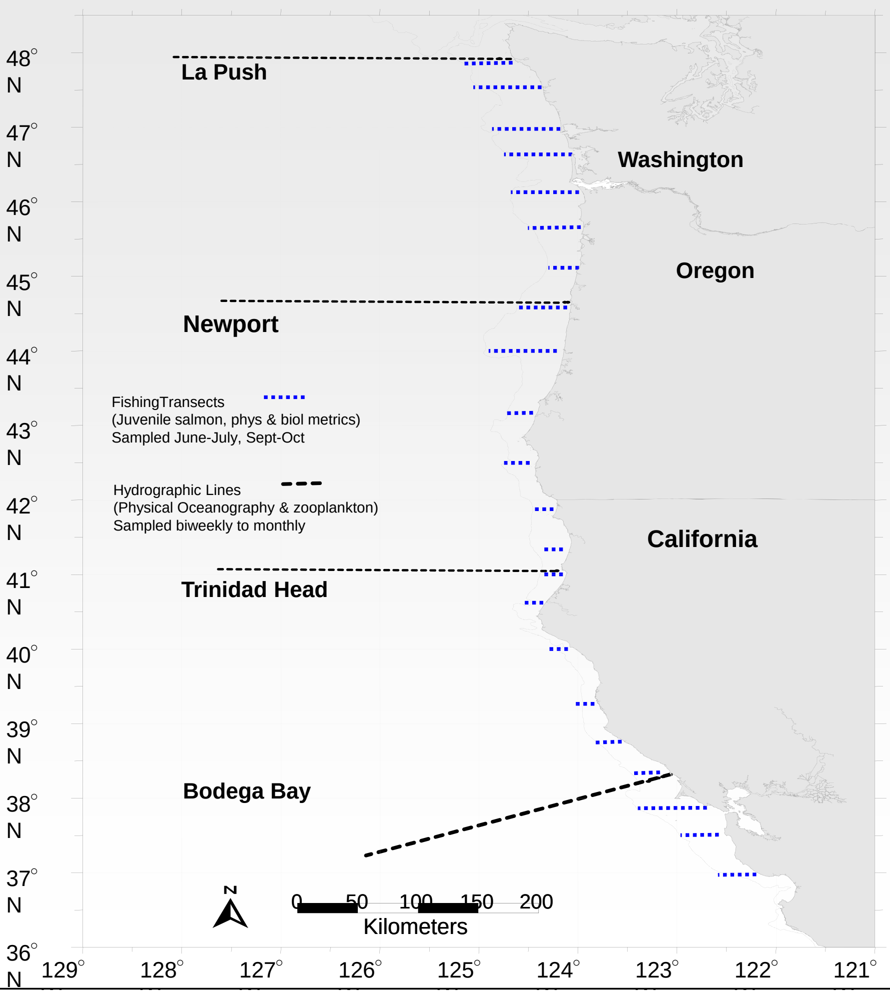
We do occasionally catch massive quantities of jellyfish during September of some years

Two new research ships:
FS/V Bell M/ Shimada – Newport
FS/V #6 – Newport in 2013

Underway Mapping of Fish and Habitat

MS 70 and EK 60 echo sounders



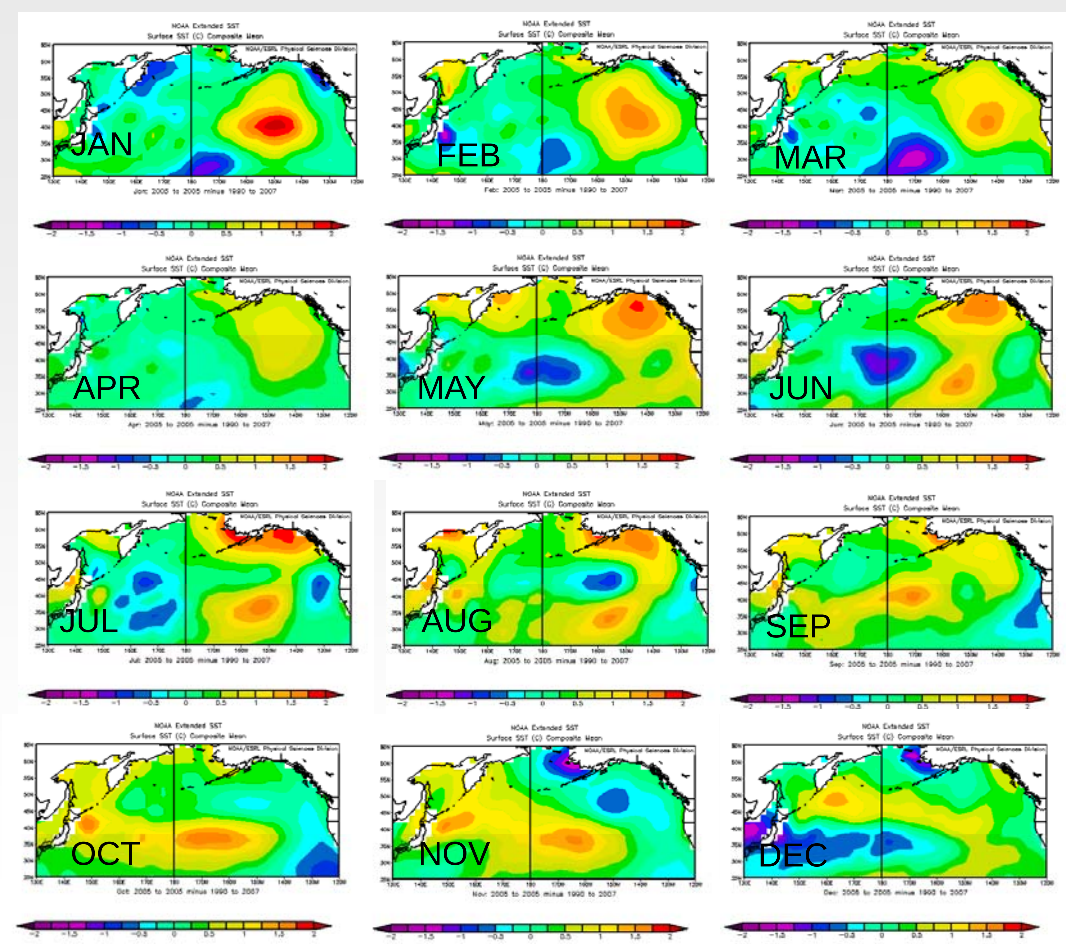


Proposal:

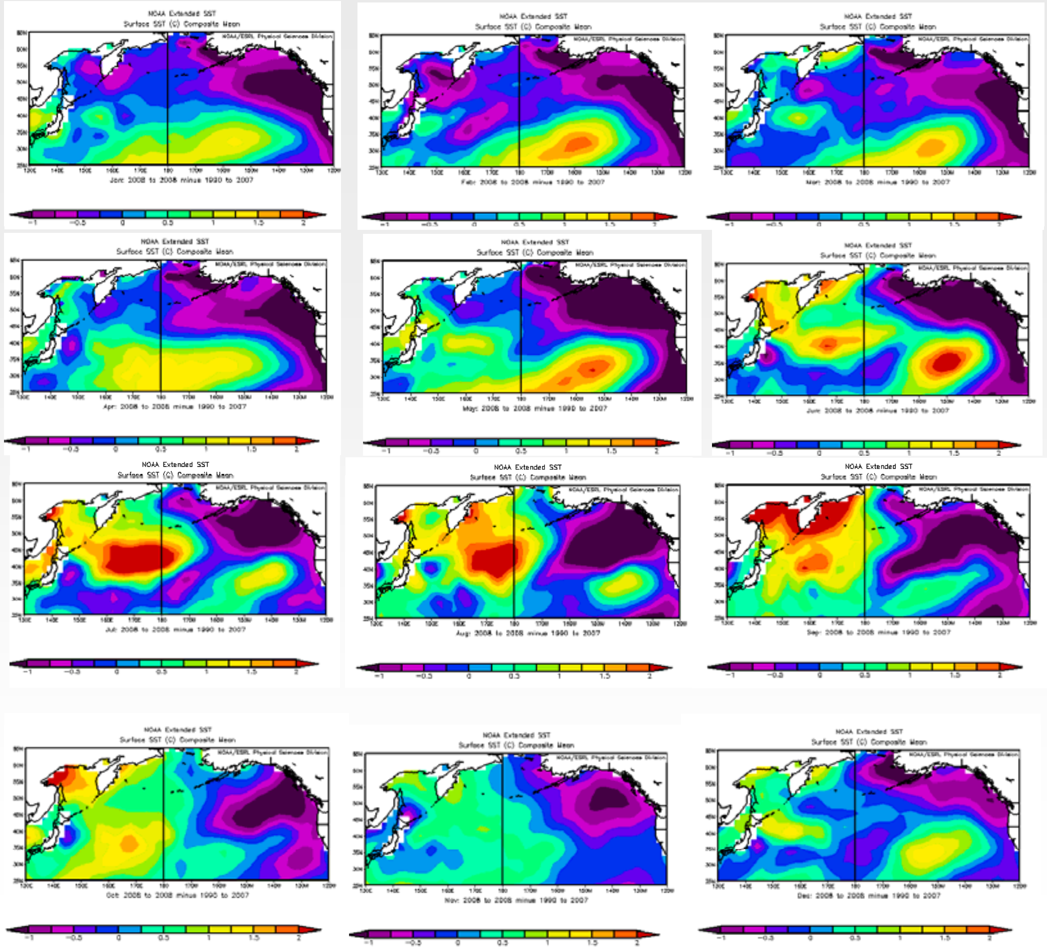
- Coast-wide survey starting in FY13
- $3 M/year
- Integrated with BPA plume studies

PDO and SST
Two Recent and Contrasting Years

- 2005. The year that resulted in collapse of the Sacramento Fall Chinook run.
- 2008. The year that resulted in near-record returns of spring and fall Chinook, coho, steelhead and sockeye to the Columbia and other rivers of the Pacific Northwest this year (2010).

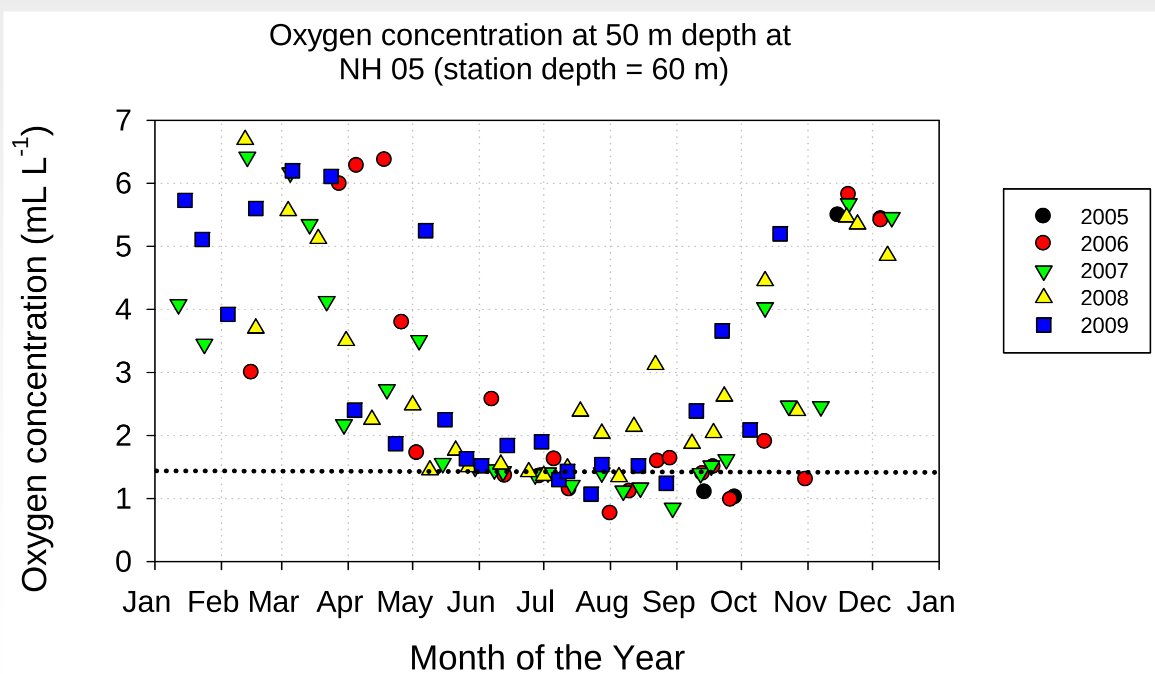


2005



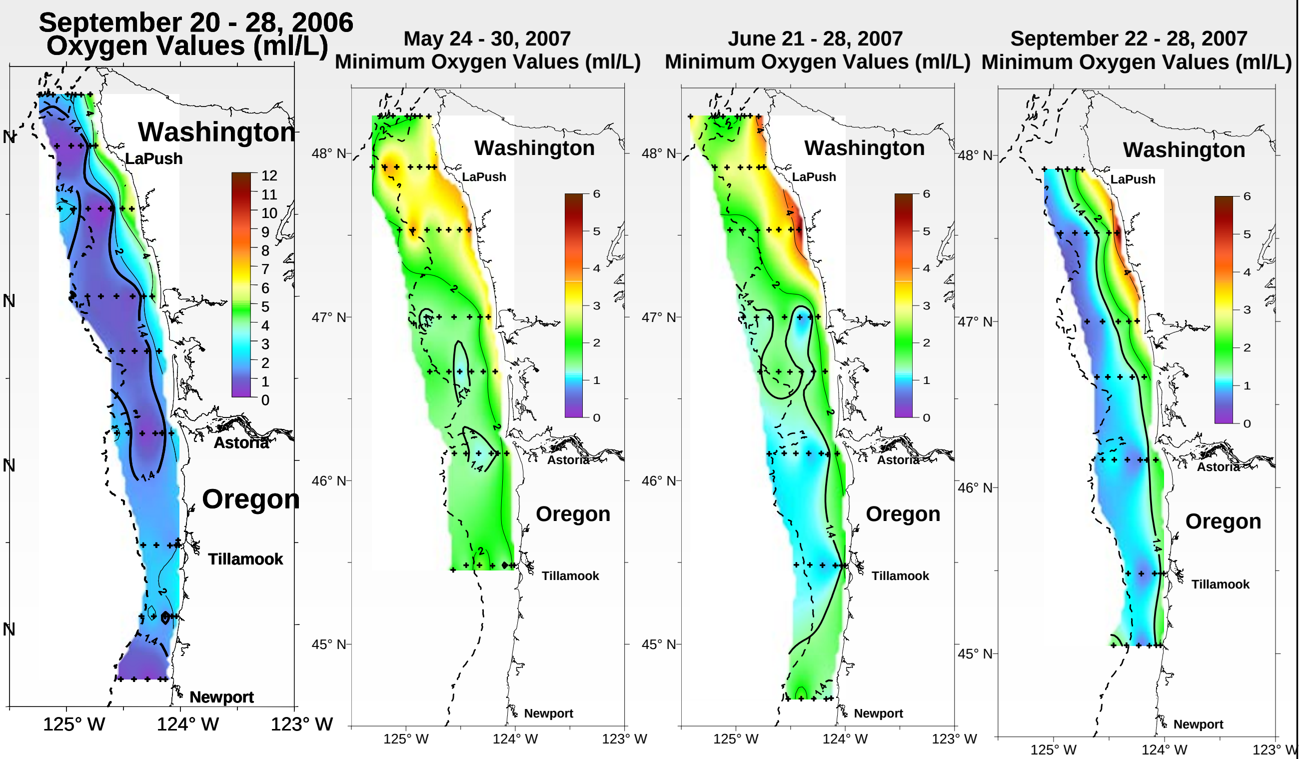
2008

Oxygen concentrations at a mid-shelf station off Newport



Area of hypoxia during summer 2006 equaled that of the Gulf of Mexico

Hypoxia off WA and OR May, June, Sept 2007



Hypoxia off WA and OR May, June, Sept 2008