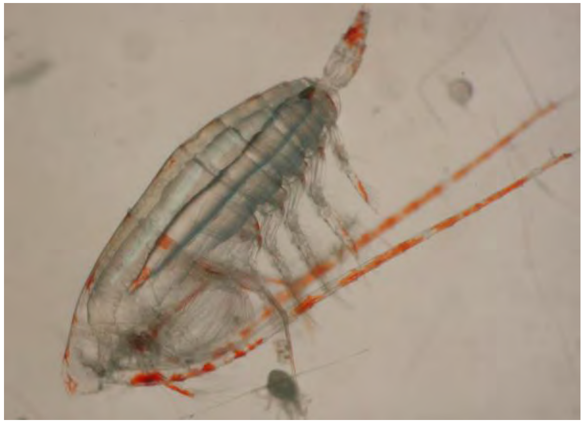
Challenges in communicating science and engaging the public – a case study from the northern California Current

Bill Peterson, Senior Scientist
NOAA-Fisheries
Northwest Fisheries Science Center
Hatfield Marine Science Center
Newport OR



Forecasting and the use of ecosystem data in fisheries management

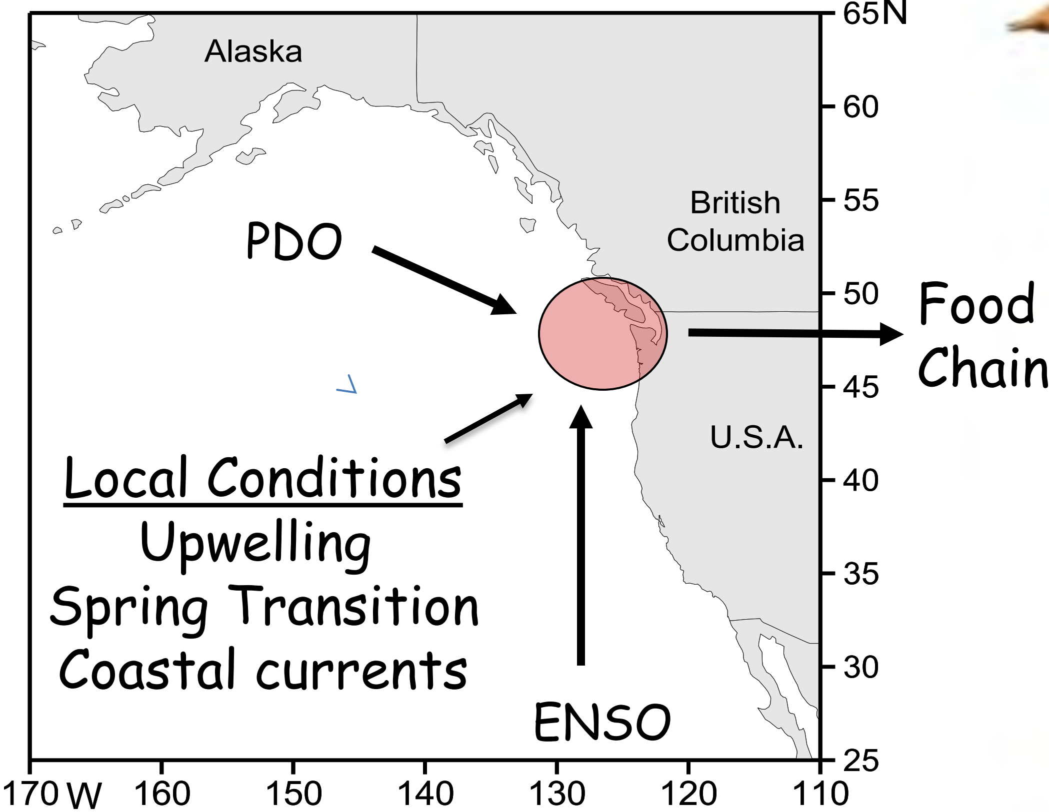
- First exposed to these concepts in 1987 during a two-year posting at the University of Cape Town, during the Benguela Ecology Programme.
- Management of anchovies and sardines (chiefly) with an eye towards maximizing catch as well as leaving enough biomass for the predatory fish, birds and mammals
- Providing the industry with outlooks of future potential catch with sufficient lead time to allow industry to adjust their fishing effort (to build more boats or reduce effort) without undue economic hardship
- Weekly seminars attended by oceanographers, stock assessors and industry representatives.

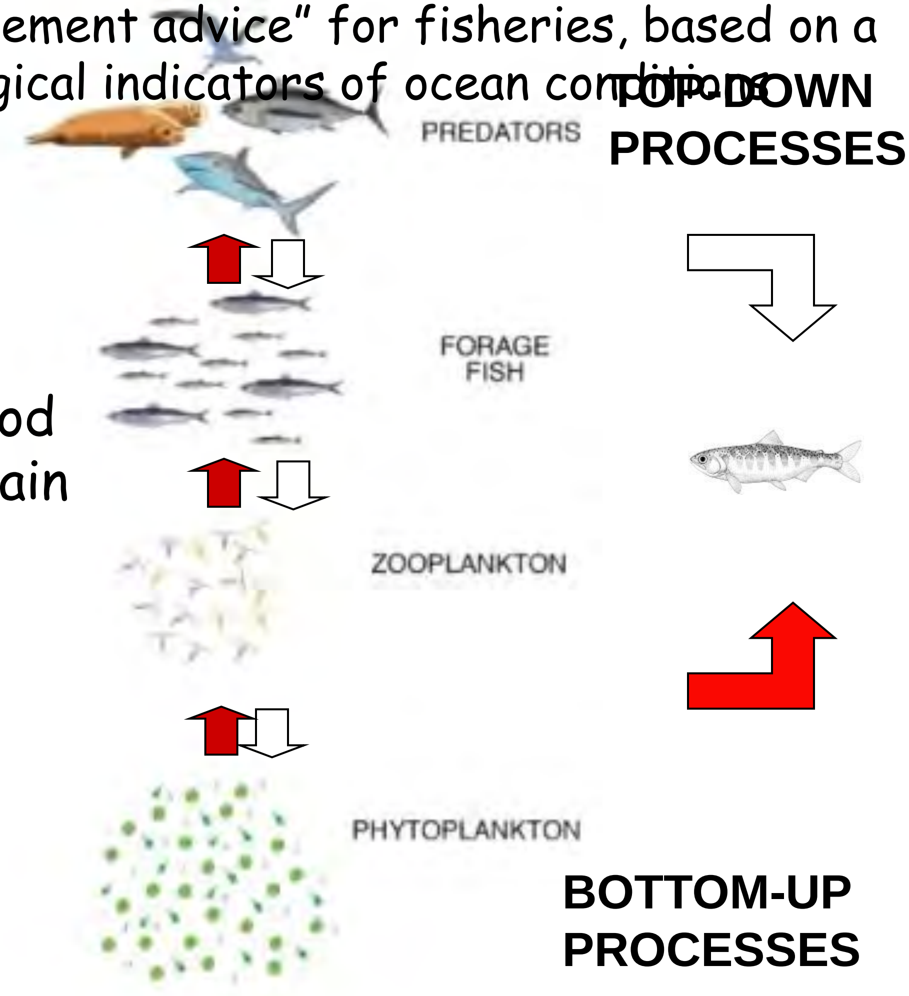
FUTURE has three Advisory Panels

- Today I will speak about the three pillars of "SOFE" (Status, Outlooks and Engagement) related to providing "management advice" concerning how many salmon will return to the Columbia River to spawn (some of which are harvested
  - Status
  - Outlooks
  - Engagement

Large scale forces acting at the local scale can influence biological process important for fishes such as salmon, sardines, and sablefish

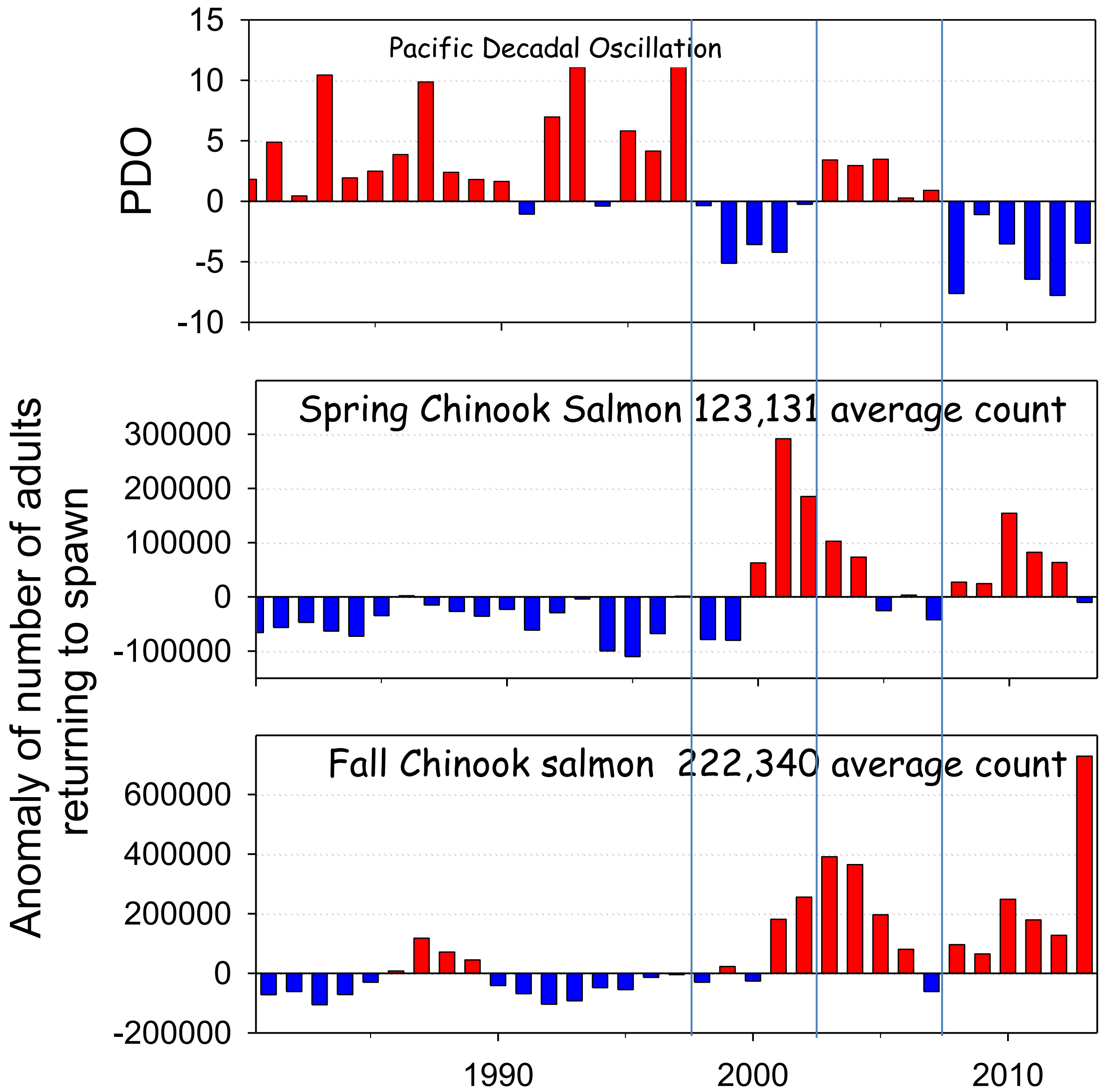
We are contributing to a general understanding of the pelagic ecosystem of the northern California Current through our long-term ocean observations program which is resulting in "outlooks" and "management advice" for fisheries, based on a suite of physical, biological and ecological indicators of ocean conditions





Local Biological Conditions:
The Food Chain

1. Status: the PDO and Chinook Salmon



Chinook salmon respond to the PDO with a 2 year lag (spring) and 3 year lag (fall Chinook).

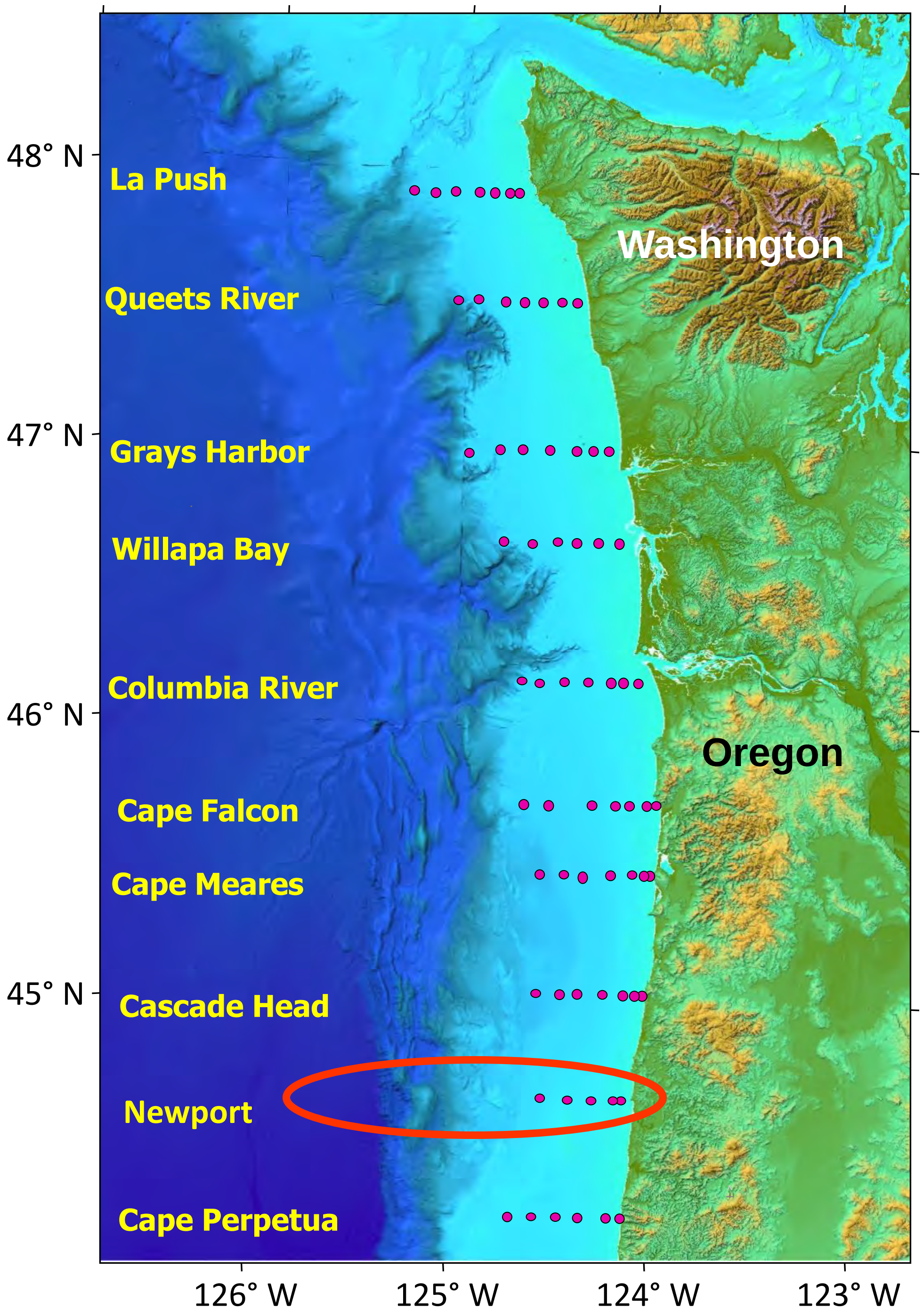
Juvenile Spring Chinook migrate northward along the coastal corridor to the Gulf of Alaska; Fall Chinook live locally, in the NCC.

Mortality high in first few weeks

We know from past research (in part by Mantua and others) that changes in the sign of the PDO (a basin scale indicator) translate into changes in salmon returns (a local response) throughout the North Pacific

But what mechanism(s) link the forces that give us the PDO with salmon production?

I will show that the PDO seems to control pelagic food chain structure as indexed by copepod species composition



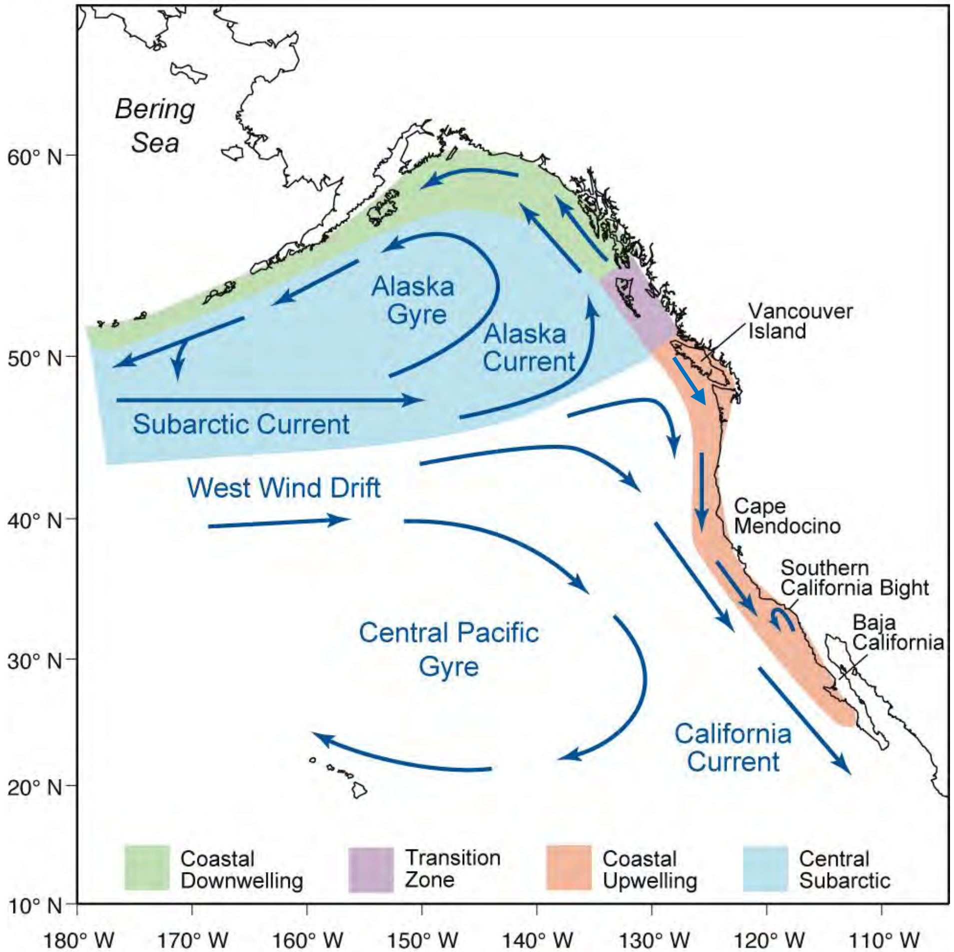
Observations

- Juvenile salmon sampling in May, June and September 1998-2013 (16 years)

- Newport Line: biweekly sampling since 1996 of hydrography, zooplankton, ichthyoplankton and krill (now in its 19th year)

- Historical data:
  hydrography, 1960s;
  zooplankton, 1969-1973;
  1983 (Charlie Miller),
  juvenile salmon, 1981-1985 (Bill Pearcy)

Basin-scale circulation in the northeast Pacific affects food chain structure



Transport is a key part of our results and is important for three reasons:

1. Subarctic Coastal Currents bring cold water and **"northern" copepod** species to the N. California Current;

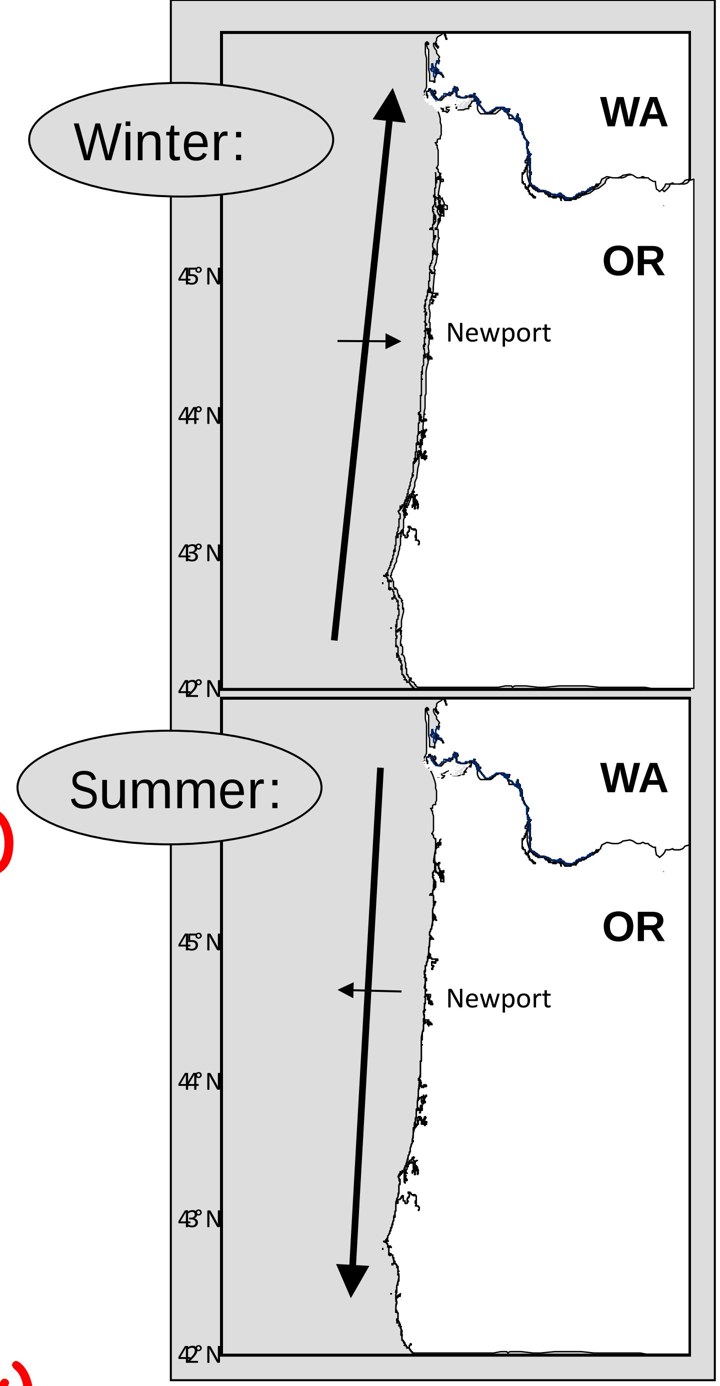
2. The West Wind Drift, a weak CC and reversals in coastal currents bring subtropical water and **subtropical "southern" copepod** species to the NCC

3. Therefore, food chain structure is affected by the source waters which feed the California Current.

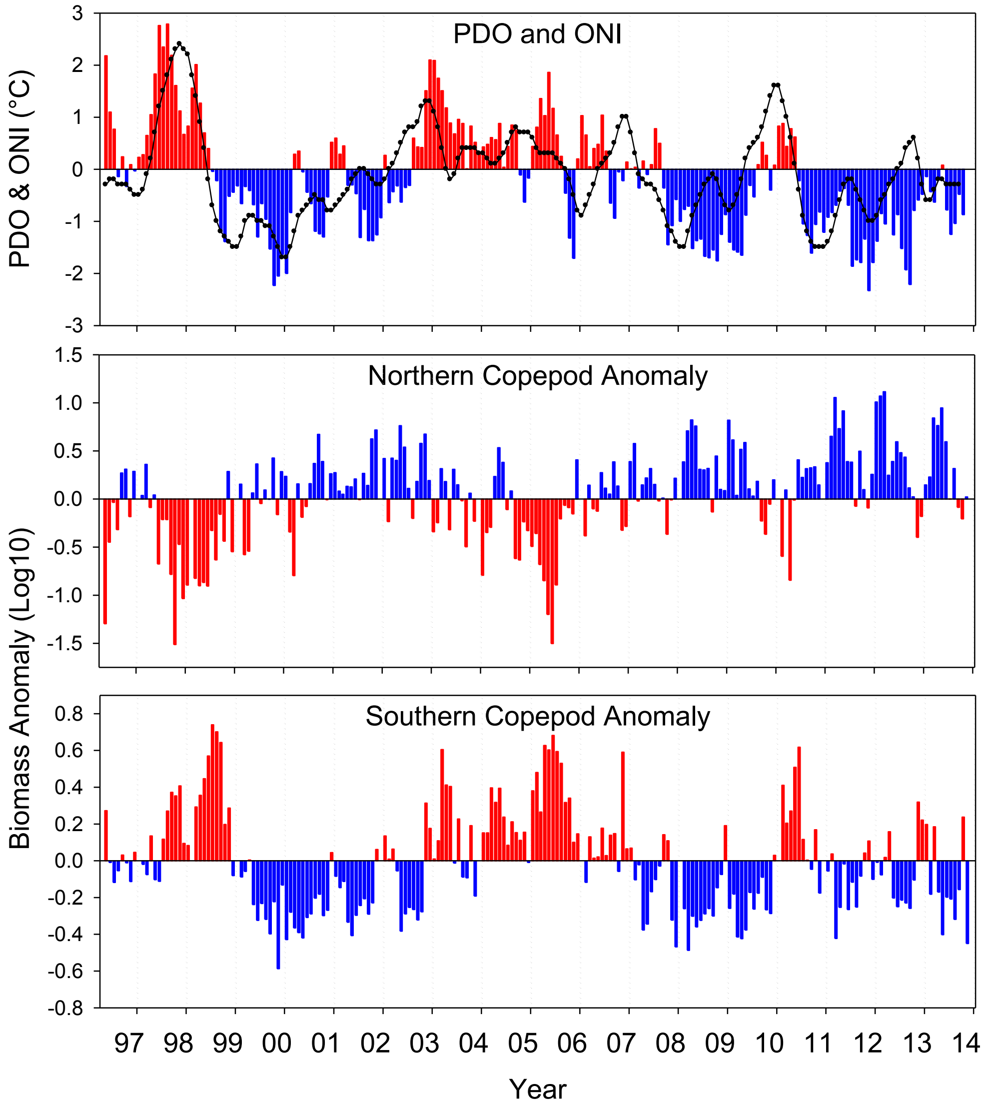
Local seasonal changes in winds and current structure also affect local food chain structure in the Oregon upwelling zone:

- Winter:
  - Winds from the South cause downwelling
  - Poleward-flowing Davidson Current
  - Subtropical and **southern species** transported northward & onshore
- **Spring Transition in April (usually)**

- Summer:
  - Strong winds from the north cause coastal upwelling
  - Equatorward alongshore transport
  - **Northern species** transported southward
- **Fall Transition in October (usually)**



PDO and Copepod Groups



- Anomalously high biomass of "southern copepod species" under three conditions:
  - when PDO is in positive phase;
  - During strong El Niño events:1997-1998 and 2009-10
  - During weak El Niño events of 03-06
  - During the non-event in 2012
- Anomalously high biomass of "northern" copepod species under conditions opposite to 'southerns'.

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)

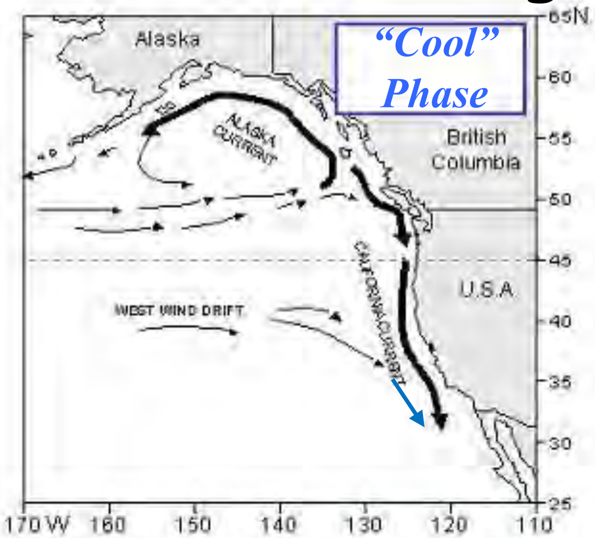
Comparisons of copepods by size and chemical composition

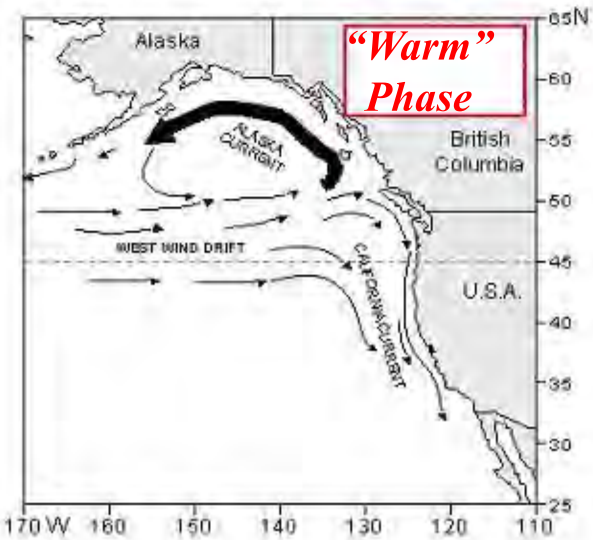
- **Warm-water subtropical taxa** - (from offshore OR and S. California) are **small** in size and have minimal high energy wax ester lipid depots
- **Cold-water taxa** – (boreal coastal species) are **large** and store high-energy **wax esters** as an over-wintering strategy

Therefore, significantly different food chains result from climate shifts

A fat salmon is a happy salmon

Dramatic changes in pelagic food webs occur with changes in phase of the PDO





1. "Cool Phase". Strong subarctic coastal currents bring cold water and large **lipid-rich copepod** species to the N. Calif. Current (NCC);

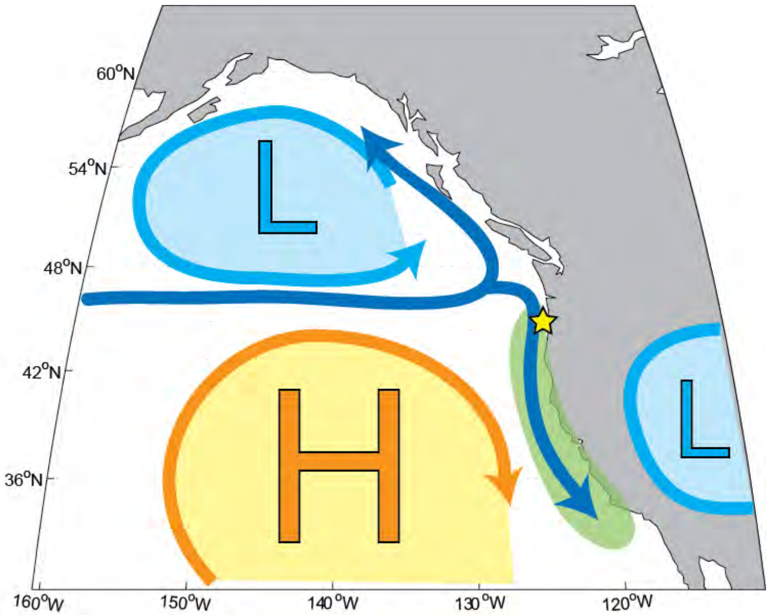
2. "Warm Phase". The West Wind Drift and seasonal reversals in coastal currents bring subtropical water and **small lipid-poor subtropical copepod** species to the NCC

3. Therefore, bioenergetic content of the food chain is controlled by the source waters which feed the NCC.

Cartoon from Ryan Rykaczewski

Cool Coastal Phase:

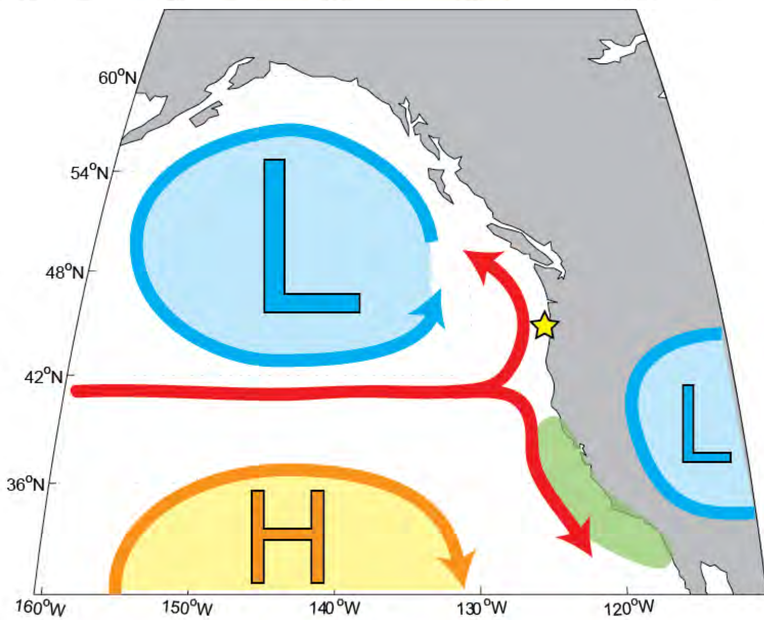
Weaker Aleutian low pressure; but **more southerly flow** along the coast; rich, boreal zooplankton at Newport



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

The importance of alongshore transport to zooplankton was first noted years ago: Chelton and Davis (1982) JPO Chelton, Bernal and McGowan (1982) JMR; Anne Hollowed picked up on this too….

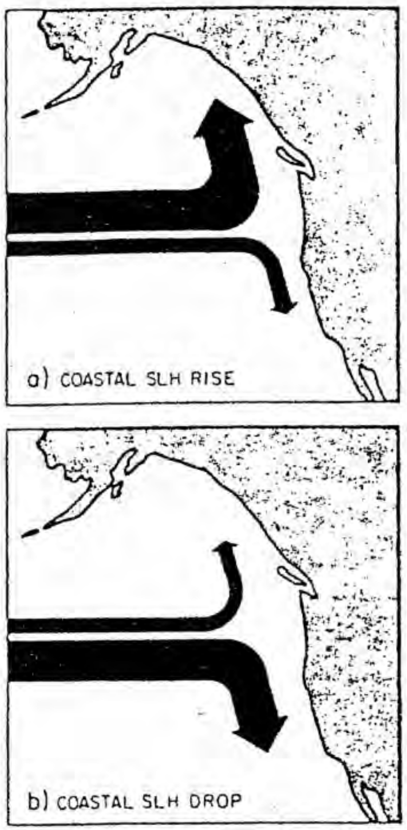


FIG. 8. Schematic picture of the eastern Pacific bifurcation of the West Wind Drift suggested by the first EOF of anomalous SLH. Positive SLH anomalies correspond to (a) and negative SLH anomalies to (b).

2. Outlooks – produced using the following variables because each is significantly correlated with salmon returns

- Basin scale physical indicators
  - PDO, ENSO (ONI)
- Local scale physical indicators
  - SST, T of upper 20 m in shelf waters, temperature and salinity of deep water which will upwell
- Local biological indicators
  - Copepod biodiversity
  - Northern copepod biomass
  - Southern copepod biomass
  - Date of biological spring transition
  - Composition of fish larvae in winter before salmon enter the sea
  - Catches of spring Chinook in June
  - Catches of coho in September
- Not used because of low information content
  - Upwelling, date of physical spring transition, length of upwelling season

DATA MATRIX

INDICATORS 1998 ← YEAR → 2013

Ecosystem Indicators	*units*	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
PDO (Sum Dec-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	2.17	-3.65	-5.07	-1.67
PDO (Sum May-September)		-0.37	-5.13	-3.58	-4.22	-0.26	3.42	2.96	3.48	0.28	0.91	-7.63	-1.11	-3.53	-6.45	-7.79	-3.47
ONI Jan-June (Average)		1.08	-1.10	-1.13	-0.42	0.23	0.33	0.20	0.37	-0.38	0.02	-1.05	-0.27	0.70	-0.77	-0.42	-0.38
46050 SST (May-Sept)	deg C	13.66	13.00	12.54	12.56	12.30	12.92	14.59	13.56	12.77	13.87	12.39	13.02	12.92	13.06	13.26	13.37
NH 05 Upper 20 m T winter prior (Nov-Mar)	deg C	12.27	10.31	10.12	10.22	10.08	10.70	10.85	10.60	10.61	10.04	9.33	10.19	11.01	10.02	9.62	10.09
NH 05 Upper 20 m T (May-Sept)	deg C	10.38	10.13	10.19	9.77	8.98	9.62	11.39	10.73	9.97	9.99	9.30	9.90	10.14	10.05	9.95	10.63
NH 05 Deep Temperature	deg C	8.61	7.63	7.74	7.56	7.45	7.81	7.89	7.97	7.83	7.58	7.48	7.73	7.89	7.86	7.56	8.30
NH 05 Deep Salinity		33.54	33.86	33.78	33.86	33.85	33.68	33.66	33.77	33.85	33.88	33.87	33.72	33.61	33.74	33.75	33.70
Copepod Richness Anomaly (May-Sept)	no. of species	4.37	-2.83	-3.61	-1.28	-1.35	1.67	1.24	4.14	2.47	-0.88	-1.01	-0.89	2.87	-2.38	-1.53	-3.16
N. Copepod Biomass Anomaly (May-Sept)	log mg C m^{-3}	-0.58	0.09	0.19	0.15	0.28	-0.08	0.05	-0.77	0.14	0.14	0.31	0.14	0.25	0.42	0.40	0.35
S. Copepod Biomass Anomaly (May-Sept)	log mg C m^{-3}	0.62	-0.30	-0.28	-0.29	-0.30	0.09	0.22	0.55	0.10	-0.10	-0.31	-0.22	0.24	-0.15	-0.23	-0.26
Biological Transition	day of year	263	134	97	79	108	156	132	238	180	81	64	65	169	82	125	91
Winter Ichthyoplankton	log mg C 1000 m^{-3}	0.12	0.90	1.80	1.25	1.05	0.53	0.58	0.83	0.59	0.60	1.84	0.89	1.65	0.61	0.99	1.16
Chinook Juv Catches (June)	fish per km	0.26	1.27	1.04	0.44	0.85	0.63	0.42	0.13	0.69	0.86	2.56	0.97	0.89	0.46	1.32	1.38
Coho Juv Catches (Sept)	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	0.03	0.30	0.13	NA
Ecosystem Indicators not included in the mean of ranks or statistical analyses																	
Physical Spring Trans UI Based	day of year	83	88	134	120	84	109	113	142	109	70	87	82	95	105	123	97
Upwelling Anomaly (April-May)		-14	19	-36	2	-12	-34	-27	-55	-14	9	0	-5	-35	-36	-35	-21
Length of Upwelling Season (UI Based)	days	191	205	151	173	218	168	177	129	195	201	179	201	161	153	161	164
NH 05 SST (May-Sept)	deg C	11.39	11.09	11.06	11.03	10.12	10.78	13.23	12.11	11.26	11.90	10.78	12.14	11.32	11.15	11.73	11.95
Copepod Community structure	x-axis ordination	0.71	-0.76	-0.75	-0.73	-0.91	-0.17	-0.14	0.53	0.01	-0.62	-0.83	-0.73	-0.19	-0.64	-0.72	-0.79

Seven Physical Indicators

- PDO (Dec-March
- PDO (May-Sept
- ONI (Jan-June)
- SST (NOAA Buoy, 22 miles offshore
- SST (upper 20 m average, mid-shelf
- T of deep water that will upwell
- S of deep water that will upwell

Seven Biological Indicators

- Copepod species richness
- Northern (cold water) copepod anomaly
- Southern (warm water) copepod anomaly
- Biological transition
- Winter ichthyoplankton biomass
- Catch of juv. chinook salmon in June
- Catch of juv. coho salmon salmon in Sep

Ecosystem Indicators	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
PDO (December-March)	15	6	3	11	7	16	10	14	12	9	5	1	13	4	2	8
PDO (May-September)	10	4	6	5	11	15	14	16	12	13	2	9	7	3	1	8
ONI Jan-June	16	2	1	5	12	13	11	14	7	10	3	9	15	4	5	7
46050 SST (May-Sept)	14	8	3	4	1	7	16	13	5	15	2	9	6	10	11	12
NH 05 Upper 20 m T winter prior (Nov-Mar)	16	10	7	9	5	13	14	11	12	4	1	8	15	3	2	6
NH 05 Upper 20 m T (May-Sept)	13	10	12	4	1	3	16	15	7	8	2	5	11	9	6	14
NH 05 Deep Temperature	16	6	8	4	1	9	12	14	10	5	2	7	13	11	3	15
NH 05 Deep Salinity	16	3	7	4	5	13	14	8	6	1	2	11	15	10	9	12
Copepod Richness Anomaly	16	3	1	7	6	12	11	15	13	10	8	9	14	4	5	2
N. Copepod Biomass Anomaly	15	12	7	8	5	14	13	16	9	11	4	10	6	1	2	3
S. Copepod Biomass Anomaly	16	3	5	4	2	11	13	15	12	10	1	8	14	9	7	6
Biological Transition	16	11	7	3	8	12	10	15	14	4	1	2	13	5	9	6
Winter Ichthyoplankton	16	8	2	4	6	15	14	10	13	12	1	9	3	11	7	5
Chinook Juv Catches (June)	15	4	5	13	9	11	14	16	10	8	1	6	7	12	3	2
Coho Juv Catches (Sept)	11	2	1	4	3	6	12	14	8	9	7	15	13	5	10	NA
Mean of Ranks	14.7	6.1	5.0	5.9	5.5	11.3	12.9	13.7	10.0	8.6	2.8	7.9	11.0	6.7	5.5	7.6
RANK of the Mean Rank	16	6	2	5	3	13	14	15	11	10	1	9	12	7	3	8
Principle Component Scores (PC1)	6.58	-2.18	-2.93	-1.56	-2.07	2.19	3.11	4.28	1.00	-0.24	-4.41	-0.96	1.67	-1.40	-2.07	-1.01
Principle Component Scores (PC2)	0.04	0.21	0.42	-1.04	-2.20	-1.73	2.24	-0.73	-1.18	0.15	-0.78	0.58	-0.35	1.24	0.96	2.16
Ecosystem Indicators not included in the mean of ranks or statistical analyses																
Physical Spring Trans (UI Based)	3	6	15	13	4	10	12	16	10	1	5	2	7	9	14	8
Upwelling Anomaly (Apr-May)	7	1	14	3	6	11	10	16	7	2	4	5	12	14	12	9
Length of Upwelling Season (UI Based)	6	2	15	9	1	10	8	16	5	3	7	3	12	14	12	11
NH 05 SST (May-Sept)	10	6	5	4	1	3	16	14	8	12	2	15	9	7	11	13
Copepod Community Structure	16	4	5	7	1	12	13	15	14	10	2	6	11	9	8	3

PHYSICS SUGGESTS AN AVERAGE YEAR

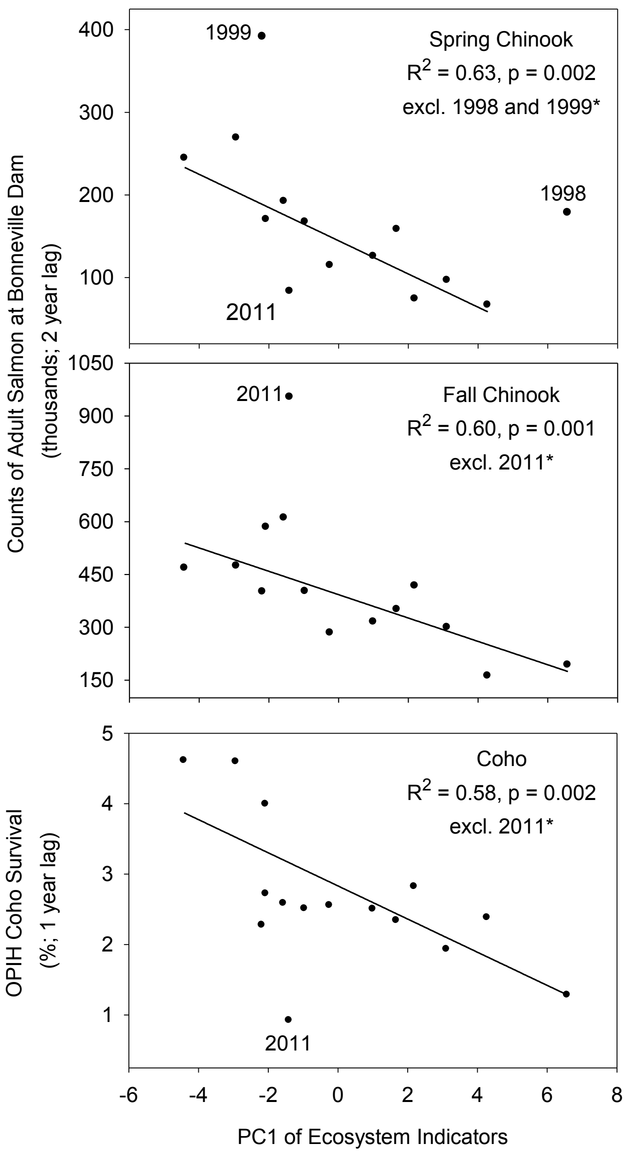
PDO 8th rank both winter and summer
Winter SST 6th coldest
Spring Transition 8th
Length of upwelling season 11th

BIOLOGY SUGGESTS A VERY GOOD YEAR

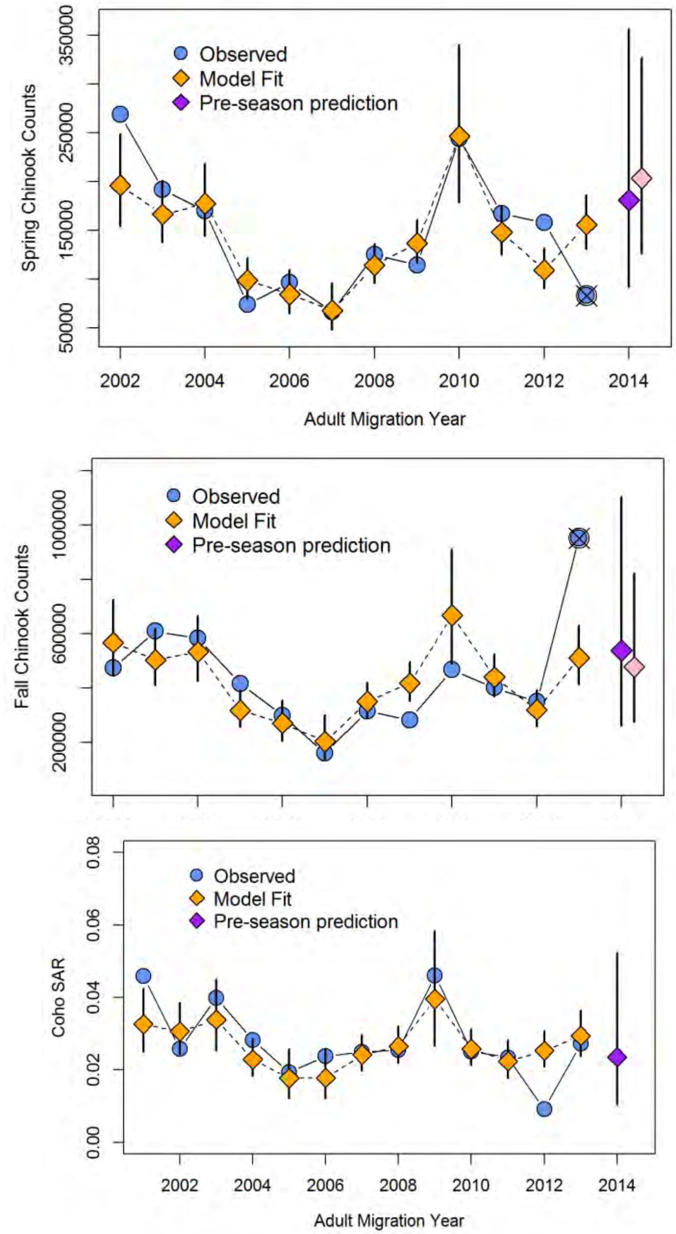
Northern Copepods 3rd highest
Copepod Community Index 3rd highest
Winter Ichthyoplankton 5th ranked
Catches of spring Chinook in June 2nd highest

PC 1 = -1.01, 8th ranked

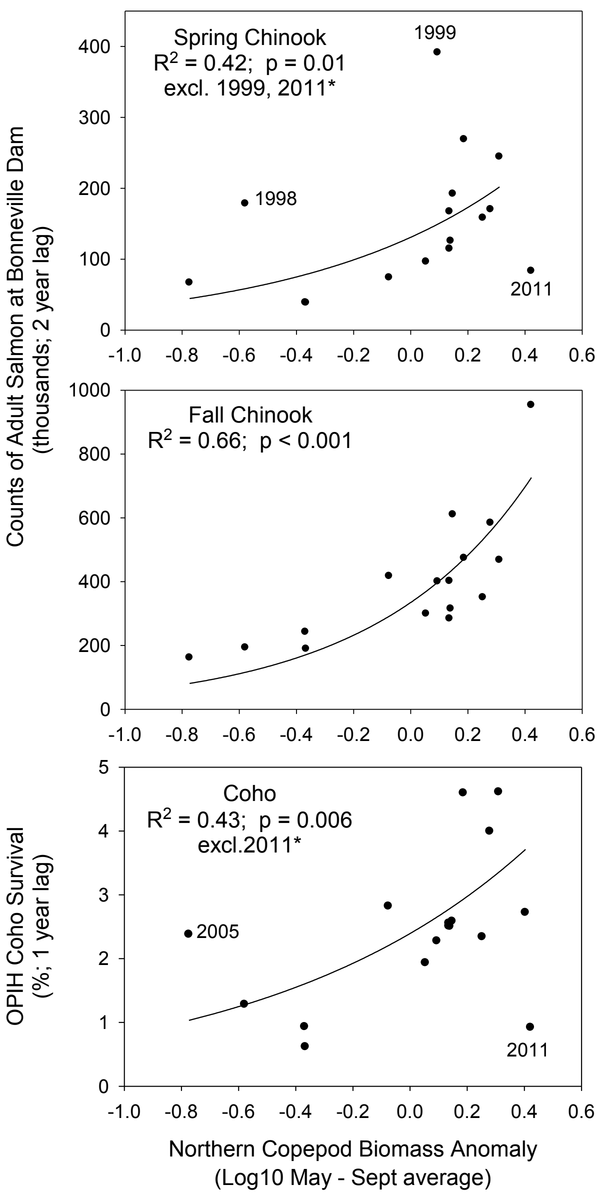
Principal Components Analysis

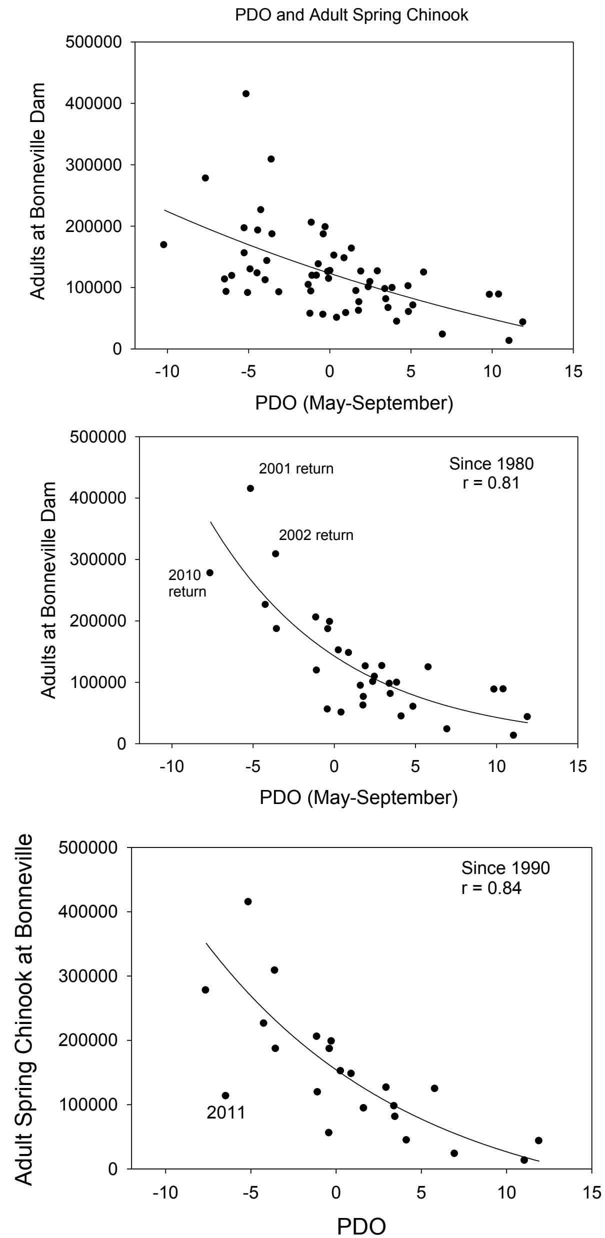


Maximum Covariance Analysis



Northern Copepods, PDO and salmon returns

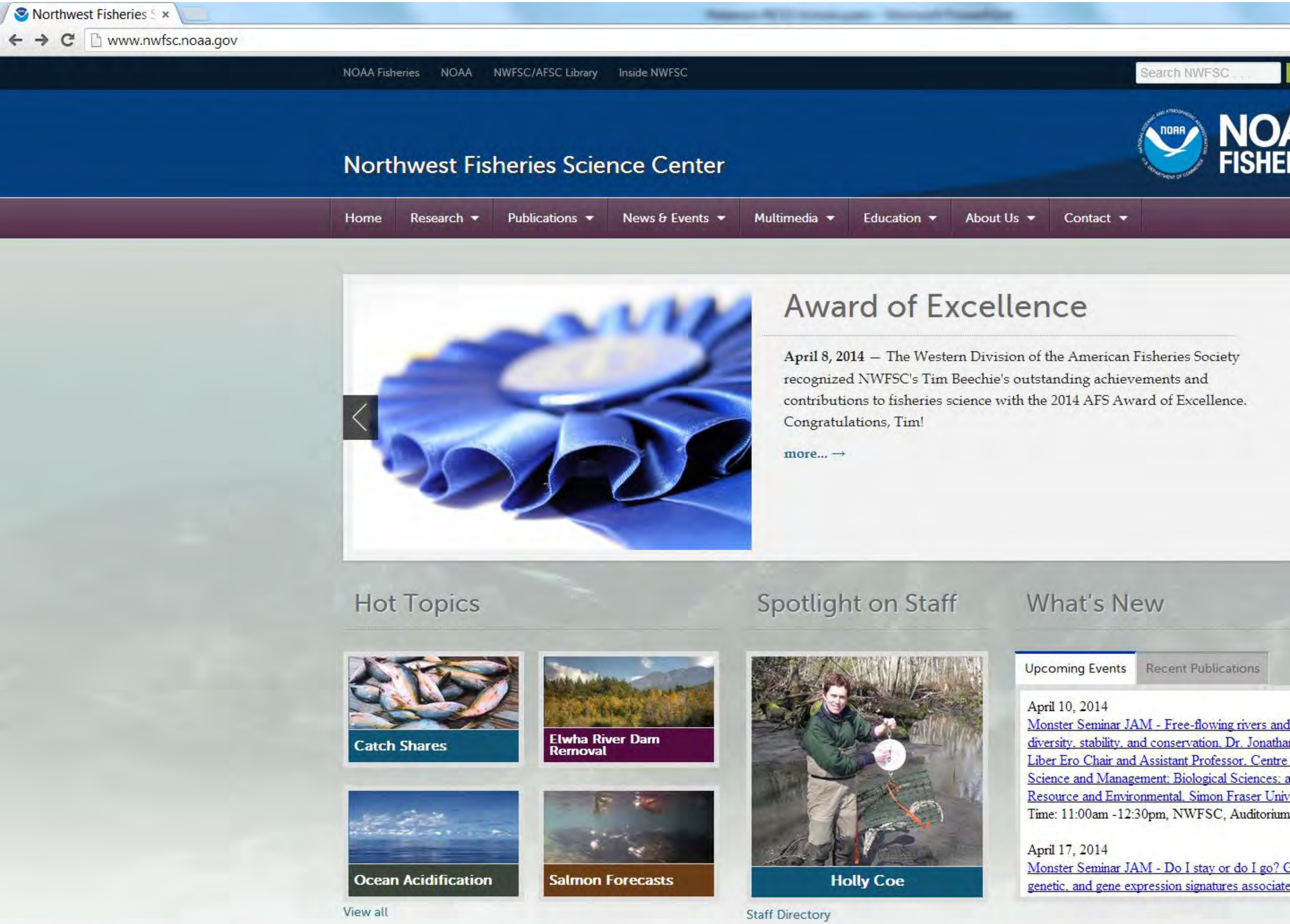




- Copepods work well for fall Chinook and for spring Chinook in most years.
- PDO and Spring chinook correlations are improving!

Our forecasts were completely wrong for salmon that went to sea in 2011 and returned in 2012 (coho) and 2013 (Chinook)

- Spring Chinook counts were 83K whereas we had forecasted 200K
- Coho were < 1% but we expected 3%
- Ocean conditions were very good in 2011 (PDO and copepods, but upwelling was delayed and weak)
- Convened a workshop in June 2013 and learned from our Alaskan colleagues that the Gulf of Alaska was not productive in summer 2011 (Zador talk this afternoon)
- Failure is a good thing because it gives one a chance to hopefully determine why the failure occurred. Working out "why" may reveal the need to add a "missing explanatory variable" or perhaps delete long-standing "explanatory variables".
  - coastal upwelling once "explained everything" but correlations with salmon returns are no longer significant
  - spring transition once "worked" but has since failed
  - PDO may be showing signs of failing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April 8, 2014 — The Western Division of the American Fisheries Society recognized NWFSC's Tim Beechie's outstanding achievements and contributions to fisheries science with the 2014 AFS Award of Excellence. Congratulations, Tim!
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Recent Publications
April 10, 2014
Time: 11:00am -12:30pm, NWFSC, Auditorium
April 17, 2014

Ocean Indicators and Salmon Forecasting

Since 1996, the Center has been monitoring the ocean environment off the Washington and Oregon coasts, its interaction with the California Current, and how ocean conditions affect salmon. This ongoing research is helping us better understand some key relationships between climate, oceanography, and biology that largely determine the fate of salmon entering the ocean during specific years.

What is the ocean index?

NWFSC scientists have developed a novel ocean index tool that combines a suite of oceanographic data, such as sea surface temperature, with biological indicators, such as the amount of salmon prey. Together, these indicators can capture the dynamics of a changing ecosystem and allow us to predict the relative abundance of Chinook and coho harvests far enough in advance for decision makers to plan for good, average, or poor-yield years. The accuracy of such predictions is invaluable to state and federal fishery managers in setting harvest limits and allocations and for tracking recovery of endangered or threatened salmon runs.

Recent salmon forecasts

In 2008, scientists tracked one of the highest levels of ocean productivity observed on record, with a negative Pacific Decadal Oscillation (PDO)

Explore More
Annual salmon
Learn more abo indicators
NWFSC top sto Predicting salm (2008)

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Ocean Ecosystem Indicators

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  - 2014 Salmon Forecast
    - Ecosystem Indicators 'stop-light charts'
  - 2013 Annual Report (pdf)
  - Adult Return Data
  - Time Series Plots
  - Past Reports
- Large-scale Ocean and Atmospheric Indicators
  - Pacific Decadal Oscillation (PDO)
  - Oceanic Niño Index (ONI)
- Local and Regional Physical Indicators
  - Temperature anomalies
  - Coastal upwelling
  - Hypoxia
  - Physical spring transition
  - Deep-water temperature and salinity
- Local Biological Indicators
  - Copepod biodiversity
  - Northern and Southern Copepods
  - Copepod community structure
  - Biological spring transition
  - Winter Ichthyoplankton
  - Juvenile Salmon Catch

Forecast of Adult Returns for coho salmon and Chinook Salmon

2013 was another year of mixed ocean conditions. The climate-indicators, such as PDO and El Niño, were 'neutral', sea surface temperatures were warmer than usual, and the majority of the upwelling occurred over a short period of time (July) with the upwelling 'season' ultimately ending much earlier than usual. The biological indicators pointed to good ocean conditions, with a high abundance of large, lipid-rich zooplankton, a moderate abundance of winter fish larvae that develop into salmon prey in the spring, and catches of juvenile spring Chinook salmon during the June survey off Washington and Oregon that were the second highest in 16 years. Overall, juvenile salmon entering the ocean in 2013 encountered average to above average ocean conditions off Oregon and Washington.

Our annual summary of ecosystem indicators during 2013 is here, and our "stoplight" rankings and predictions are shown below in Table 1, Table 2, and Figure SF-01.

Table 1. Ocean ecosystem indicators of the Northern California Current. Colored squares indicate positive (green), neutral (yellow), or negative (red) conditions for salmon entering the ocean each year. In the two columns to the far right, colored dots indicate the forecast of adult returns based on ocean conditions in 2013 (coho salmon) and 2012 (Chinook salmon).

	Juvenile Migration Year				Adult Return Outlook	
	2010	2011	2012	2013	Coho 2014	Chinook 2014
Large- scale ocean and atmospheric indicators						
PDO (May – Sept)	yellow	green	green	yellow	yellow	green
ONI (Jan-Jun)	red	green	green	yellow	yellow	green
Local and regional physical indicators						

A new table that will go on the web next year. The advantage is that we can include predictor variables that are less than the full 18 year time series in length (e.g., Bongos, IGF, others) plus it provides a range.

	Outlook for 2014 Adult Salmon Returns		
Metric	coho (SAR, %)	Spring Chinook (Adults at BON)	Fall Chinook (Adults at BON)
Multivariate			
MCA	2.82	199,993	461,381
PCA	3.07	186,094	461,259
Rank	2.71	191,295	479,592
Single factor			
Northern Copepods	3.52	230,014	702,386
Prey (Bongo Nets)	3.06	270,999	682,970
CCI	3.02	173,844	453,186
IGF	NA	300,211	NA
Jacks	NA	317,673	402,609
Winter Ichthyo.	2.99	152,749	384,287

Our work goes beyond providing "outlooks" on salmon returns

- **Habitat Restoration**. With regards to salmon, managers need to interpret freshwater actions within the context of ocean conditions.
- **In-season predictions of ocean conditions:** useful for timing of release of hatchery salmon and when to barge fish down-river.
- **Early Warning Indicators (EWI).** The length and diversity of our Newport Line time series (19th year) allows our findings to serve as EWIs.
  - NOAA produces El Niño forecast – what will be the outcome for fisheries?
  - PDO changing sign rapidly – what will be the outcome for fisheries?
  - Delays to upwelling -- interruptions of normal upwelling also affects fisheries
  - Ocean acidification and hypoxia are another set of big problems for fisheries
  - Northward shifts in populations
- **Ecological Indicators** used in the California Current Integrated Ecosystem Assessment; hyrographic data are used in the "Drivers" section of the IEA
- **Why settle for an upwelling index or just ENSO or the PDO when we have much of the food chain indexed**? If you'd like to get a better understanding of "ocean conditions", just visit our website regularly to track how the ocean is changing biologically. http://www.nwfsc.noaa.gov

3. Engagement

- **Presentations**
  - Pacific State Marine Fisheries Commission: Annual Meetings
  - NOAA-Fisheries Regional Office (Portland; Columbia River salmon)
  - Washington and Oregon State Department of Fish and Game
  - Several Native American tribes
  - Columbia River Intertribal Fish Commission
  - Columbia River Power & Conservation Council
  - Citizen-led Watershed Councils
  - High School Teachers (training sessions)
  - Salmon and Trout Enhancement Program (STEP)
  - National Association of Marine Educators (NAME)
- **Print Outlets**
  - Local and Regional Newspapers
  - Columbia Basin Bulletin
  - Northwest Fish Letter
  - E-mail list serve

3. Engagement

- Website is very popular
- Direct use of data by managers is a problem!
  - Managers are reluctant to make rigorous use of our data because there is no guarantee that it will be available next year.
  - All of our work is based on “research dollars” generated through the “proposal process”. It could all end tomorrow!
- Planning to add a blog within the next few weeks with biweekly updates on “ocean conditions”; should be especially interesting with a major El Niño brewing at the equator right now

My Friends

FATE
FISHERIES AND THE ENVIRONMENT

GLOBEC
Global Ocean Ecosystem Dynamics

BONNEVILLE
POWER ADMINISTRATION

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NOAA
U.S. DEPARTMENT OF COMMERCE

NSF

U.S. GLOBEC
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Pacific Ocean Boundaries
POBEX
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CAMEO
COMPARATIVE ANALYSIS OF MARINE ECOSYSTEM ORGANIZATION

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