# Ocean Conditions; plankton, marine food chains, salmon, hypoxia and climate change

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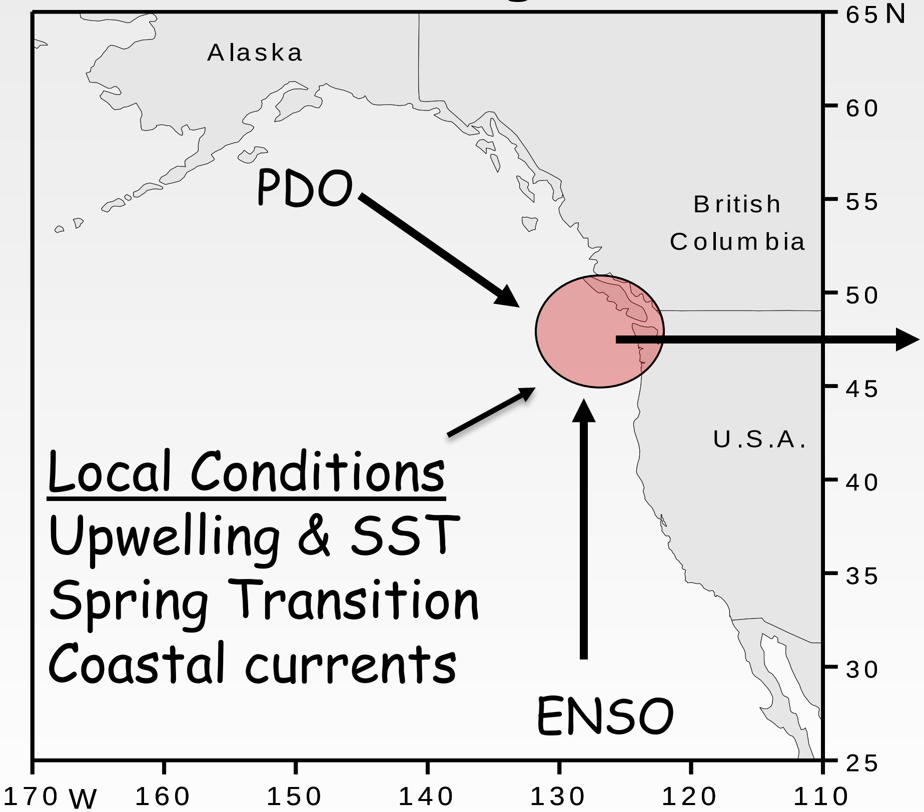
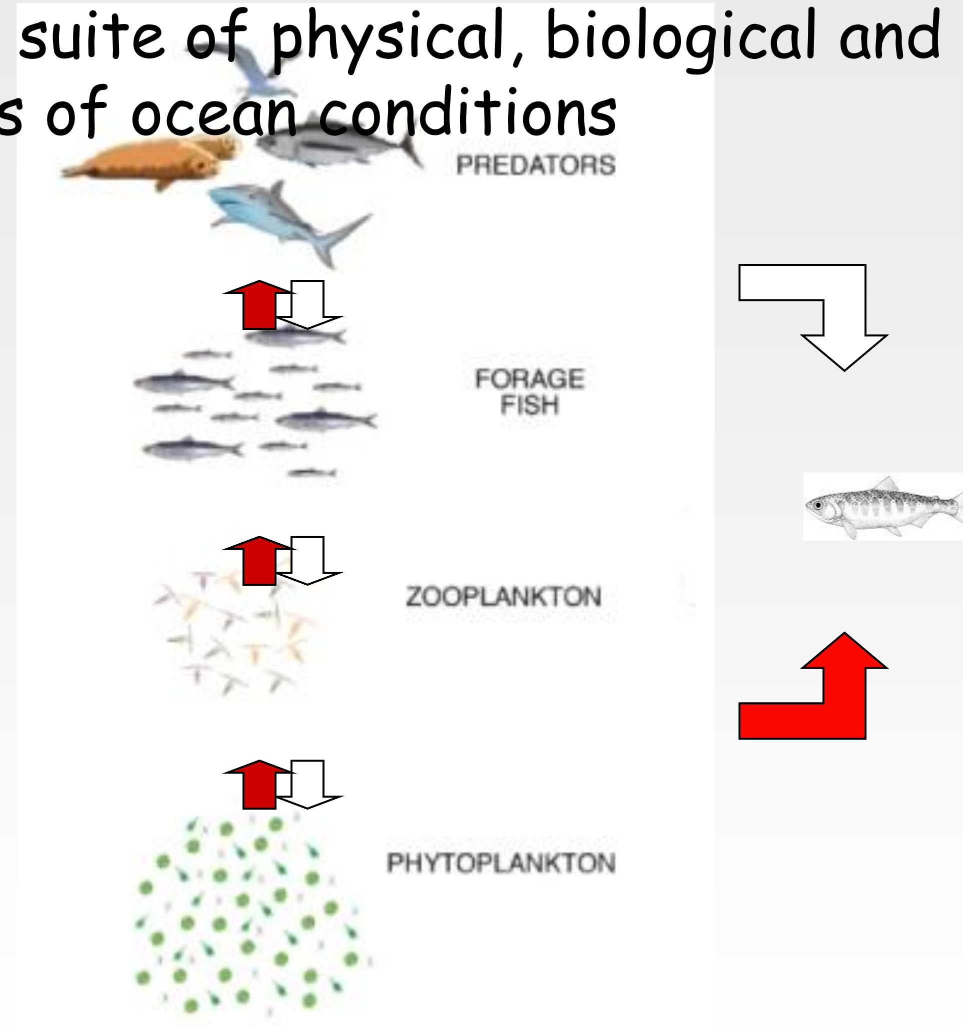
See www.nwfsc.noaa.gov, "Ocean Conditions and Salmon Forecasting"

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

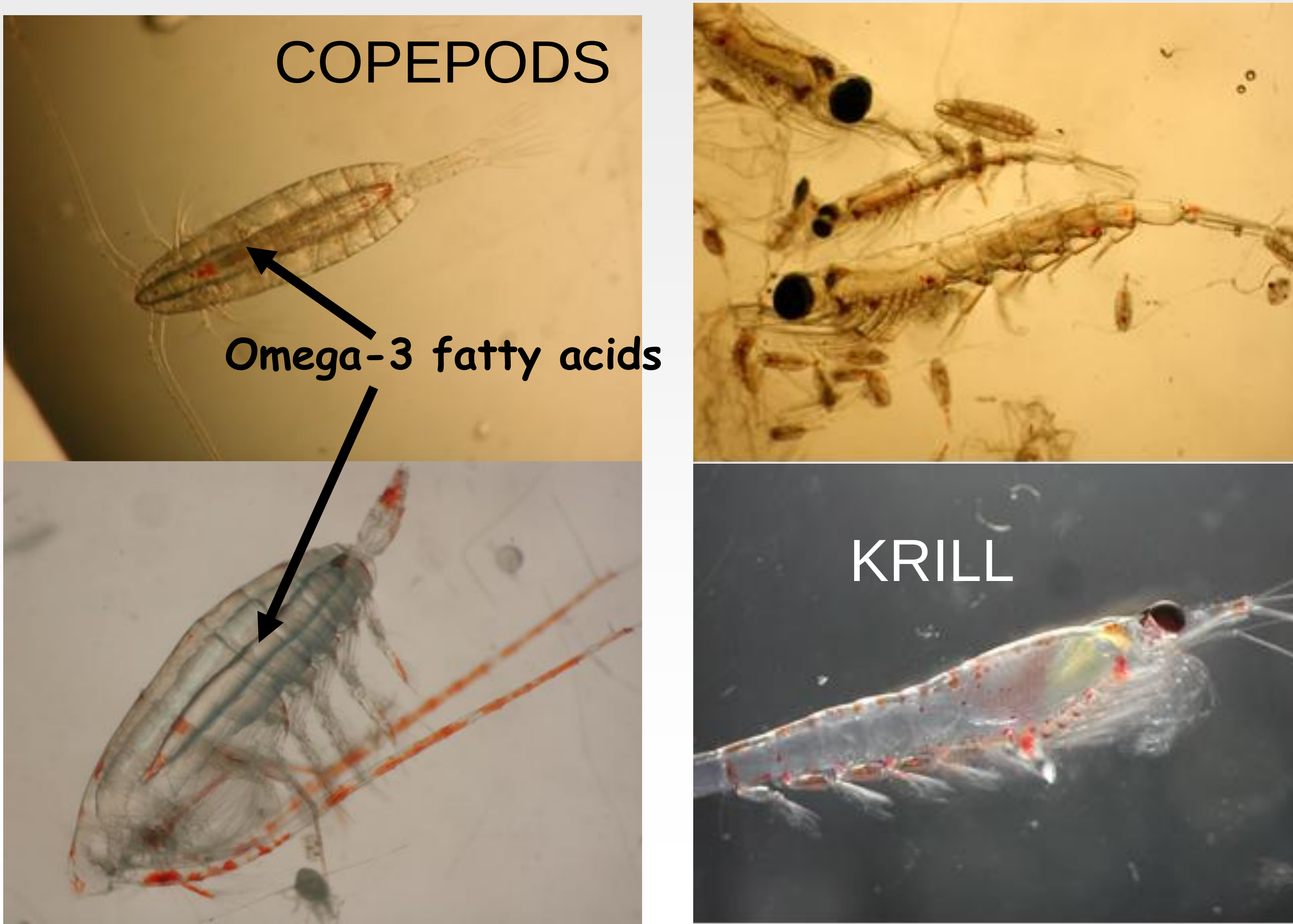



This work is an example of an ecosystem approach to management, one based chiefly on active sea-going programs

Local Biological Conditions: The Food Chain

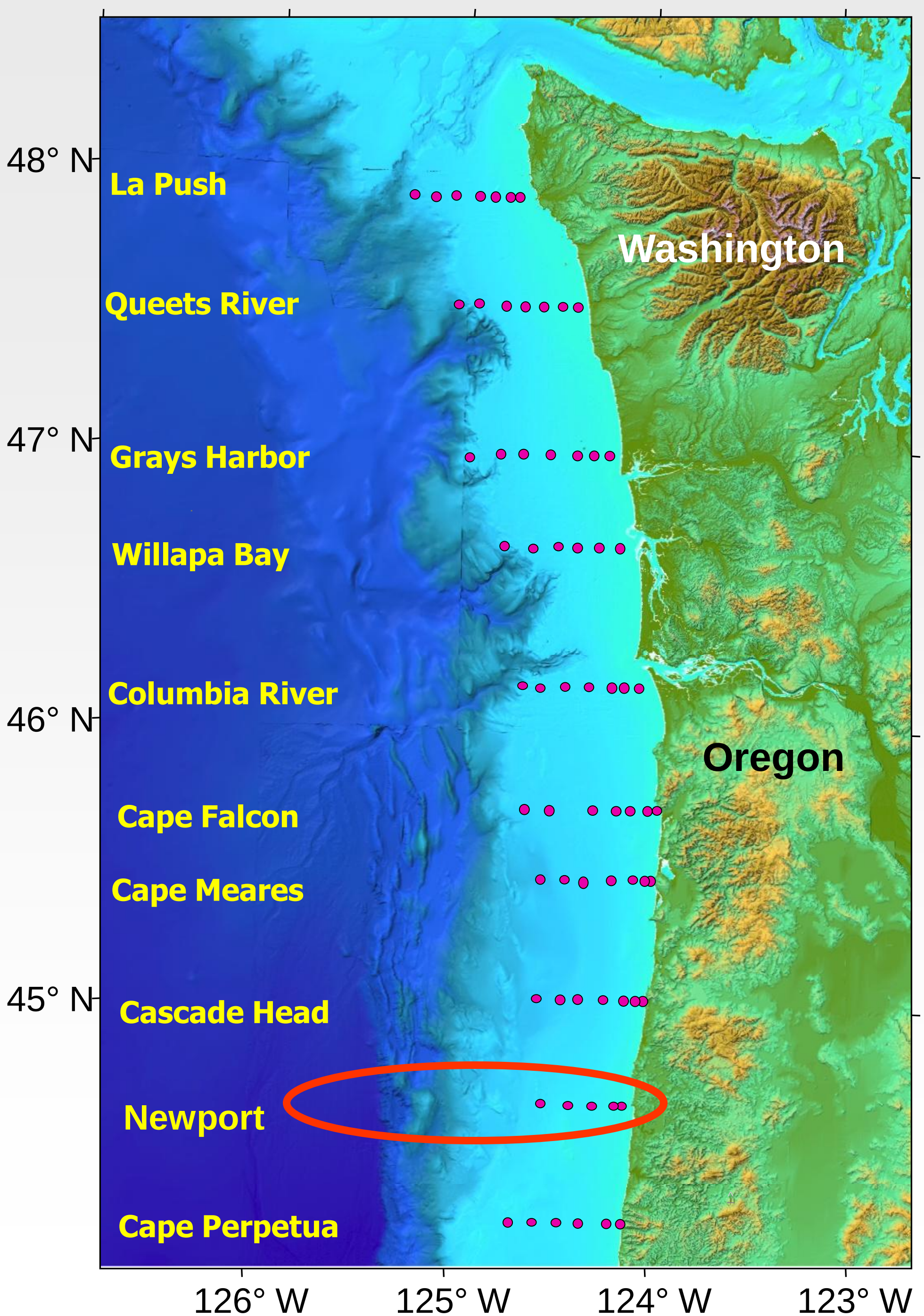
# Images of two types of plankton that play key roles in a salmon's food chain: copepods and krill,



# Outline

- Four events in the ocean have shaped salmon returns over the past 20 years:
  - Poor returns in the 1990s due to extended warm ocean conditions
  - Spectacular (and historic) returns in early 2000s
  - A salmon disaster resulting from the 2005 warm ocean event
  - Another relatively spectacular recovery shortly thereafter
- Current Issues That I will Touch On (if there is time)….
  - What happened to the squid invasion of 2008-2009?
  - What happened during the moderate El Niño of 2010
  - How is this year (2011) shaping up?
    - Strong upwelling this year,
    - A potential problem with hypoxia on the horizon

# Observations



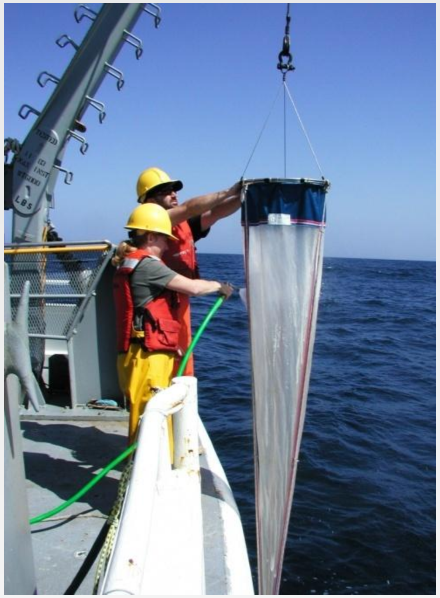

- Newport Line biweekly sampling since 1996 (16th year)

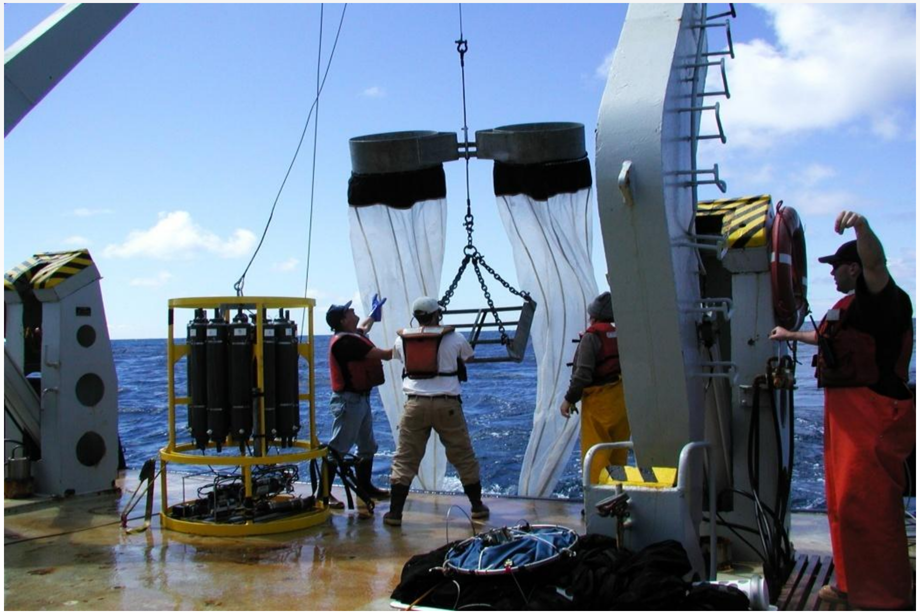
- Juvenile salmon sampling in June and September since 1998 (14th year)

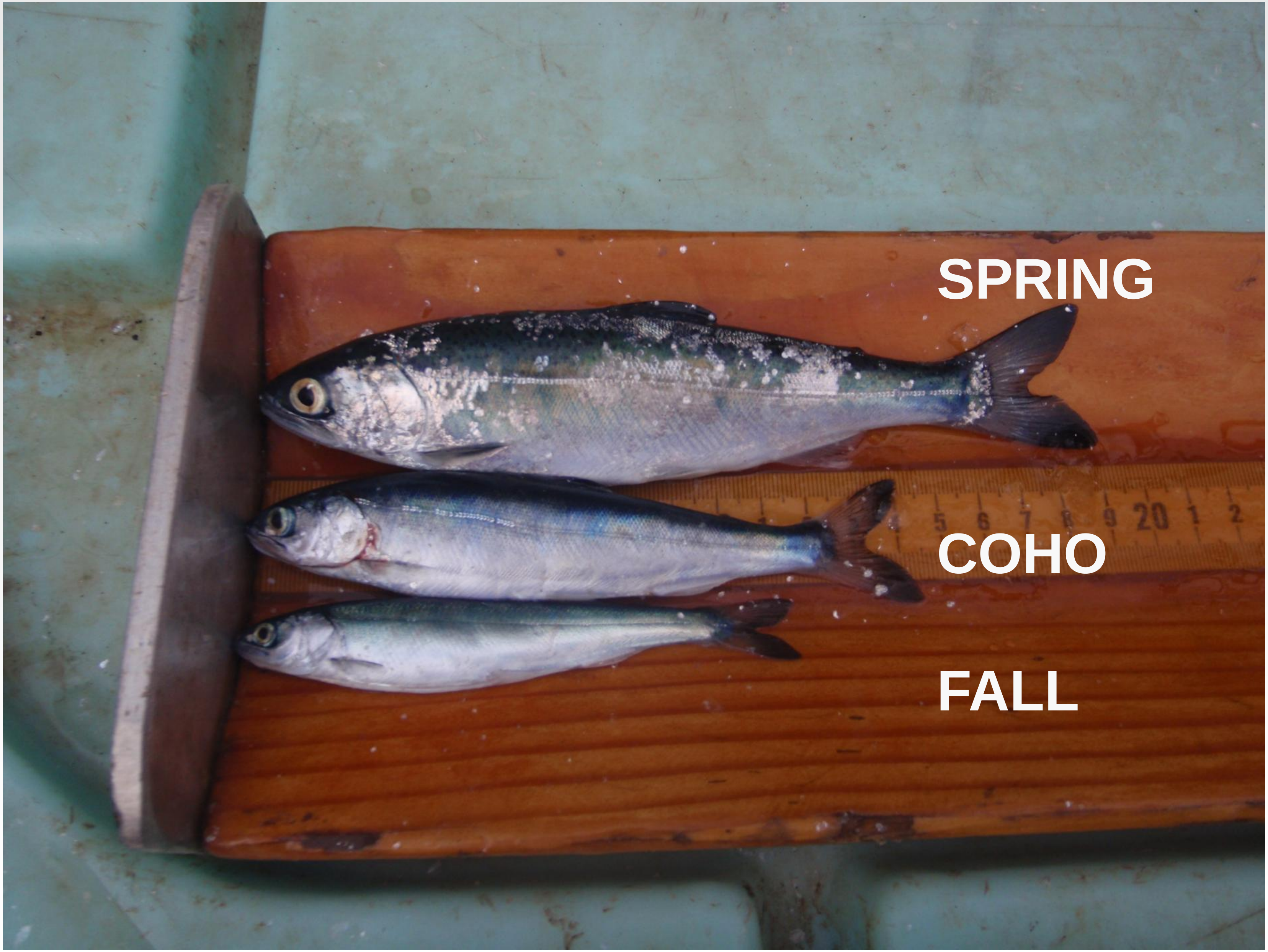
- Historical data:
  - hydrography, 1960s;
  - plankton, 1969-1973; 1983, 1990-1992
  - juvenile salmon, 1981-1985

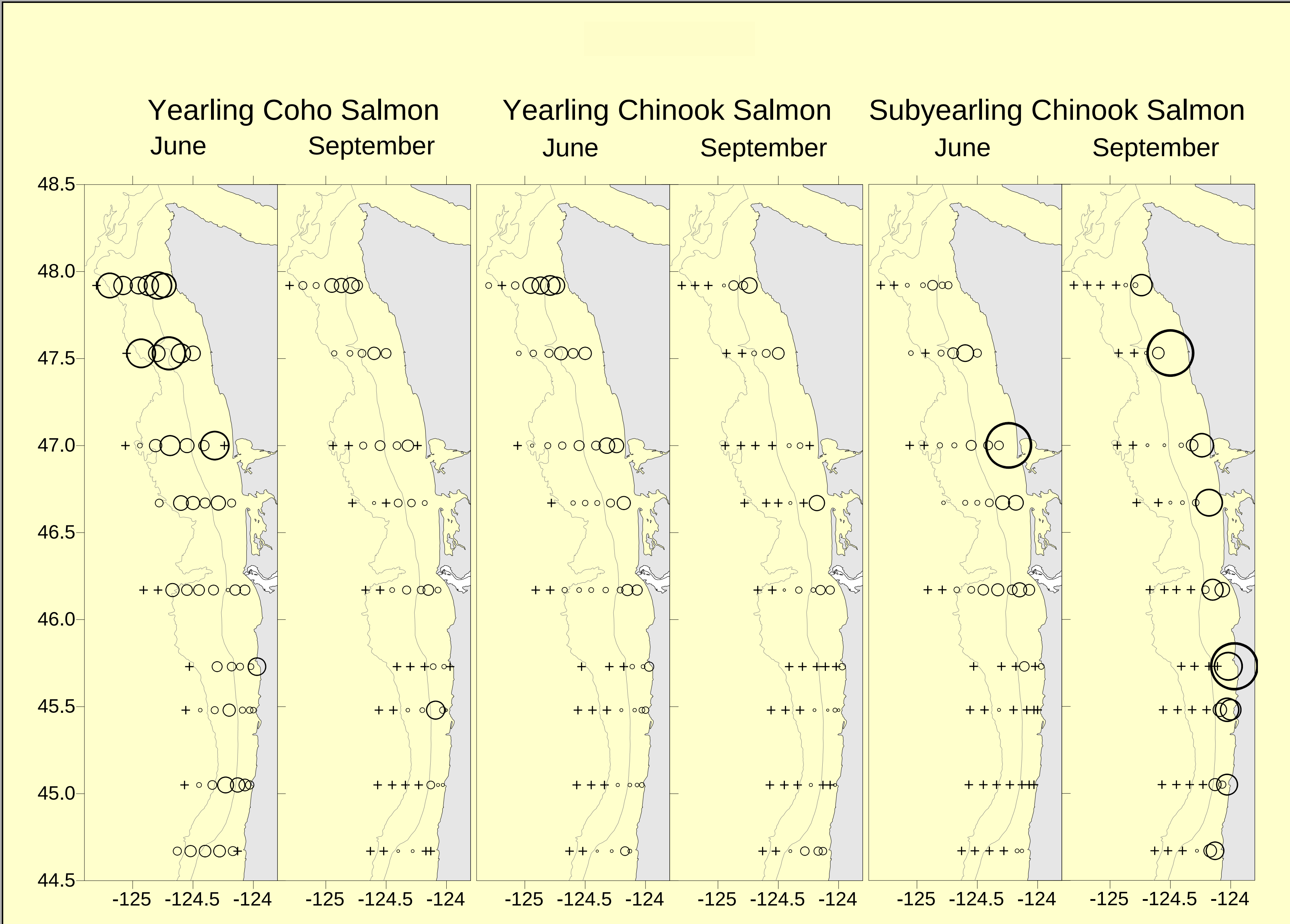
# Sampling methods

- 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

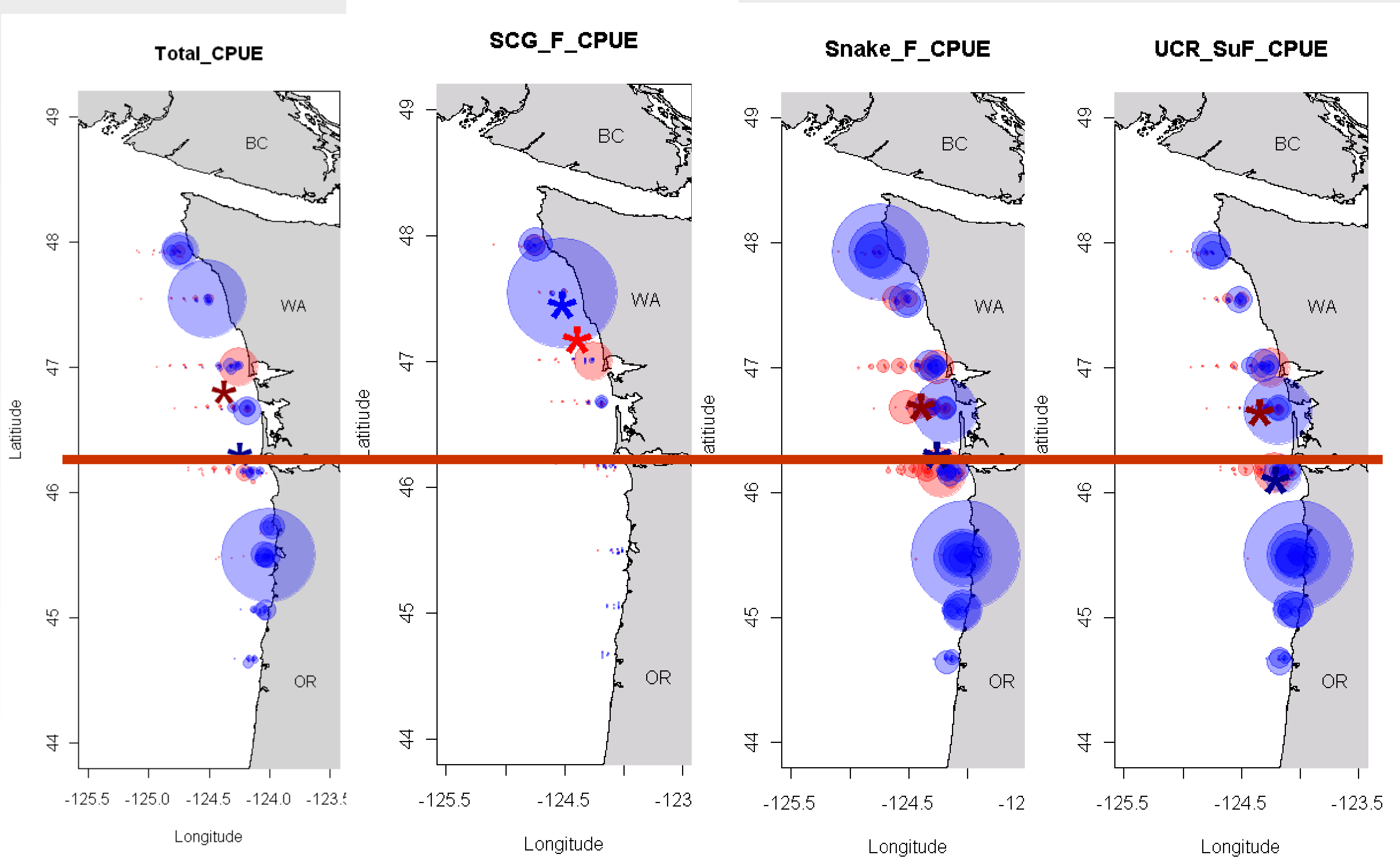





SPRING
COHO
FALL


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

# Salmon Stock Groups: Total is all Fall "ocean type" Chinook SCG = Spring Creek Group; Snake = Snake River; UCR =upper Columbia River

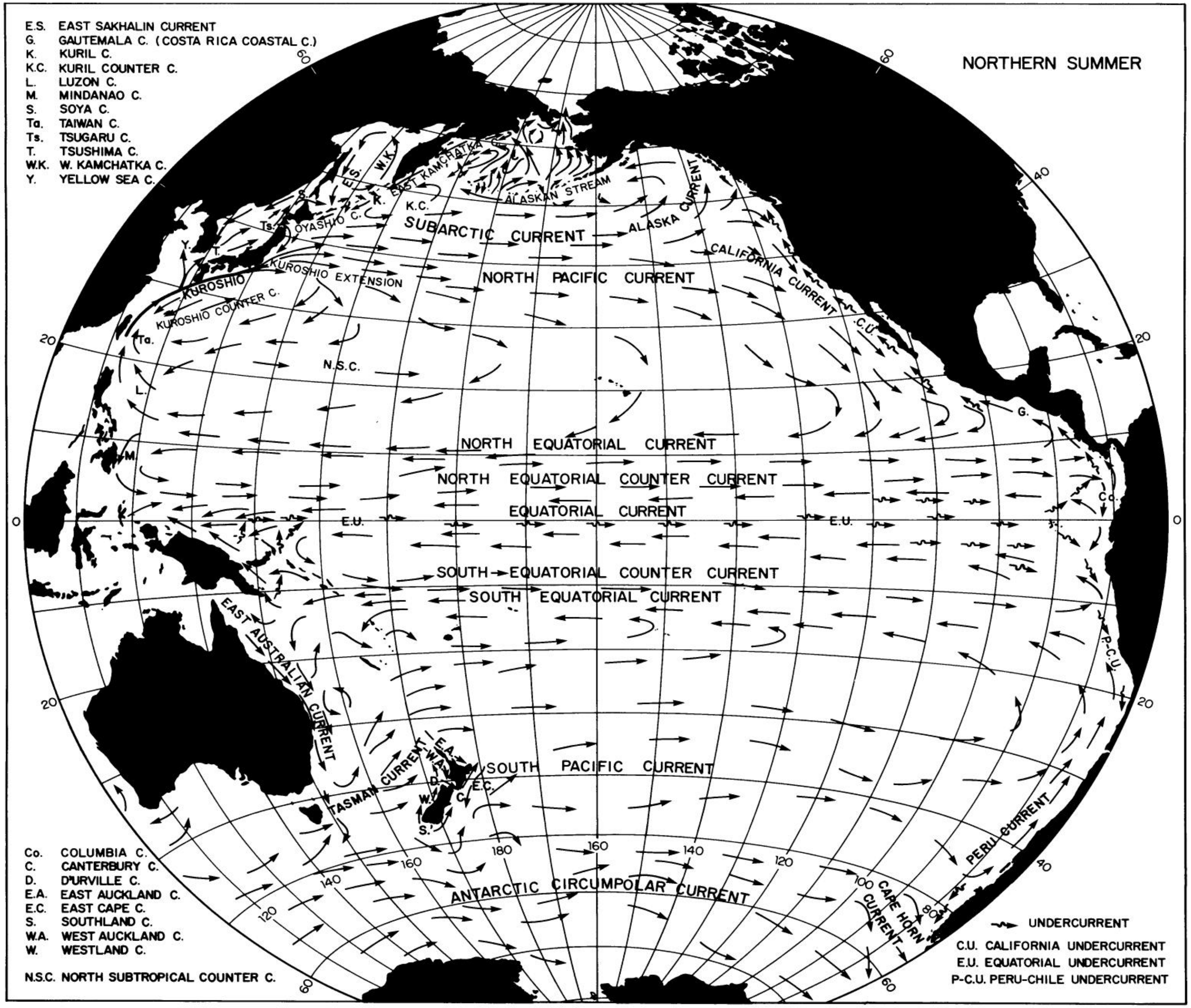


# Four physical factors affect plankton, food chains, pelagic fish and the growth and survival of salmon in the northern California Current

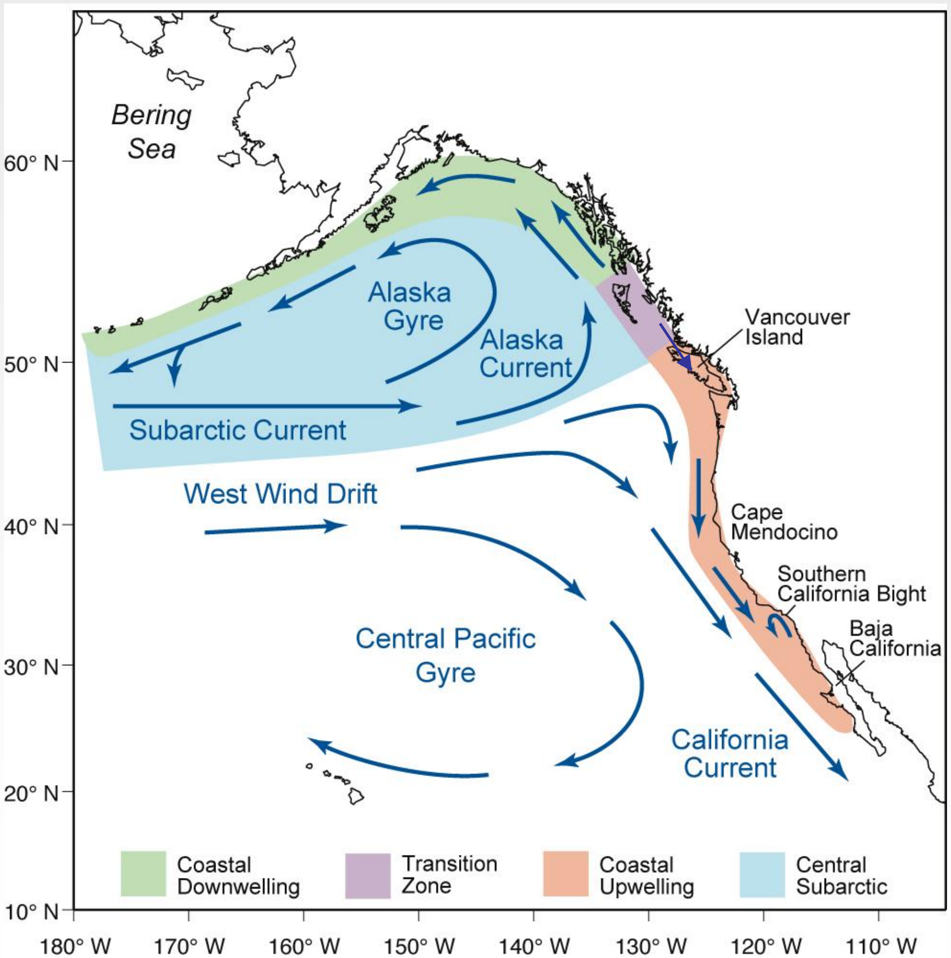
- Large-scale circulation patterns and the kinds of water that feed the California current
- Seasonal reversal of coastal currents: southward in summer – northward in winter
- Coastal Upwelling
- Phase of the Pacific Decadal Oscillation (PDO)

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

# Oceanography 101



# Circulation off the Pacific Northwest



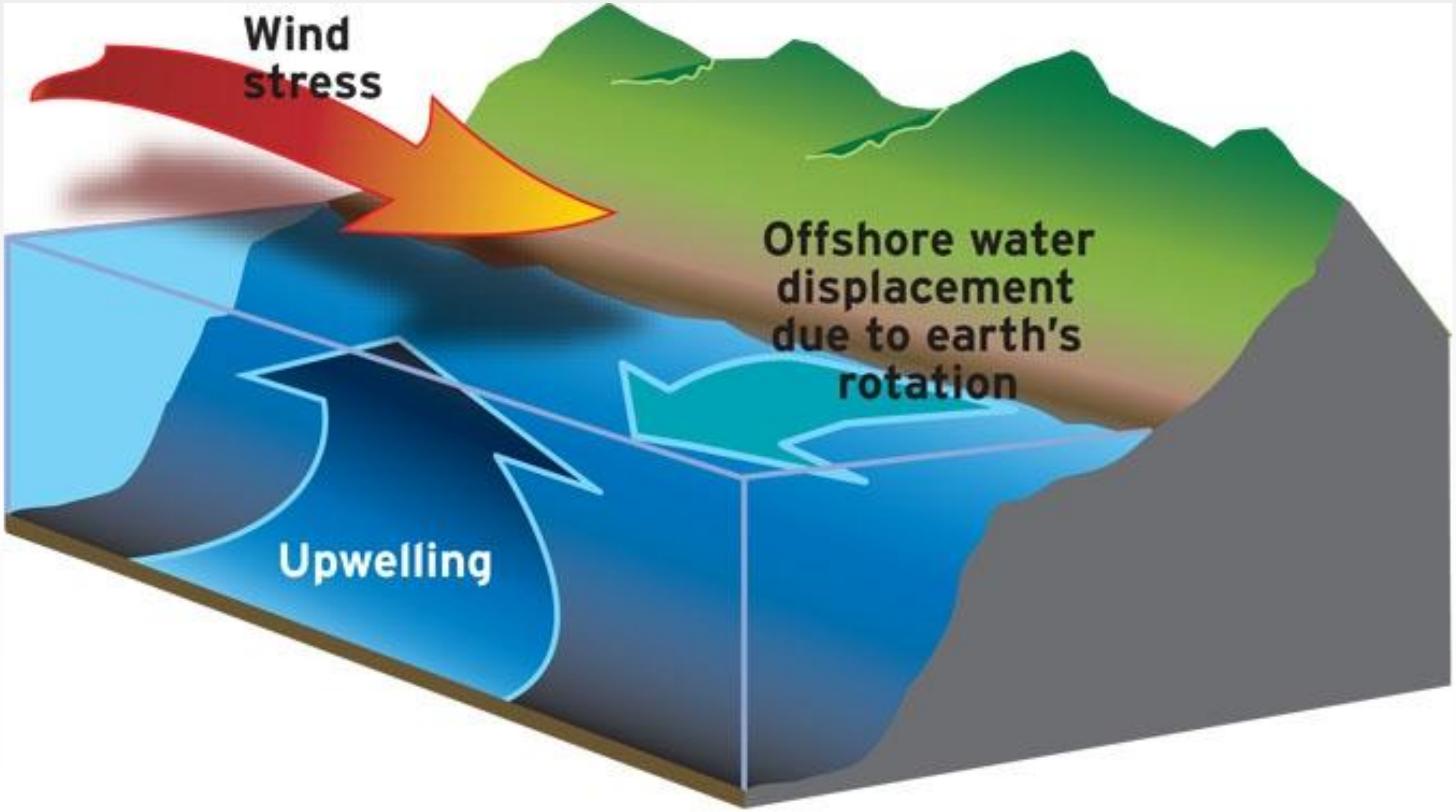

Plankton are "drifters", thus…

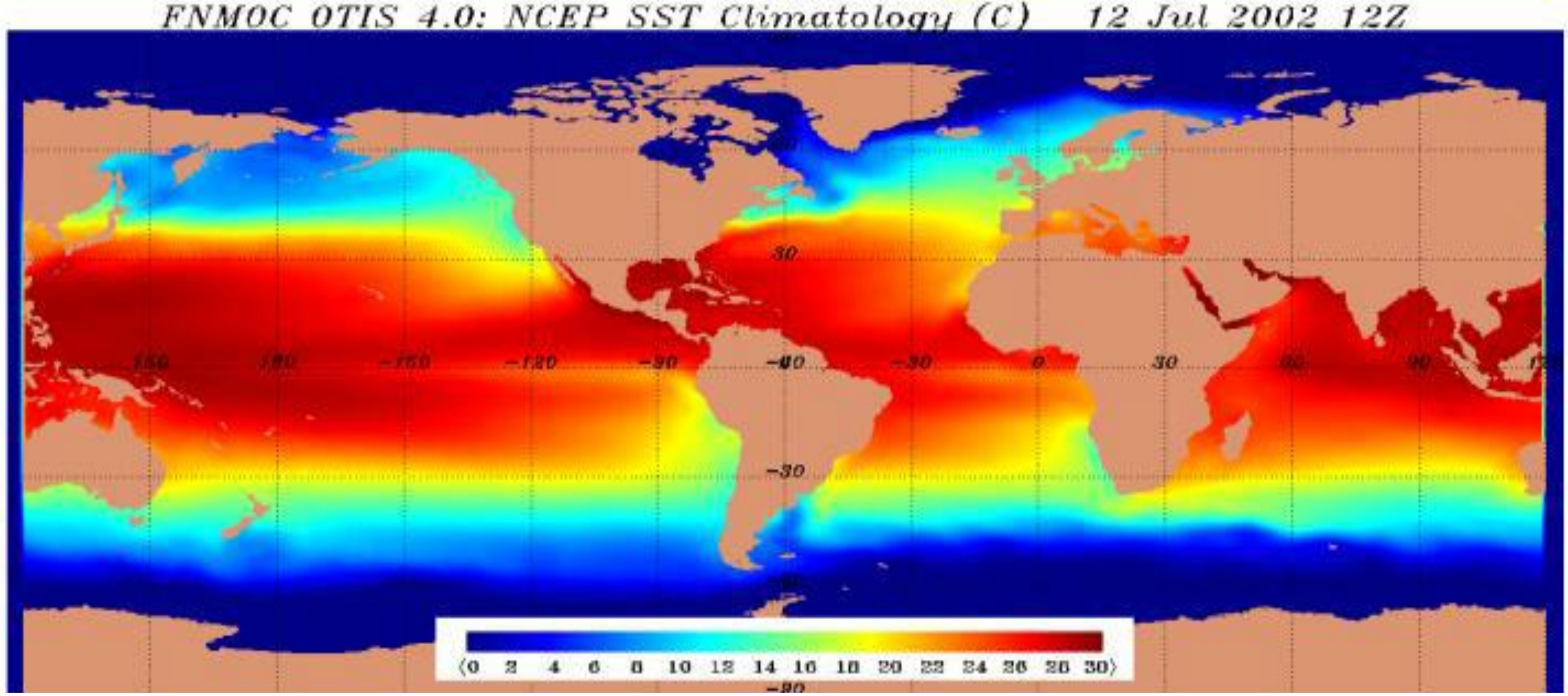
Subarctic Current brings cold water and northern species towards the N. California Current;

The West Wind Drift brings subtropical water and subtropical species towards 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



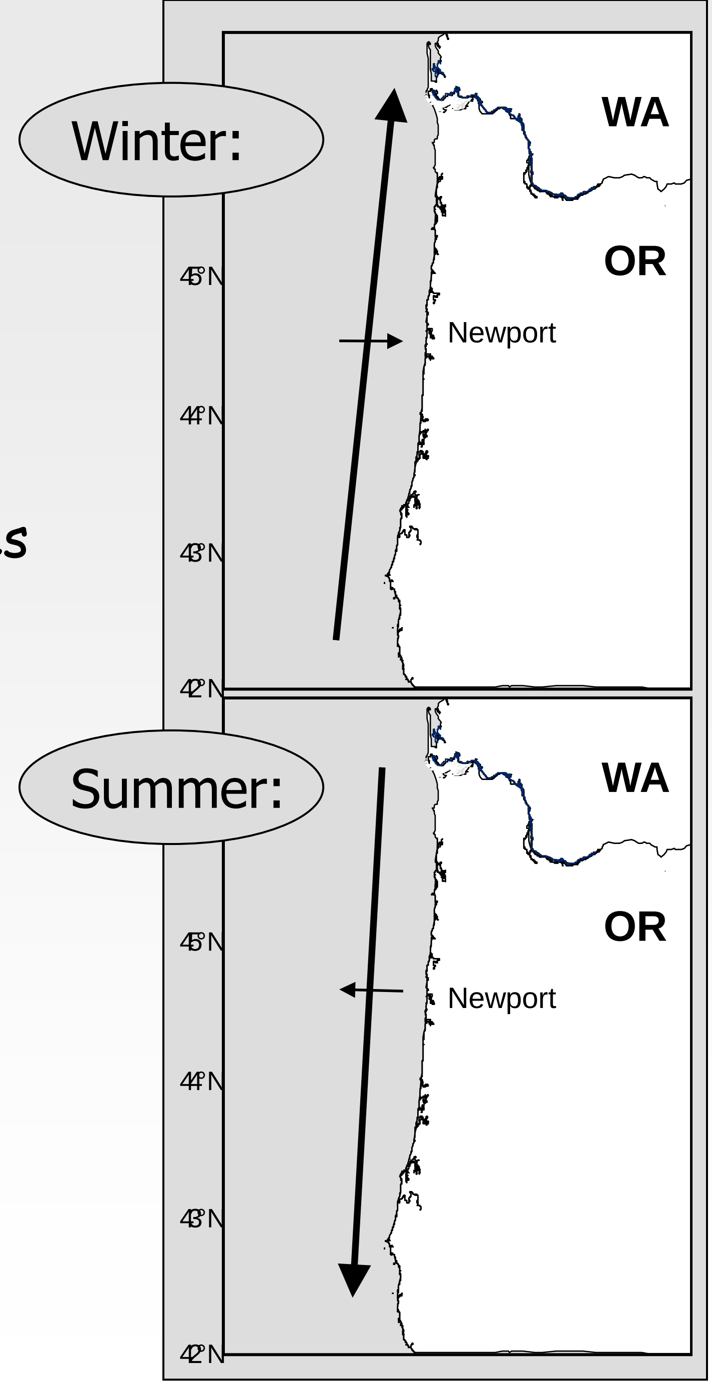



# CHART OF SEA SURFACE TEMPERATURE

- Note: warm water between the equator and ~ 30 N
- Because of upwelling off North America, S. America N. Africa and S. Africa, cool water is found at the coast. Without upwelling, the coasts would be ~ 5-10EC warmer during summer because offshore waters would move shoreward.
- Without upwelling we would have no salmon off PNW

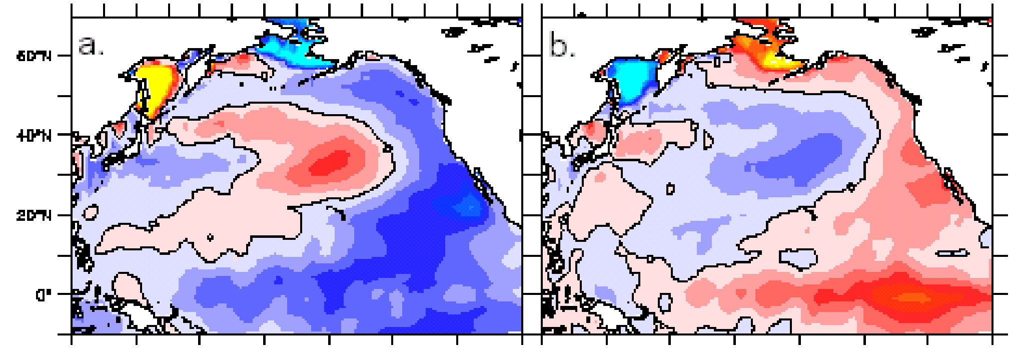
# Winds and current structure off coastal Oregon:

- Winter:
  - Winds from the South
  - Downwelling
  - Poleward-flowing Davidson Current
  - Subtropical and southern plankton species transported northward & onshore
  -
- **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**



# PDO & SST

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



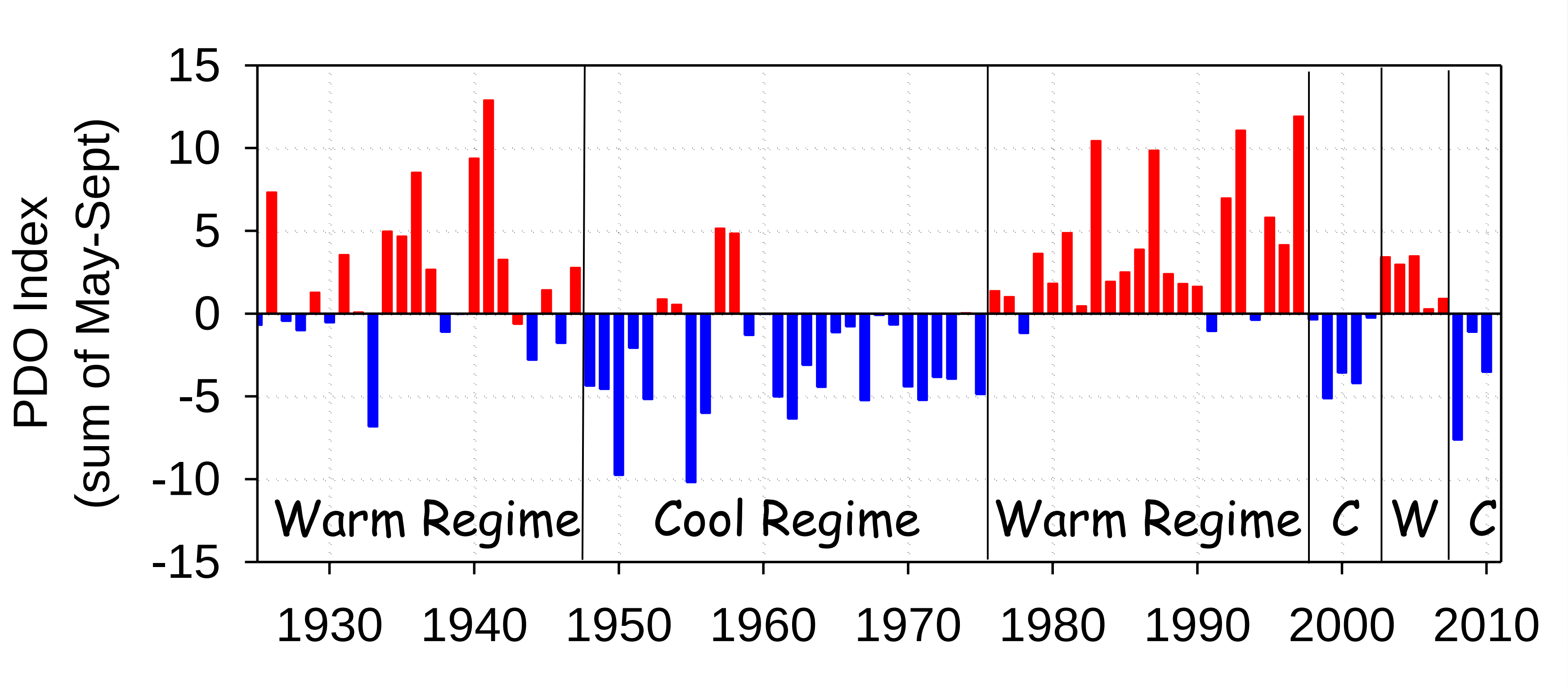

The SST anomaly patterns shown on the right results from basin scale winds: W'ly and NW'ly [negative phase] and SW'ly [positive phase]

Blue is anomalously cold
Red is anomalously warm

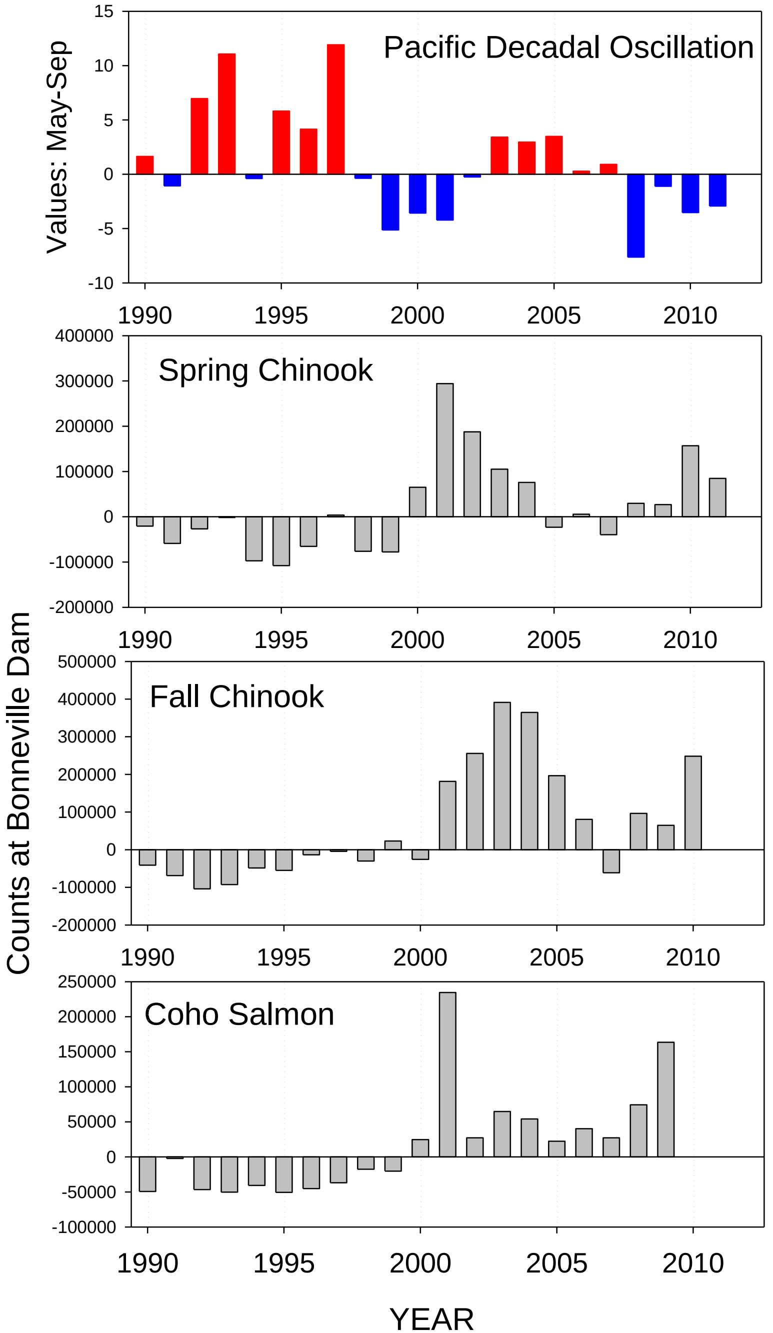
Westerlies dominated during winter 07-08; SW'ly winter 09-10.

EOF Analysis produces a "score" which describes the SST pattern across the entire North Pacific

# PDO: May-Sep Average, 1925-2010




- From 1925-1998, PDO shifted every 20-30 years between warm and cool regimes.
- 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




# Salmon returns since 1990: counts at Bonneville Dam

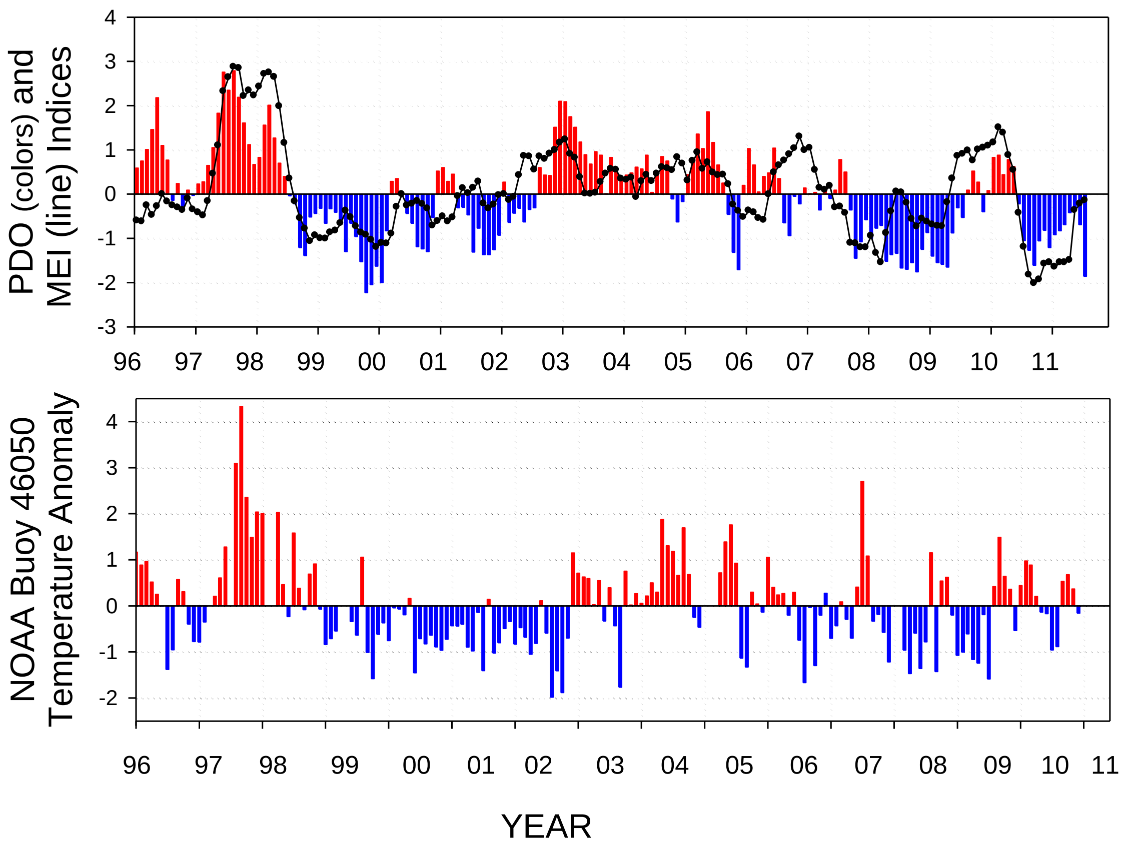
PDO in "warm phase" until 1998 & salmon had poor survival

PDO phase shift in late 1998 followed by record returns

Another phase shift in late 2002 saw declining salmon stocks

Yet another shift in 2008 saw another round of enhanced returns

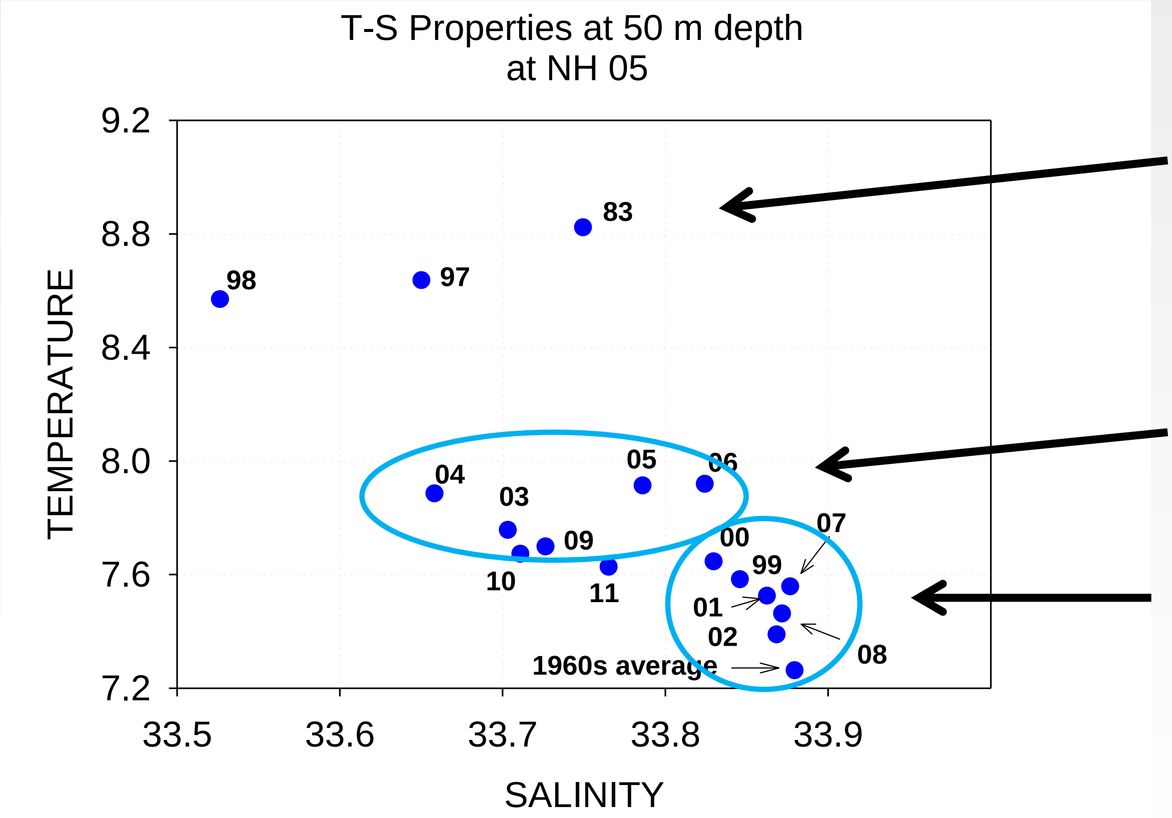
# 15 year time series of SST off Newport shows that PDO downscales to local SST




Temperature differences usually ± 1° 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

# Deep water on the continental shelf is also different depending on the PDO: Temperature-Salinity at 50 m

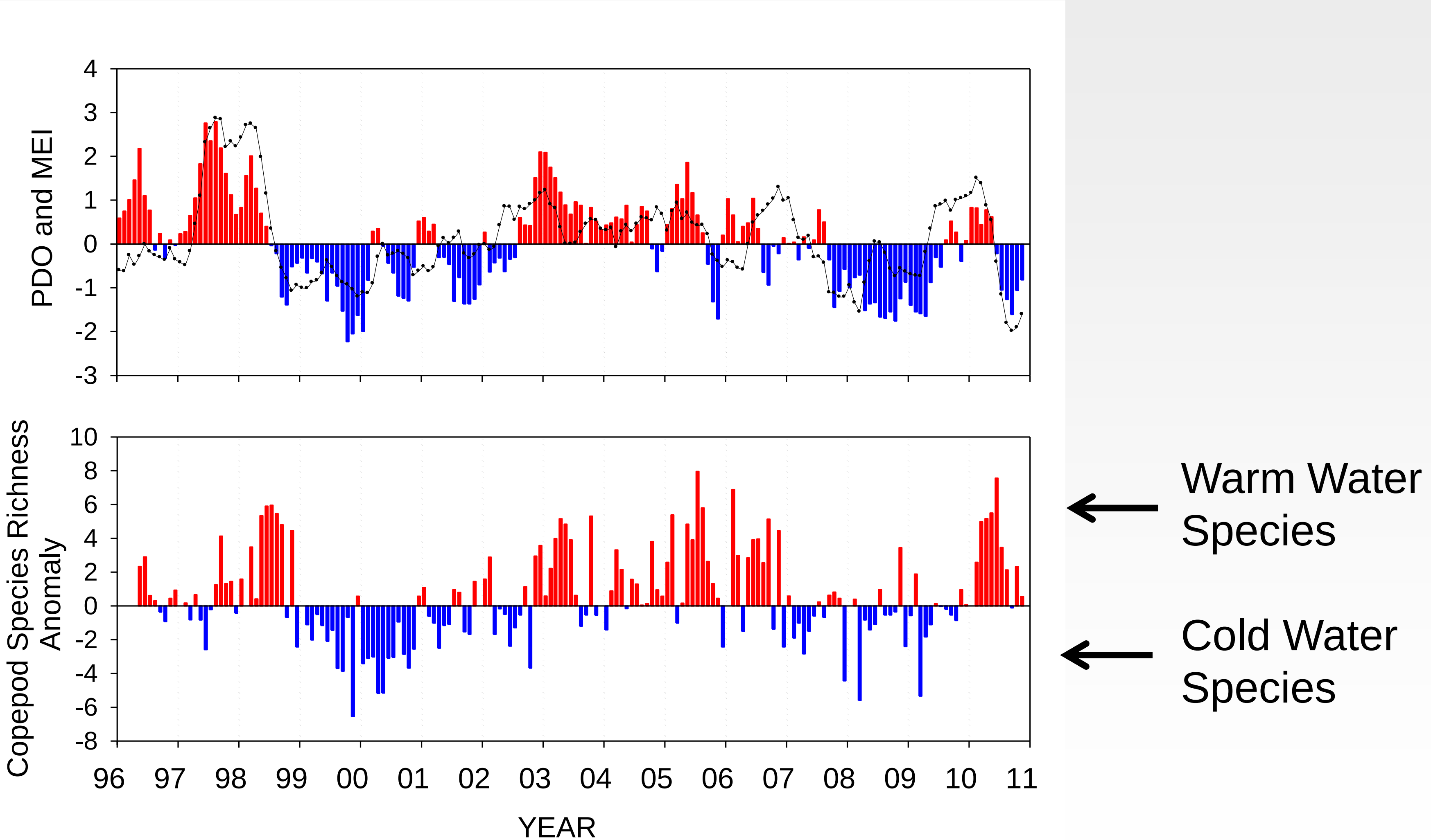



ENSO: 83, 97, 98

Positive PDO: 03-06
Weak PDO: 09-10

Negative PDO: 99-02, 07-08,1960s

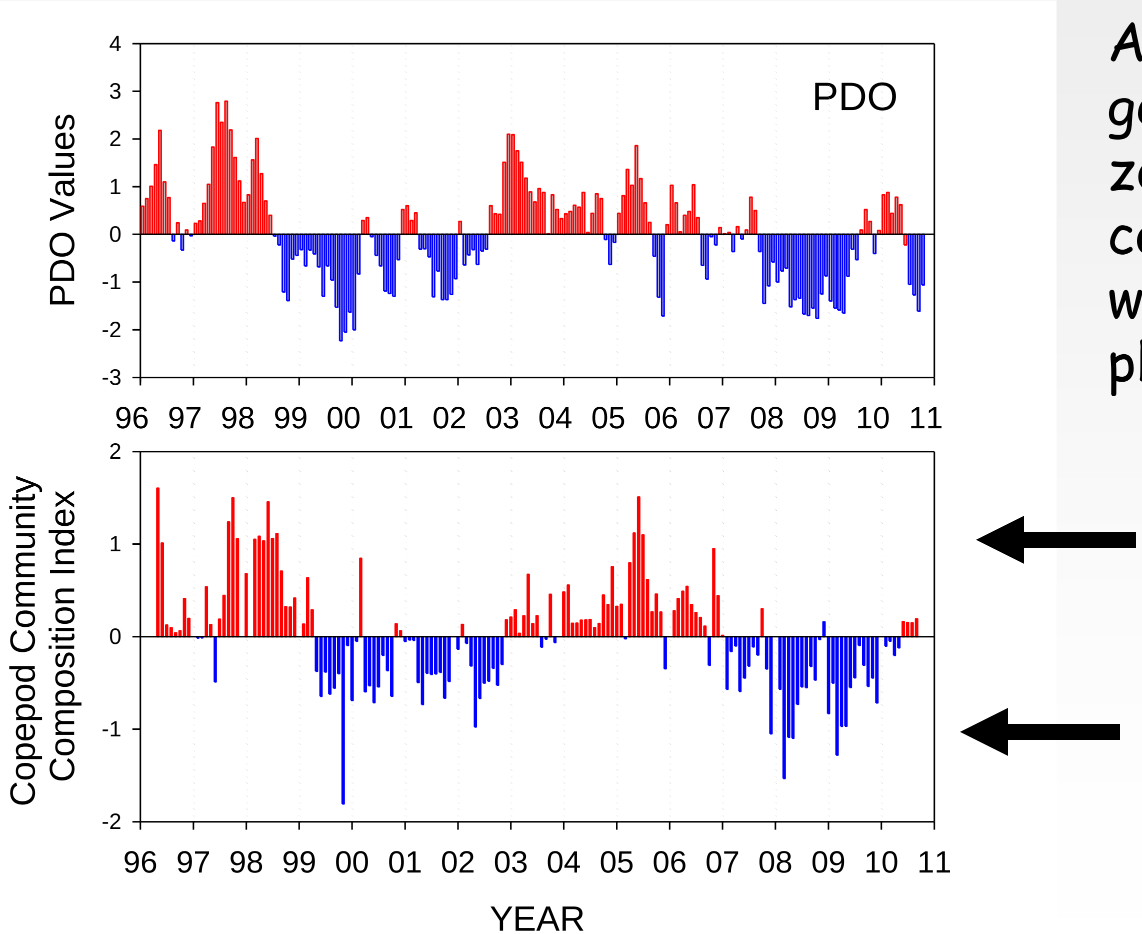
# PDO, MEI and Copepod Species Richness Anomaly



# PDO and zooplankton: copepod community composition

As I suggested earlier, the sign of the PDO is associated with advection of either warm or cold water 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.



# 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)**

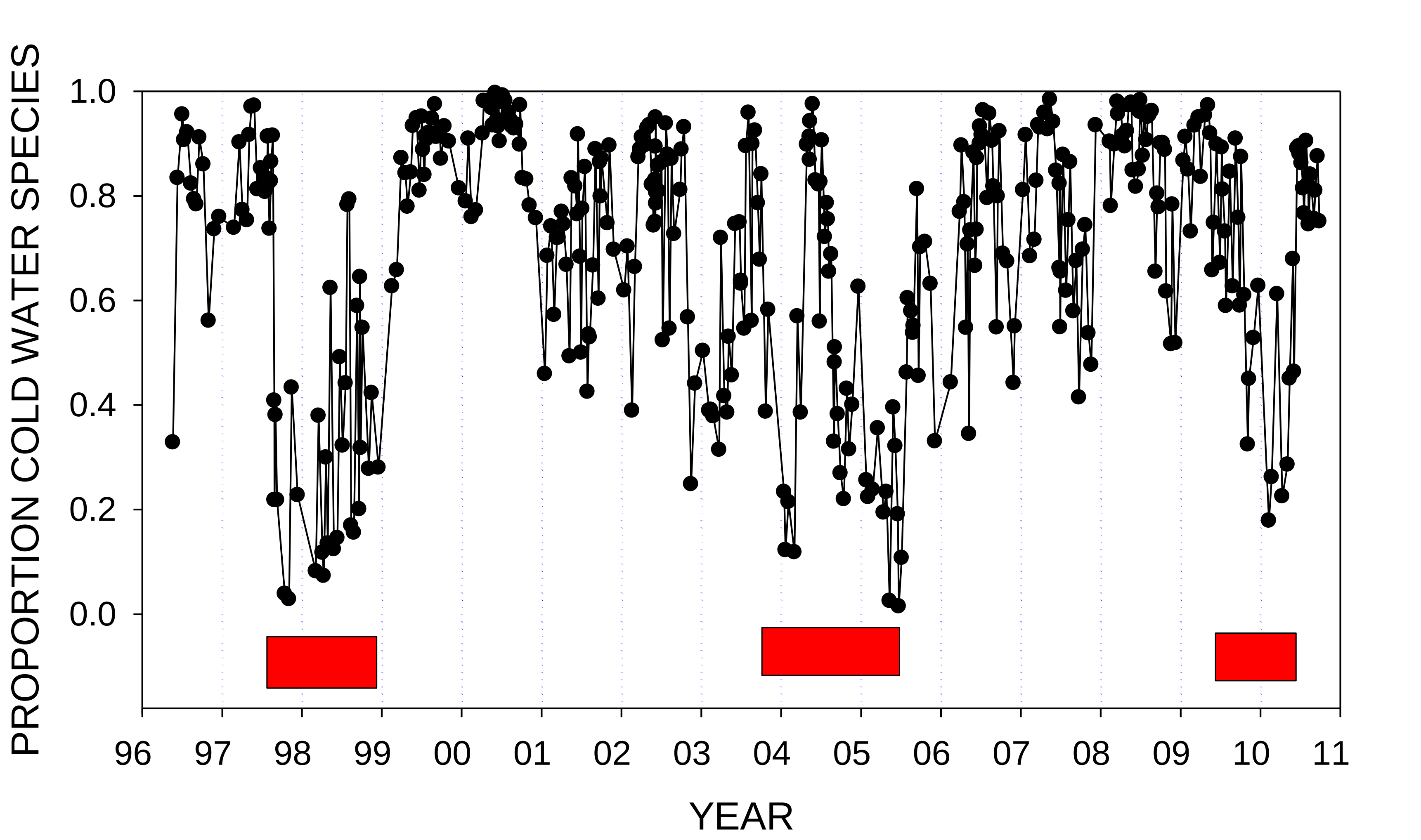
# Comparisons in size and chemical composition

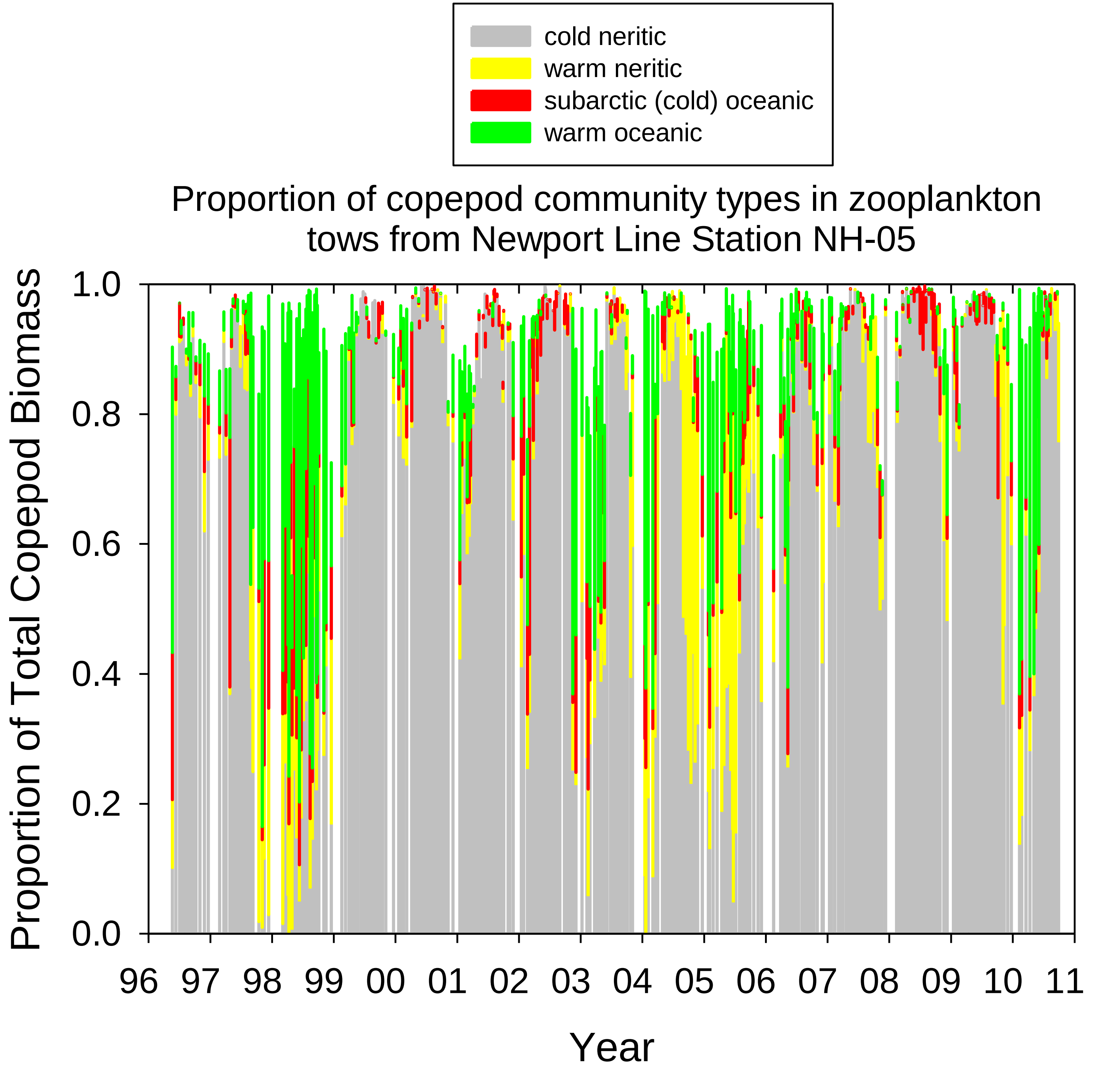
- **Warm-water taxa** - (from offshore OR) are **small** in size and have minimal high energy wax ester lipid depots

- **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;

# Proportion of cold water species: 1996-2010 (*Pseudocalanus, Calanus marshallae* and *Acartia longiremis)* showing seasonal cycle as well as differences between cold and warm phases of the PDO



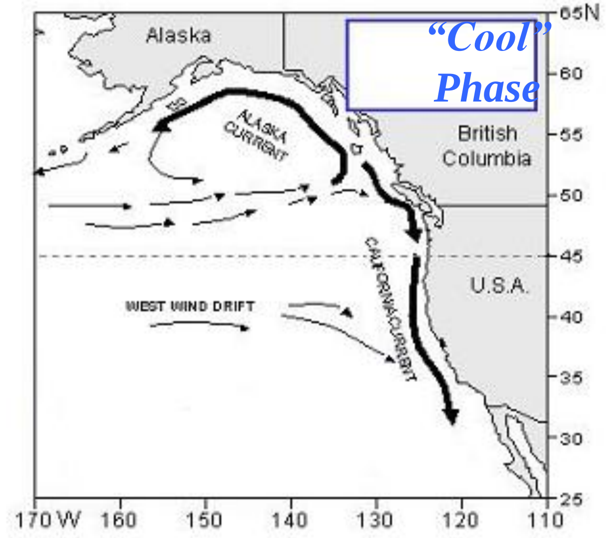


cold neritic
warm neritic
subarctic (cold) oceanic
warm oceanic
Proportion of copepod community types in zooplankton tows from Newport Line Station NH-05
Proportion of Total Copepod Biomass
1.0
0.8
0.6
0.4
0.2
0.0
96
97
98
99
00
01
02
03
04
05
06
07
08
09
10
11
Year

# A working mechanistic hypothesis: source waters. . .

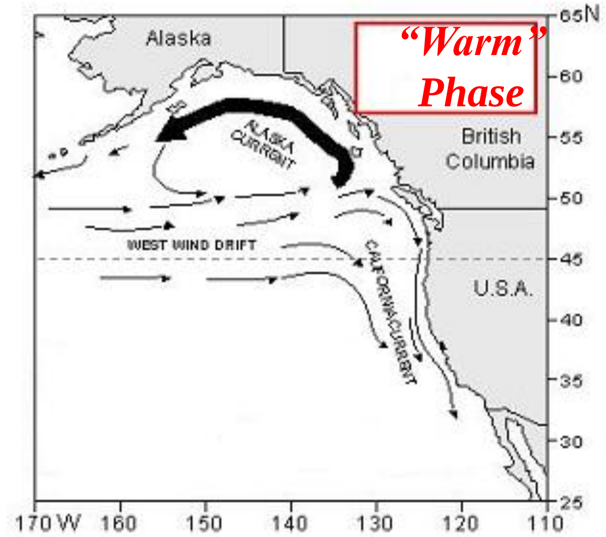
**Cool Phase →**

Transport of boreal coastal copepods into NCC from Gulf of Alaska




**Warm Phase →**

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




Verified in Keister et al. 2011 GCB and Bi et al. 2011 GRL

# Salmon Habitat and Forecasting

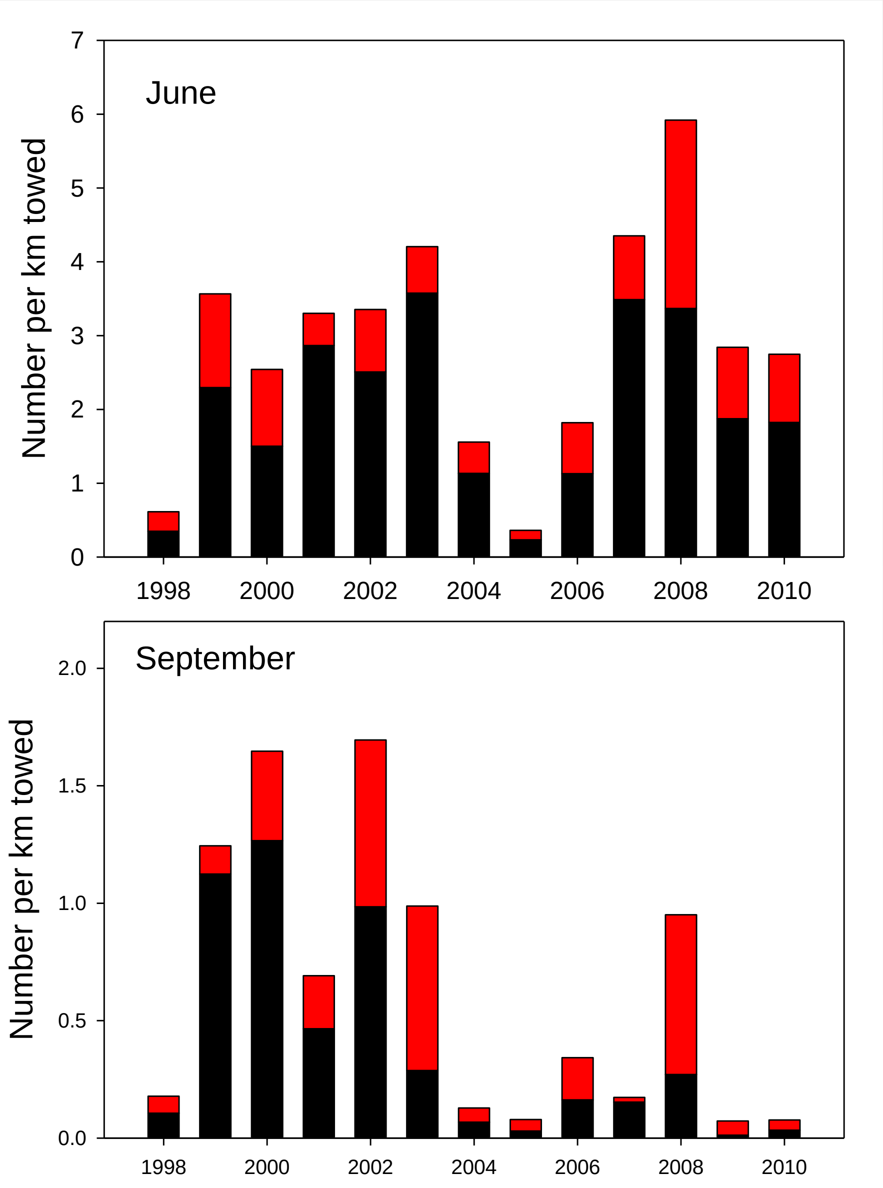
- In order to forecast returns of various salmon life history types, and to better understand interannual variaiblity, we must first establish where they live in the ocean.

- As shown earlier, we have done this from our surveys in May, June and September since 1998 and have established that they are found only on continental shelf waters

# Forecasting –- since we know that juvenile salmon live in continental shelf waters, we use indices relevant to shelf waters and as I said earlier, we must also consider forces acting from great distances

- 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
  - Biological Spring Transition
  - Copepod Community Structure
  - Fish larvae collected in winter
  - Catches of spring Chinook in June
  - Catches of coho in September

# Catches of juv. Salmon in trawl surveys




- Black bars = coho
- Red bars = spring Chinook

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- Sept 2010 among the lowest catches of coho (rank 11/13)
- June 2010 among the highest catches spring Chinook (rank 5/13)

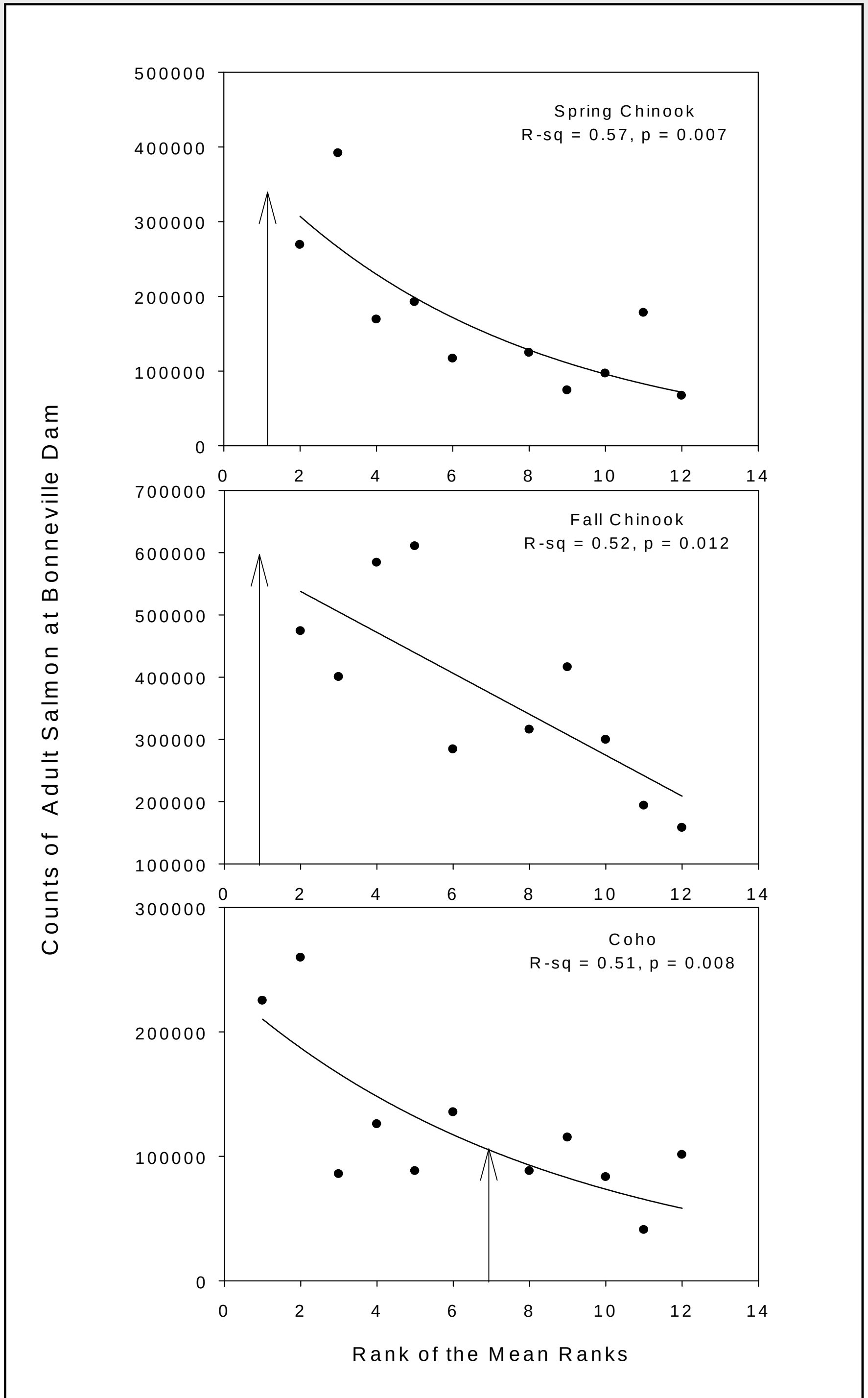
| | |
|---|---|
| **Basin Scale Physical Indicators** | |
| PDO | Negative is good |
| MEI | Negative is good |
| | |
| **Local Physical Indicators** | |
| SST | Cold is good |
| Date of spring transition | Early is good |
| Length of upwelling season | Long is good |
| Deep water temperature | Cold is good |
| | |
| **Local Biological Indicators** | |
| Copepod species richness | Low is good |
| Northern copepod biomass | High is good |
| Winter fish larvae | High is good |
| | |
| **Catches of juvenile salmon on surveys** | |
| Chinook catches in June | High is good |
| Coho catches in September | High is good |

# Indicator Values

| | | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | 2.17 |
| 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 |
| MEI Annual | | 0.80 | -0.89 | -0.53 | -0.18 | 0.58 | 0.45 | 0.43 | 0.29 | 0.31 | -0.33 | -0.67 | 0.38 | -0.42 |
| MEI Jan-June | | 2.22 | -0.85 | -0.67 | -0.30 | 0.31 | 0.57 | 0.26 | 0.62 | -0.27 | 0.25 | -0.84 | -0.17 | 0.84 |
| | | | | | | | | | | | | | | |
| SST 46050 | 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 |
| SST NH 05 Summer | deg C | 11.26 | 10.79 | 10.64 | 11.08 | 10.73 | 10.91 | 13.11 | 12.00 | 11.11 | 12.08 | 10.74 | 12.00 | 11.50 |
| SST NH 05 Winter Befor | deg C | 12.00 | 10.80 | 9.96 | 10.04 | 10.11 | 10.78 | 11.02 | 10.74 | 10.47 | 9.84 | 9.36 | 10.03 | 11.28 |
| SST NH 05 Winter After | deg C | 10.80 | 9.96 | 10.04 | 10.11 | 10.78 | 11.02 | 10.74 | 10.47 | 9.84 | 9.36 | 10.03 | 11.28 | |
| Physical Spring Trans U | Day of Yea | 83 | 88 | 134 | 120 | 84 | 109 | 113 | 142 | 109 | 70 | 87 | 82 | 95 |
| Upwelling Anomaly (April-May) | | -14 | 19 | -36 | 2 | -12 | -34 | -27 | -55 | -14 | 9 | 0 | -5 | -35 |
| Length of upwelling sea | days | 191 | 205 | 151 | 173 | 218 | 168 | 177 | 129 | 195 | 201 | 179 | 201 | 161 |
| NH 05 Deep T | deg C | 8.58 | 7.51 | 7.64 | 7.50 | 7.38 | 7.75 | 7.88 | 7.91 | 7.92 | 7.55 | 7.46 | 7.70 | 7.67 |
| NH 05 Deep S | | 33.51 | 33.87 | 33.83 | 33.87 | 33.86 | 33.70 | 33.66 | 33.79 | 33.82 | 33.88 | 33.87 | 33.73 | 33.71 |
| Copepod richness anor | no. of spec | 5.49 | -2.46 | -3.03 | -0.41 | -0.72 | 1.52 | 0.57 | 5.02 | 3.67 | -0.39 | -0.53 | -0.35 | 3.70 |
| Northern Copepod Bion | log biomas | -1.97 | 0.08 | 0.72 | 0.49 | 0.83 | -0.08 | 0.26 | -1.74 | 0.16 | 0.62 | 0.87 | 0.66 | 0.68 |
| Biological Transition | Day of Yea | 365 | 134 | 97 | 79 | 108 | 156 | 146 | 230 | 150 | 81 | 64 | 65 | 135 |
| Copepod Community st | X-axis ordi | 0.75 | -0.84 | -0.83 | -0.78 | -0.98 | -0.18 | -0.11 | 0.57 | 0.00 | -0.66 | -0.93 | -0.81 | -0.19 |
| Winter Ichthyoplankton | log biomas | 0.16 | 0.90 | 1.80 | 1.25 | 1.05 | 0.63 | 0.58 | 0.83 | 0.59 | 0.60 | 1.84 | 0.89 | 1.65 |
| | | | | | | | | | | | | | | |
| 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 | 2.56 | 0.97 | 0.89 |
| 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 | 0.03 |

# 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 | 10 |
| PDO (May-September) | 7 | 2 | 4 | 3 | 8 | 12 | 11 | 13 | 9 | 10 | 1 | 6 | 5 |
| MEI Annual | 13 | 1 | 3 | 6 | 12 | 11 | 10 | 7 | 8 | 5 | 2 | 9 | 4 |
| MEI Jan-June | 13 | 1 | 3 | 4 | 9 | 10 | 8 | 11 | 5 | 7 | 2 | 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 Anomaly | 13 | 2 | 1 | 5 | 3 | 9 | 8 | 12 | 10 | 6 | 4 | 7 | 11 |
| N.Copepod Anomaly | 13 | 10 | 3 | 7 | 2 | 11 | 8 | 12 | 9 | 6 | 1 | 5 | 4 |
| Biological Transition | 13 | 7 | 5 | 3 | 6 | 11 | 9 | 12 | 10 | 4 | 1 | 2 | 8 |
| Copepod Community structure | 13 | 3 | 4 | 6 | 1 | 9 | 10 | 12 | 11 | 7 | 2 | 5 | 8 |
| Winter Ichthyoplankton | 13 | 6 | 2 | 4 | 5 | 9 | 12 | 8 | 11 | 10 | 1 | 7 | 3 |
| | | | | | | | | | | | | | |
| 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 | 4.1 | 4.5 | 5.4 | 4.6 | 9.4 | 10.0 | 11.0 | 8.2 | 5.9 | 2.7 | 6.1 | 8.1 |
| RANK of the mean rank | 12 | 2 | 3 | 5 | 4 | 10 | 11 | 13 | 9 | 6 | 1 | 7 | 8 |

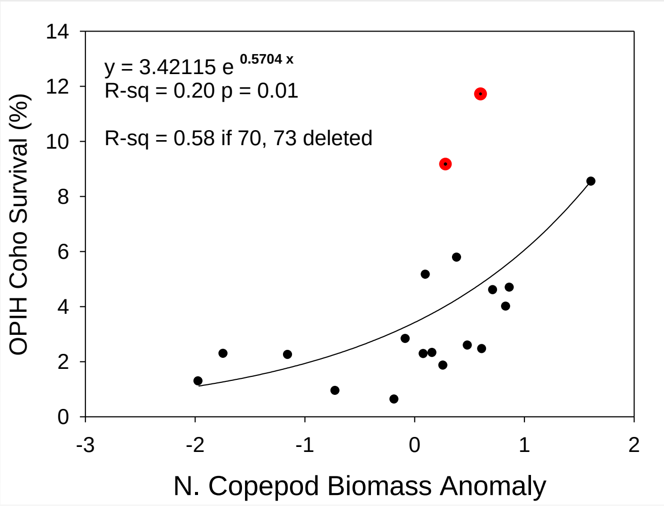


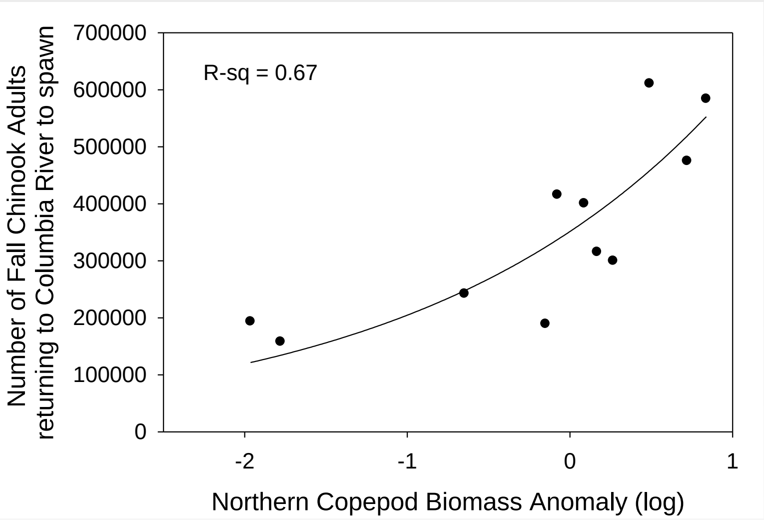

# 2008 and 2009 Ocean Entry

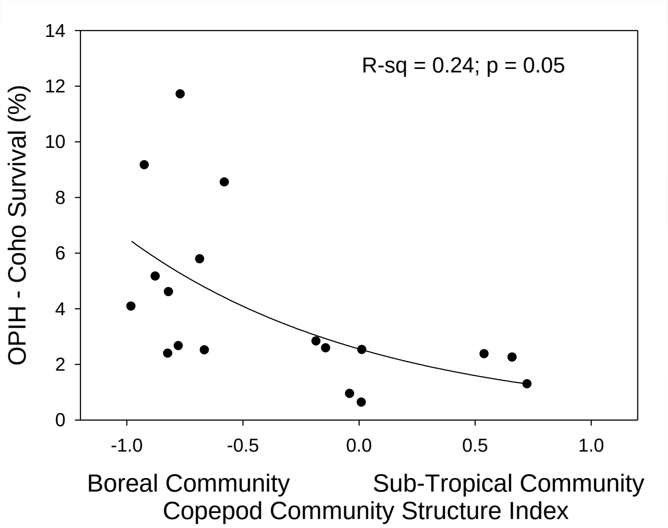
Salmon counts at Bonneville Dam vs. mean rank of all variables. Arrows indicate forecast for 2010:

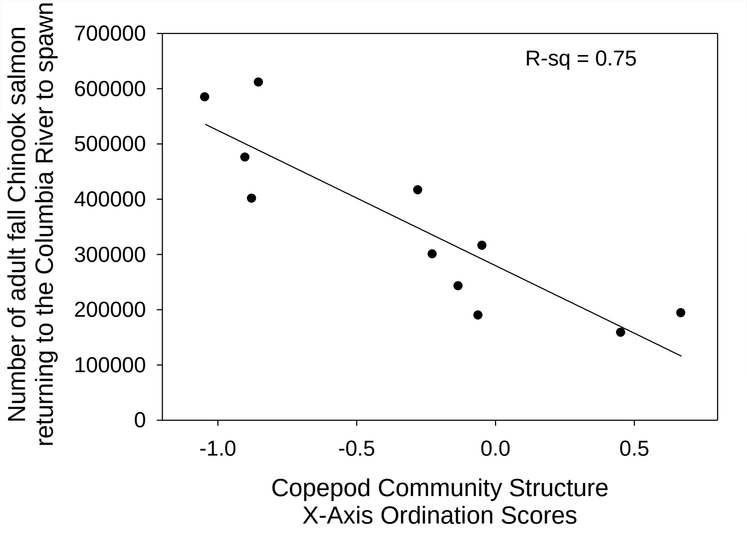
- Spring Chinook (2008 ocean entry): 278K returned in 2010, forecast was ~ 350K
- Fall Chinook (2008 ocean entry): 467K returned in 2010; forecast was ~ 550K.
- Of the coho that went to sea in 2009, 121K returned in 2010; forecast was 110K.
- Of the coho that went to sea in 2008, 225 K; forecast was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

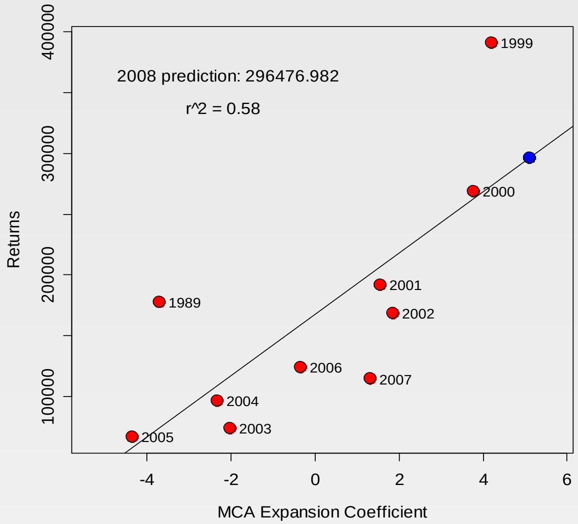
# Copepod data alone fit the counts at Bonneville fairly well



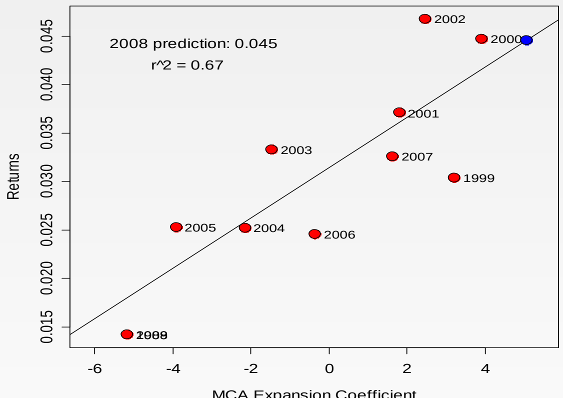



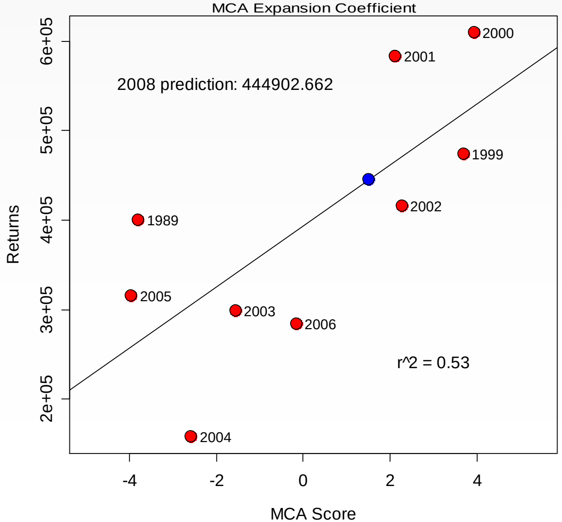






Spring Chinook Salmon




Coho Salmon



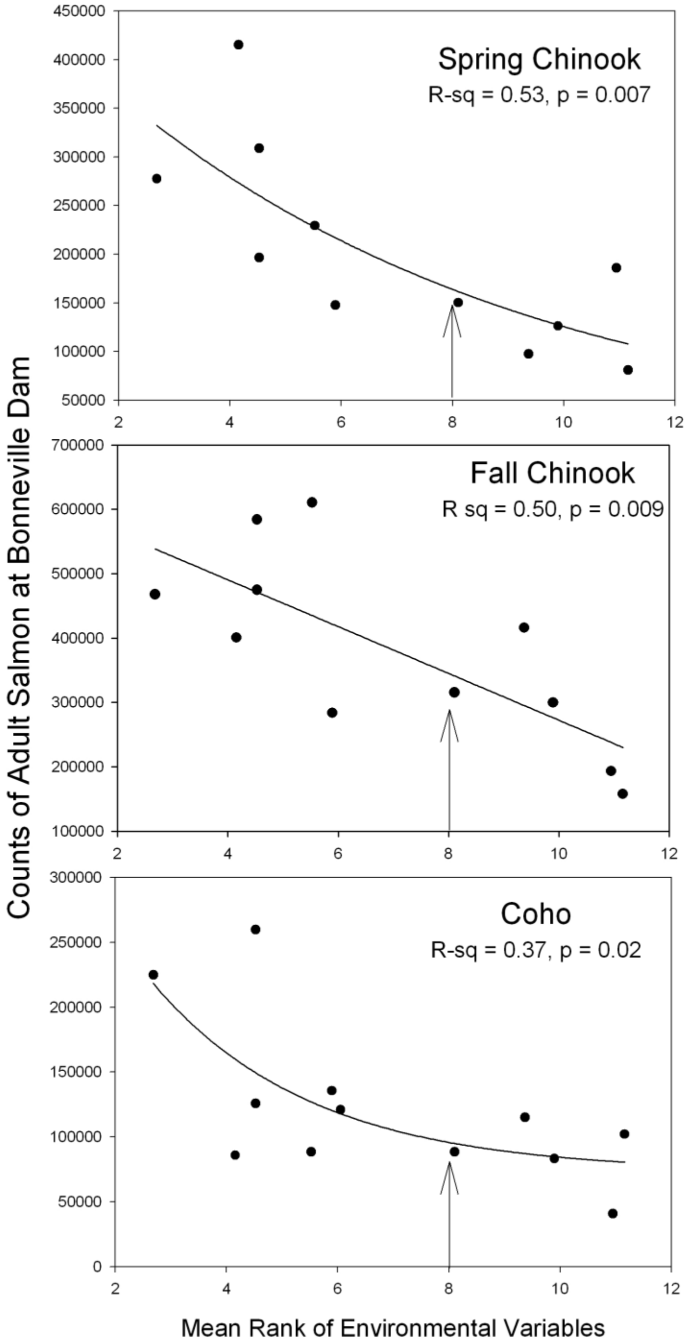

Fall Chinook Salmon

- New Goal: to develop <u>quantitative</u> relationships between the suite of indicators and adult returns

- Using <u>M</u>aximum <u>C</u>ovariance and partial least squares <u>A</u>nalysis

- Spring Chinook returns in 2010:
  - Bonneville Dam Count was 278K
  - MCA Index Prediction: 289,000
  - Peterson: ~ 350 K

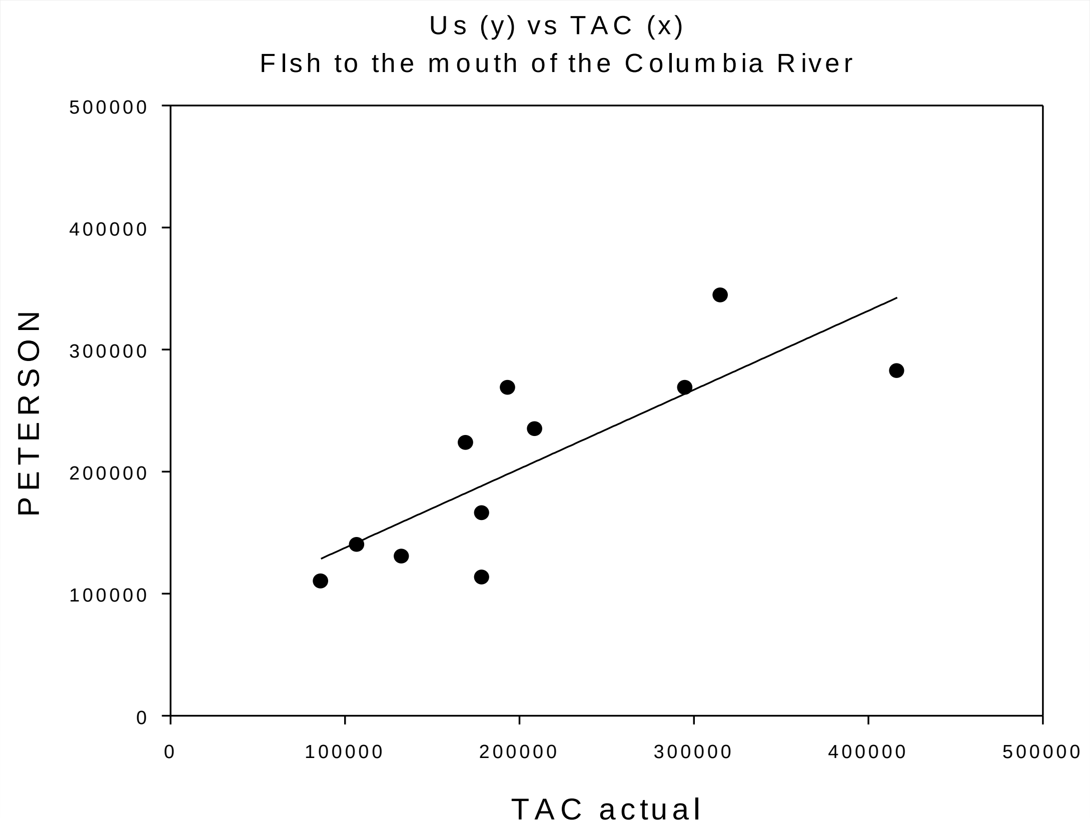
# 2010 Ocean Entry




Salmon counts at Bonneville vs. mean rank of environmental variables

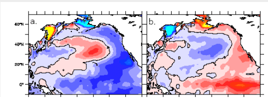
- Expect 150,000 spring Chinook in spring 2012
- Expect ~ 310,000 fall Chinook in fall 2012
- Expect ~ 100,000 coho in fall 2011
- Expect ~ 2.6% OPIH

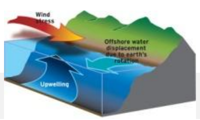
# Spring Chinook at mouth of Columbia

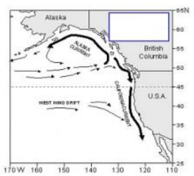


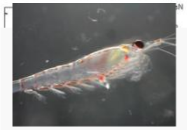

- "TAC Actual" from the TAC
- "Peterson" data from the composite index (mean rank from stoplight chart)
- $R^2 = 0.64$

# Even you can make a forecast.  Just check our webpage







- Phase of the PDO
- Upwelling
- Cold water coming from northern BC coast
- Cold water lipid-rich zooplankton, krill and small fish
- www.nwfsc.noaa.gov, “Ocean Conditions and Salmon Forecasting”

# 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 between PDO changes can complicate interpretations as do pesky El Niño events

What about climate change?

Climate is what you expect; weather is what you get!

Climate change means that the weather (and the ocean) will change but in ways that we may not expect!

# The surprises: the unanticipated events

- Ocean acidification (now less of a surprise)
- Waters of low oxygen content are shoaling in CC
- Summer of 2005 – no upwelling until mid-July
- Fish Kills in 2006 + nearly anoxic waters on Heceta Bank
- Humboldt squid appeared in large numbers in 2008-2009
- Collapse of Sacramento River fall Chinook salmon runs in 2007, 2008 and 2009 but record runs to the Columbia River
- Record runs of steelhead recently.
- Massive bloom of the dinoflagellate *Akashiwo sanguinea,* a first (!) resulting in deaths of large numbers of seabirds off the coast of Washington
- *Mola mola,* ocean sunfish, extremely common in September 2009
- 2010: a moderate El Niño event that proved strong
- 2011: negative PDO and fairly strong upwelling

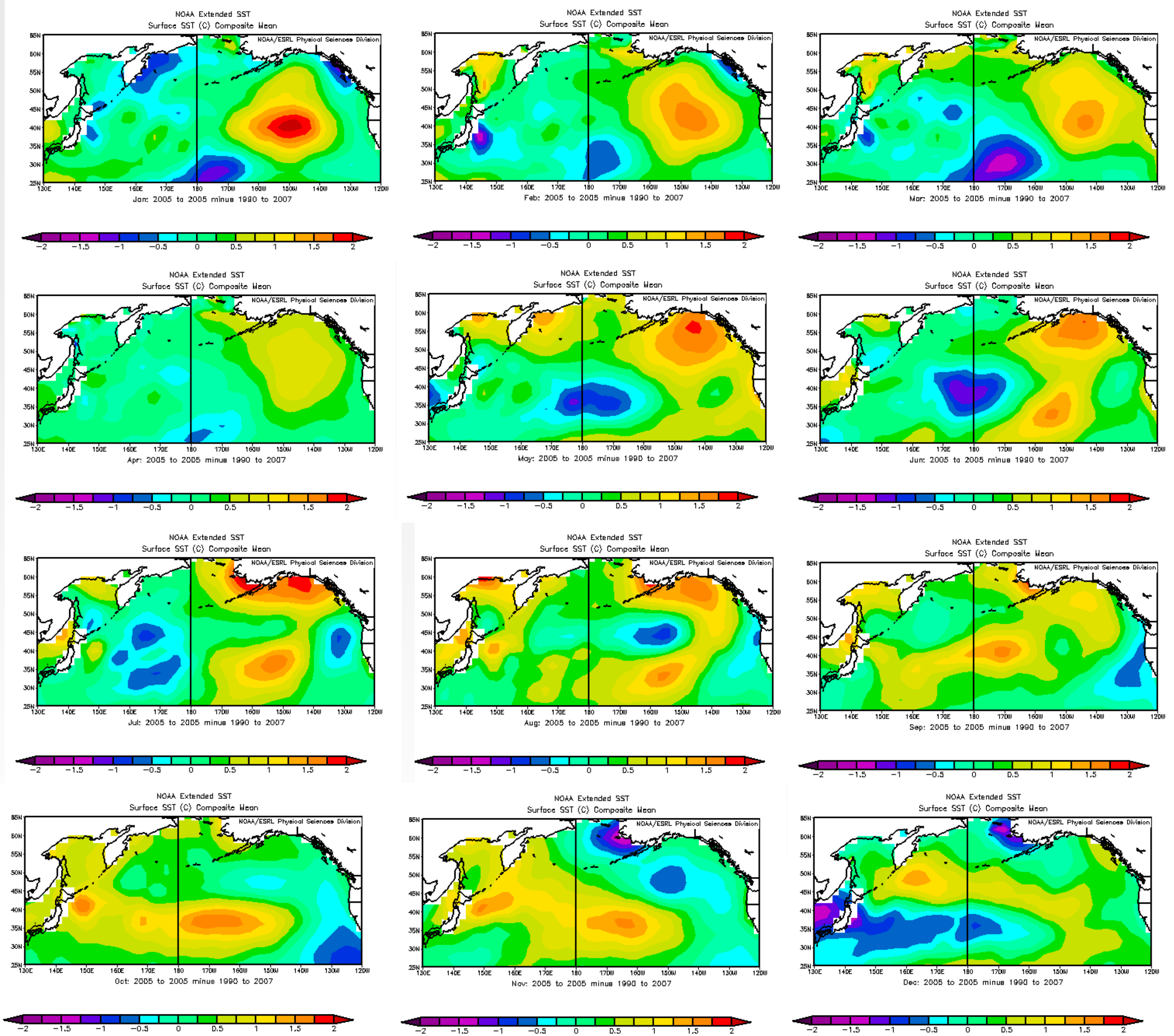
# What problems lie ahead for salmon and other fishes off the Pacific Northwest?

- Will coastal upwelling become weaker, stronger or stay the same?
- Will warming of the ocean lead to greater stratification thus reducing the effectiveness of coastal upwelling?
- Will the Pacific “Decadal” Oscillation return to “Decadal”?
- Will the central North Pacific Gyre expand northward and make the waters off Oregon more subtropical?
- Alternatively, will expansion of the gyre make coastal upwelling more productive?
- Of great concern in coastal upwelling systems is the trend toward decreased oxygen concentration and of decreased pH in waters which upwell at the coast.

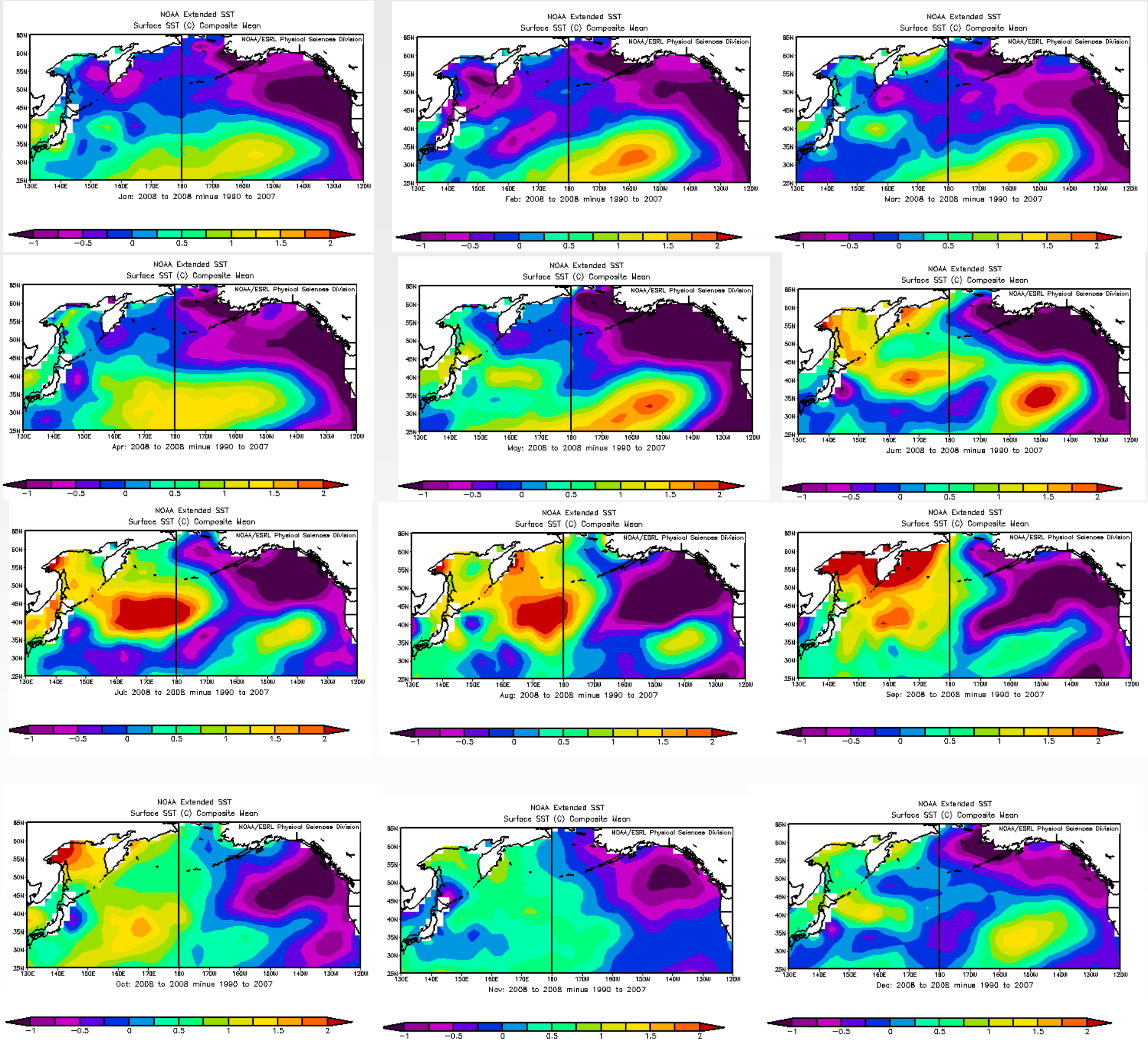
# Two Contrasting Years

- 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.


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

2005


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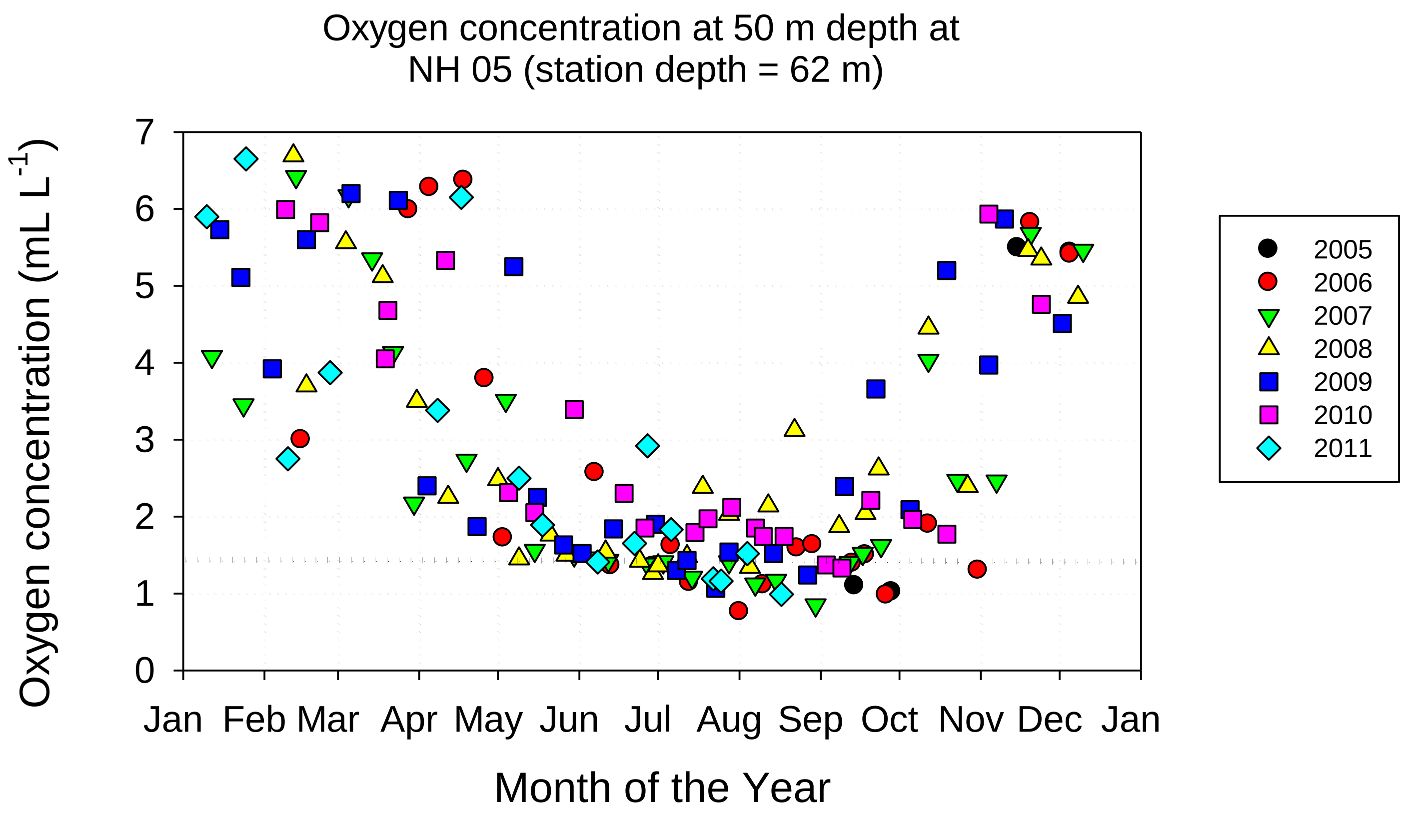
Jul: 2008 to 2008 minus 1990 to 2007
Aug: 2008 to 2008 minus 1990 to 2007
Sep: 2008 to 2008 minus 1990 to 2007
Oct: 2008 to 2008 minus 1990 to 2007
Nov: 2008 to 2008 minus 1990 to 2007
Dec: 2008 to 2008 minus 1990 to 2007
−1 −0.5 0 0.5 1 1.5 2

# 2008

# Humboldt Squid:
# Changes in marine food chains

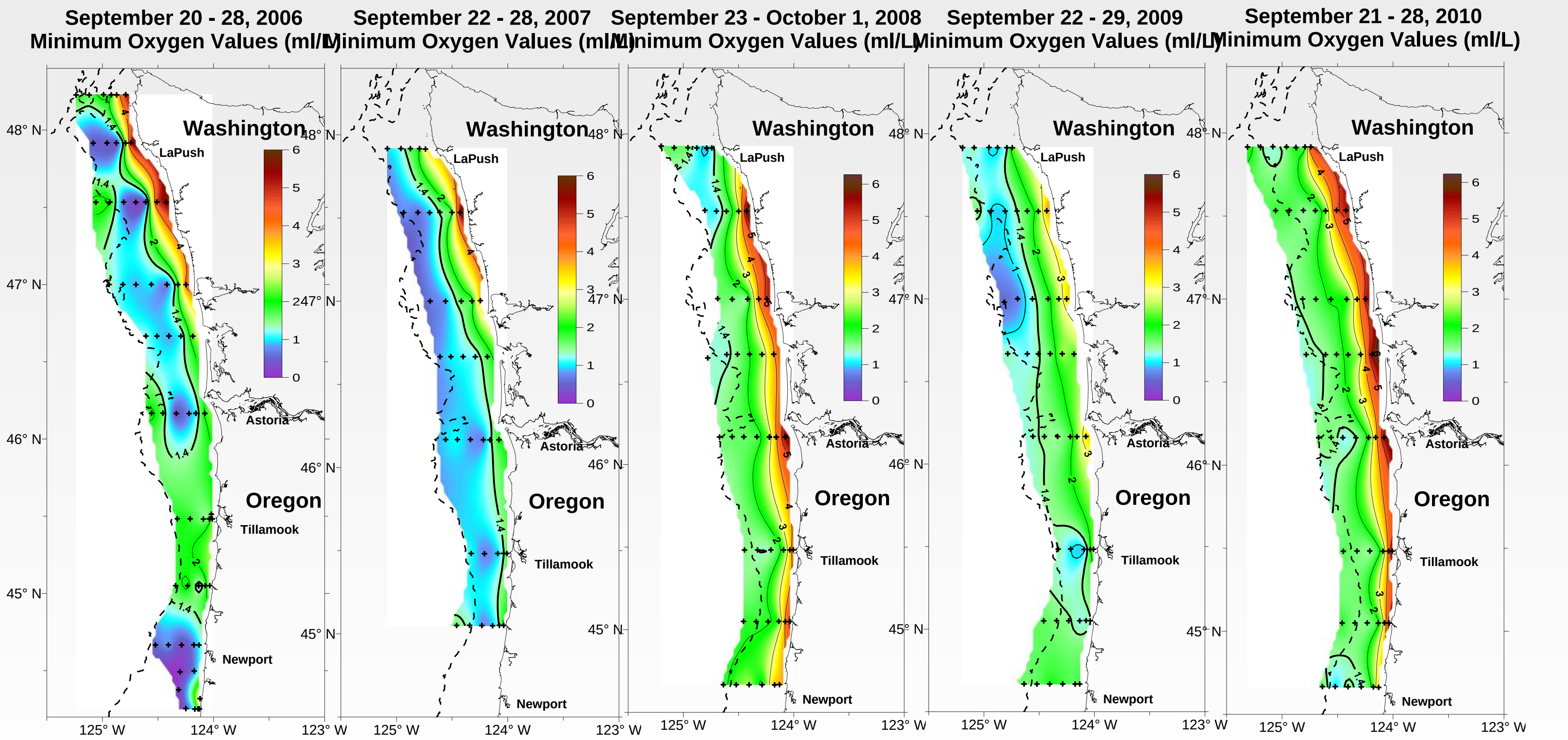
Photo taken just outside Ucluelet near Tofino BC…
Published in <www.westcoaster.ca>

# Oxygen in shelf waters off Newport




| | | |
|---|---|---|
| 2006 | 17 Jun – 31 Oct | ~ 130 d |
| 2007 | 12 Jun- 12 Sep | ~ 90 d |
| 2008 | 24 Jun – 5 Aug | ~ 45 d |
| 2009 | 8 Jul- 27 Aug | ~ 50 d |
| 2010 | 3 Sep - 9 Sep | ~ 7 d |
| 2011 | 8 Jun- | ~ 80 d (at least) |

# Oxygen data from CTD casts during the September Juv. Salmon trawl survey:2006-2010




Widespread hypoxia (blue/purple color) in 2006 and 2007;
Virtually none anywhere in 2010

# 2010 was a confusing year

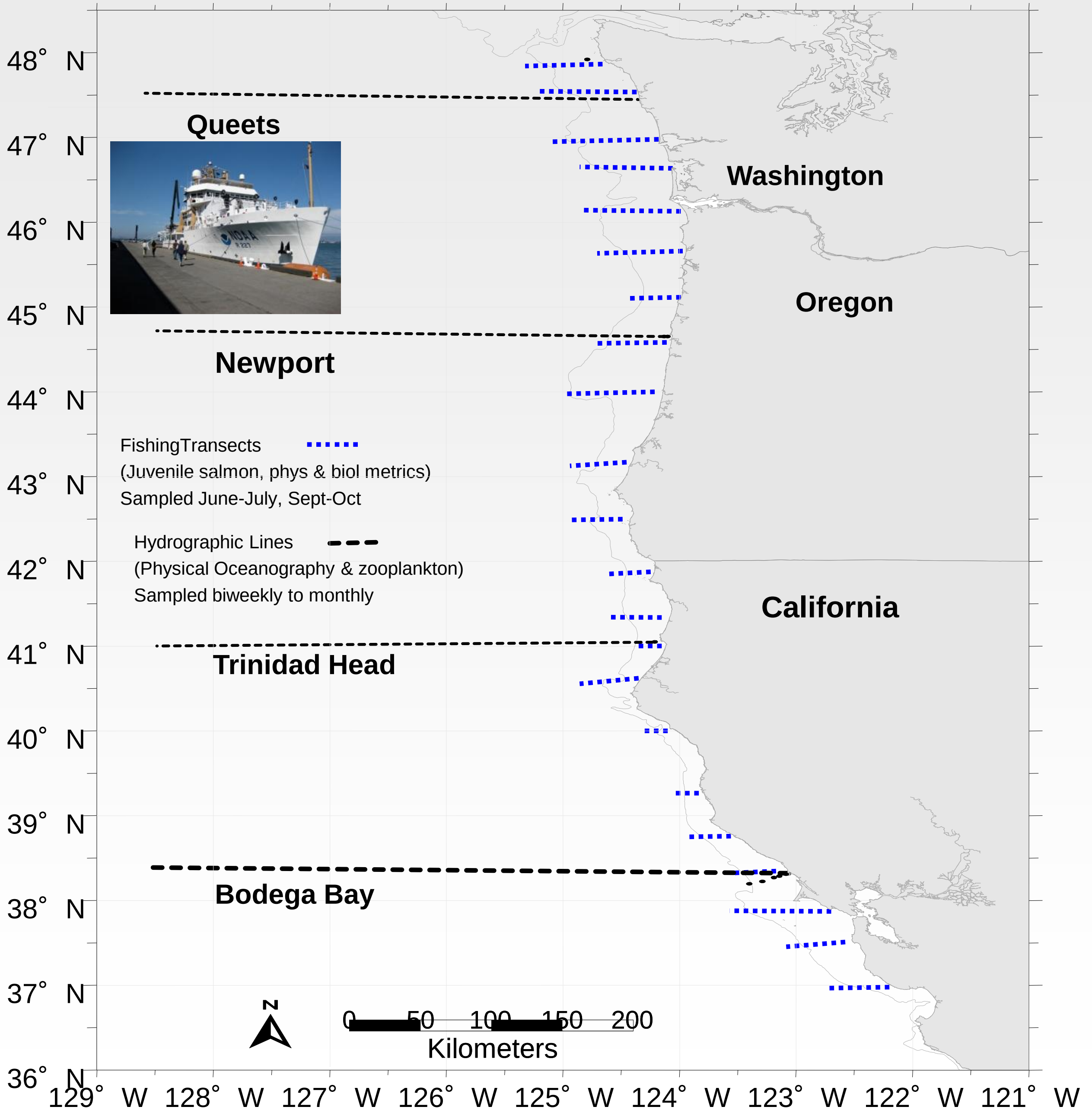
- My yard in Newport was overrun by Townsend's chipmunks in 2010 (live trapping dealt with that – as bait, they seemed to prefer cantaloupe over grapes)
- My cherry tomatoes did not ripen until October
- Our wild blackberries never ripened!

# Where is our work headed?

- Expanded surveys of salmon with Southwest Center and of hydrography and plankton with NOAA ships
- Copepod indicators along (Workshop last week in Newport)

# Coast-wide Surveys: Scope

- An annual coast-wide survey, supported by NOAA ships?
- Gather physical and biological data from the Canadian border south to Monterey
- Each year: 3, 30-day cruises (Feb-March, May, June, and September)
- Establish/maintain long term biweekly-monthly observations of ocean conditions (partly with contract vessels) along 4 lines



# Acknowledgements

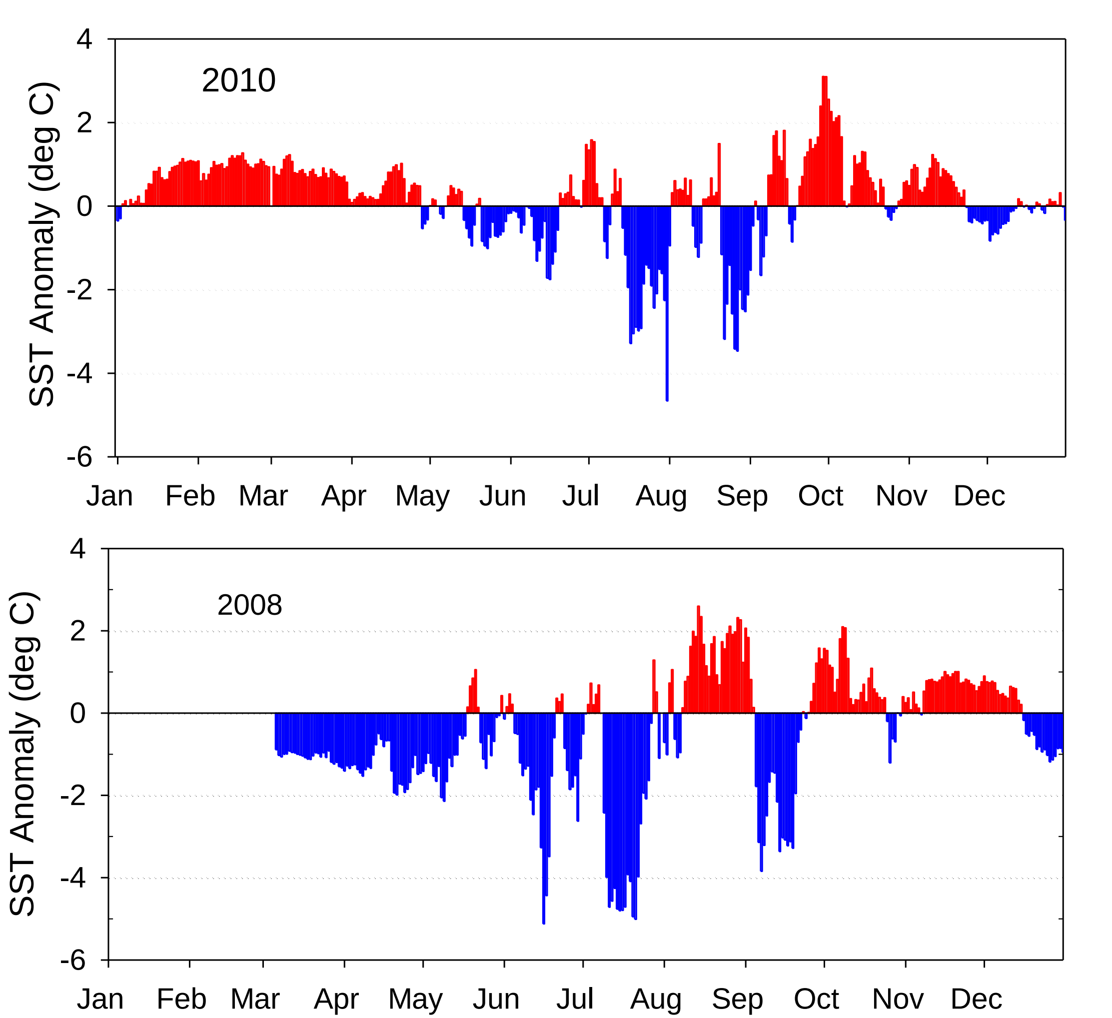
- Bonneville Power Administration
- U.S.GLOBEC Program (NOAA/NSF)
- NOAA Stock Assessment Improvement Program (SAIP)
- Fisheries and the Environment (FATE-NOAA)
- National Science Foundation
- Office of Naval Research
- NASA

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

# Summary: 2010 had to be a confusing year from the viewpoint of a salmon (red=bad; green = good):

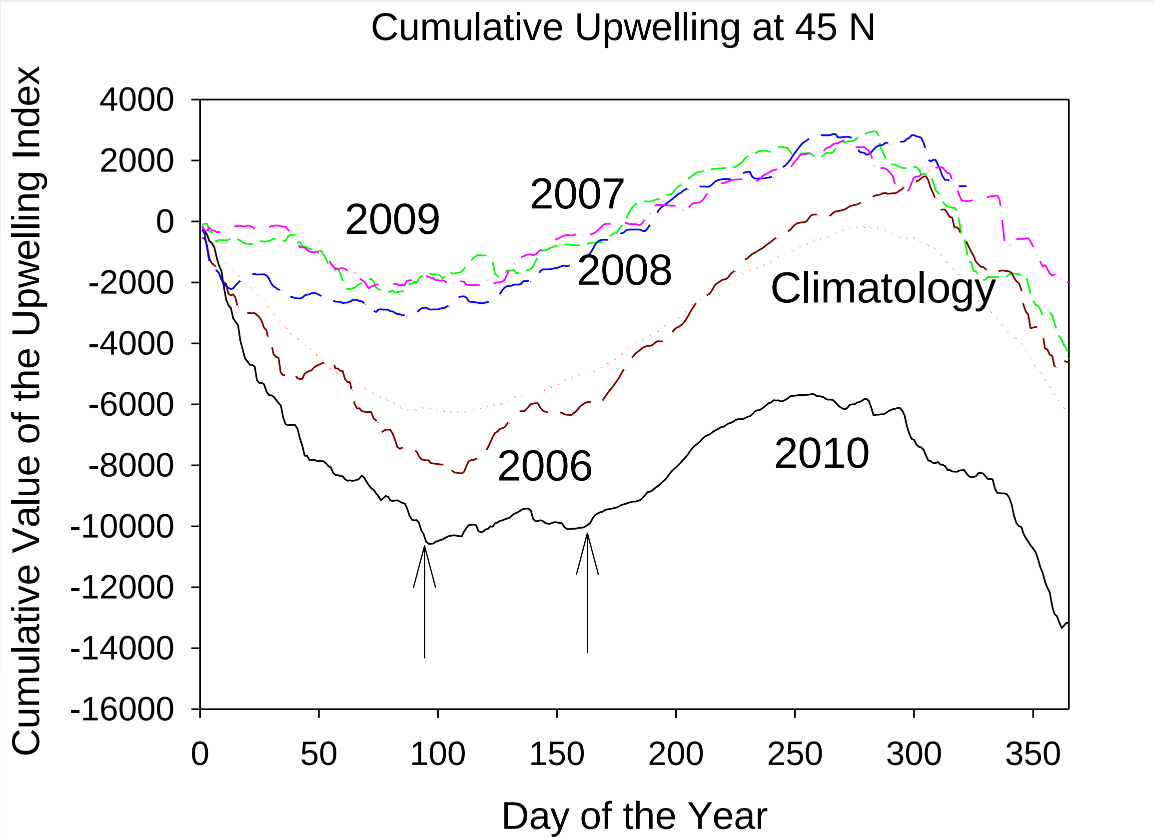
- PDO strongly positive in winter (El Niño) then strongly negative in summer (La Niña), similar to MEI.
- SST warm early; cold late
- Spring transition early (~day 90) but significant upwelling did not begin until two months later, on ~ day 160
- Barely a hint of hypoxia
- Copepod species richness high throughout spring/summer/fall;
- Northern copepod biomass low in spring but very high in summer;
- Fish larvae in winter (this is a new index) very abundant (rank 3/13) suggesting good feeding for juv. Salmon when they enter the ocean in May
- Fairly high catches of spring Chinook in May & June but really lousy catches of coho in September;

# SST Anomalies at the NOAA Buoy 46050: SST in summer 2010 similar to 2008, however the winter of 2008 was very cold (with few storms) whereas winter 2010 was warm due to many SWly storms




No data: Jan-Feb 2010 due to sensor failure

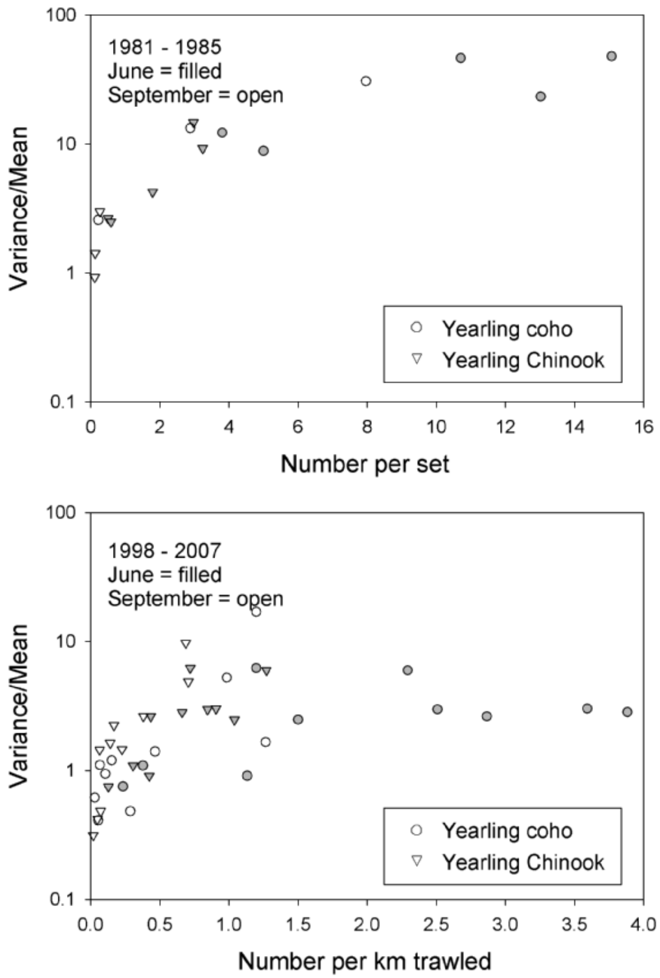
# PFEL Cumulative Upwelling Index 45 N

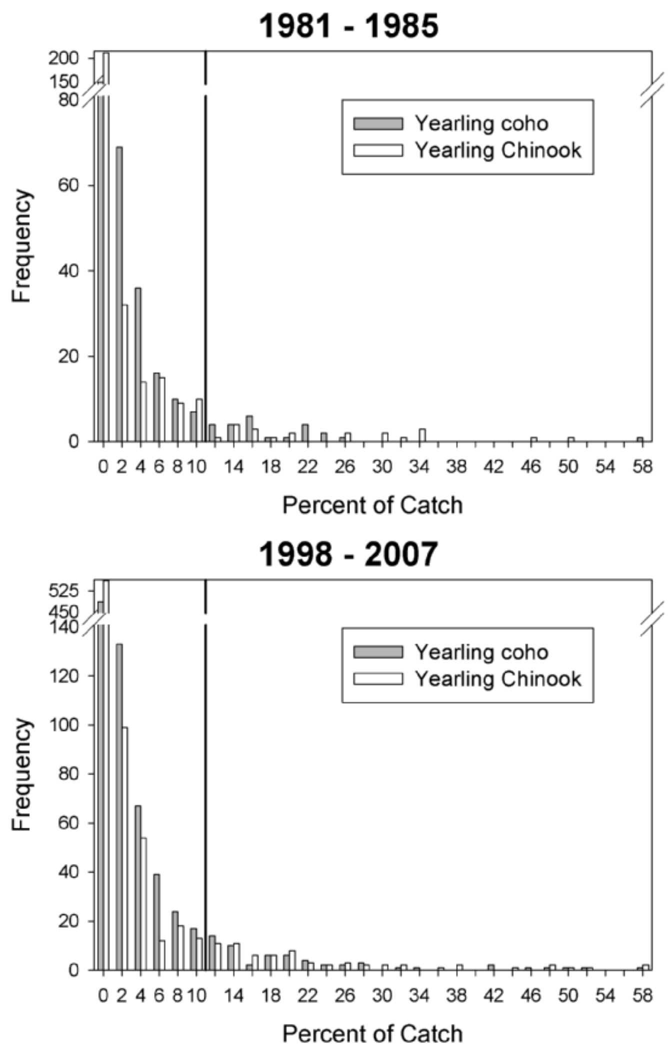



- 2006 strong upwelling
- 2007-2009 no winter storms but not much upwelling either
- 2010. Intense winter storms; summer similar to 2007-2009.

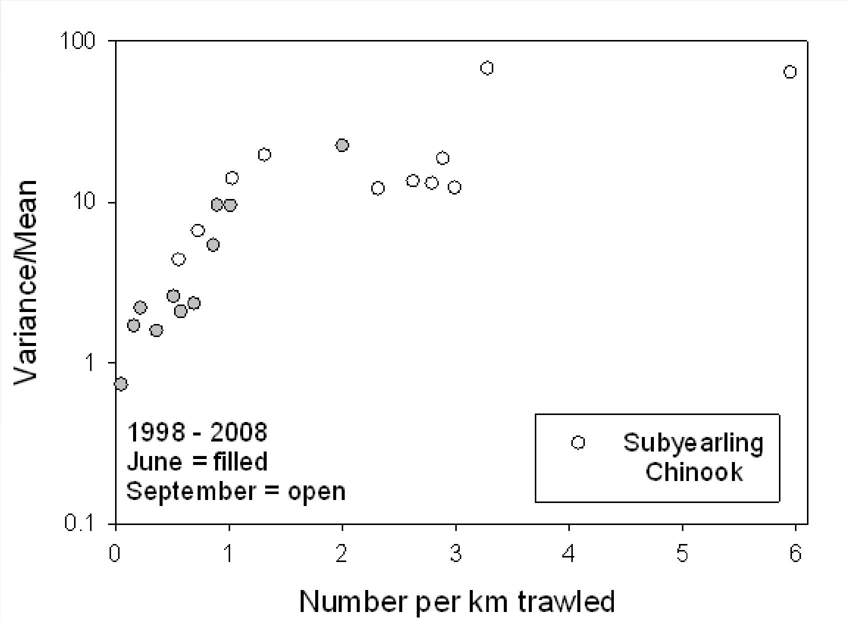
Climatology is the red dotted line

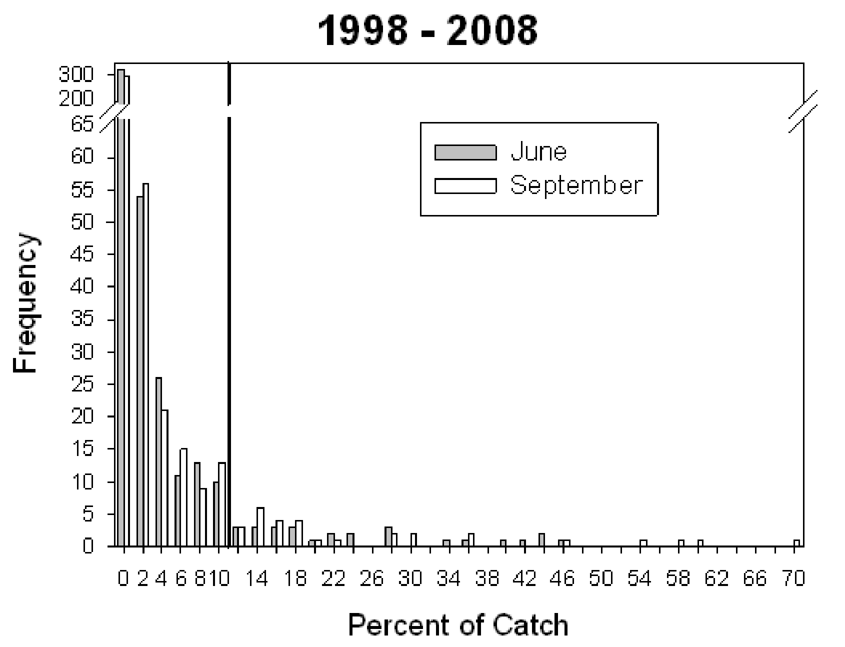
# Salmon have a patchy distribution



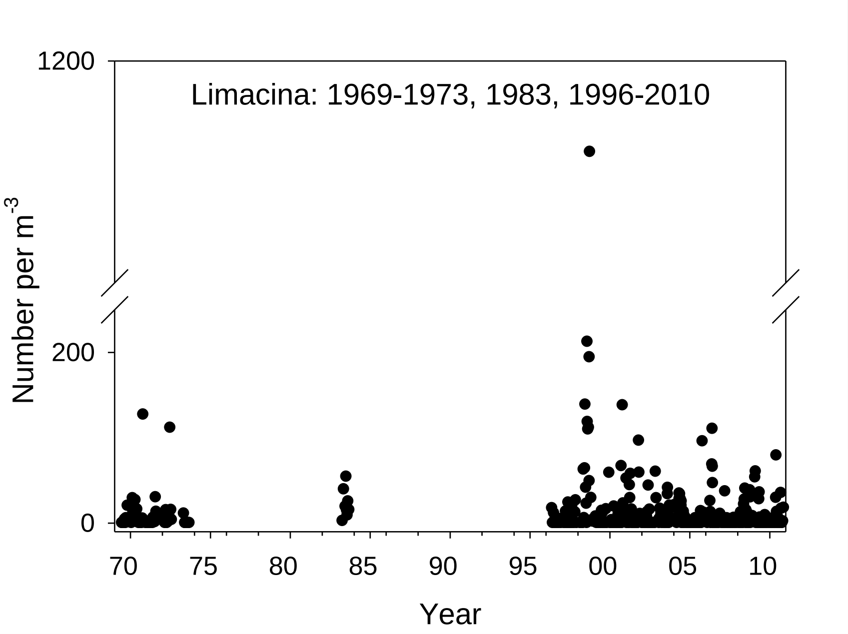



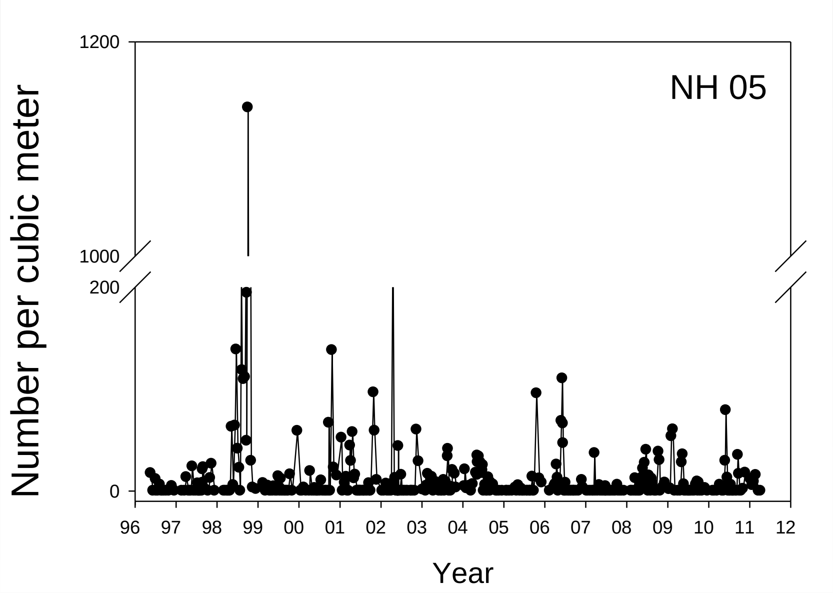
# Fall (subyearling) ocean-type Chinook salmon

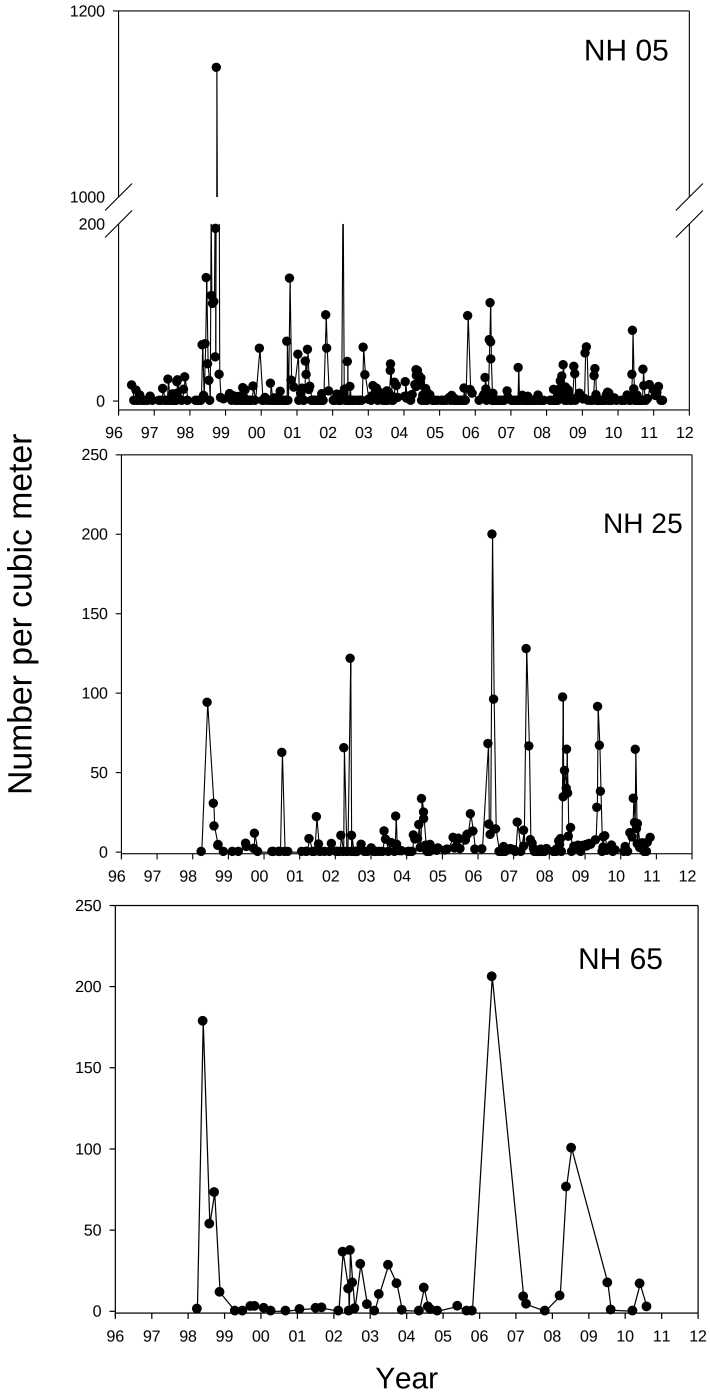


# Pteropod Time Series (*Limacina helicina*)

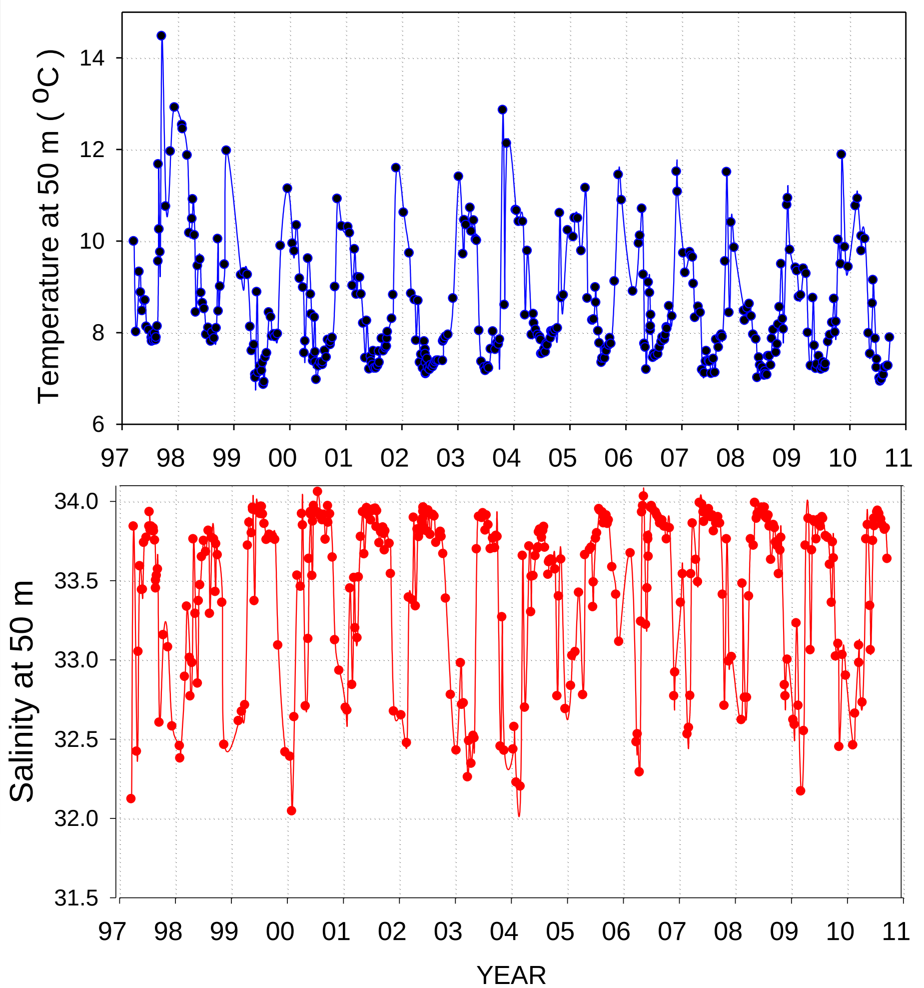


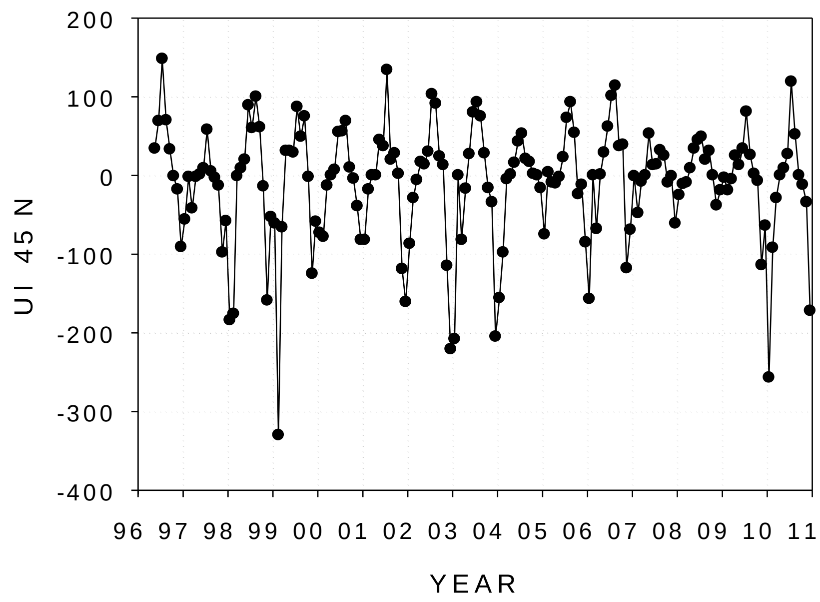





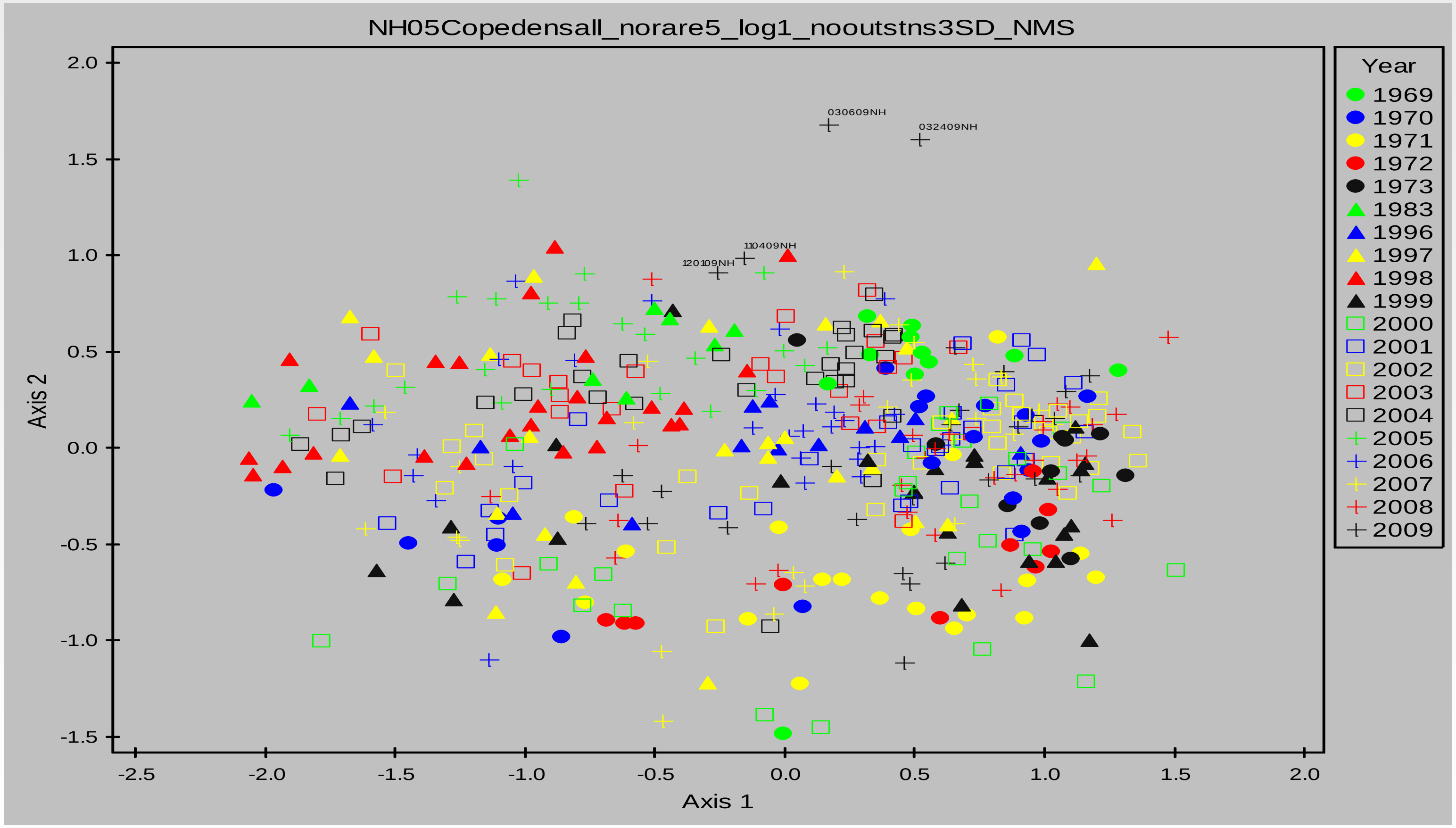

# Limacina
# NH 05 = 62 m
# NH 25 = 300 m
# NH 65 = 3000 m

# Seasonal cycle of upwelling and temperature and salinity



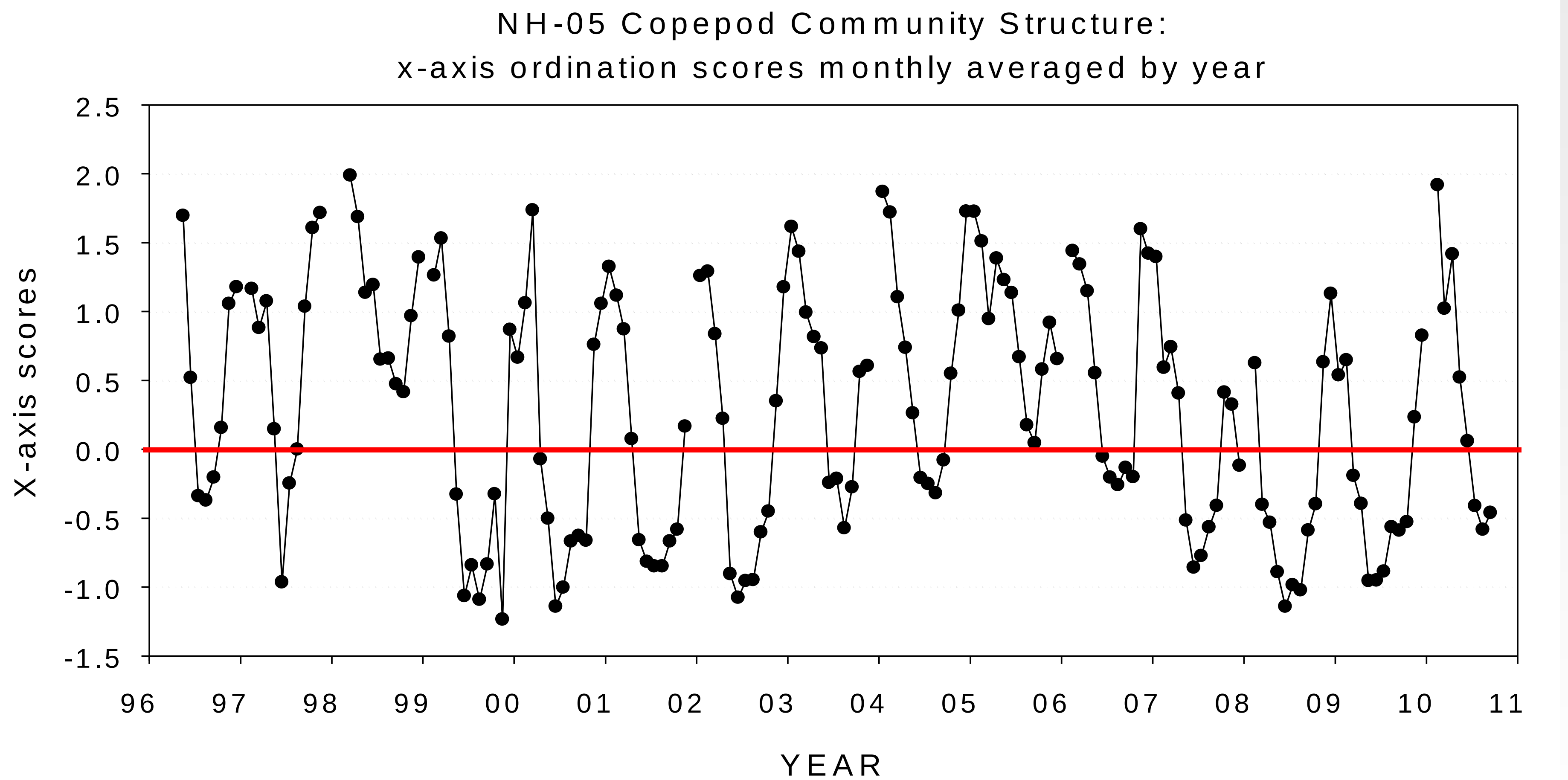



# NMDS (Non-Metric Multidimensional Scaling) Plot of Copepod Community Structure




X-axis explains about 70% of the variance

# Interannual Variability in Copepod Community Structure




Positive scores = warm water community; usually in winter

Negative scores = cold water community; usually in summer

Exceptions: El Nino 1998 and summer 2005