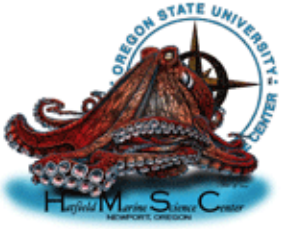
Ocean Conditions, Salmon, and Climate Change

John Ferguson[1]
NOAA Fisheries
Northwest Fisheries Science Center
Seattle, Washington

[1] Talk represents work by dozens of scientists at NWFSC and OSU



Today's talk

- Past (why study the ocean?)
- Present (how we study the ocean)
- Future (what we're finding - adult forecasts and climate change)

1. Past (for context)

- The coastal pelagic ecosystem is dynamic
- Multiple species increase and decrease in abundance over various time scales
- For salmon, ocean productivity sets salmon recruitment levels - return rates can vary >10x with similar freshwater conditions/survival

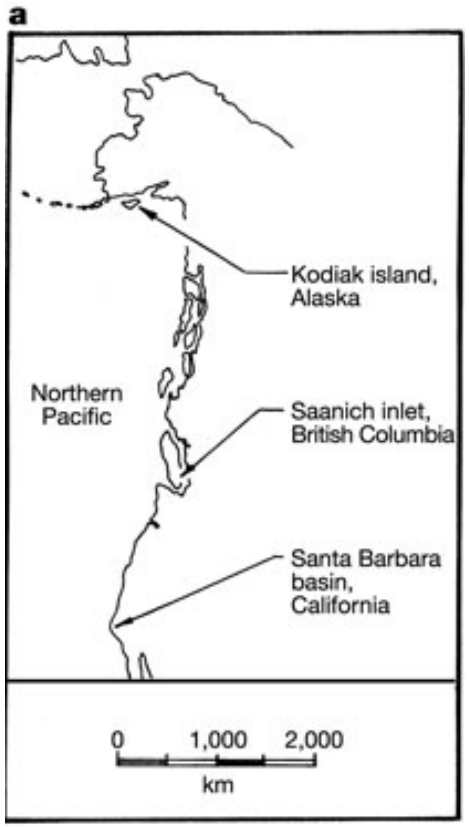
NE Pacific Ocean fisheries productivity, 200 BC to 2000 AD (by Finney et al. 2002 Nature)

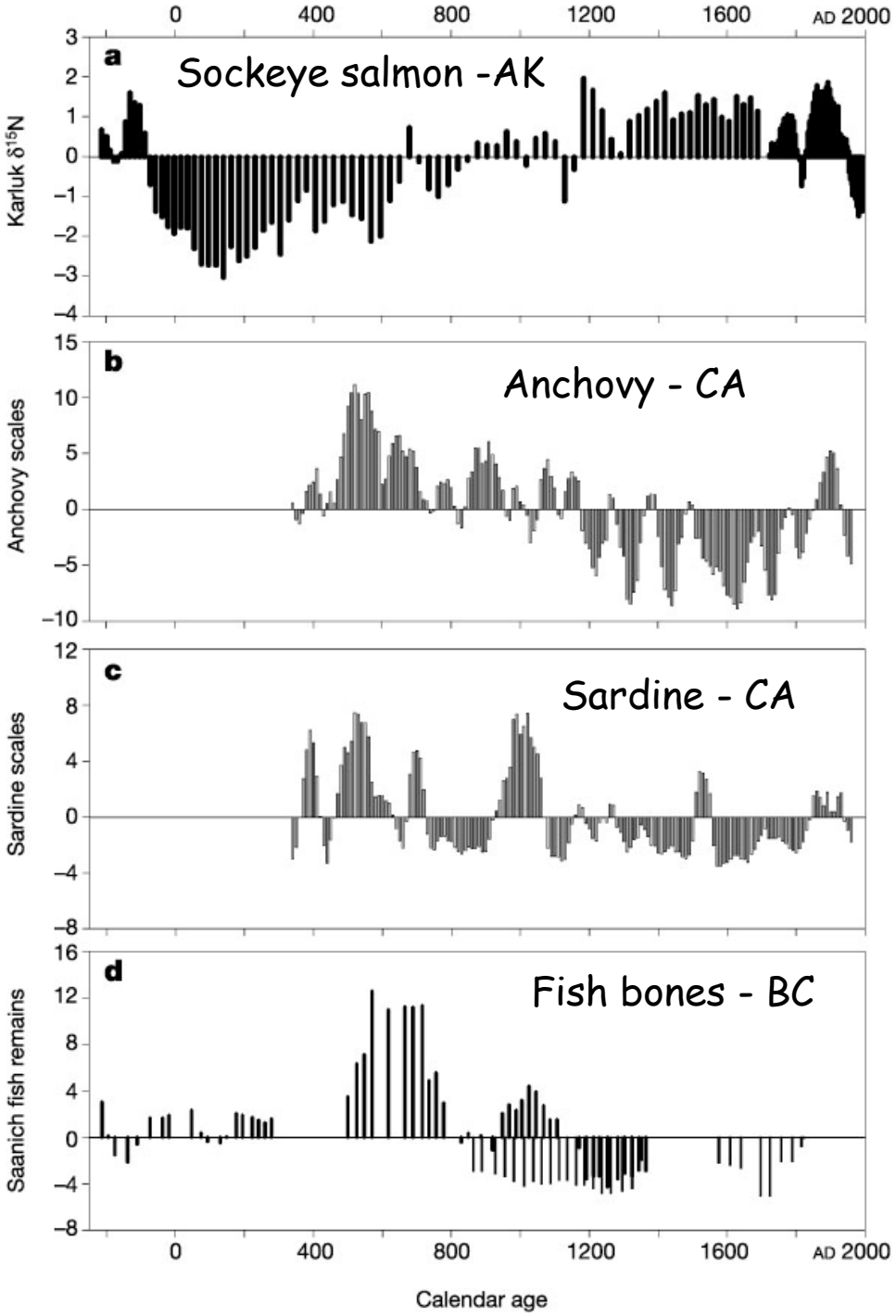
Main points:

-Salmon cycles can last ~1,000 years

-Anchovy & sardines out of phase with salmon in Alaska

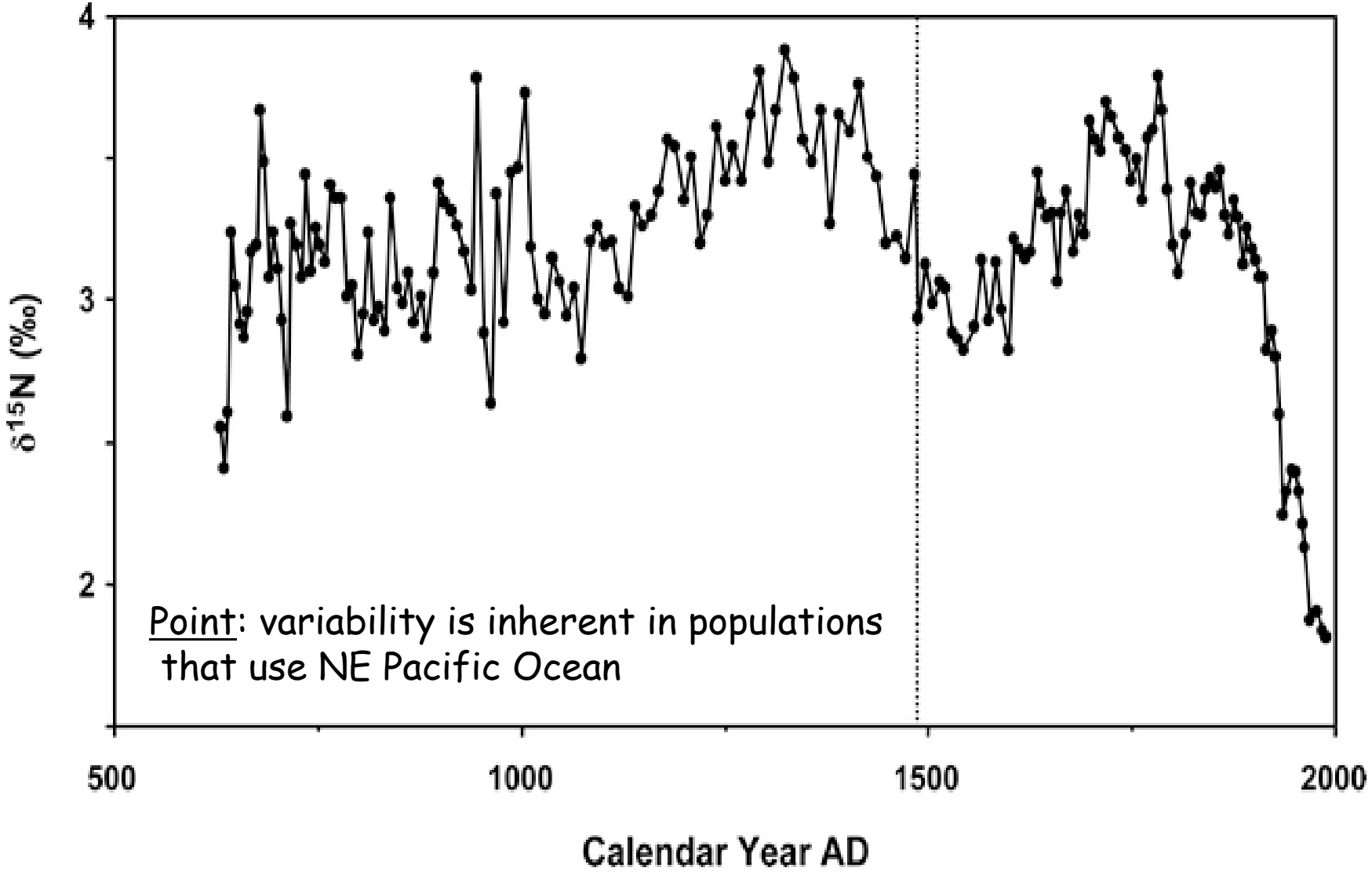
-Within millennia, cycles last 60-100 years



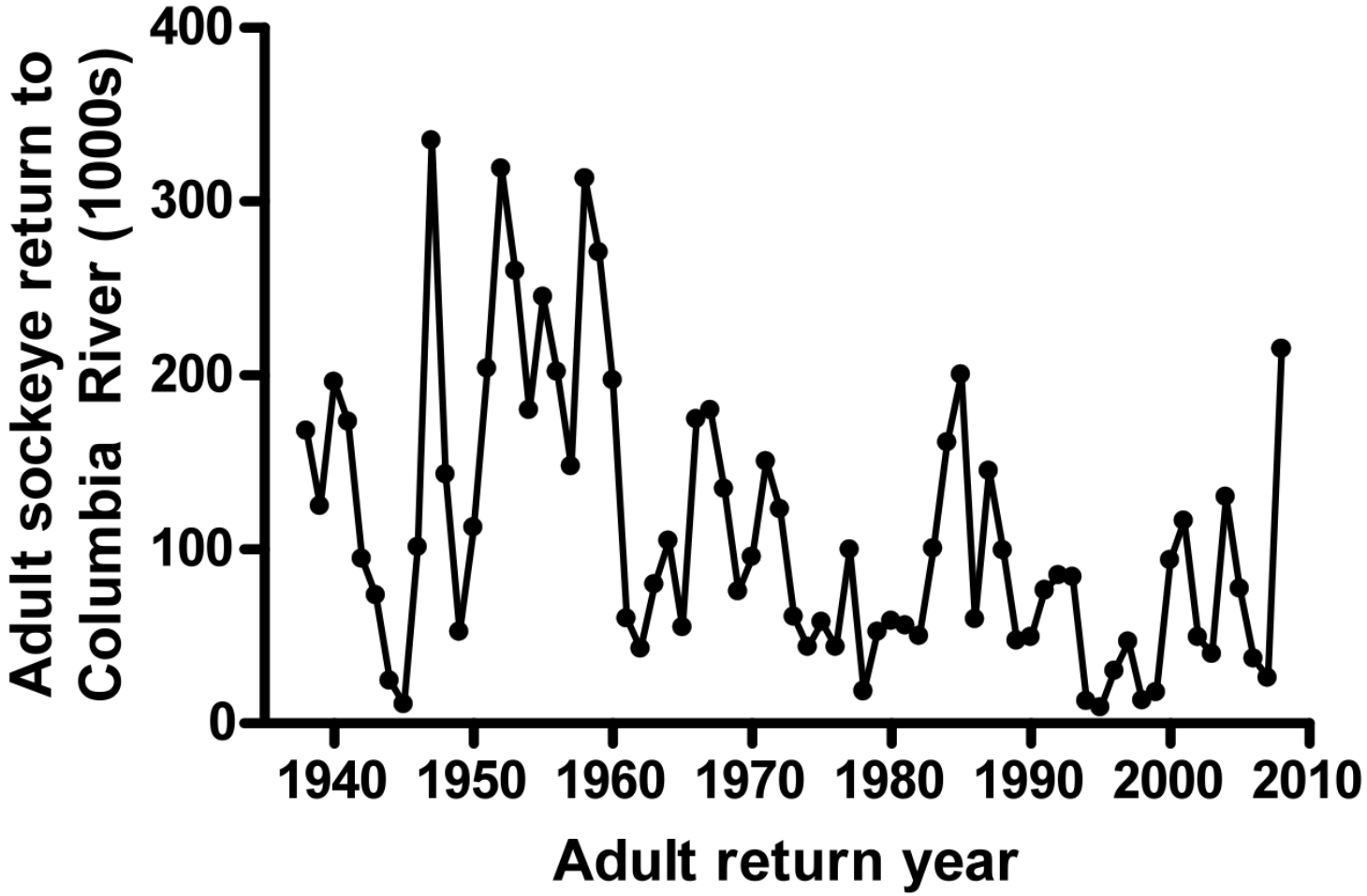


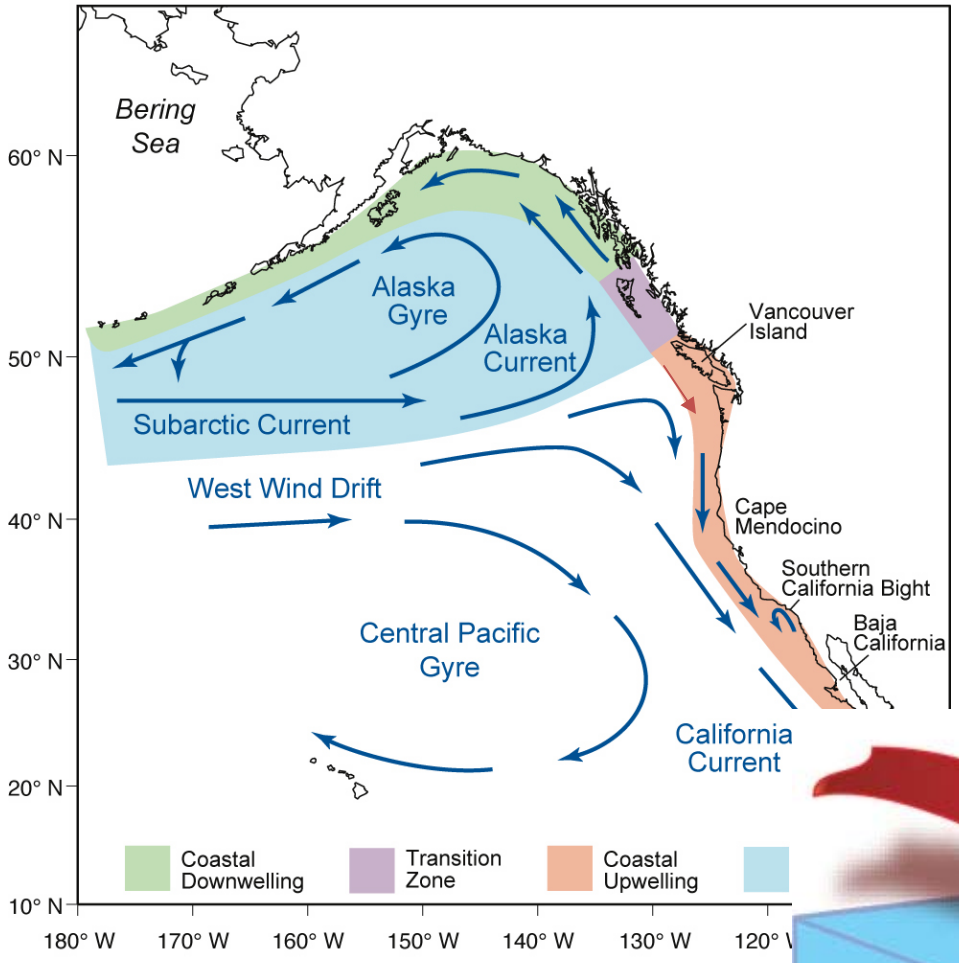
Closer to home…Redfish Lake sockeye

(Selbie et al. 2007 Trans. Am. Fish. Soc.136:800-821)



Recent Columbia River sockeye dam counts display variability on shorter time scales

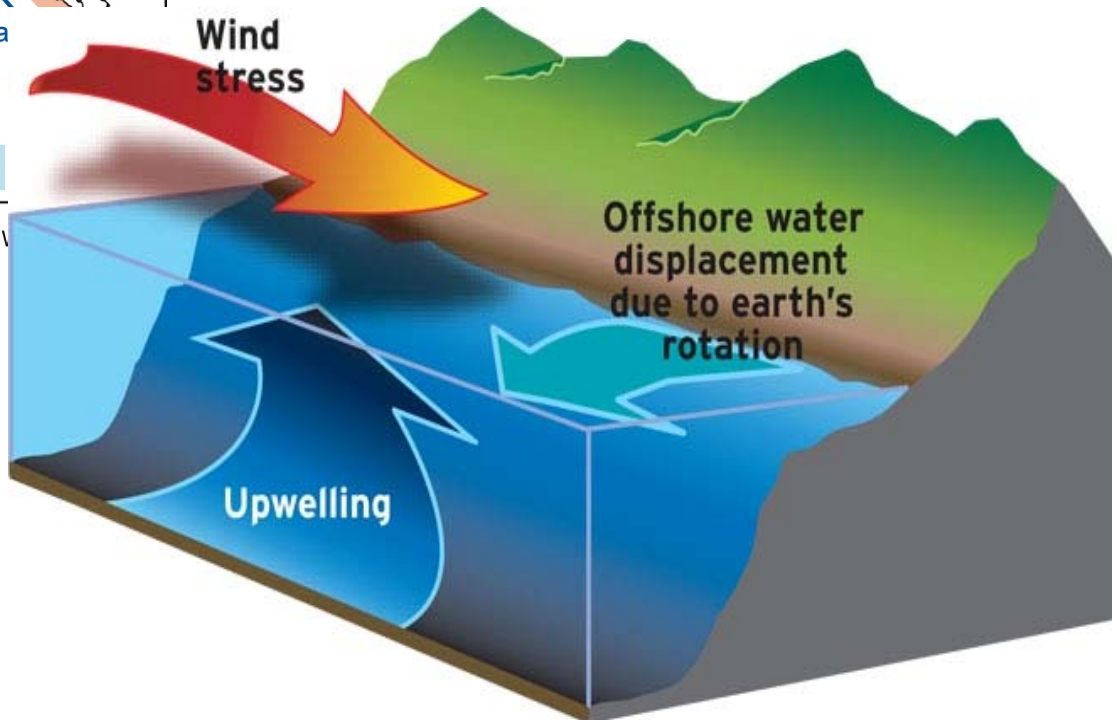




For good salmon conditions we want:

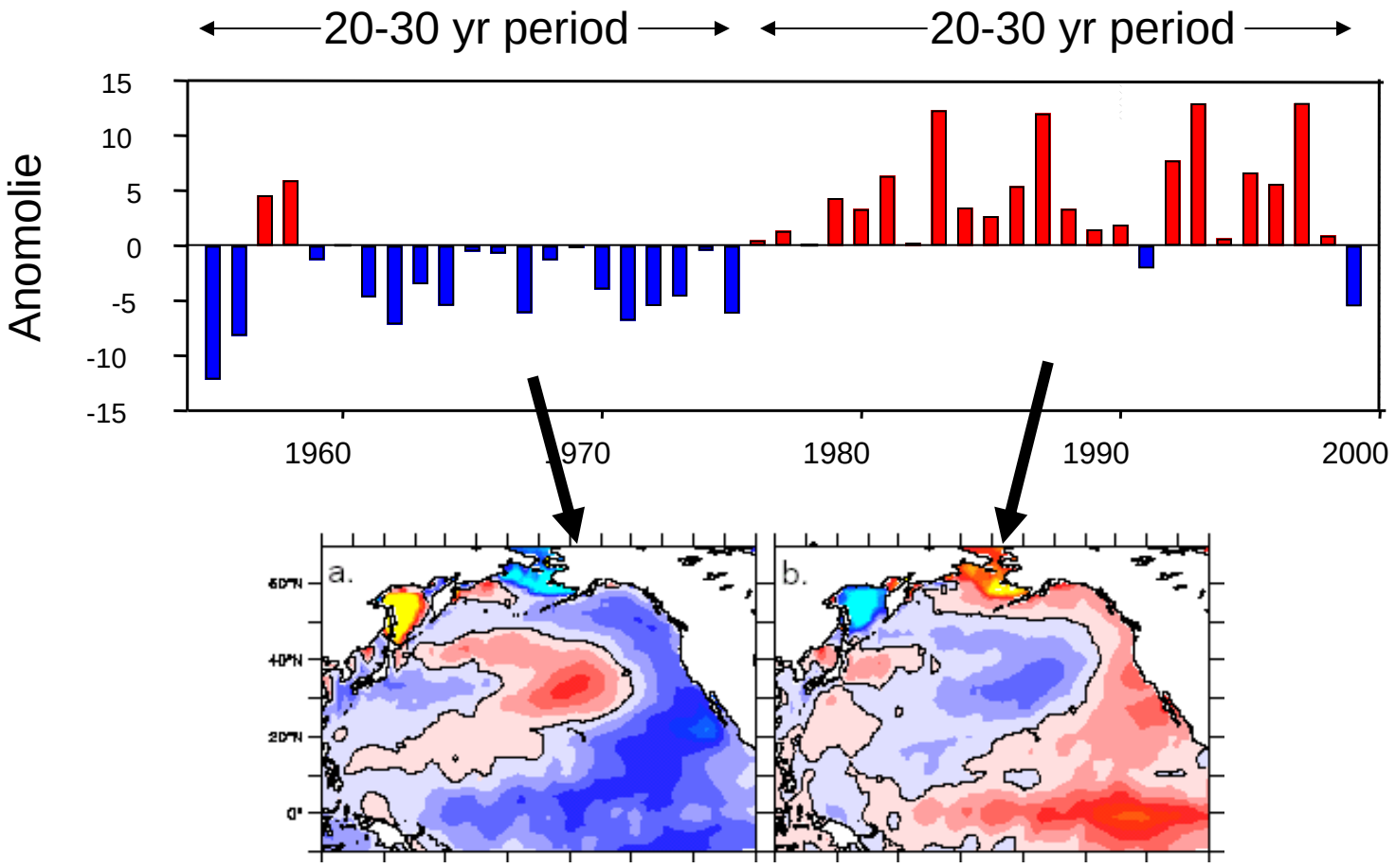
1. Atmospheric circulation patterns to drive water flow from the north

2. Winds during spring and summer to cause coastal upwelling



Note: California Current begins at ~ N end of Vancouver Island

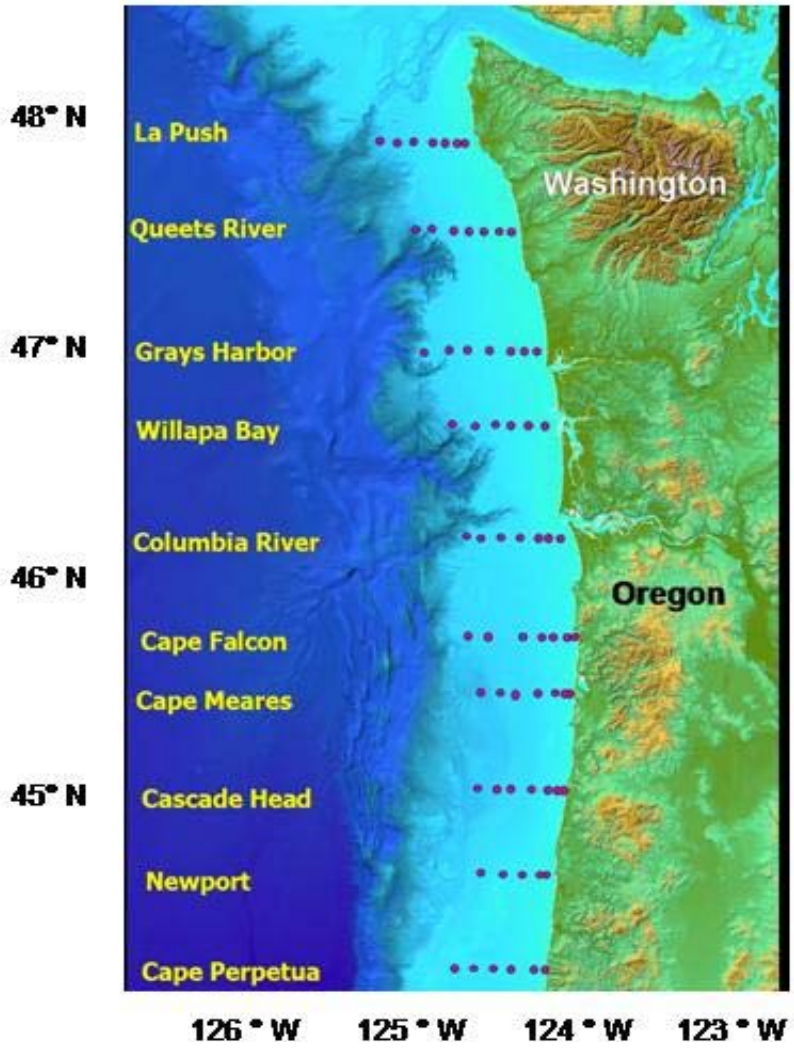
Atmospheric and ocean phase shifts are tracked by the Pacific Decadal Oscillation (PDO): negative values = cool phase; positive values = warm phase.



2. Present (current activities and results)

- Sampled ocean from 1998 to 2008
- Developed a suite of indicators to understand processes affecting variability in ocean productivity and juvenile salmonid survival
- Goal:
  - Forecast adults returns
  - Allow FW actions to be placed in this context

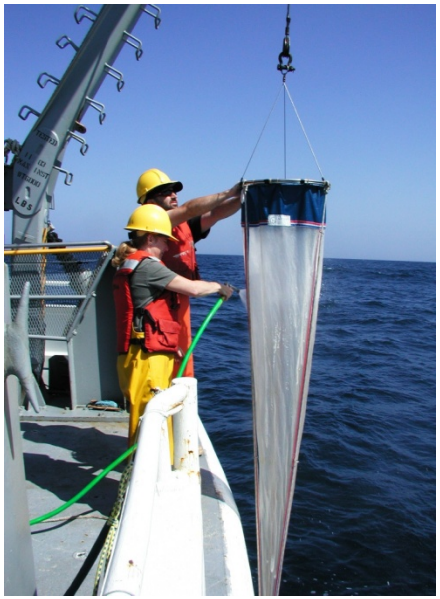
Spatial and temporal scale of plankton, salmon and pelagic fish sampling

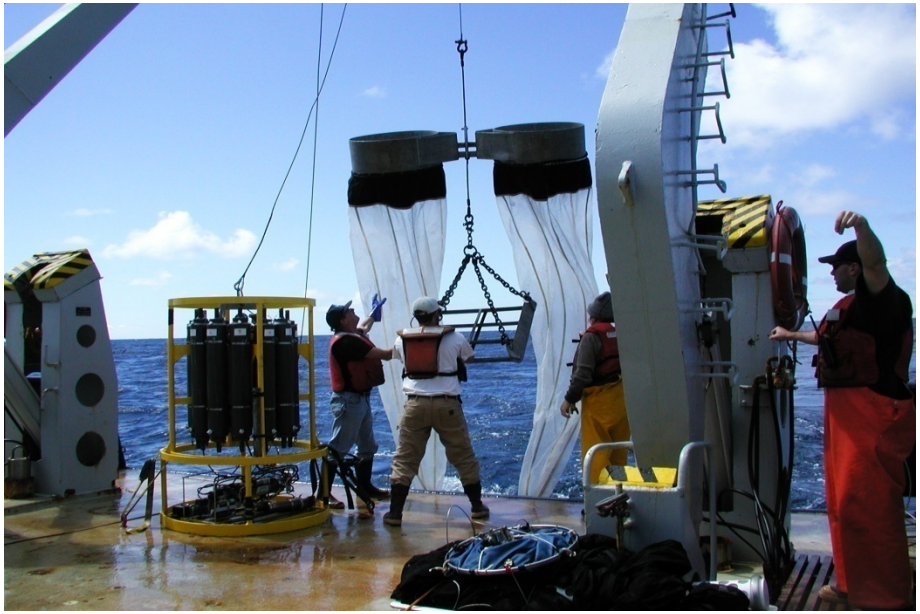


- Sample in May, June and September (50 stations) since 1998
- Sample Columbia River and Willapa Bay every 10 days from April through July (AT NIGHT) at ~ 10 stations; since 1998
- Sample off Newport every two weeks, since 1996
- Have historical data on hydrography and zooplankton from 1970s and 1983; salmon abundance data from 1981-1985 but only some of these data are part of this talk

Sampling Methods

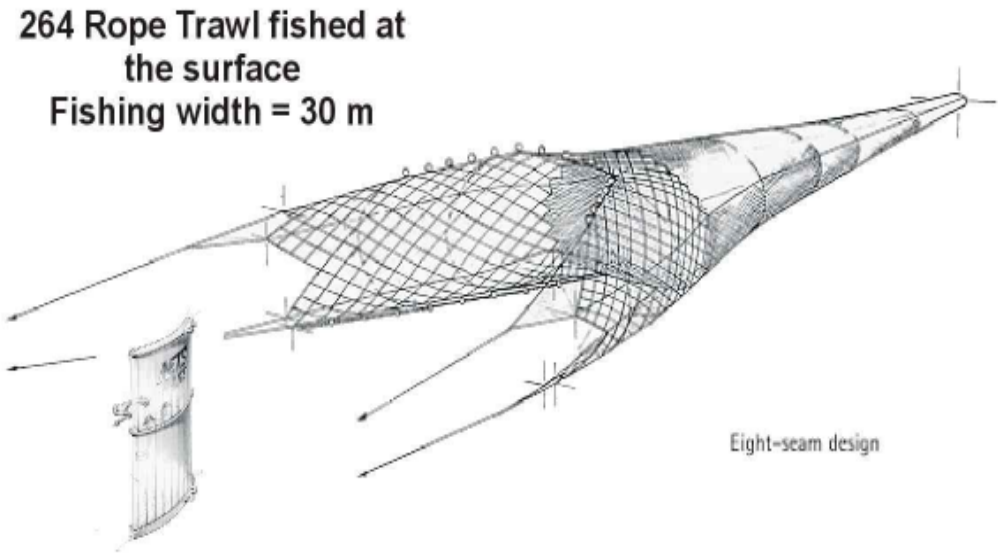
- Water sampling with CTD, Niskin Bottles, and buckets for hydrography, chl-a and nutrients
- Mesozooplankton with ½ m 200 μm mesh net towed vertically
- Euphausiids with 70 cm 505 μm mesh net towed obliquely





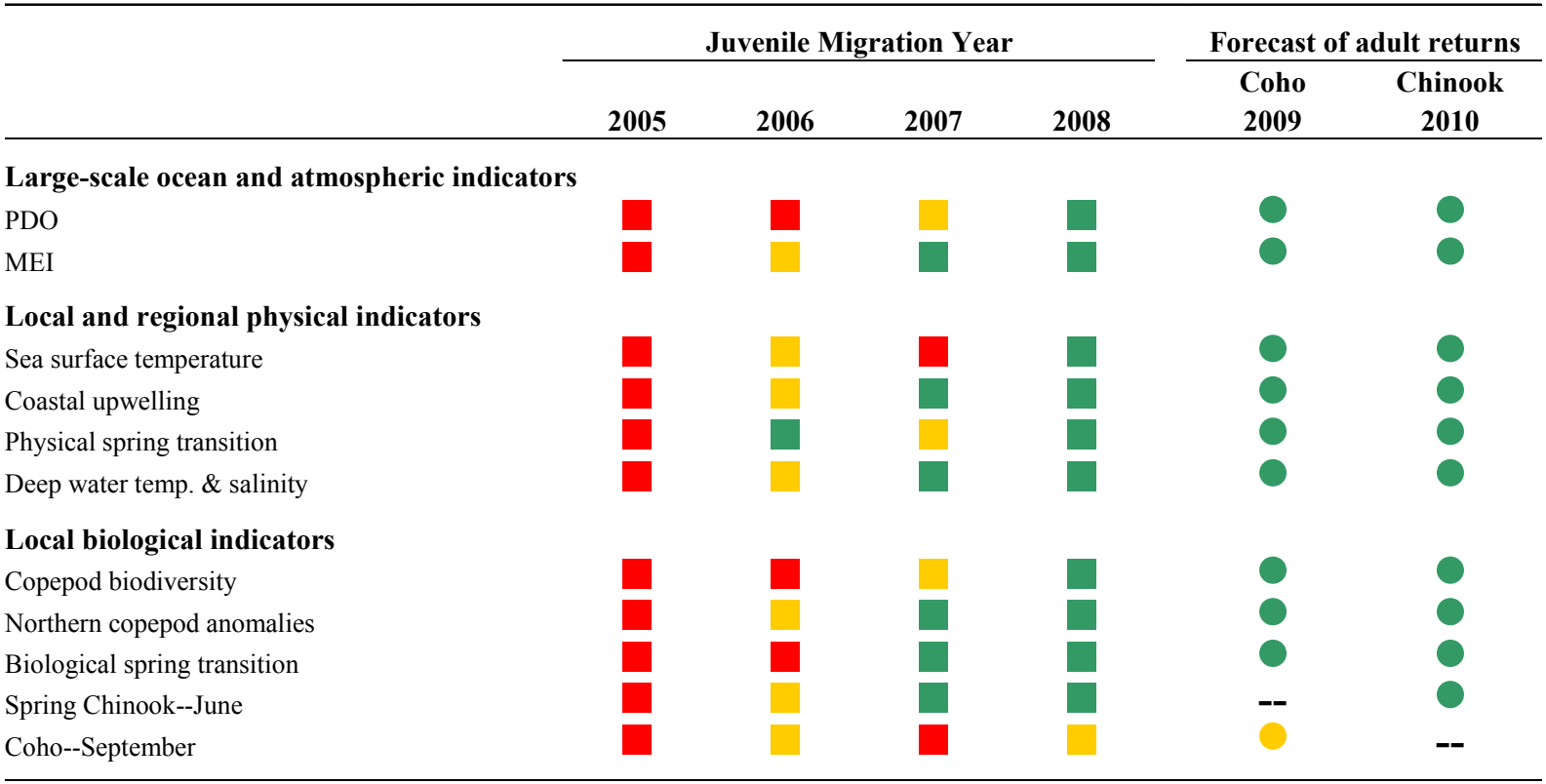
Sampling Methods

- Sample fish with a NET 264 rope trawl: 20 m high x 30 m wide x 200 m long



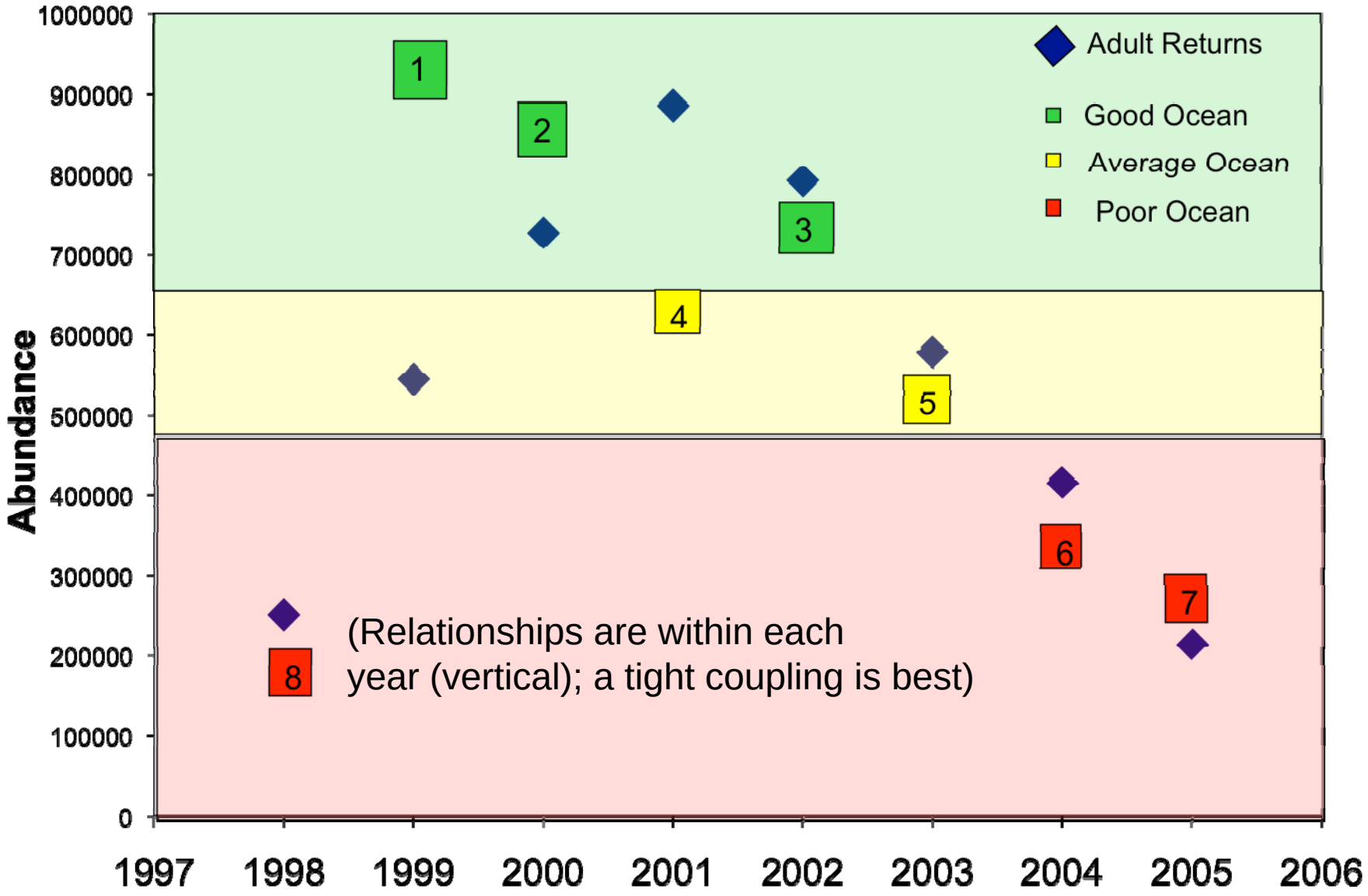
- Standard oceanographic measurements
  - CTD
  - Secchi disc
  - Nutrients & chlorophyll
  - Zooplankton

Product: Ocean condition index of 11 indicators to forecast salmon trends

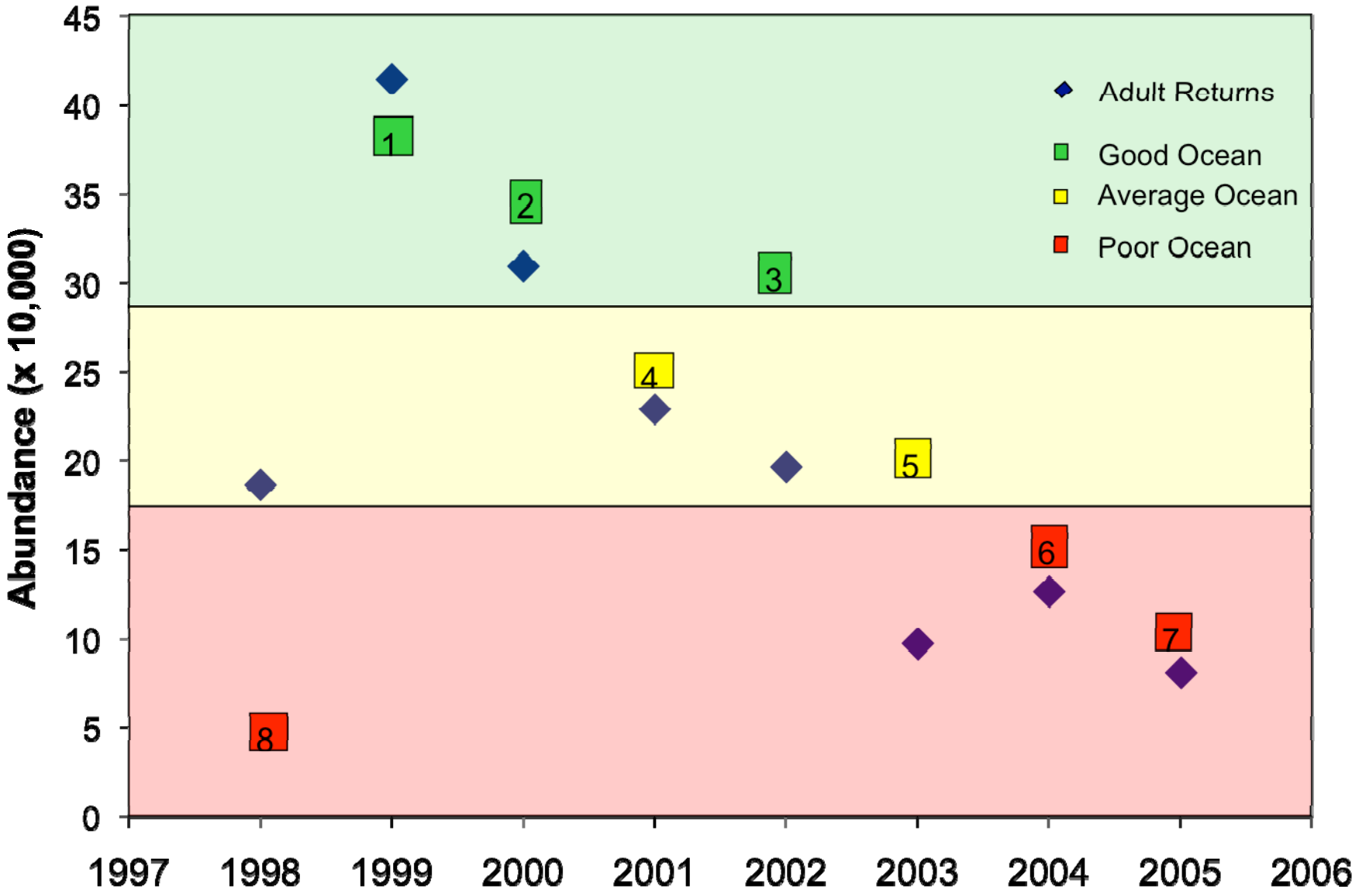


Web Page: www.nwfsc.noaa.gov (look for 'ocean index tool')

Results – returns of Columbia River fall Chinook vs. rank order of ocean conditions



Results - Spring Chinook



Sockeye

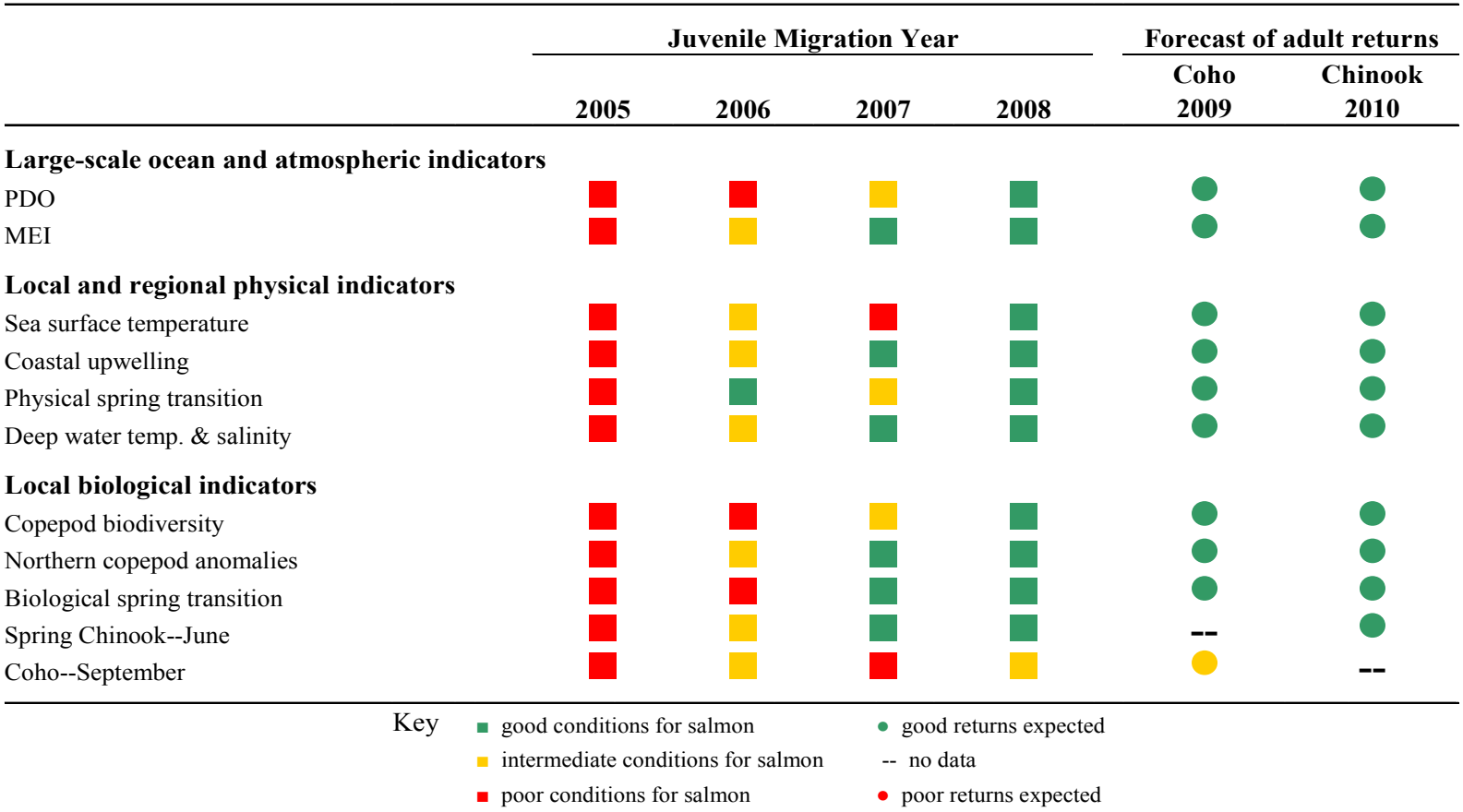
(from our 2009 report on factors influencing 2008 returns)

- Correlation between sockeye and Snake River sp/su Chinook SARs (1985-2006) was poor:
  $R^2 = 0.16$; $P = 0.076$
- Correlation between rank order of ocean indicators and sockeye SARs (1998-2006) was poor:
  $R^2 = 0.13$; $P = 0.33$
- So….<u>the indicators developed for Chinook and coho were not a good predictor of sockeye SAR patterns</u>:
  - Sockeye feed at lower trophic level
  - Indicators for sockeye will require development

3. The future….

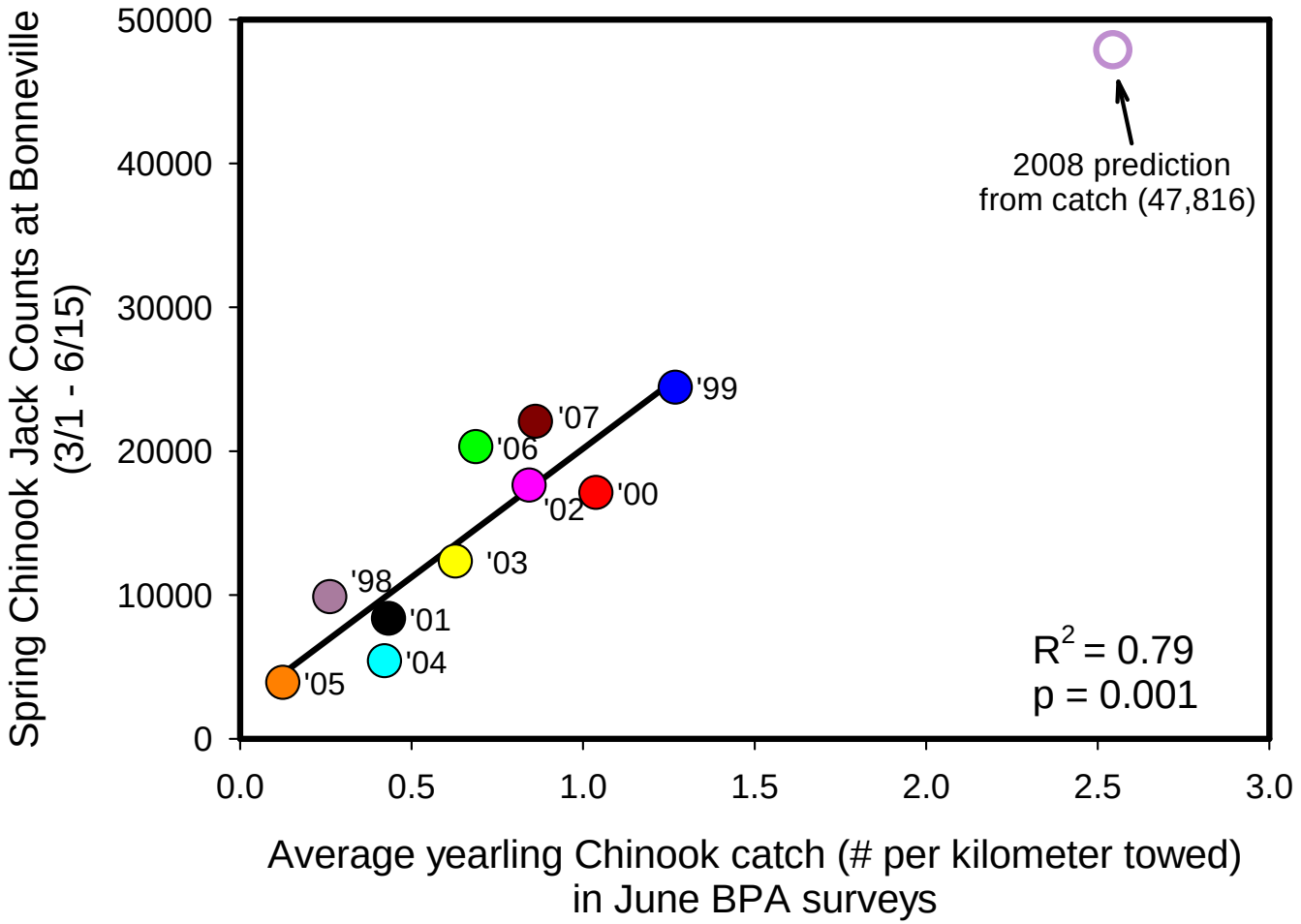
- Near term: Adult trends in 2009 and 2010 based on 5 methods:
  - All stocks (composite ocean index)
  - Columbia River Spring Chinook jacks (ocean juvenile catch)
  - Coastal hatchery coho jacks (ocean juvenile catch)
  - Snake River sp/su Chinook (upwelling time series model)
  - Columbia River sockeye (expanding jack counts)

1. Ocean index (all 11 indicators) in 2008 indicates 'good' adult salmon returns in 2009-2010 (all stocks)



Web Page: www.nwfsc.noaa.gov (look for 'ocean index tool')

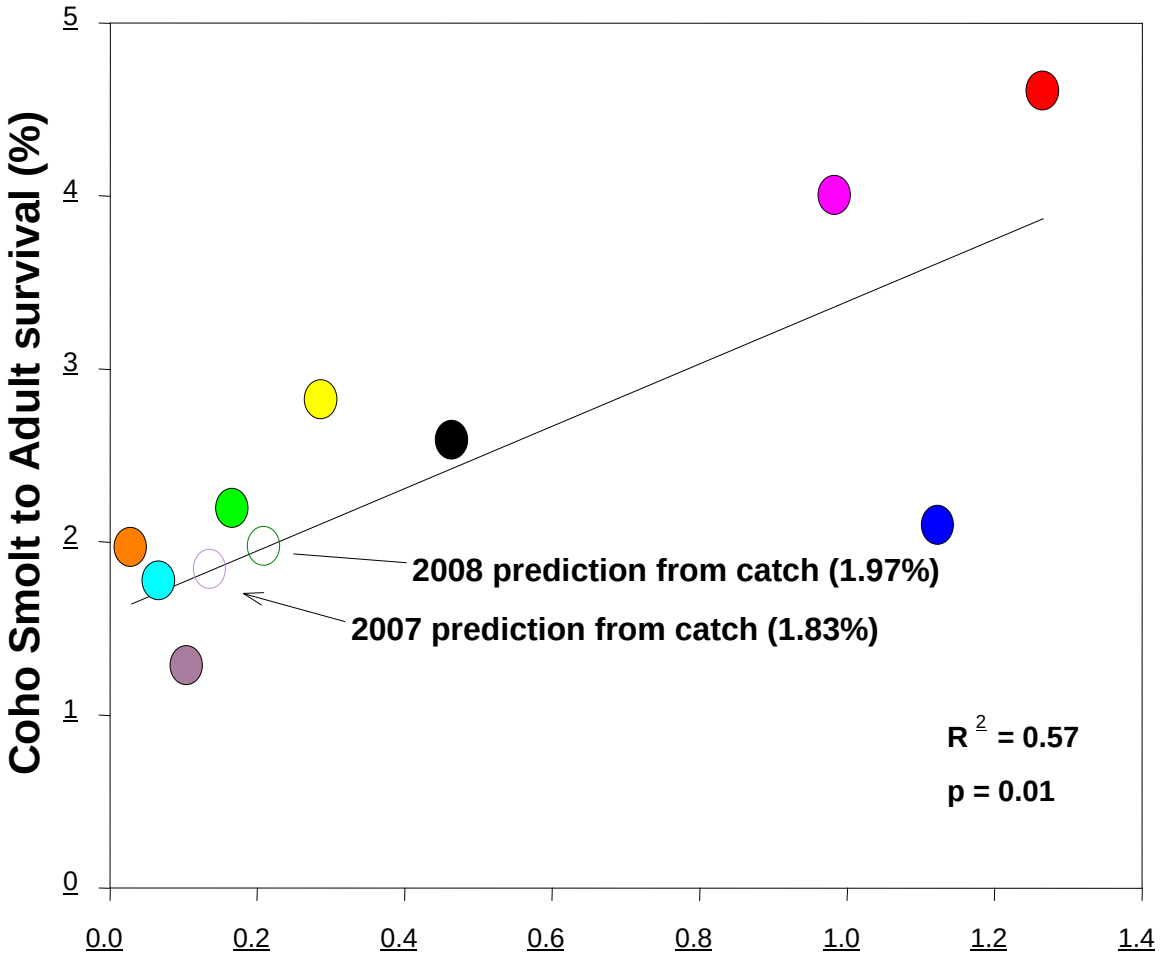
2. Predicted number of spring Chinook jacks counted at Bonneville Dam, based on catches of juvenile yearling Chinook salmon during ocean sampling: 2008 was "off the chart"



2. From the last slide…..predicted spring Chinook jack counts based on juvenile catch in ocean trawls

Migration year (MY 0)	Smolt catch per unit effort in ocean trawls (MY 0)	Predicted jack count @ BON (MY +1)	Observed jack count @ BON (MY +1)	Observed 2-ocean count @ BON (MY +2)
2005	0.13	3,432	2,969	66,624
2006	0.69	11,929	16,860	124,336
2007	0.86	14,509	17,552	-
2008	2.55	40,151	-	-

2. Predicted Oregon Production Hatchery Index (% return) based on catches of juvenile yearling coho salmon in ocean trawls (by Cheryl Morgan, OSU)



3. Predicted wild Snake River sp/su Chinook smolt-to-adult (SAR) based on an April & Sept upwelling & Oct downwelling model, based on 1964-2002 time series (Scheuerell & Williams 2005 Fisheries Oceanography 14(6):448-457)

- 2008 outmigration:
  - Predicted SAR: 1.56% (0.29 – 3.87)
- For comparison to another high SAR year, the 1999 outmigration:
  - Predicted SAR: 1.49% (0.34 – 3.45)
  - Observed SAR: 3.56% (~415,000 sp/su Chinook passed over BON Dam through 6/15/2001; ~172,000 over Lower Granite Dam)

4. Predicted adult return to Bonneville Dam of Columbia River sockeye, using the median percentage of 1-ocean fish counted at Bonneville, outmigration years 1987-2005 (estimated by John Williams using methods developed in our report on 2008 sockeye returns)

- Smolt migration 2007:
  - In 2008, a total of **19,210** 1-ocean fish were counted at Bonneville Dam

  Predicted 2009 return ~ **340,000**
- Smolt migration 2006:
  - Predicted 2008 return ~183,500 fish (range ~77,000 to ~544,000)
  - Observed 2008 return ~ 194,000

Looking ahead to 2009, what can the ocean state this winter tell us?

- PDO is still strongly negative, ocean is cold, and there are very few storms

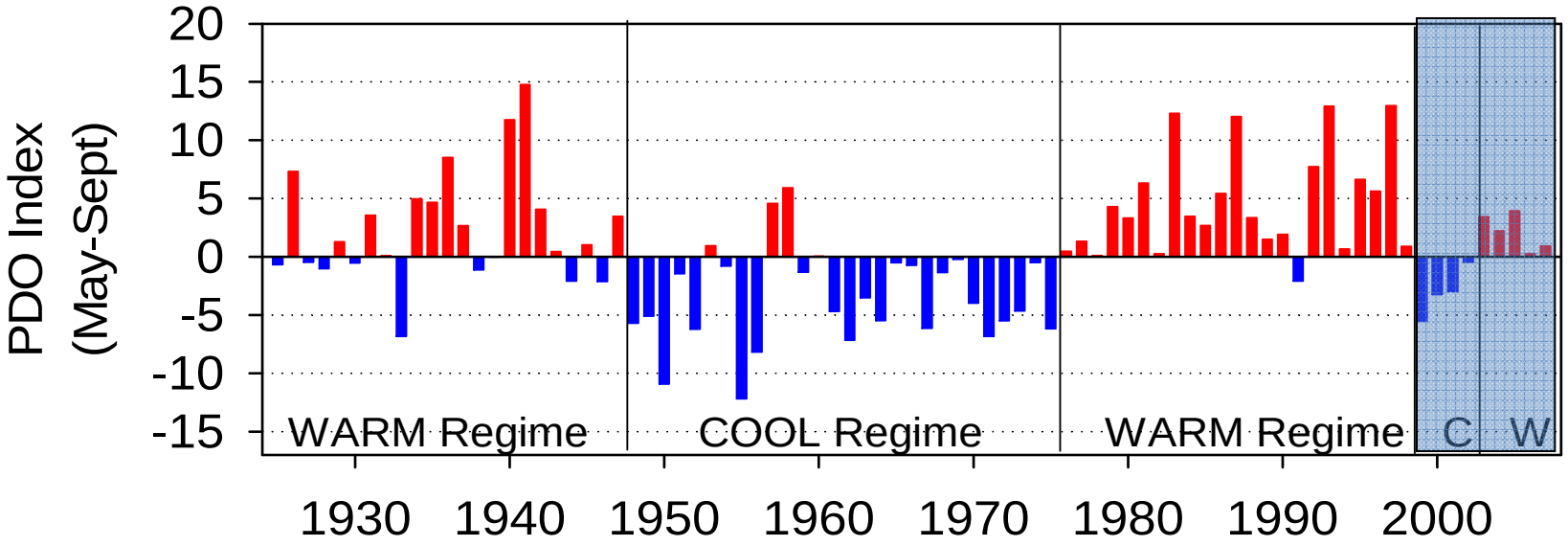
- Although there are a lot of "southern" copepod species, their numbers are very low -- the cold water northern species are already dominating, just like they did last winter

- "The pump is primed and ready to go" (per Bill Peterson)

3. The future…..

- Long term: What trends are we seeing (effects of climate change?)?
  - Ocean variability seems to be increasing
  - Ocean is predicted to warm

Point #1: Variability may be increasing? (PDO: May-Sep Average, 1925-2007)



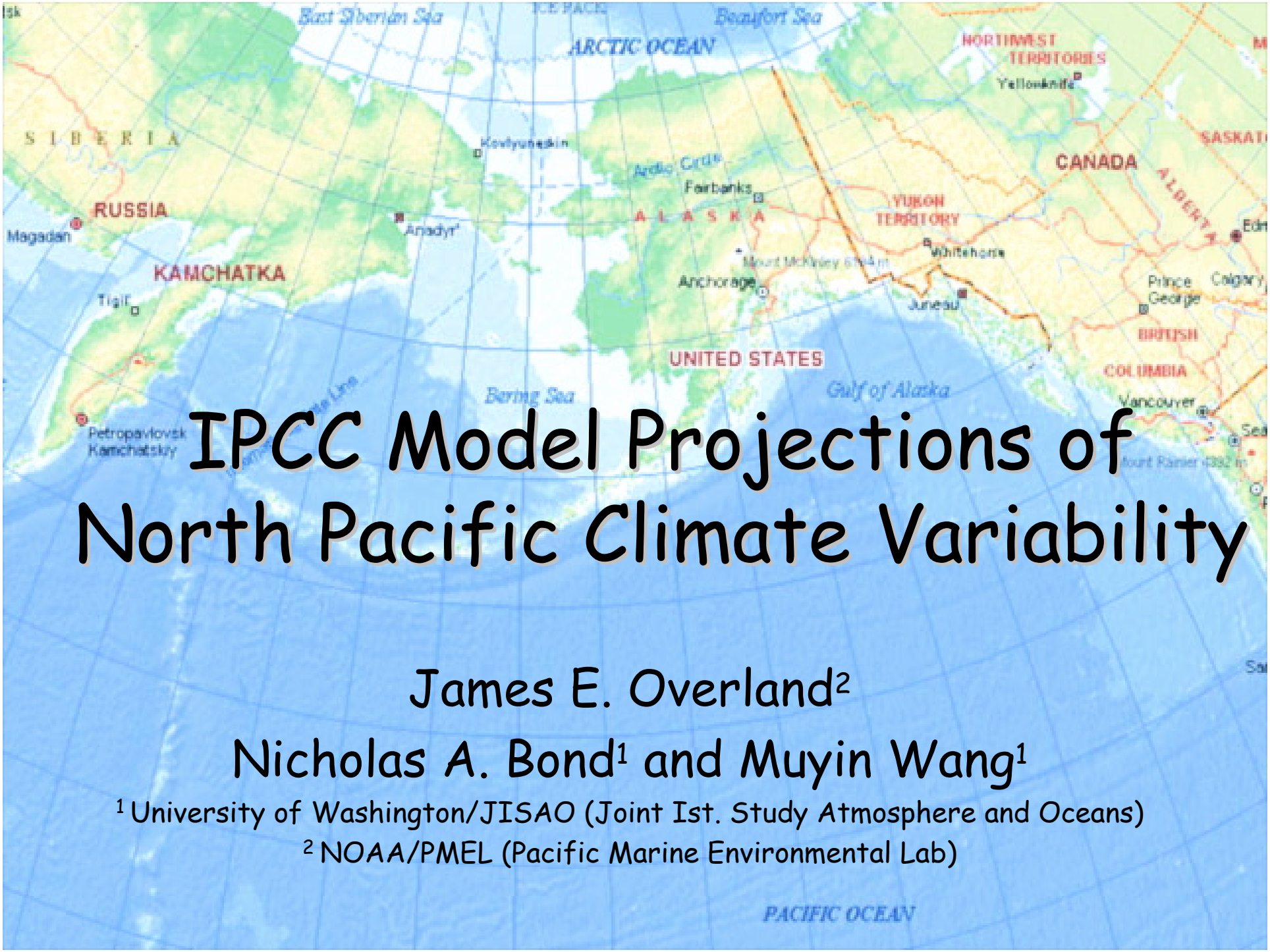
- We have had two shifts of four years duration recently: 1999-2002 and 2003-2006.
- Is this the future?

Cassin's Auklet Breeding Success by Decade

Decade	Mean	CV(%)
1971-1979	0.761	8.9
1980-1989	0.670	26.4
1990-1999	0.644	36.5
2000-2007	0.614	75.1

- **declining mean & increasing variance...**

Farallones Islands, CA; Thanks to Bill Sydeman



IPCC Model Projections of North Pacific Climate Variability

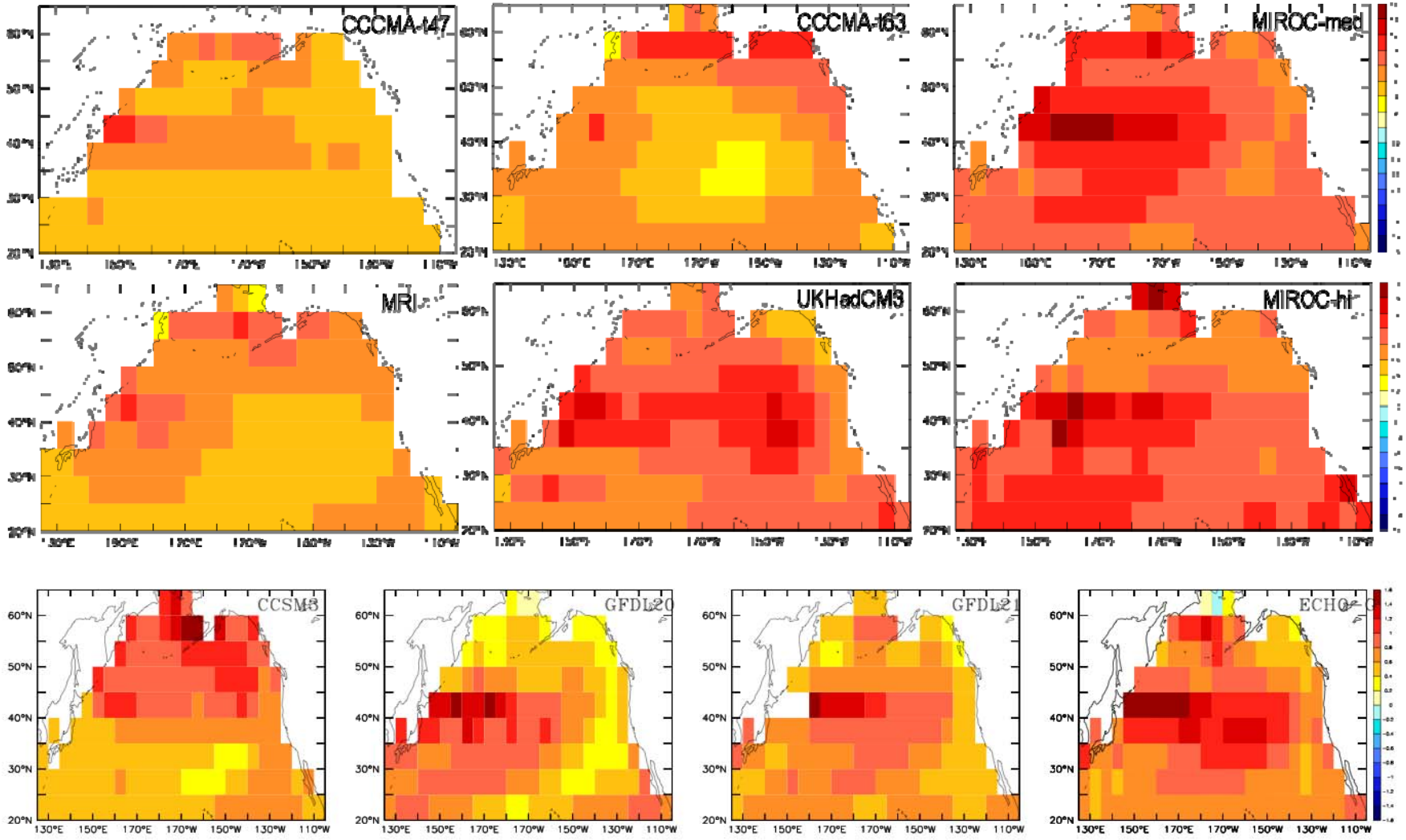
James E. Overland[2]

Nicholas A. Bond[1] and Muyin Wang[1]

[1] University of Washington/JISAO (Joint Ist. Study Atmosphere and Oceans)

[2] NOAA/PMEL (Pacific Marine Environmental Lab)

Predicted change in sea surface temperature from 2001 to 2099 based on 10 different IPCC models



Point #2: IPCC modeling predicts ocean warming:

- 21st Century simulations feature a uniform warming trend in NE Pacific water temperature
- This warming will exceed the natural variability over most of the North Pacific before about 2050
- PDO signal persists, but we don't know whether its influence will persist

How do we use this information?

- View FW actions in context of marine ecosystem variability & integrate with marine productivity:
  - Adjust flow, hatchery release, and transportation timing to match marine productivity
  - Scale hatchery production to marine productivity
- Increase salmon population diversity and complexity to buffer effects of climate change (including estuary habitat)

Summary

- Marine ecosystem productivity varies due large-scale forces (reflected in the PDO)
- Near term: Ocean productivity has been very good; can expect 'good' salmon returns next couple of years
- Long term: Seeing evidence of increased variability in ocean productivity; PDO signal persists, but the ocean will be warmer -- effects on salmon?
- To address variability: Integrate FW actions and marine productivity; increase habitat complexity and salmon life history diversity (i.e., portfolio theory)
- Fishery managers need quick responding forecasting tools; meeting with TAC in May to discuss how ocean indicators can help improve adult forecasts

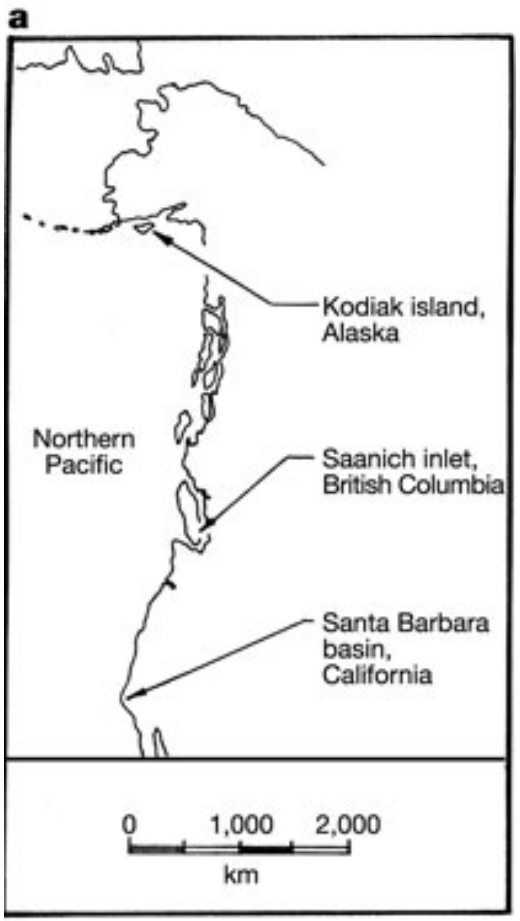
Funding acknowledgements:

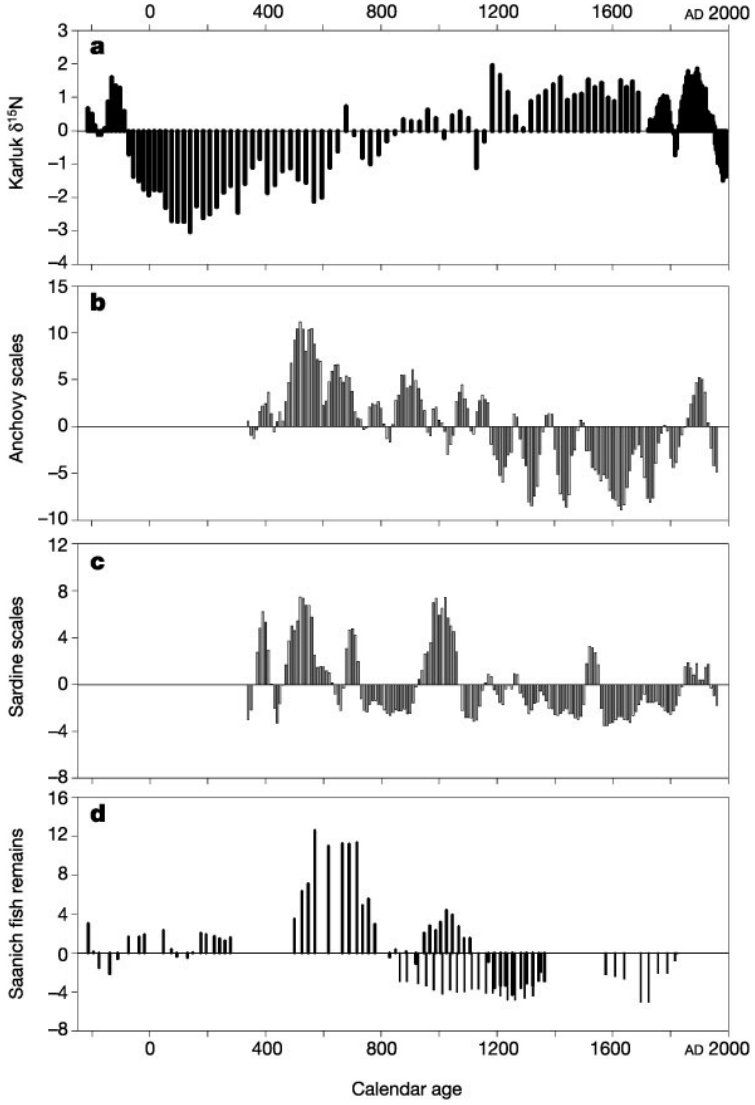
- **Bonneville Power Administration, NPCC

- U.S. GLOBEC Program (NSF, NOAA)
- Stock Assessment Improvement Program (NOAA Fisheries)
- Fisheries and the Environment (NOAA Fisheries)
- Endangered Species Act (NOAA Fisheries)

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

NE Pacific fisheries productivity over the last 2000 years (Finney et al. 2002 Nature)





Kodiak Island sockeye

California anchovy

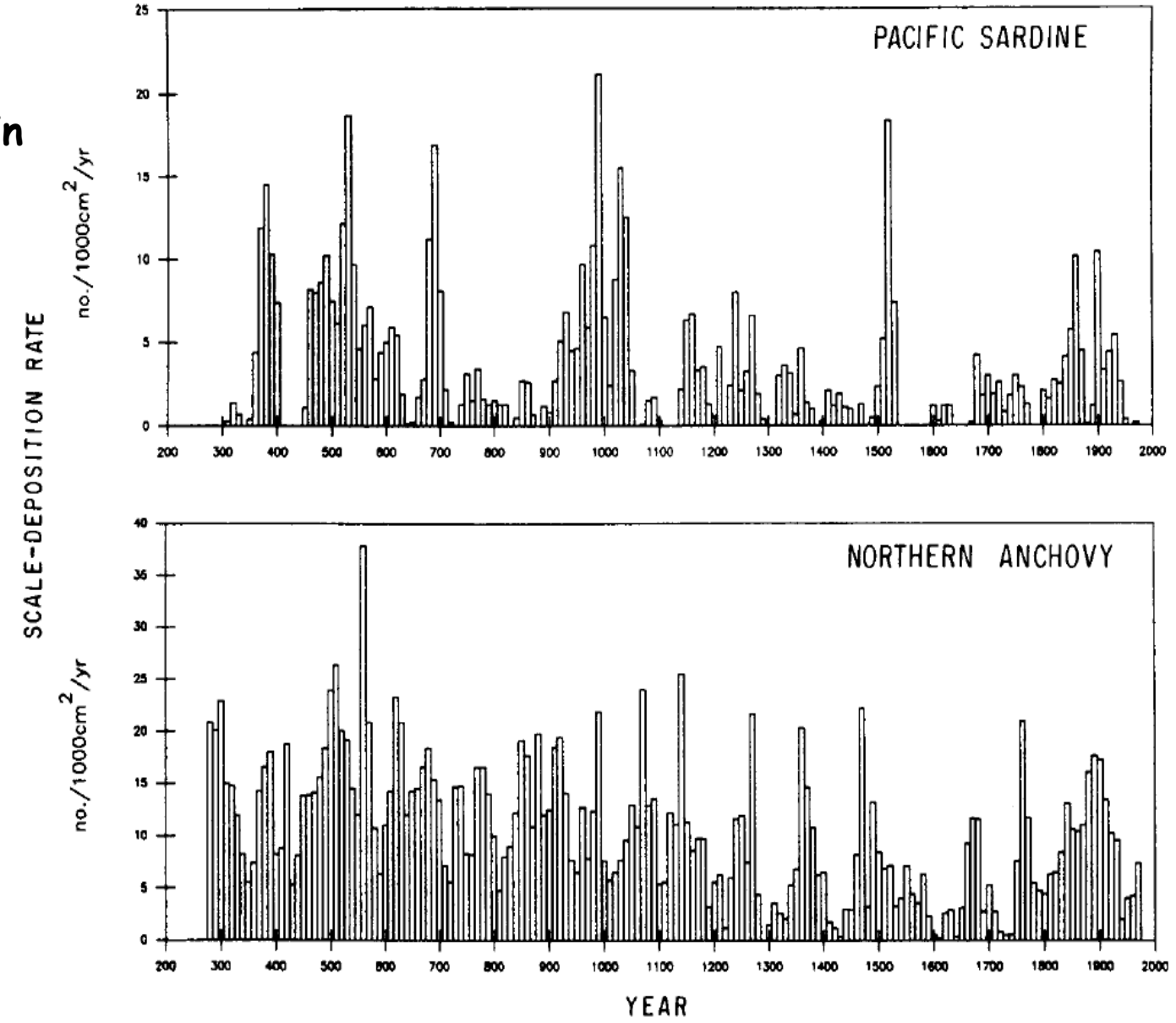
California sardine

BC total fish

BAUMGARTNER ET AL.: HISTORY OF PACIFIC SARDINE AND NORTHERN ANCHOVY POPULATIONS
CalCOFI Rep., Vol. 33, 1992

From scales in Santa Barbara basin sediment:

Anchovy and sardine cycles last 60-100 years



Results – coho (Oregon Prod. Hat. Index)