Present oceanic conditions in the North Pacific

and possible consequences to NOAA trust resources (including an update on the outlook for a 2014/2015 El Niño)

NOAA FISHERIES

Alaska

Northwest

Pacific Islands

Southwest

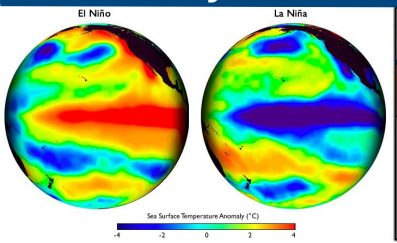
Fisheries Science Centers

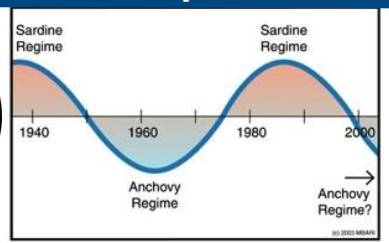
Cisco Werner
SWFSC

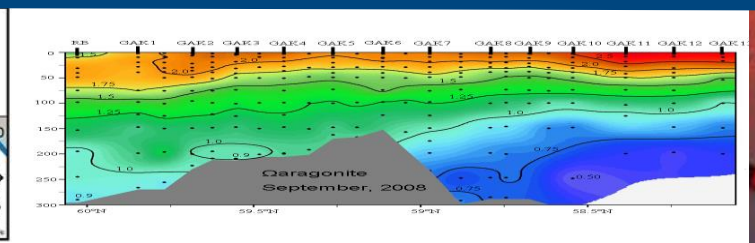
John Stein
NWFSC

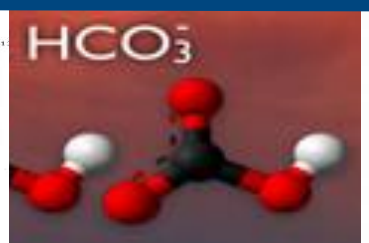
67th PSMFC Annual Meeting
25 August 2014
Skamania, WA

Thanks to: Nate Mantua, Steven Bograd, Mike Sigler, Bill Peterson, Jeff Polovina, and many others for their input.





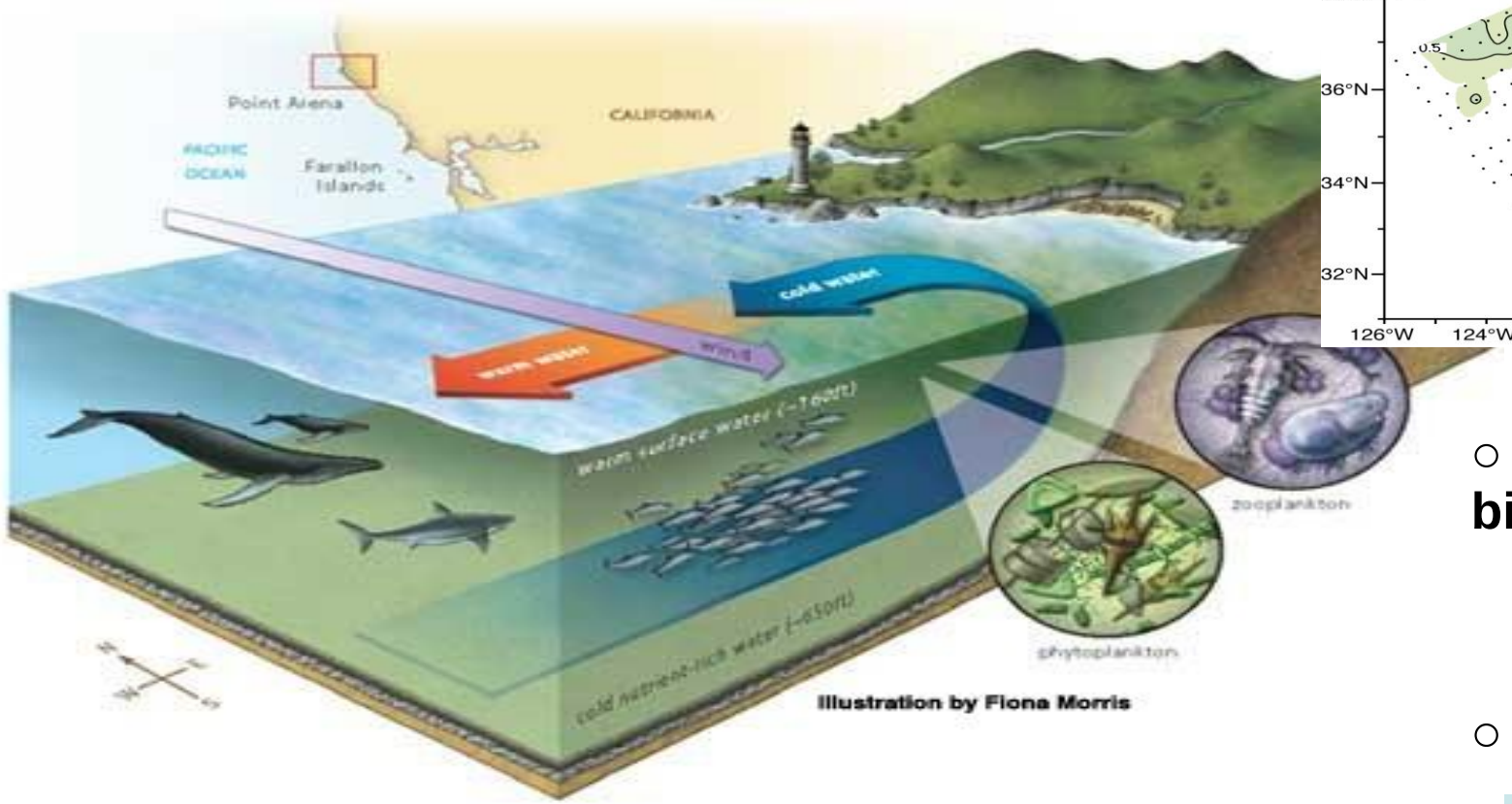


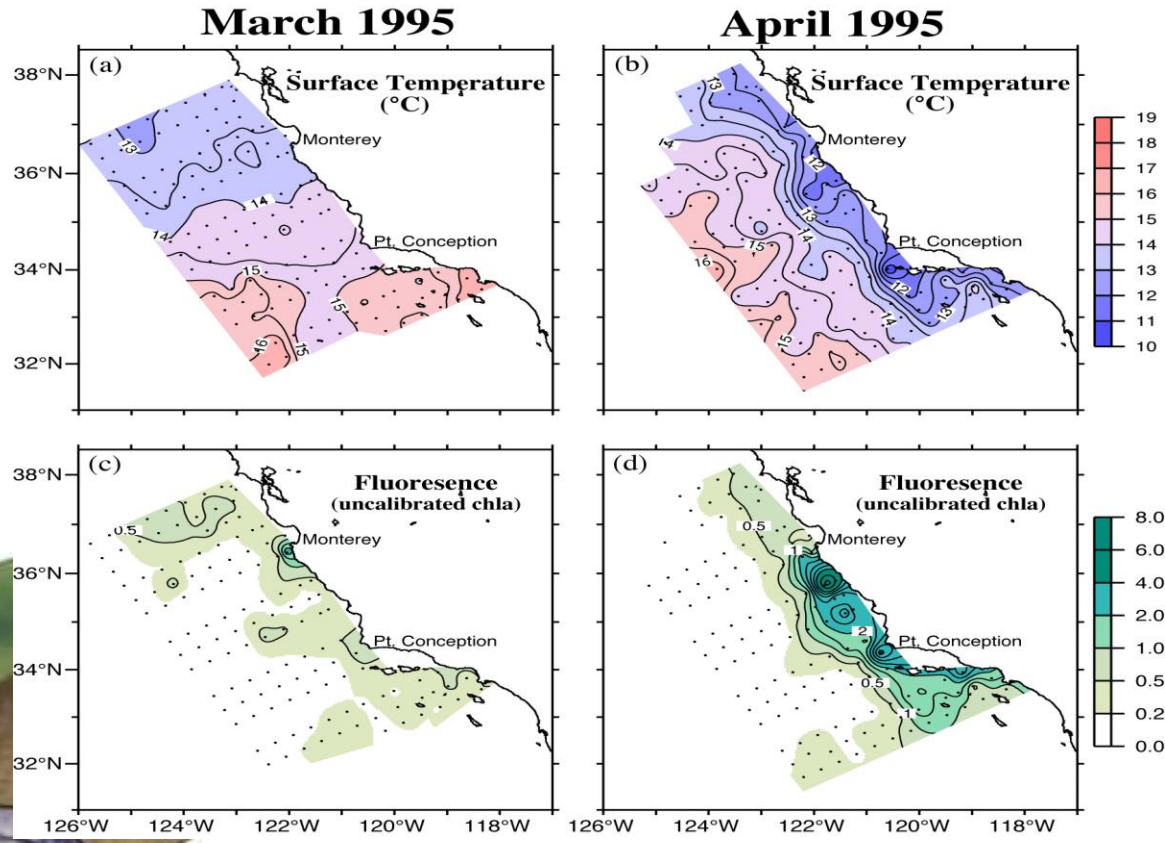


Outline

- North Pacific scales of variability – seasonal, interannual, decadal
- What are we seeing out there now?
- El Niño Update
- Ocean Acidification

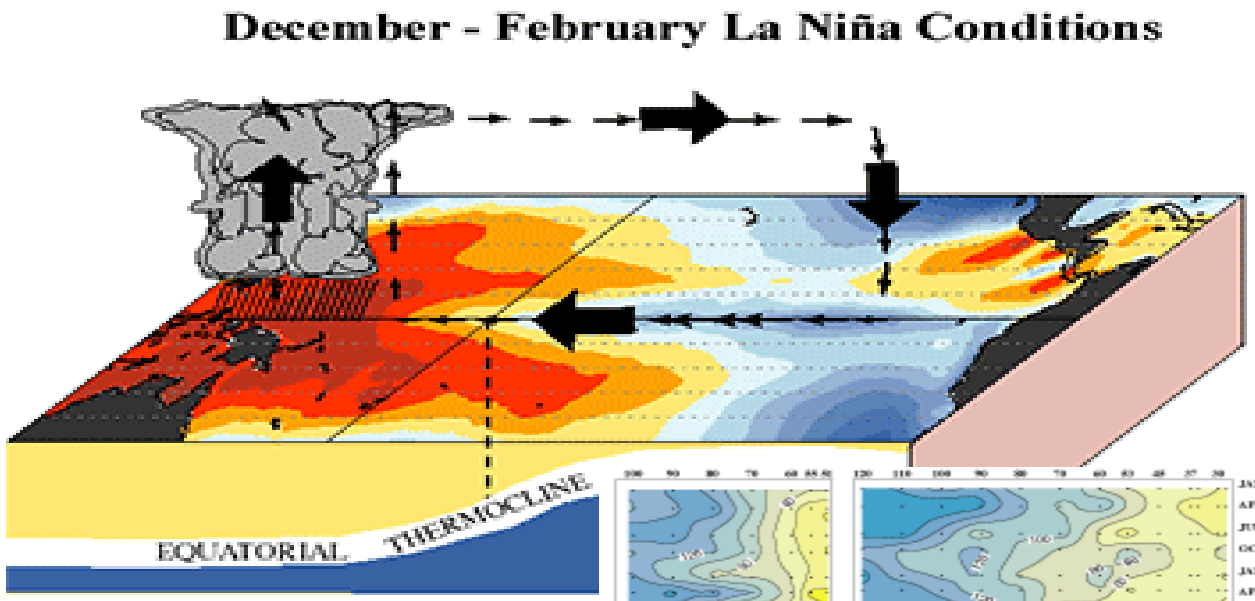
Seasonal scales of variability (upwelling)

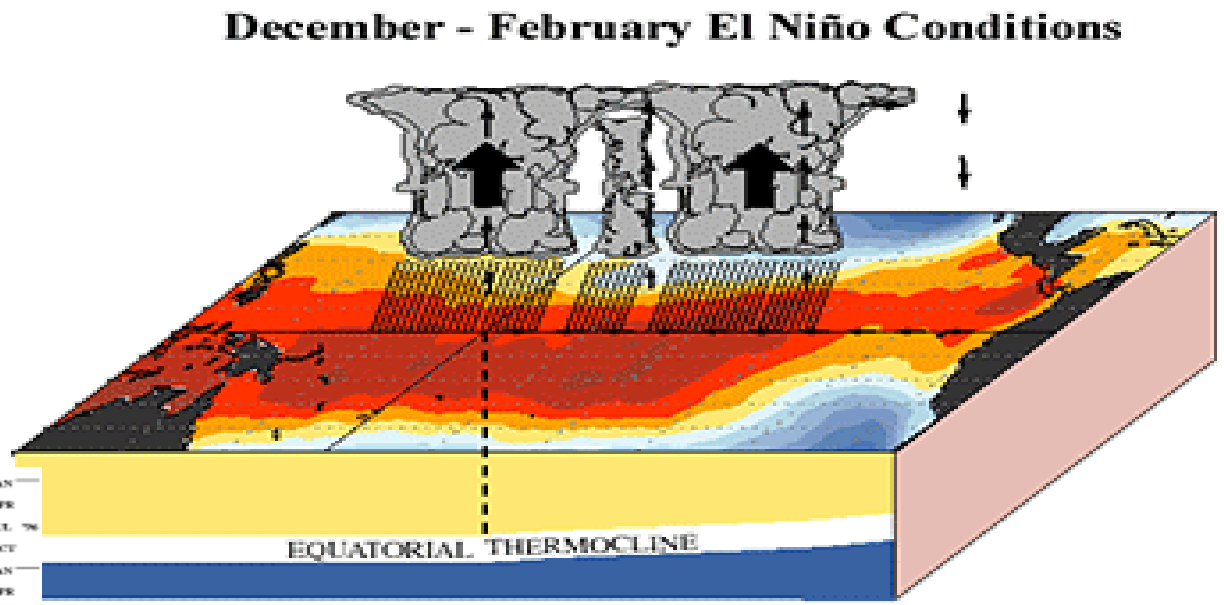




- Marked transition in physical-biological environments
  - 2-4˚ C decrease in coastal SST
  - large increase in fluorescence
- Duration of transition < one month

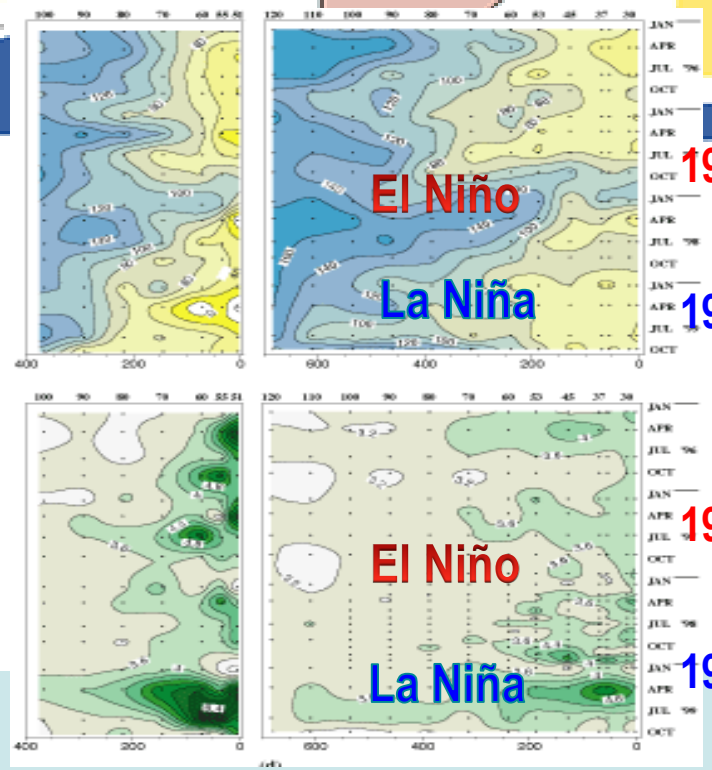
Interannual scales of variability (ENSO)





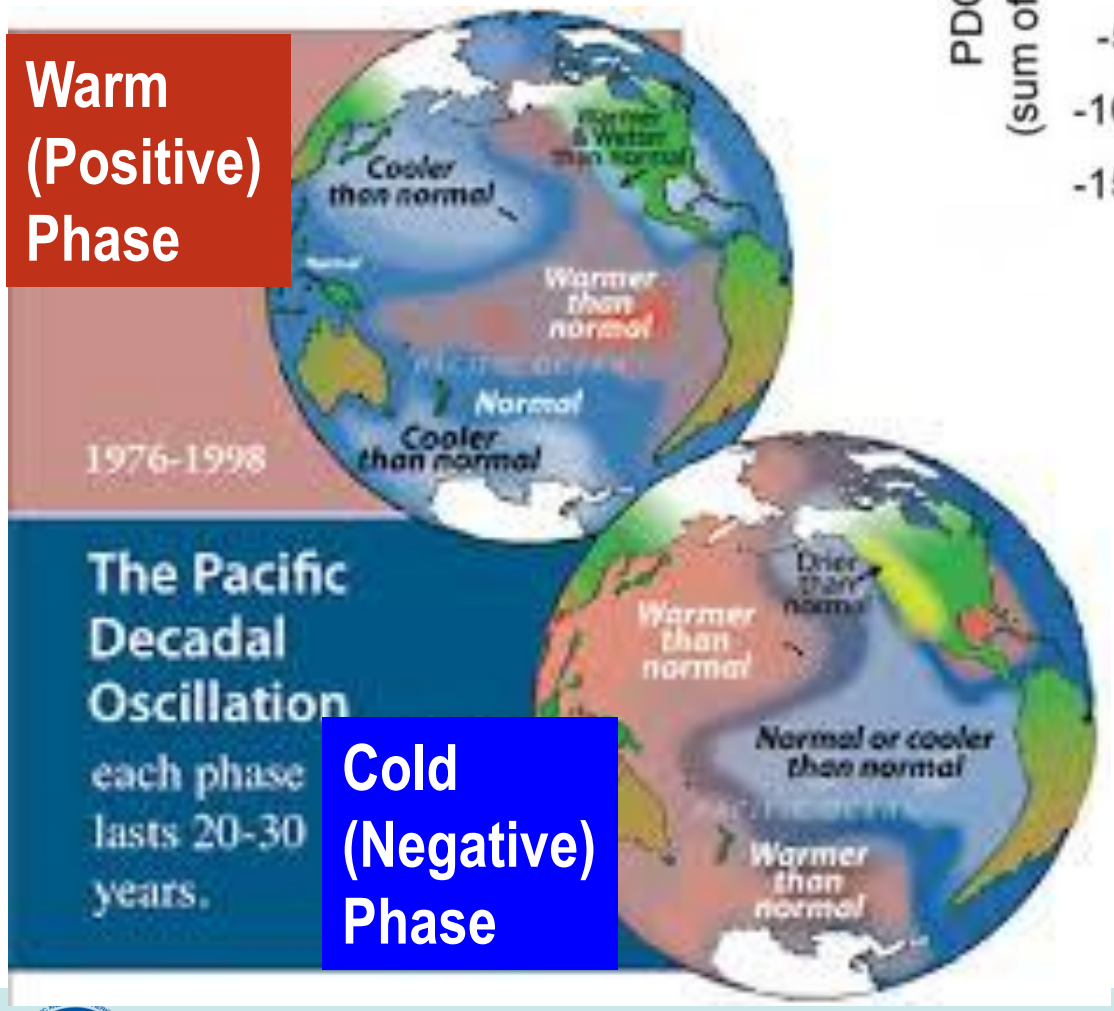
Nutricline Depth

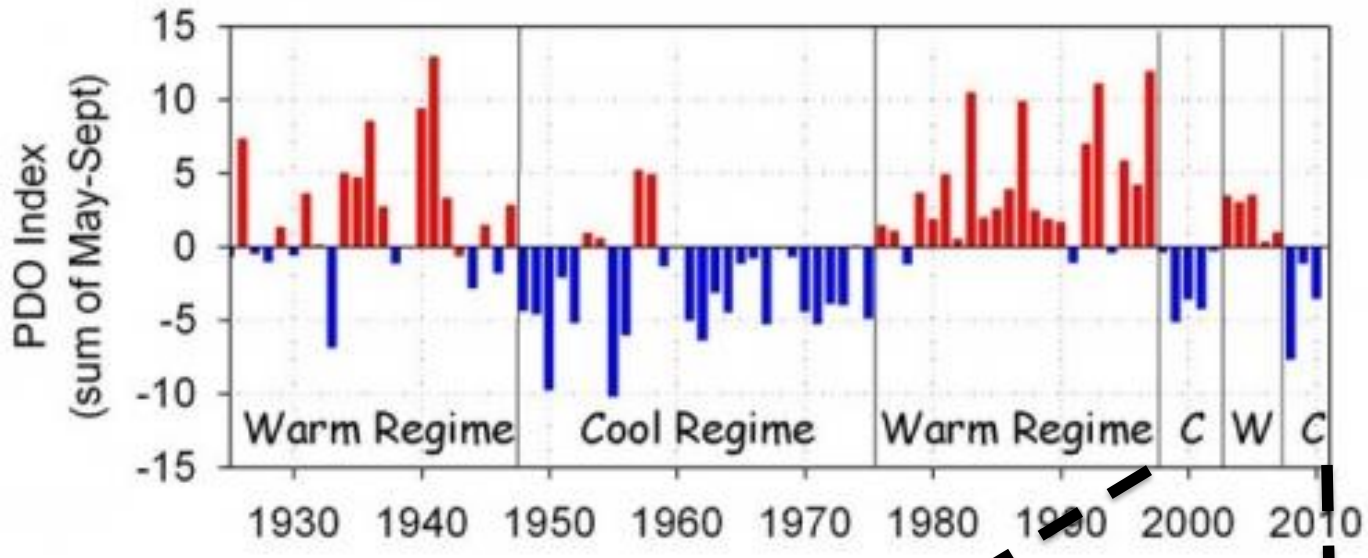
Chlorophyll (0-100m)

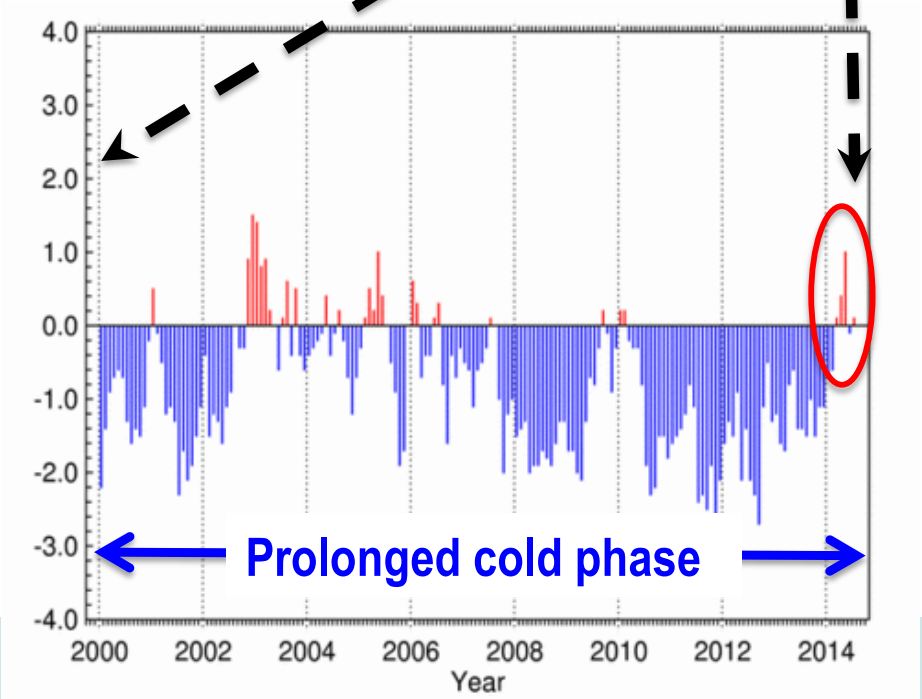


- January 1996 – October 1999
- Rapid changes in physical structure and biological response
  - El Niño: low productivity
  - La Niña: high productivity

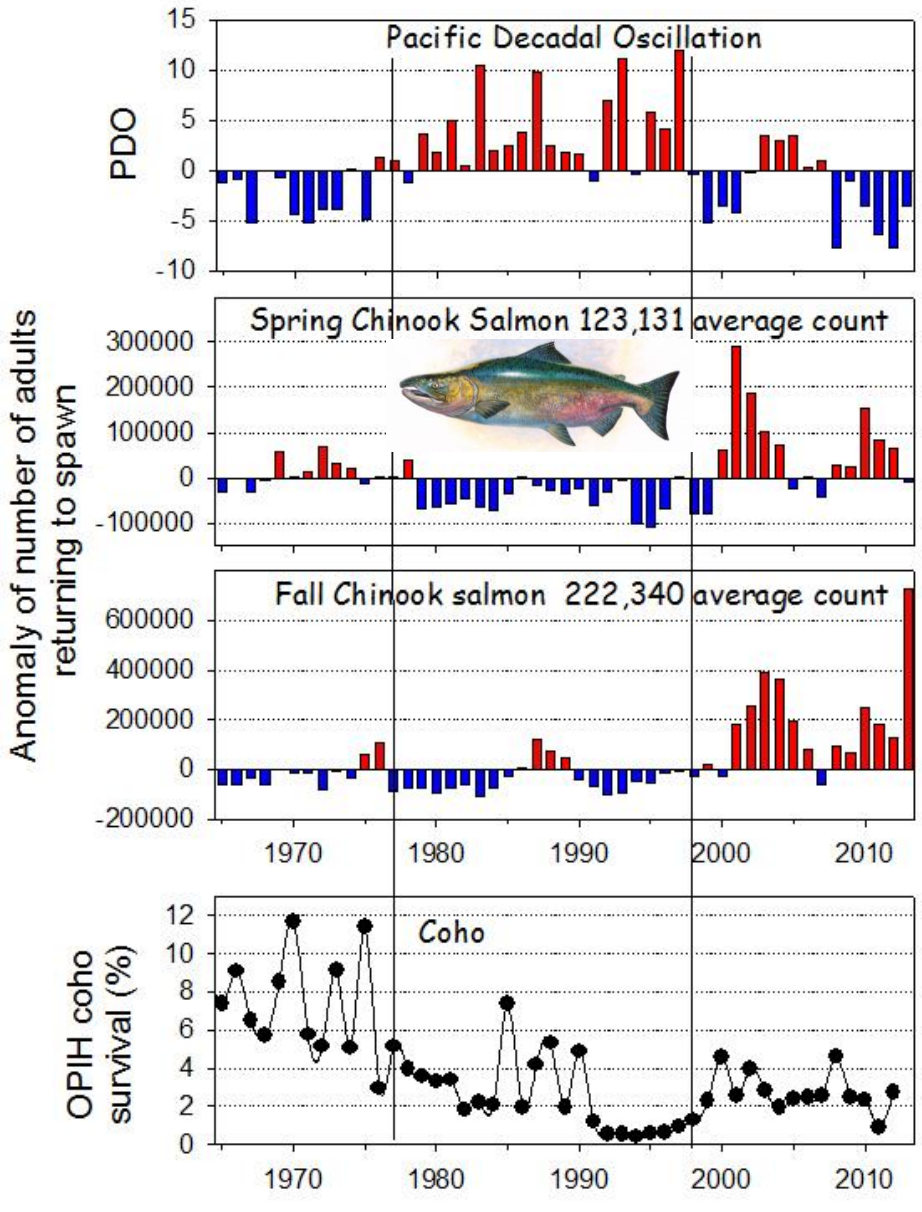
Pacific Decadal Oscillation (PDO)

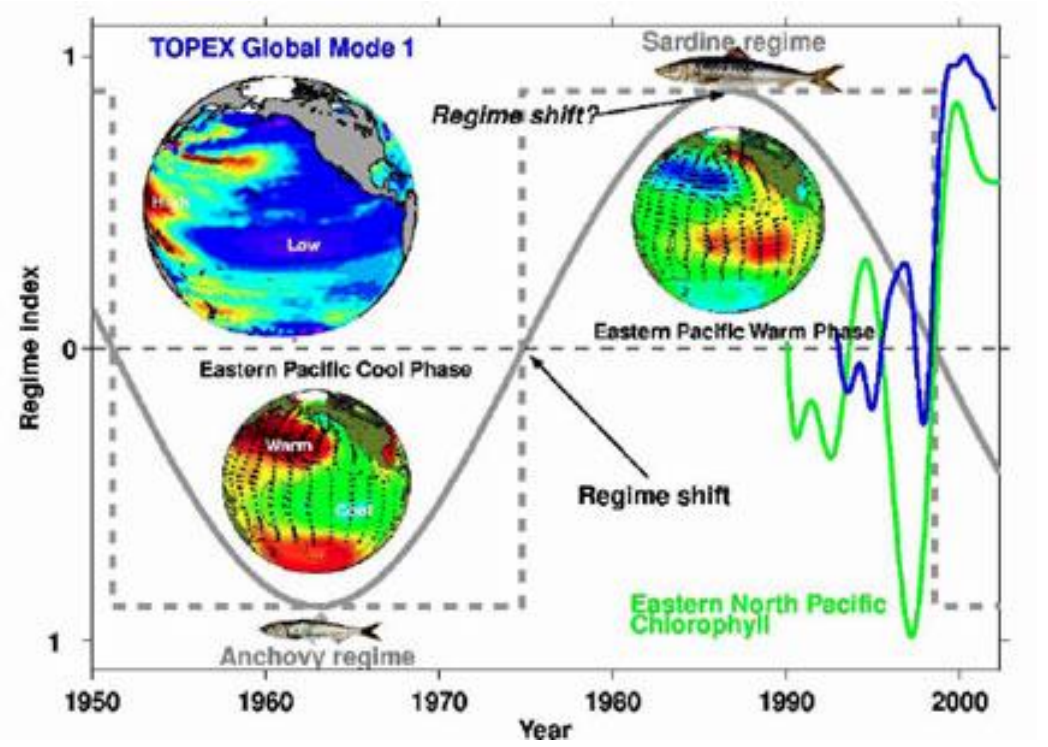


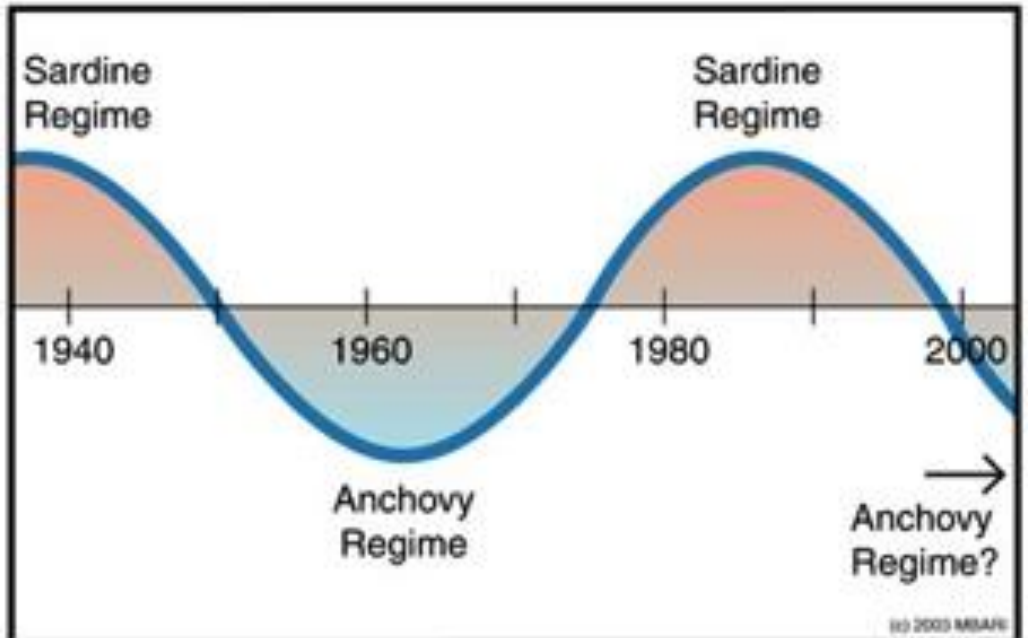




PDO and fisheries

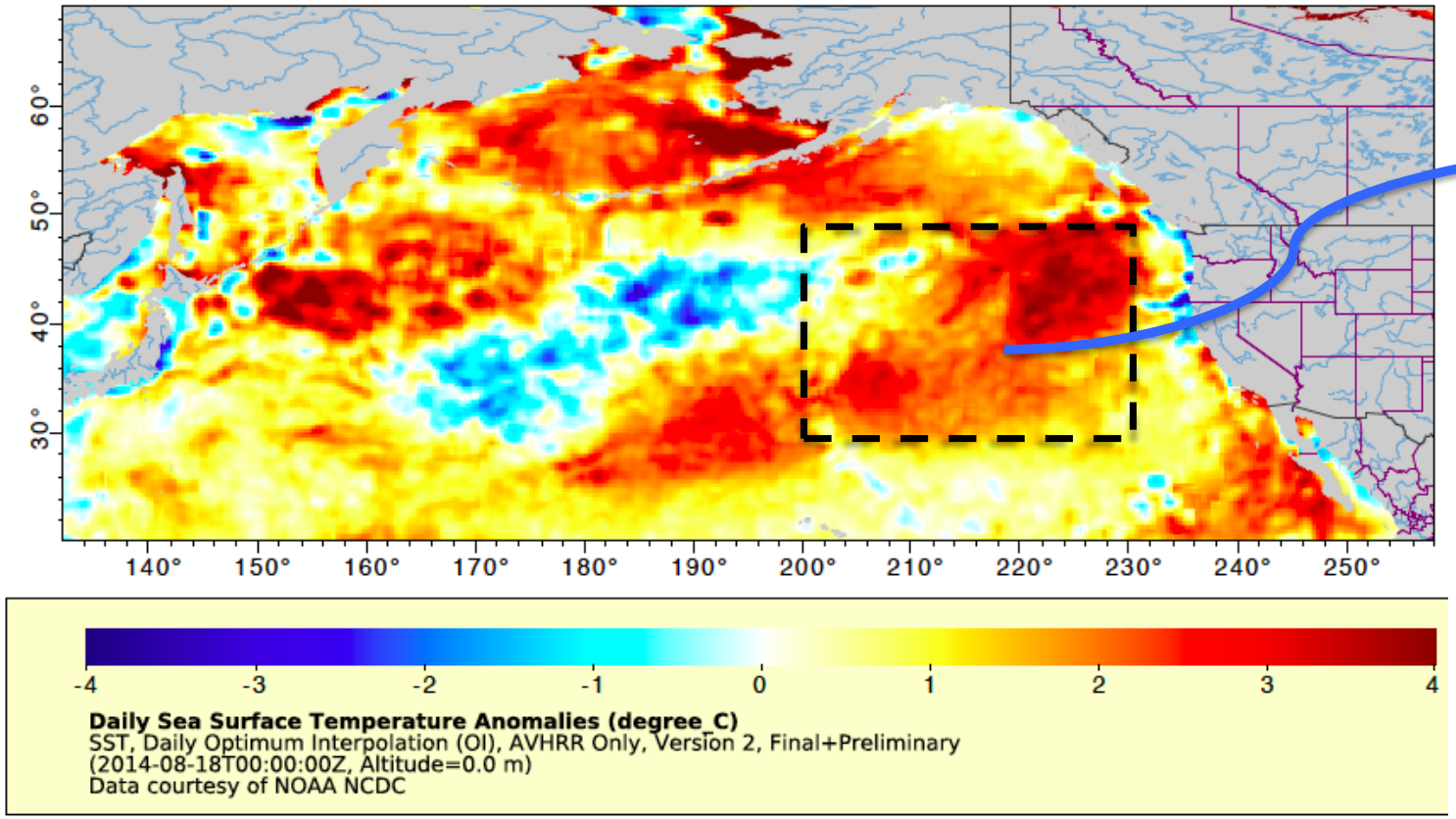


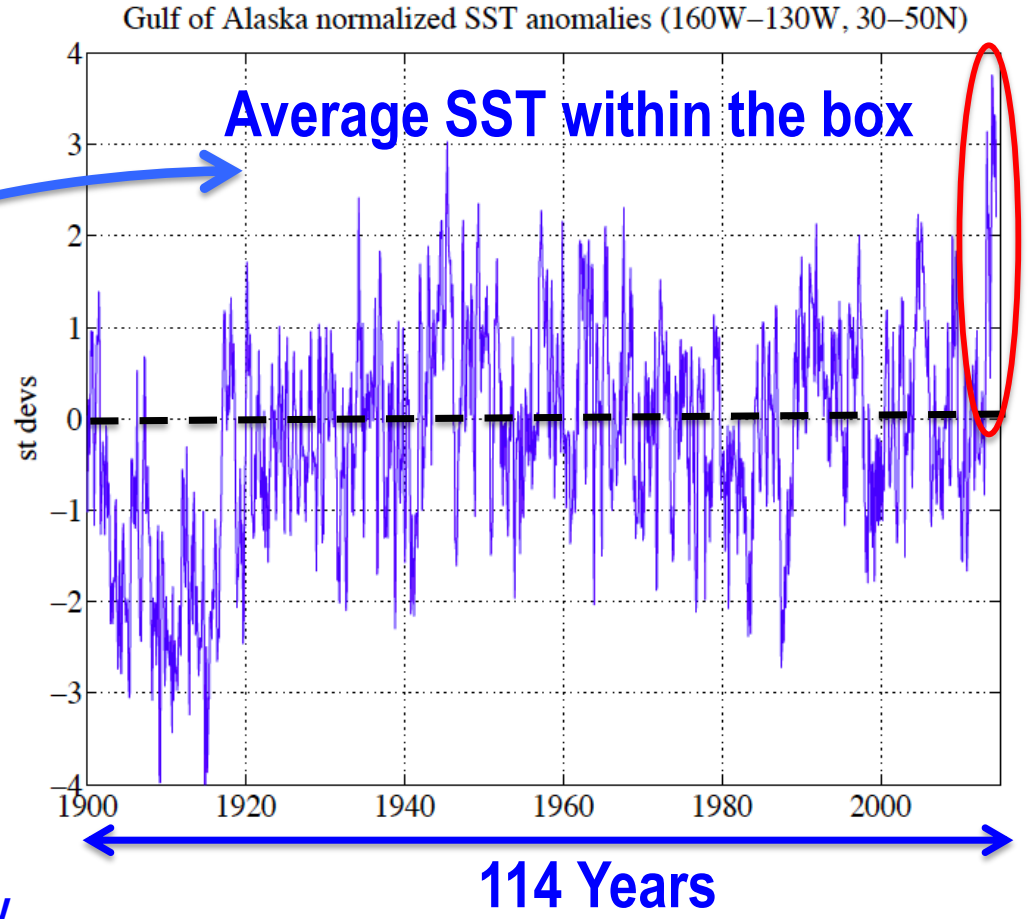




Present state and ~100-year time series of SST

"There's something happening here, what it is ain't exactly clear…" (Buffalo Springfield)





Daily SST anomaly (18 Aug 2014) relative to the 30-year (1982-2010) climatology

Update on the outlook for a 2014/2015 El Niño

NOAA FISHERIES

Alaska

Northwest

Pacific Islands

Southwest

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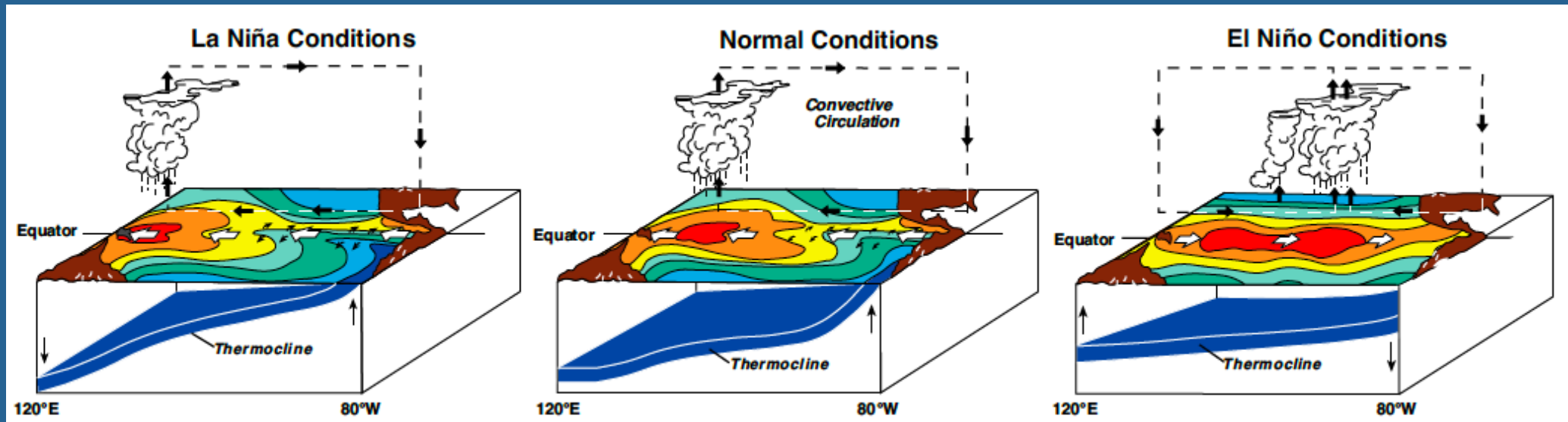


Figure 1. Schematic showing the El Niño/Southern Oscillation cycle of warm events (El Niño), cold events (La Niña), and normal conditions in the tropical Pacific.

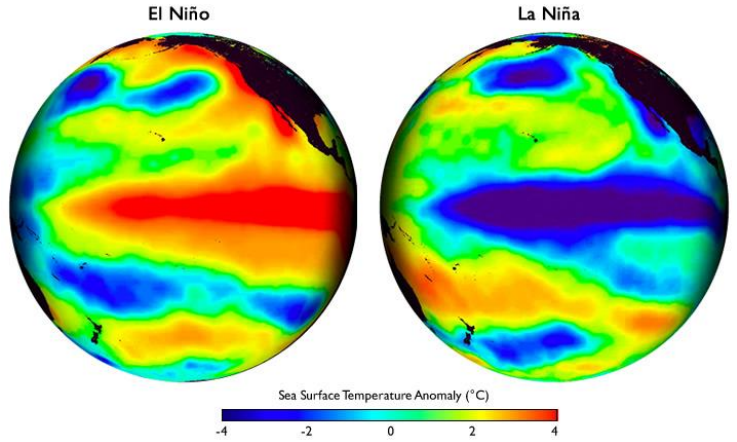


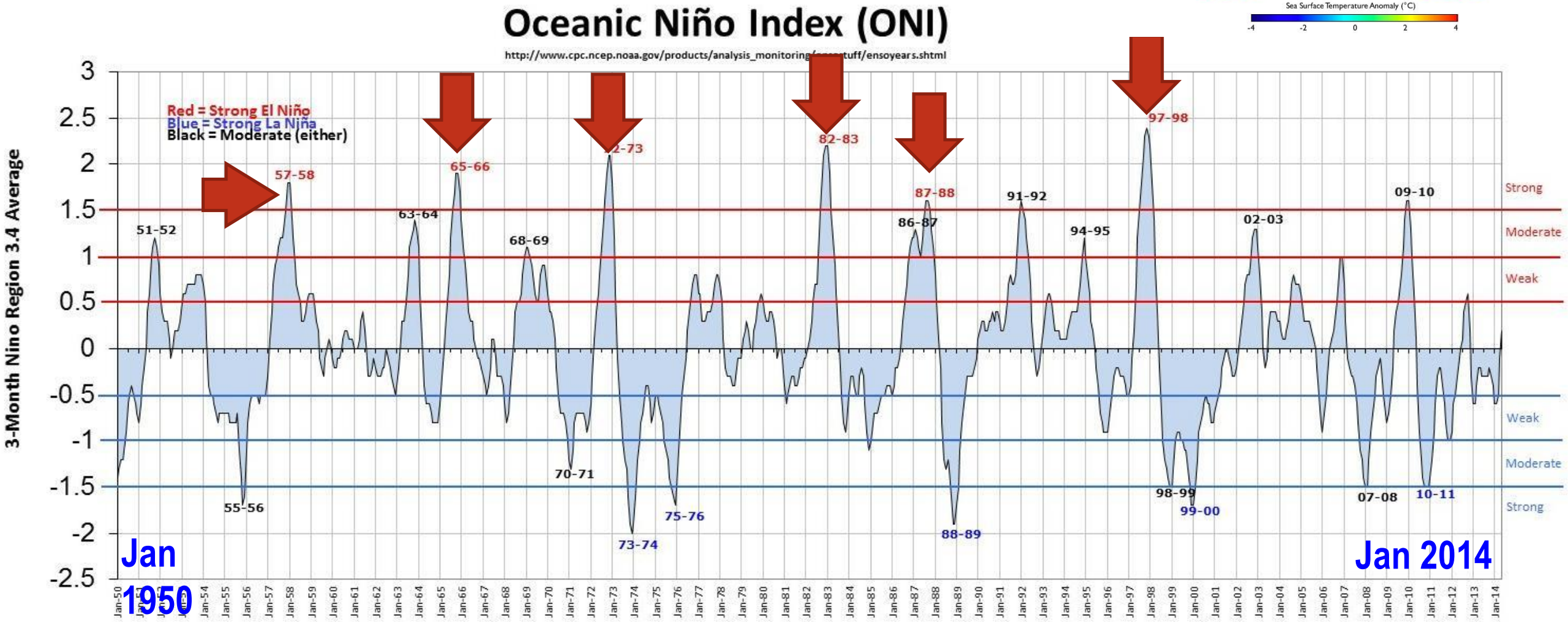


History since 1950 of El Niño/La Niña occurrences

Six "strong" and eight "moderate" *El Niños*

And five "strong" and four "moderate" *La Niñas*.





What do observations and forecasts say?

http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_advisory/index.shtml (week of 18 August 2014)

- ENSO-neutral conditions continue
- Chance of El Niño is about 65% during the fall and winter *(down from 80% six weeks ago)*
- Most models favor a moderate strength El Niño *(greater or equal to +0.5ºC)*

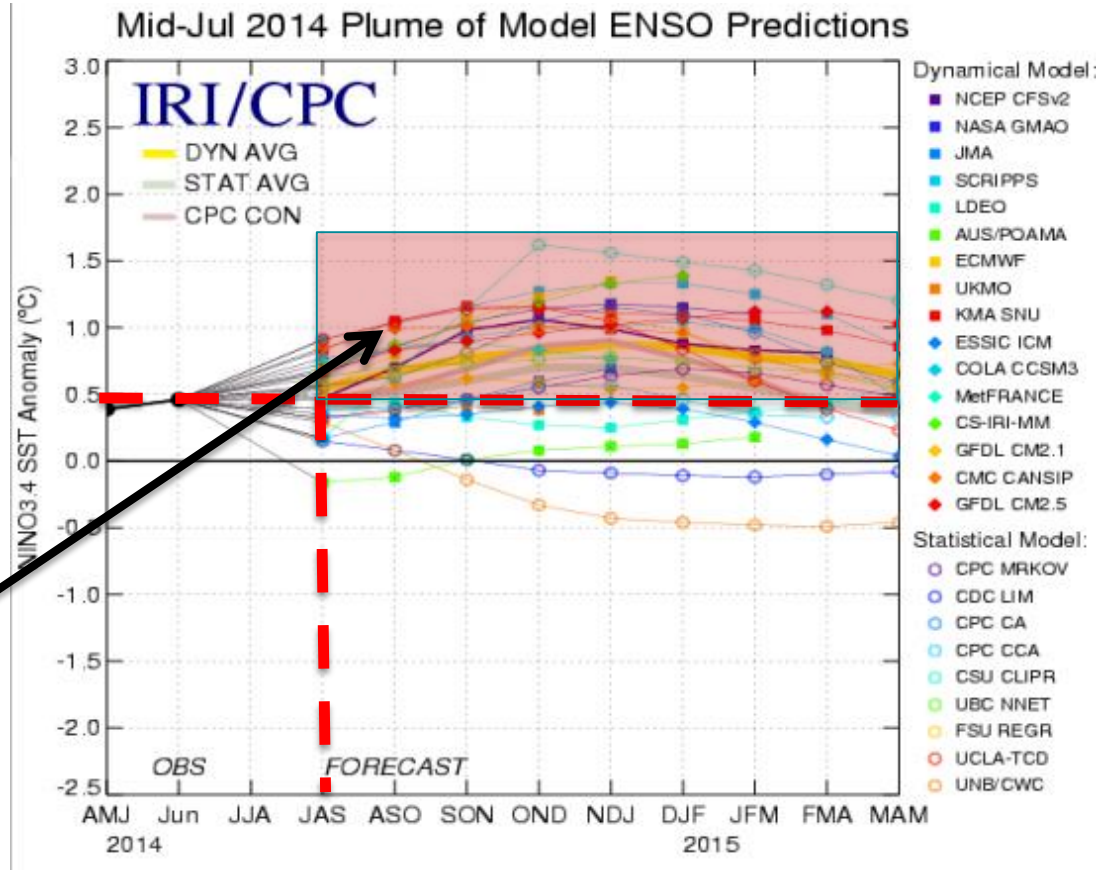
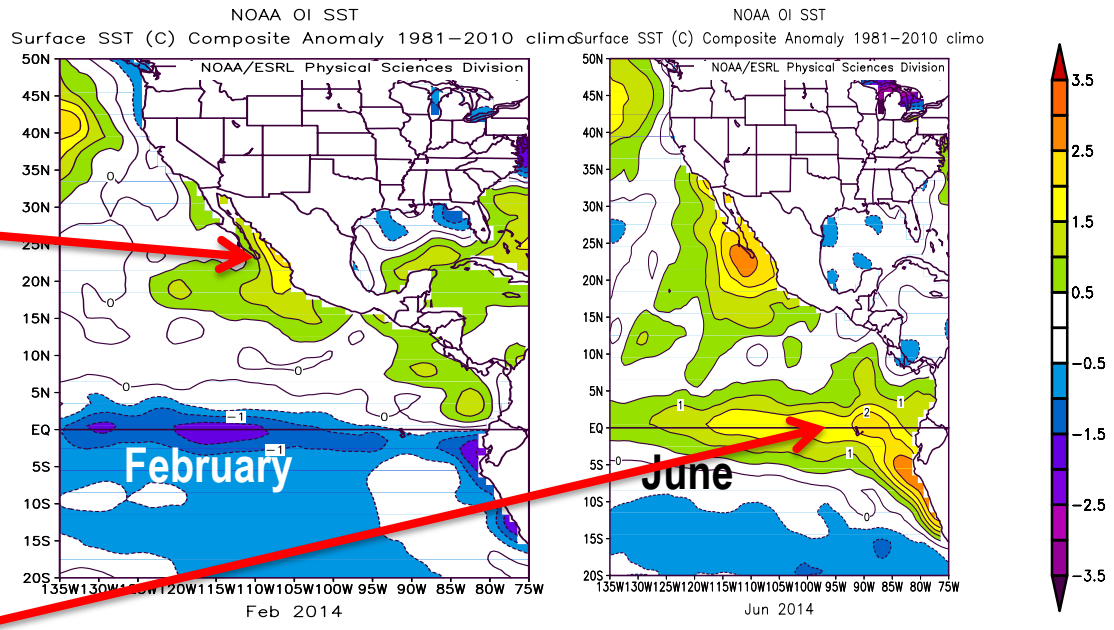


Figure provided by the International Research Institute (IRI) for Climate and Society (updated 15 July 2014).

Subtropical Pacific east of 120°W

- Sea surface temperature (SST) off Baja California and So. Cal. Bight above average since January 2014
  - these warmer temperatures are not connected to ENSO
- Only since May 2014 warm anomaly in the Eastern Tropical Pacific.

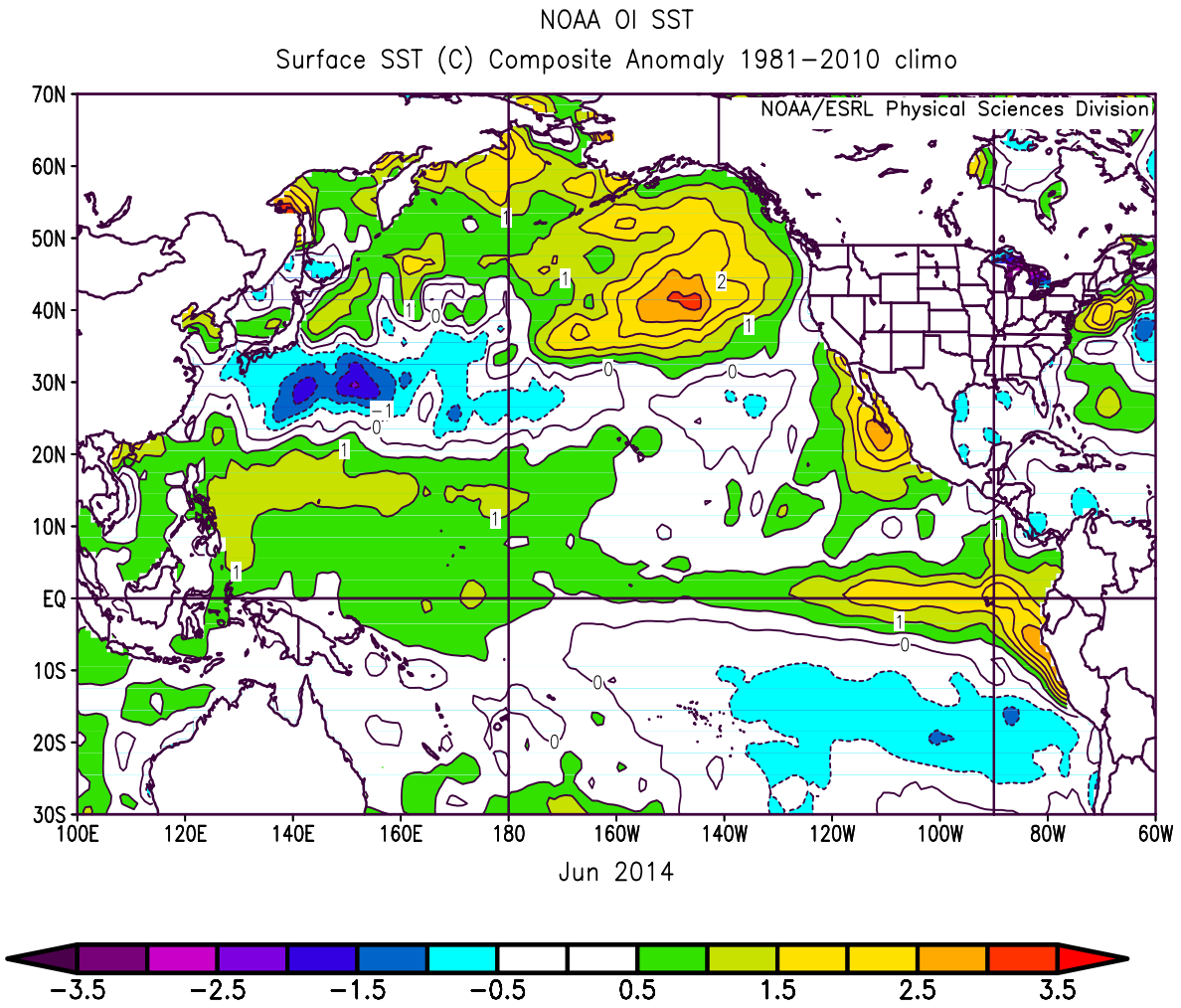


February (left) and June (right) 2014 SST anomalies (°C) for the Eastern Pacific.

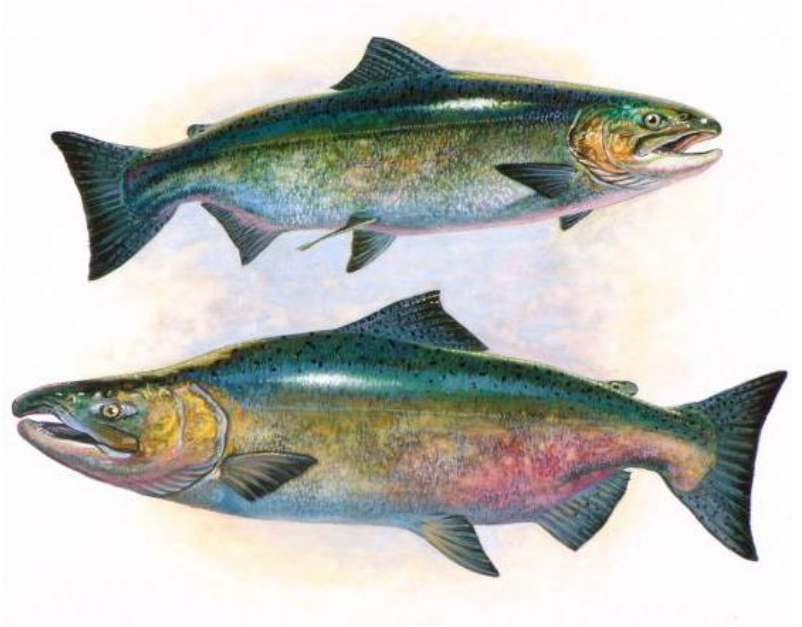
Note: if it were a "classical" El Niño, the Kelvin wave propagation would be from Equatorial regions to the poles, and the warm temperatures would have occurred later off Baja and So. California. The present sequence of conditions is just the opposite.

Northeast Pacific warmed before the Eastern Tropical Pacific warmed in May 2014

- Gulf of Alaska has been extremely warm for the past year
- Baja and So. California near-shore have been warm since January
- PDO appears to now be entering into a positive (warm) phase.



El Niño's Effects: Salmon in the California Current

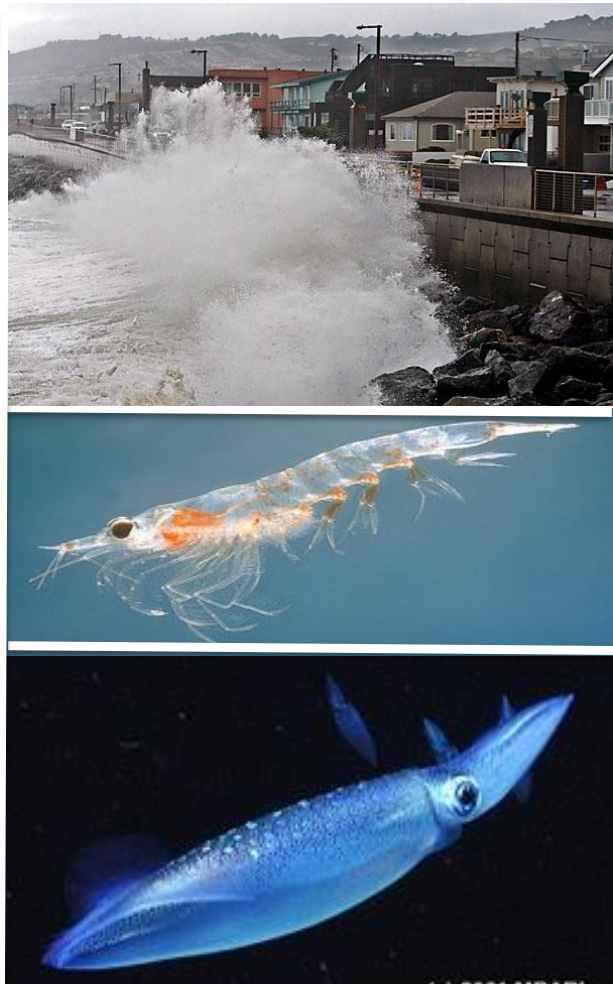


- **Positive PDO** = base of food web nutrient limited.
  - Bodes ill for west coast salmon marine growth and survival

- **El Niño or not**, juvenile salmon in the CA Current in 2015 are likely to experience low survival and returns could be below average
  - This has implications for fisheries and Threatened and Endangered species management in 2016 for coho, and 2017-18 for Chinook
  - And expands beyond PNW to Alaska, as PNW salmon migrate to the Gulf of Alaska

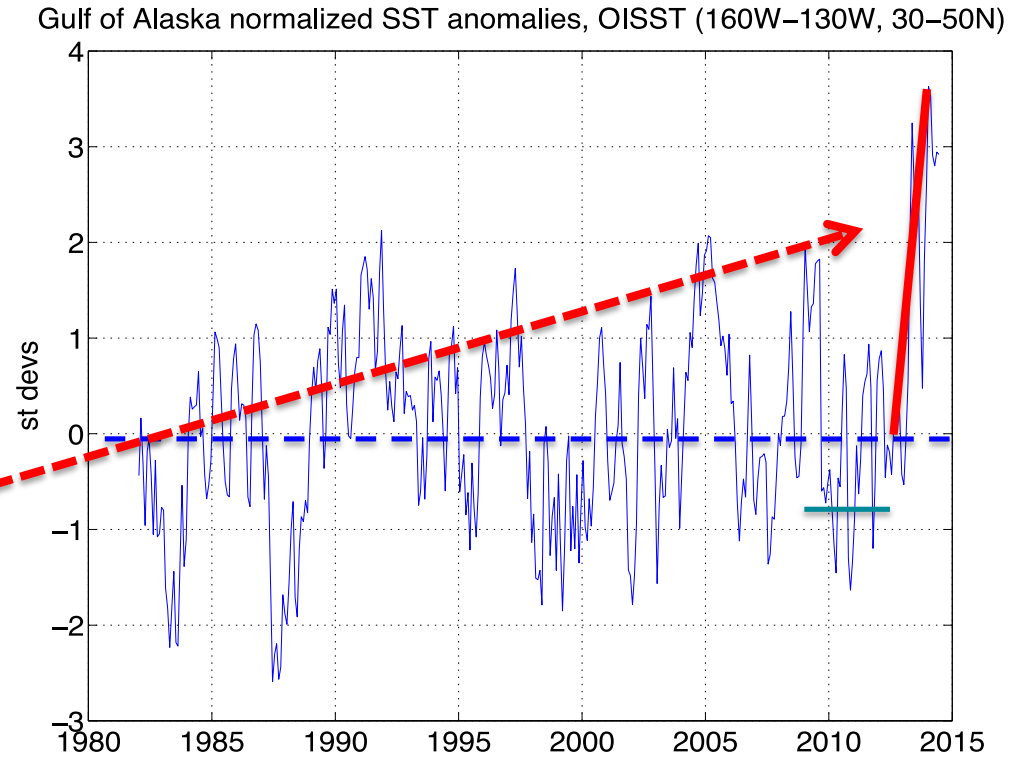
El Niño's Effects in the California Current

- Increased winter storms and rainfall in ***Southern CA.*** Only 33% chance of increased rainfall in ***Central/Northern CA*** *(not a drought buster this year)*
- Warmer, more subtropical, ocean conditions; reduced primary and secondary production
- Anchovy, market squid and CA sea lion populations in So. California decline; whiting and sardines migrate further north, into Canadian waters
- Improved growth and recruitment for some species, such as sardines; reduced recruitment for rockfish, squid, anchovies, etc.
- Tropical fish like mahimahi, swordfish, and marlin, and subtropical fish like Albacore and Pacific bonito, move north/onshore



El Niño's Effects: Gulf of Alaska

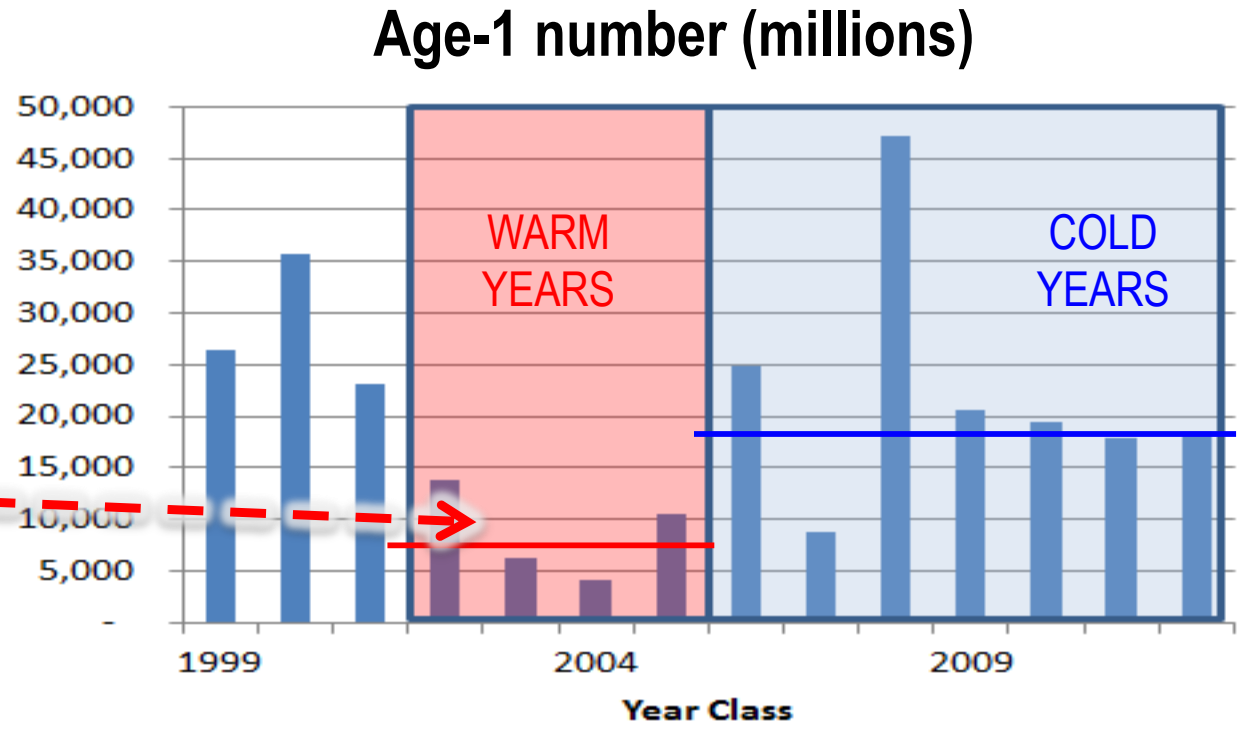
- Increases in early marine survival (faster growth) and adult returns for Alaska's Pacific salmon
- Increases in flatfish recruitment
- But the extremely warm water in the central Gulf of Alaska may ultimately lead to poor survival
  - Why? Likely declines in prey production



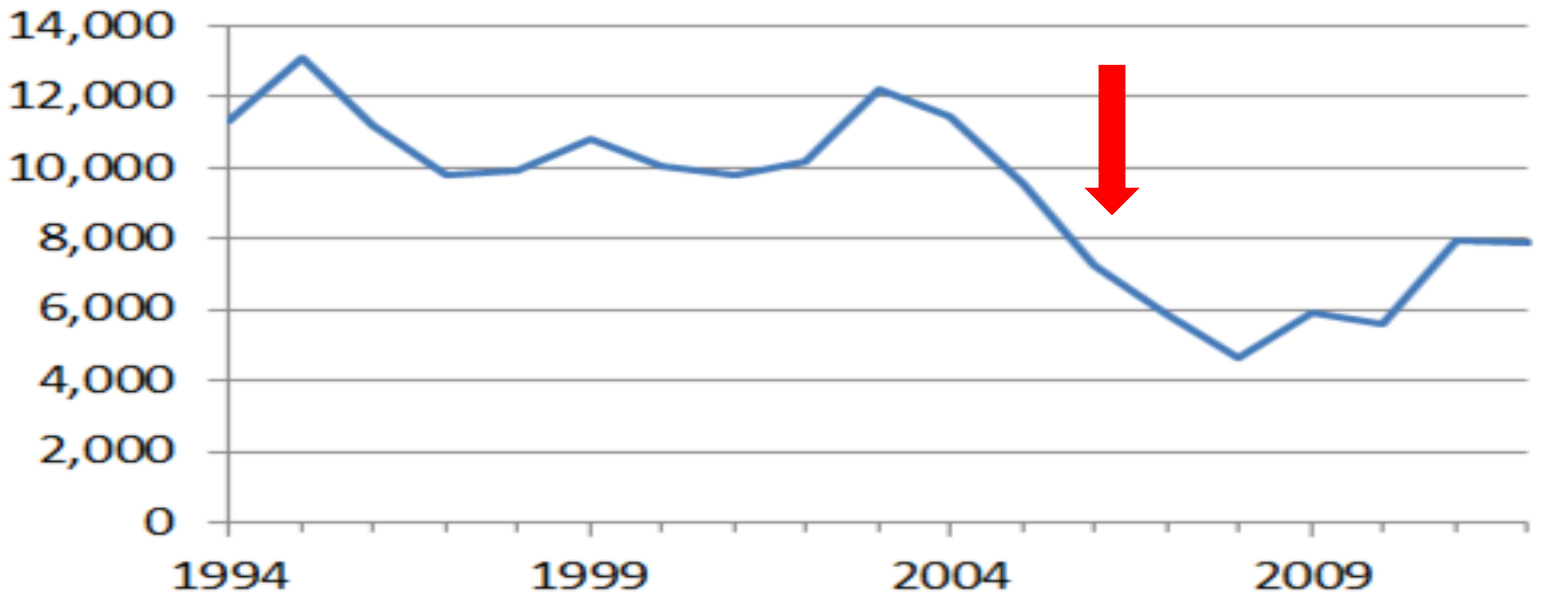
Time series of normalized monthly SST anomalies in the GOA (160W-130W, 30-50N)

Climate research in Alaska

Walleye pollock abundance dramatically fell in the early 2000's, leading to a 40% drop in the quota for the largest single fishery in the US, and then rebounded.



Age-3+ Biomass (thousands t)



Phytoplankton bloom timing matches copepod egg production in cold years but not warm years

Calanus egg production

Spring open water blooms

Fall open water blooms

Ice assoc. blooms

COLD YEAR

Low energy demand

ICE

WARM YEAR

High energy demand

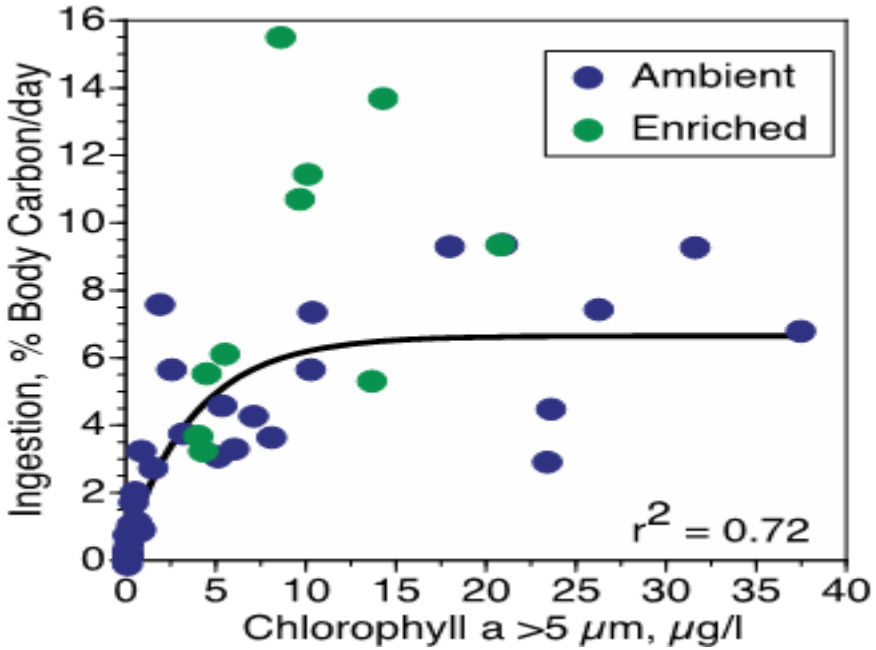
Feb Mar Apr May June July Aug Sept Oct

Baier and Napp, Hunt et al, Coyle et al

Copepods and krill are more abundant in cold years

Eisner et al.

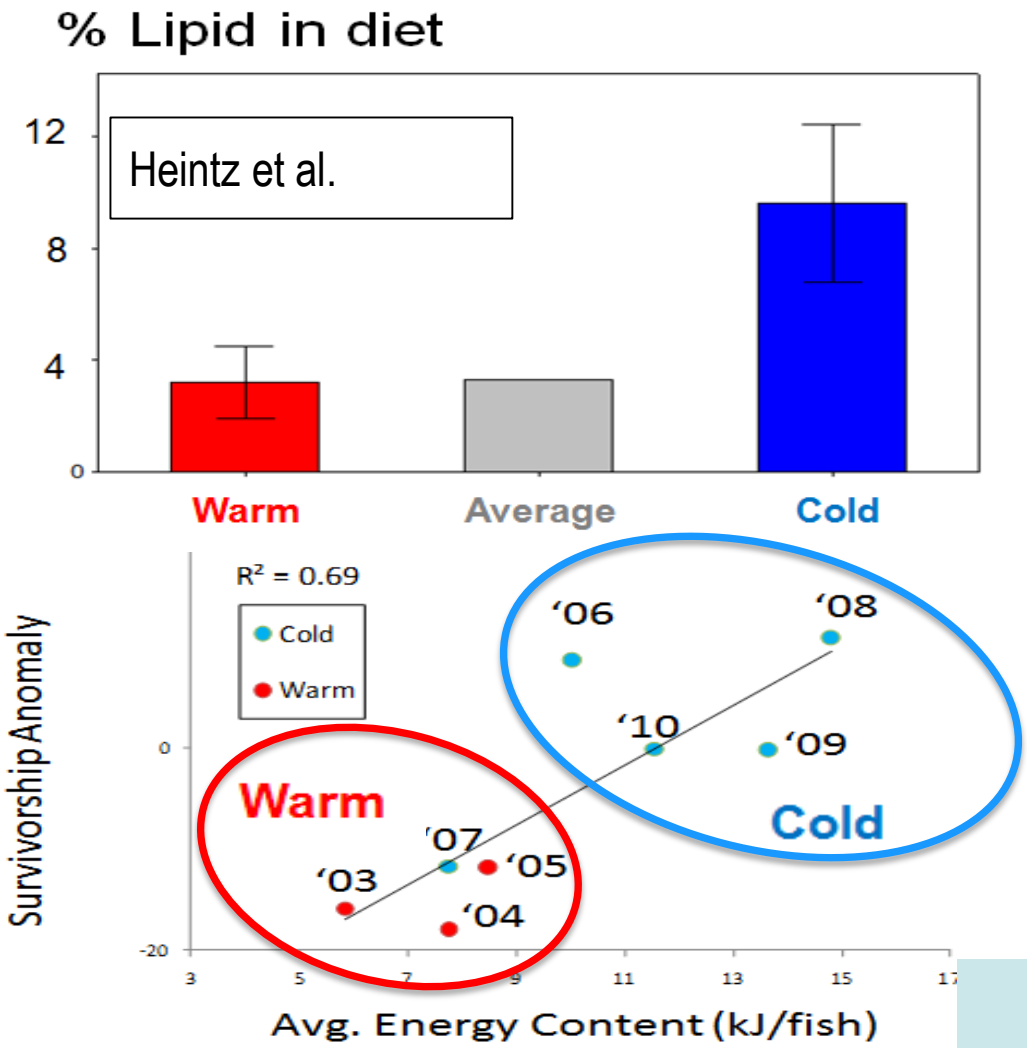
Ice algae likely enhances copepod reproduction



Higher ingestion rate when feeding on ice algae than water column phytoplankton

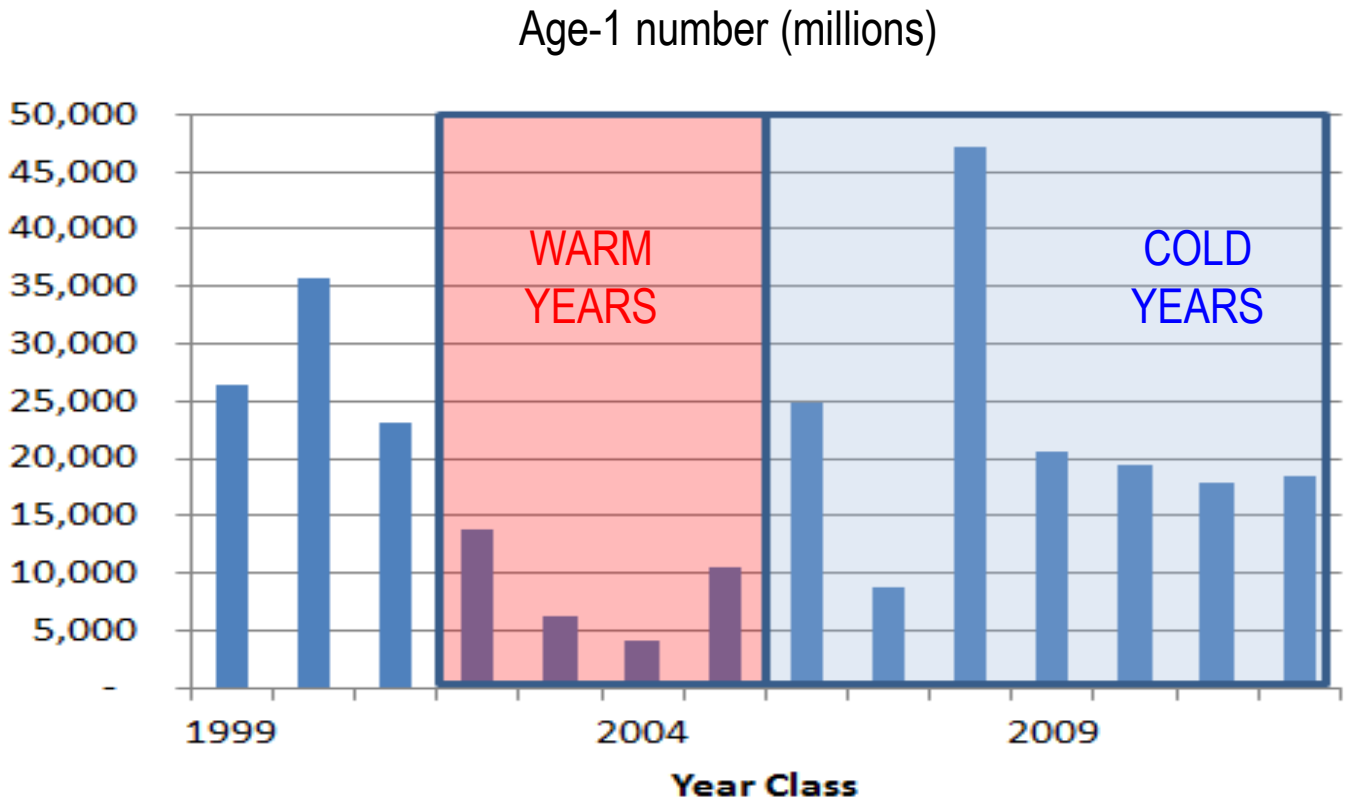
Campbell, Lessard, Ashjian, Durbin, Rynearson, Casas

As a consequence, **age-0 pollock consume richer diets in cold years**, better preparing them for their first winter and enhancing survivorship.



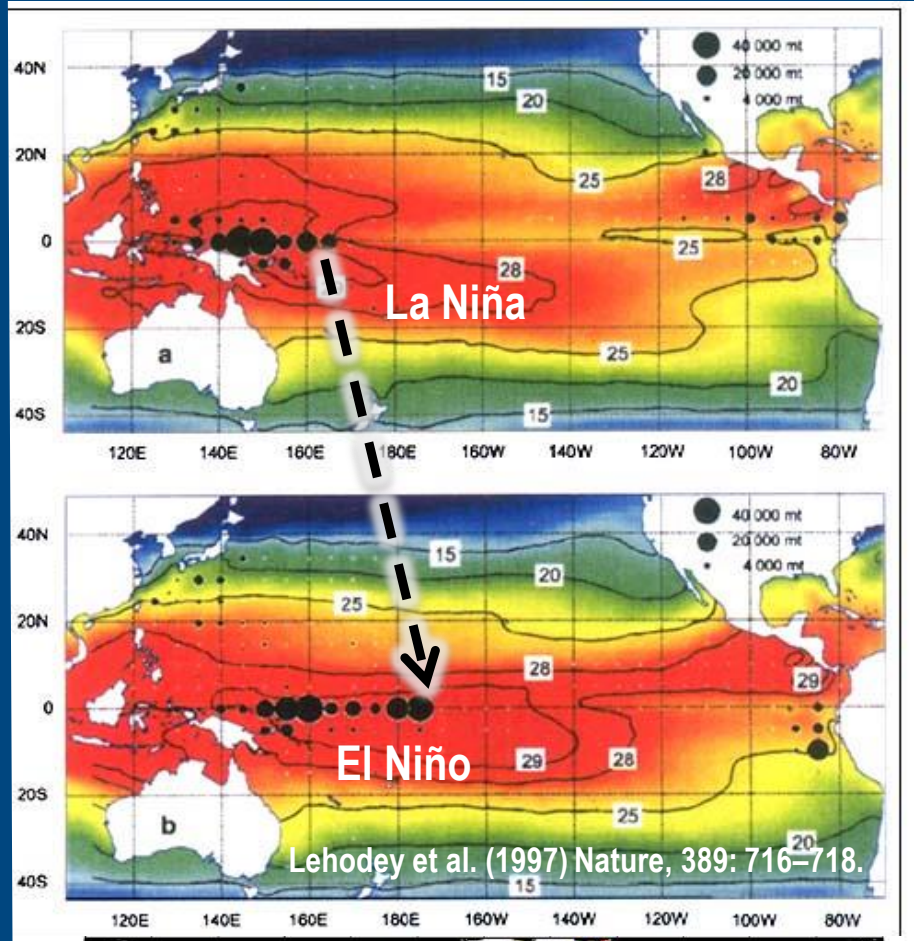
Therefore:

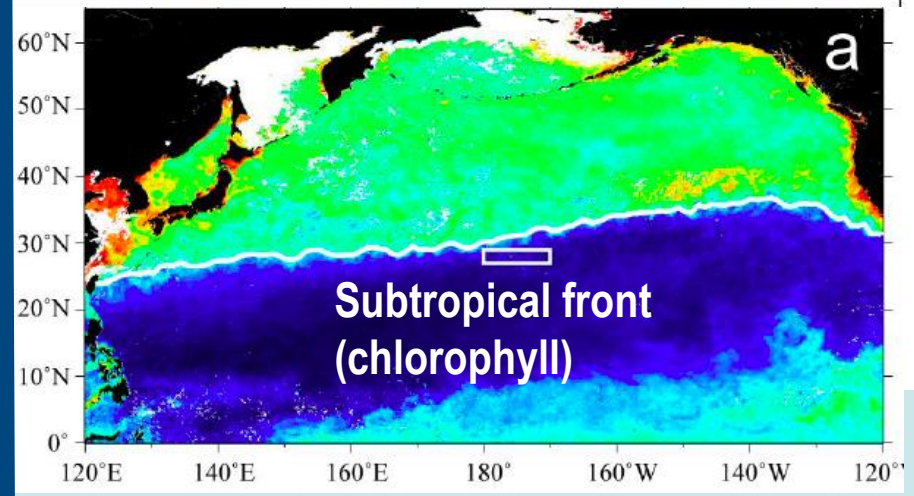
Due to bloom timing, **large crustacean zooplankton benefit from icy winters, providing prey for age-0 pollock** to enter their first winter fat (and happy?)



El Niño's Effects: Central and Western Pacific

- Purse seine and longline fleets from the Western Pacific shift eastward by up to 2,000 km
- Sea levels drop around American Samoa and the Marianas exposing shallow corals to bleaching
- Bleaching also likely due to elevated temperatures in the Pacific Remote Island Areas (PRIAs)
- *Can enhance monk seal pup survival* 1-2 years after the El Niño in the northern atolls of the Hawaiian Archipelago





Management Implications (example)

- WCR recommended closing drift gill net fishery east of 120°W. (Expected increased interaction with Pacific loggerhead turtles)

- Decision based on expectations of persistence of warm waters. Perhaps not as much on the possibility of a tropical El Niño (EN) coming.

- The drift gillnet fishery regulations revisited?
  - Parts of the present language keys to EN. This year's warming was not due to EN.

CENTER for BIOLOGICAL DIVERSITY

Suit Filed to Protect Endangered Pacific Loggerhead Sea Turtles From Nets

Feds Fail to Enforce Drift Gillnet Fishery Closure During El Niño

http://www.biologicaldiversity.org/news/press_releases/2014/loggerhead-sea-turtle-07-10-2014.html

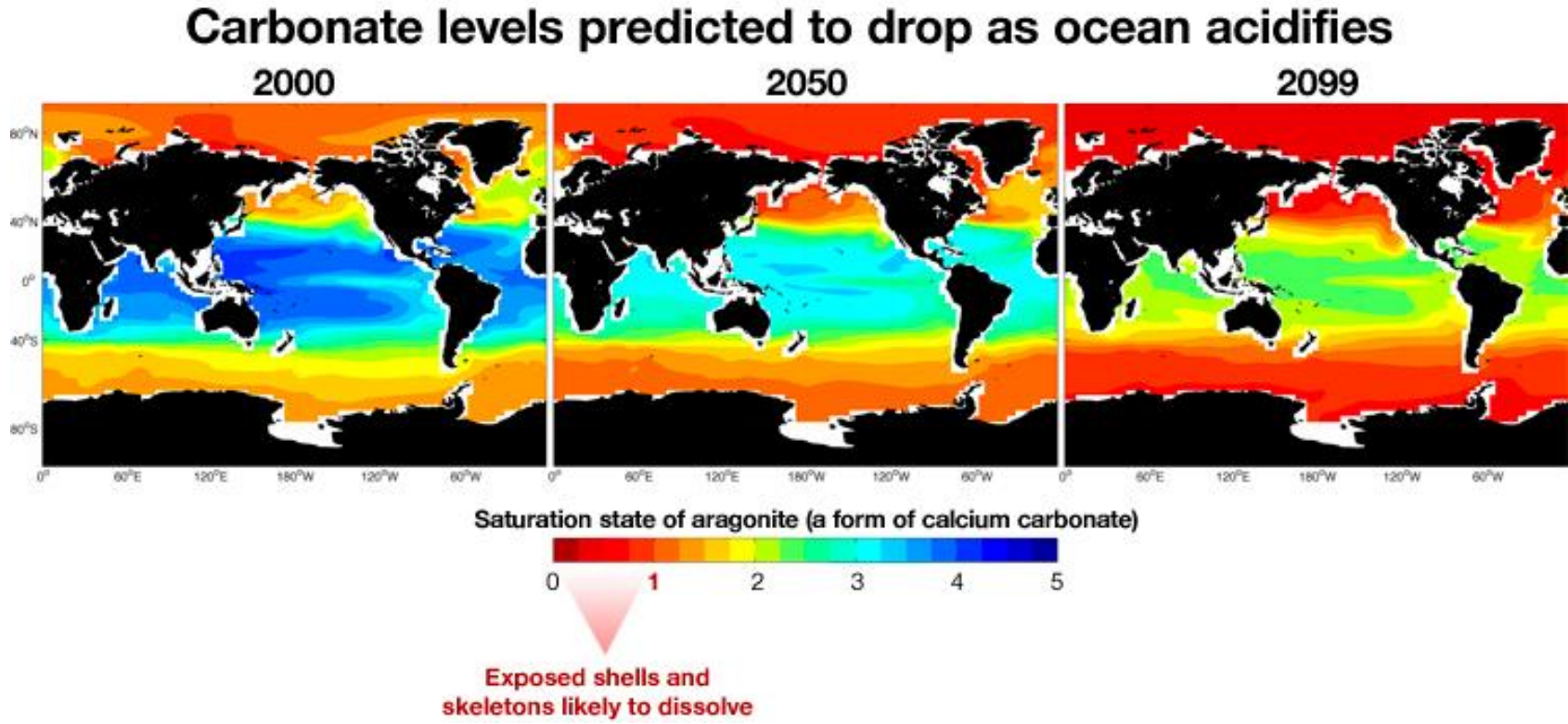
Ocean Acidification (OA)

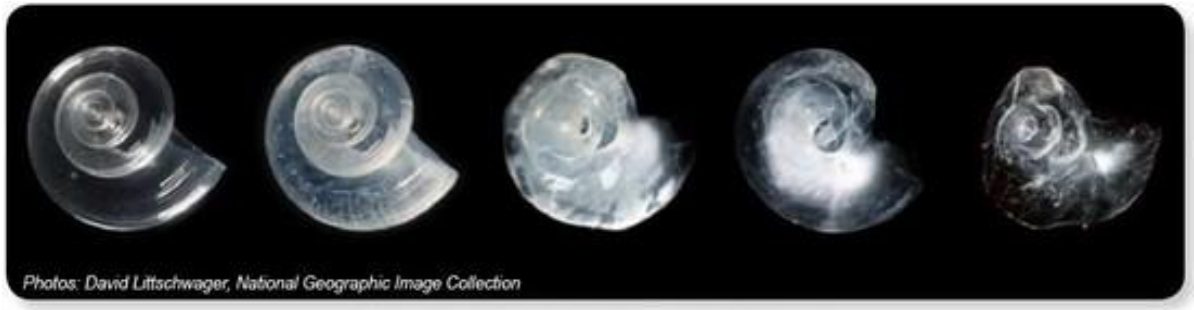
"The *other* CO_2 problem"

- ✓ Climate change and ocean acidification
- ✓ Ecosystems and ocean acidification
- ✓ What should we do now and in the future

Start with the Bottom Line

- CO_2 is changing the ocean
- OA can be treated as a toxicological issue
- Input is global not local
- Uncertainty
  - who will be the winners and losers
  - what are the ecosystem consequences
  - interactions with other stressors
  - rate of change



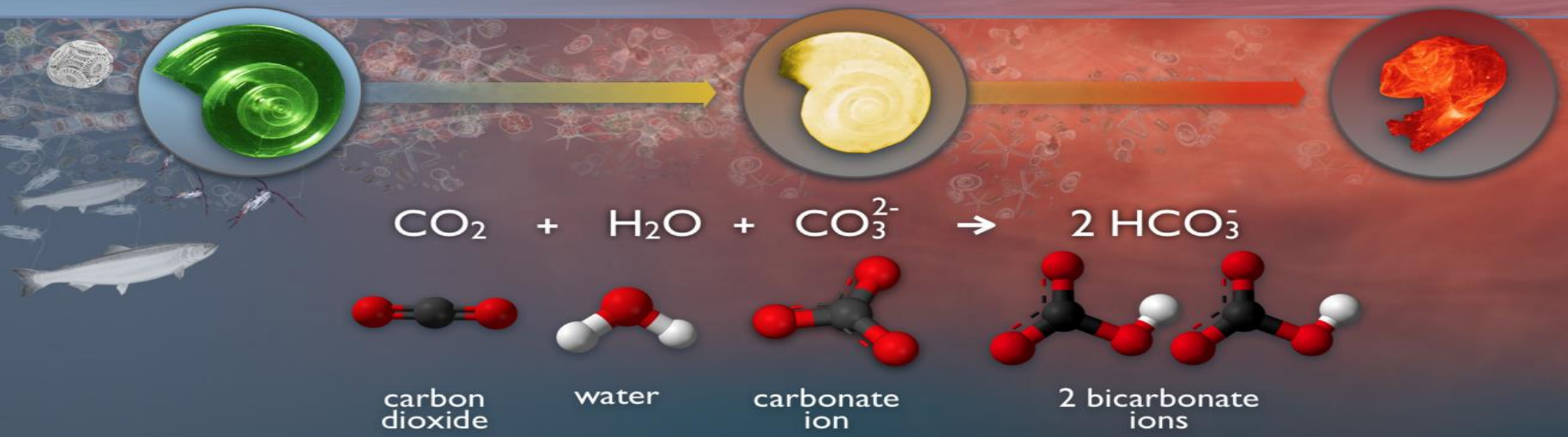


Dissolution of pteropod shell in acidified water

Ocean Acidification

How will changes in ocean chemistry affect marine life?

CO_2 absorbed from the atmosphere



$CO_2 + H_2O + CO_3^{2-} \rightarrow 2\ HCO_3^-$

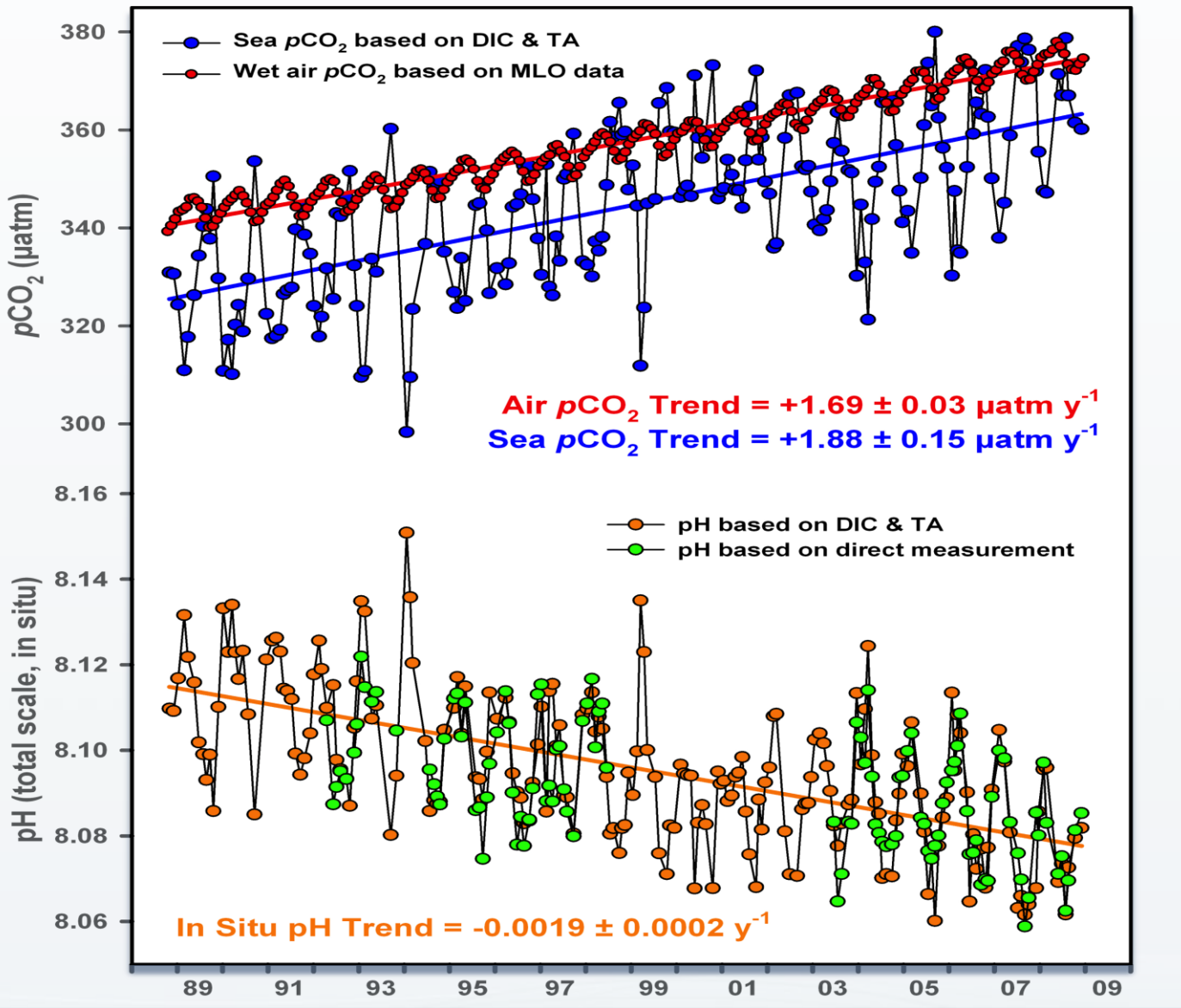
carbon dioxide | water | carbonate ion | 2 bicarbonate ions

consumption of carbonate ions impedes calcification

$Ca^{+2} + CO_3^{-2} \longleftrightarrow CaCO_3$

What do the data say?

Doney, Science, 2010
Dore et al., PNAS 2009



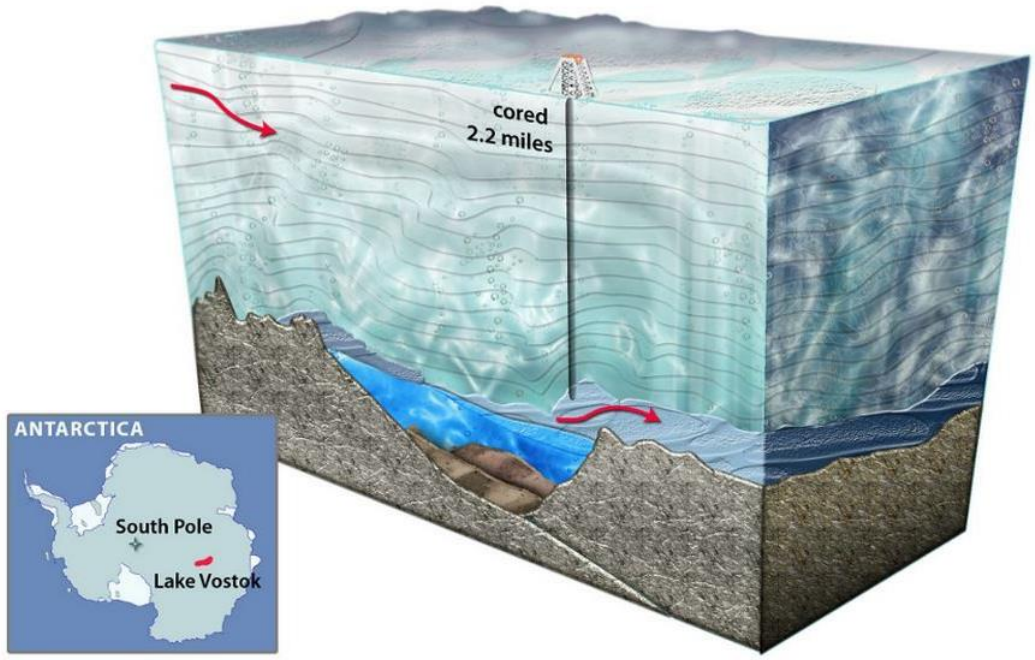
Recent Events

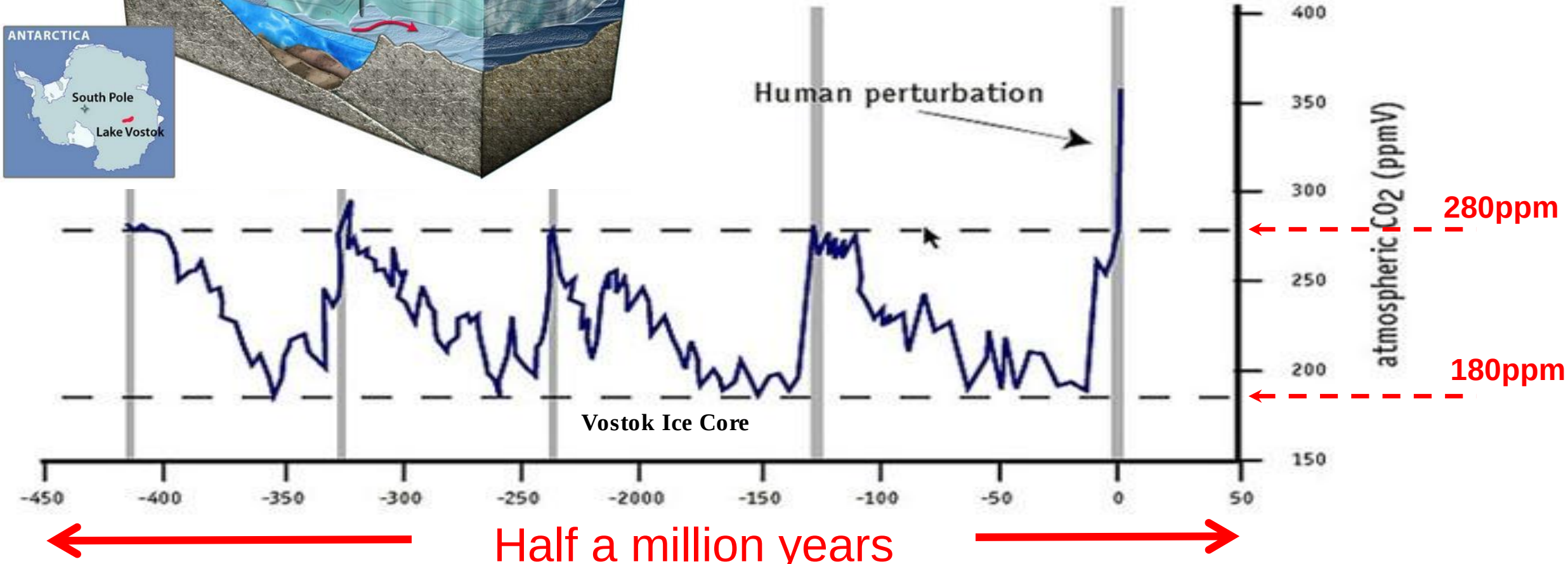
- 1st time in 800,000 years
- Atmospheric $C0_2$ at 400 ppm for the 1st time in April 2014
- 3rd National Climate Assessment PNW Chapter “ Threats to infrastructure and habitat, and increasing ocean acidity collectively pose a major threat to the region.”

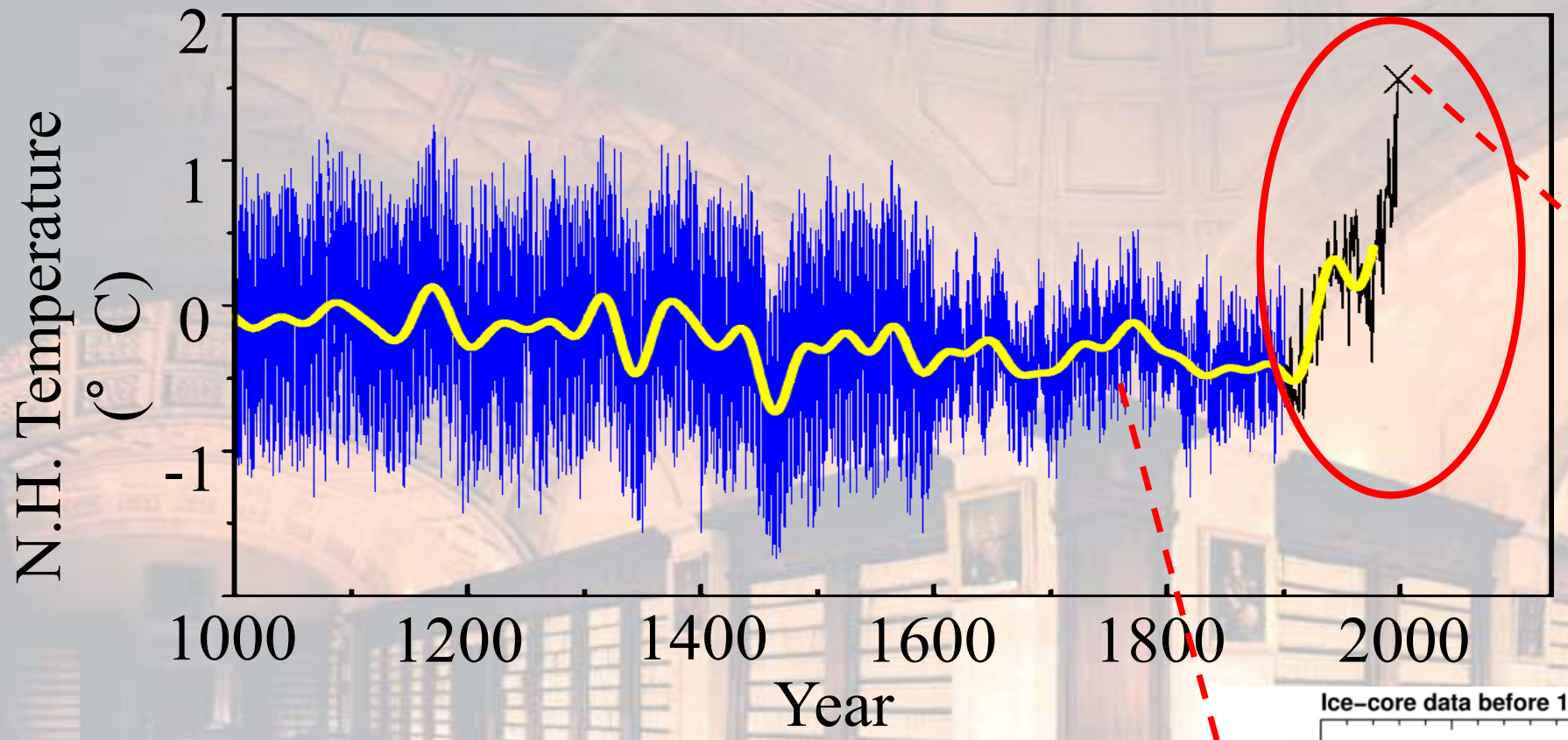
Vostok Ice Core

and

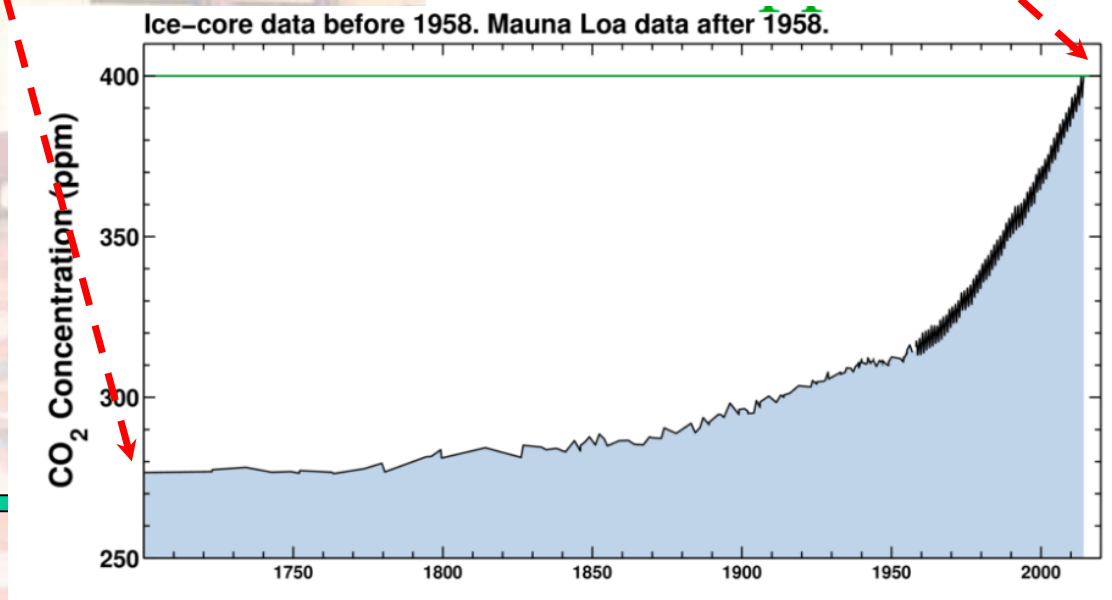
Mauna Loa's "Keeling Curve"







Latest reading: 399.96ppm
CO_2 concentration
August 21, 2014



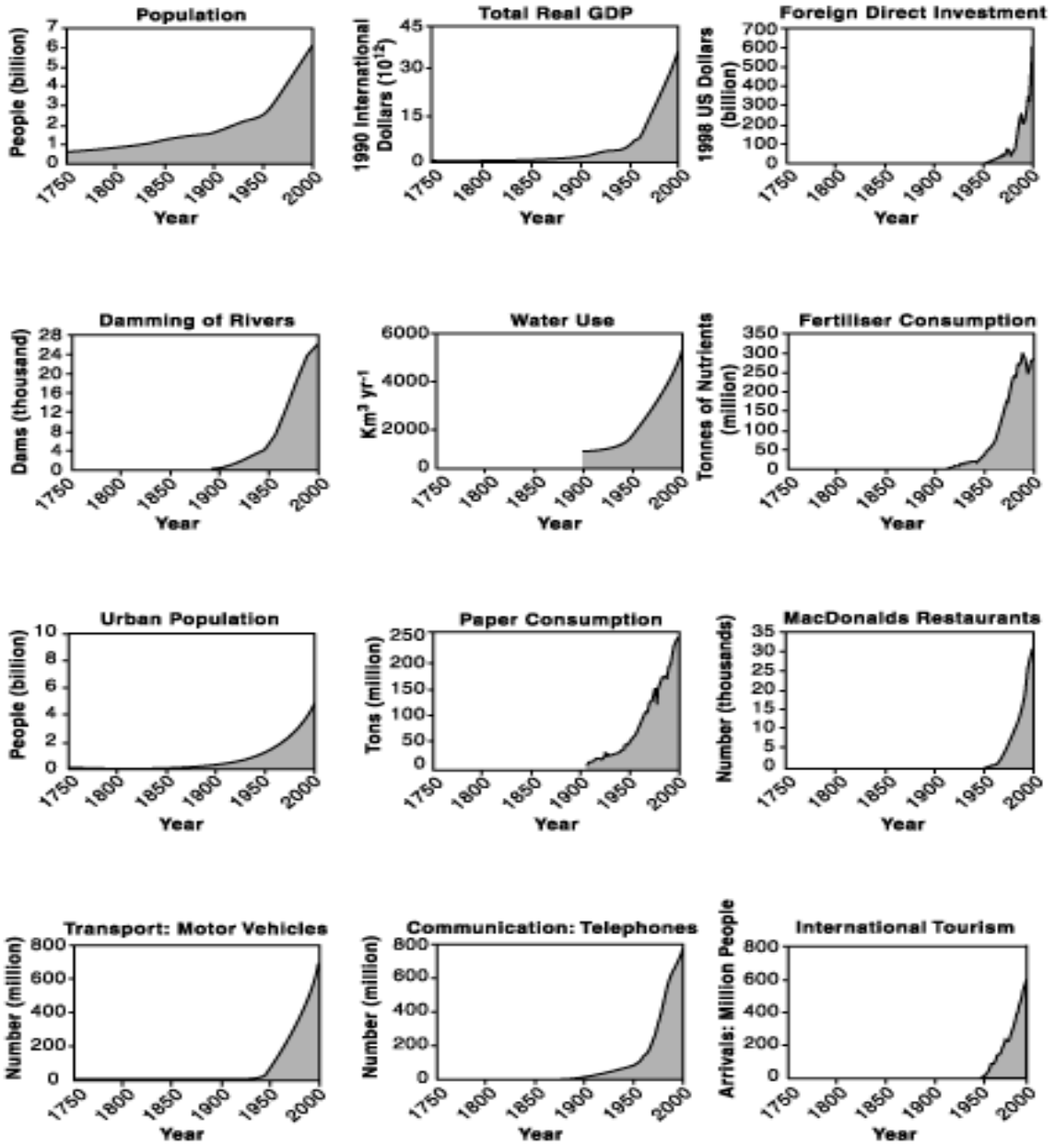
A Millennium Scale Perspective ...

Mann et al. (1999) GRL 26:759-762

The Earth is currently operating in a ***no-analogue*** state. In terms of key environmental parameters, the Earth System has recently moved well outside the range of natural variability exhibited over at least the last half million years.

The ***nature*** of changes now occurring ***simultaneously*** in the Earth System, their ***magnitudes*** and ***rates of change*** are unprecedented.

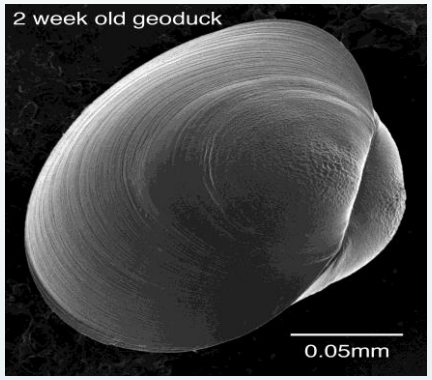
From: Steffen et al. (2003)



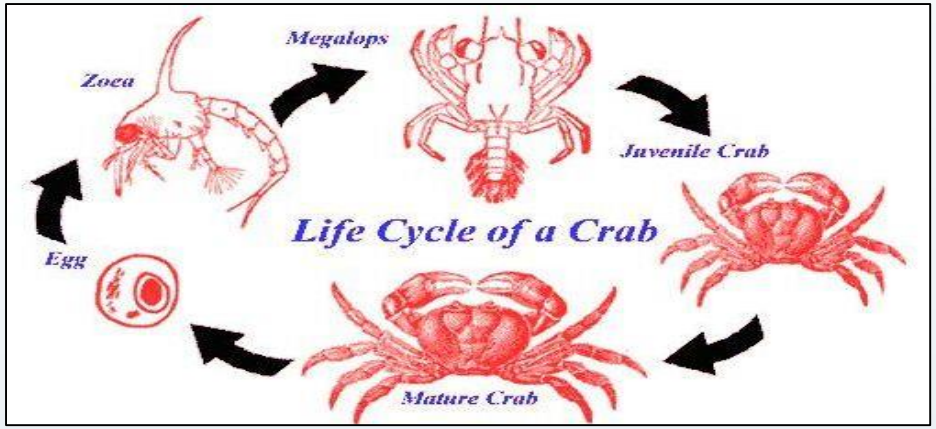
OA has many effects

Growth & Survival

Calcification

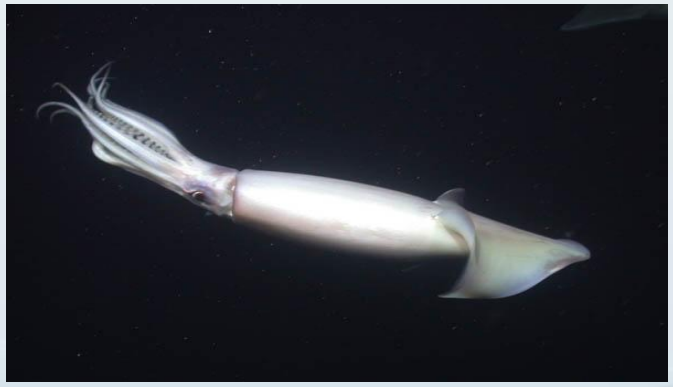


Development

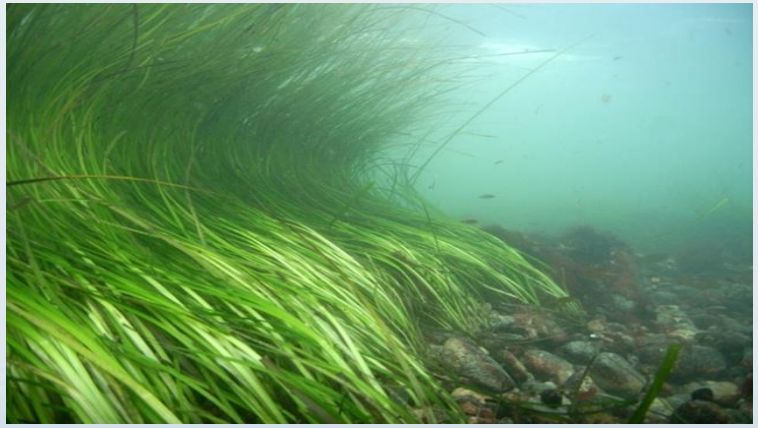


Behavior & Nervous System

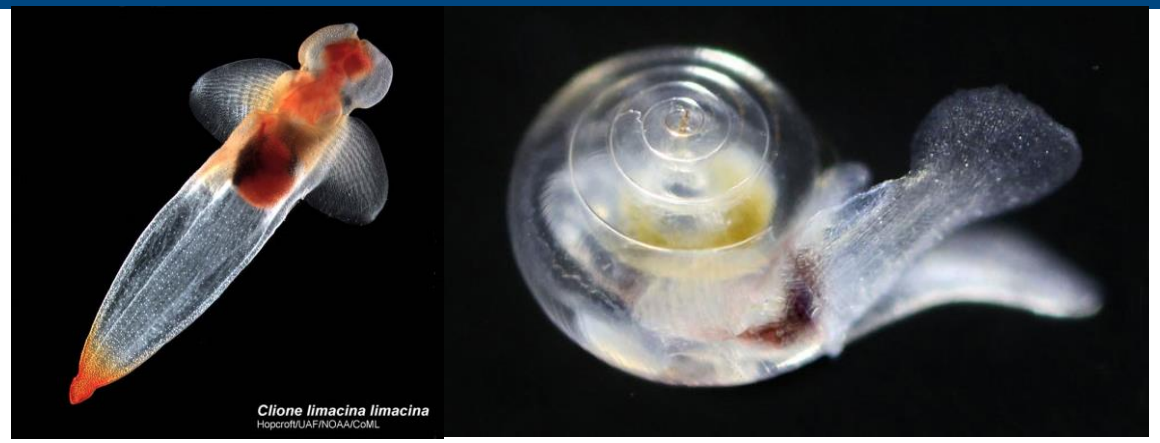
Respiration



Photosynthesis

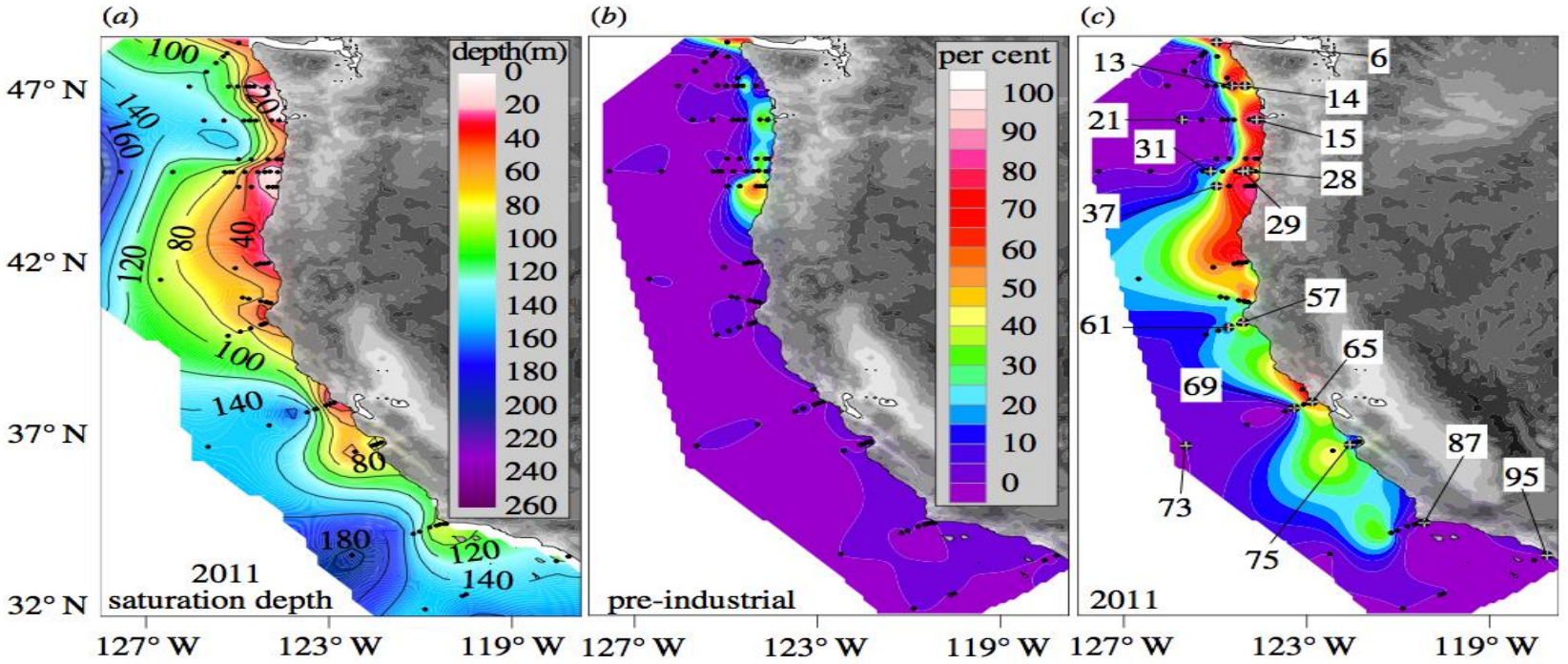


Field Results: Pteropods (also reproduced in the laboratory)

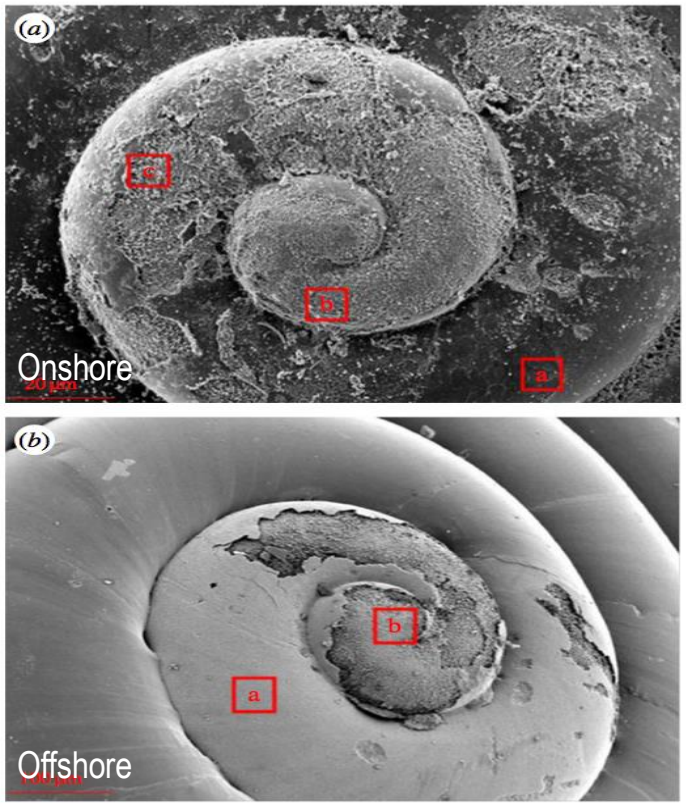


Aragonite Saturation Horizon on West Coast

Saturation Depth | Pre-Industrial | Aug-Sept 2011



Observed Shell Dissolution (SEM Images)



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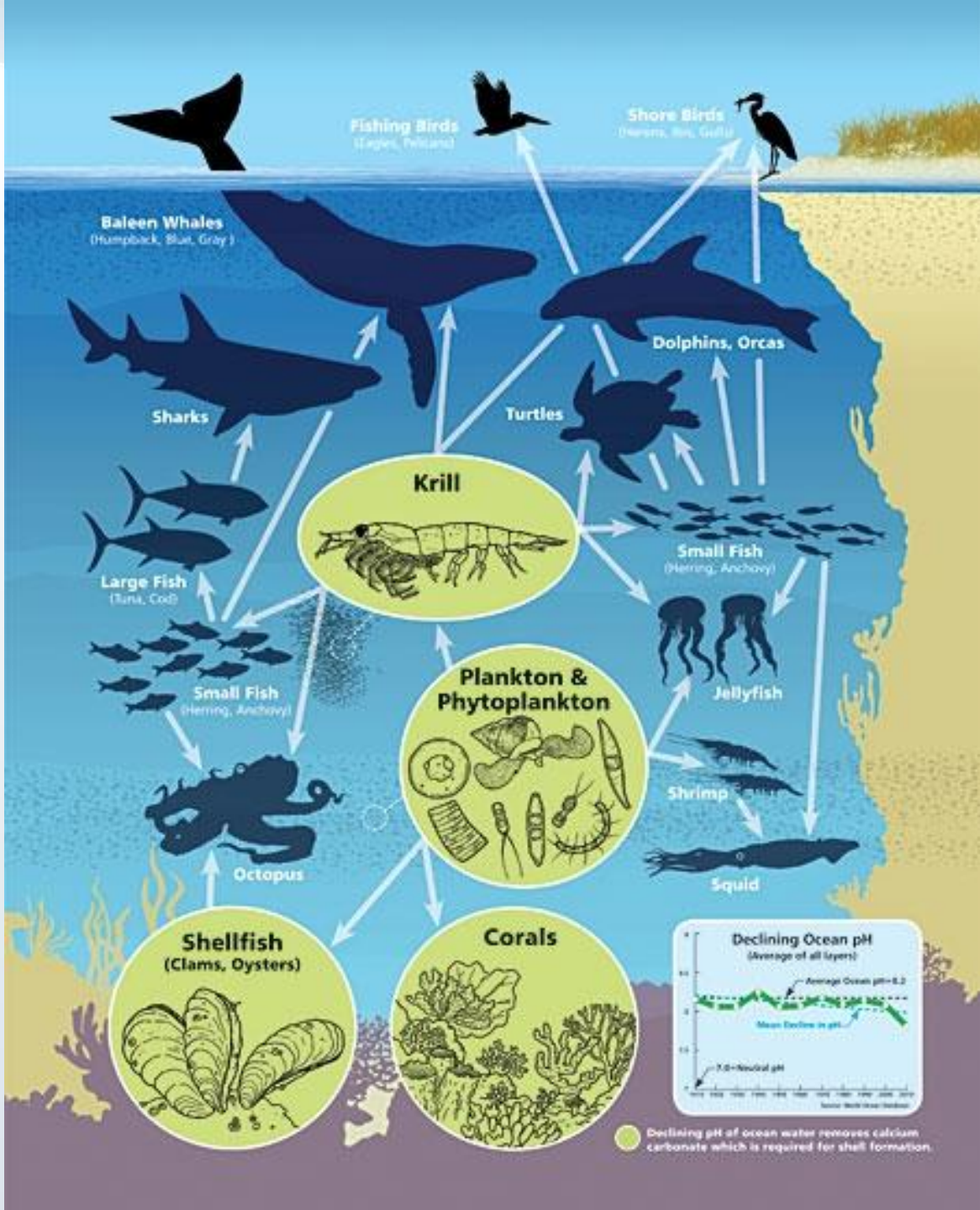
Busch et al. NWFSC Bednarsek et al. 2014 PMEL

Species are interdependent

- Some of the predators of pteropods are whales, fish and seabirds.
- Pteropods located in northwest Pacific salmon fishing grounds can make up over 60% of juvenile salmon diets (Armstrong et al., 2005, Turley et al., 2010).
- In Japanese waters a deep-water myctophid fish, *Centrobrachus brevirostris*, exclusively eats pteropods (Watanabe et al., 2002).
- Pteropods are also the dominant grazers of polar phytoplankton, out-consuming copepods by up to 33% (Bernard & Froneman 2009).



What to Do About OA?

Reduce CO_2!

Policy and Management Considerations

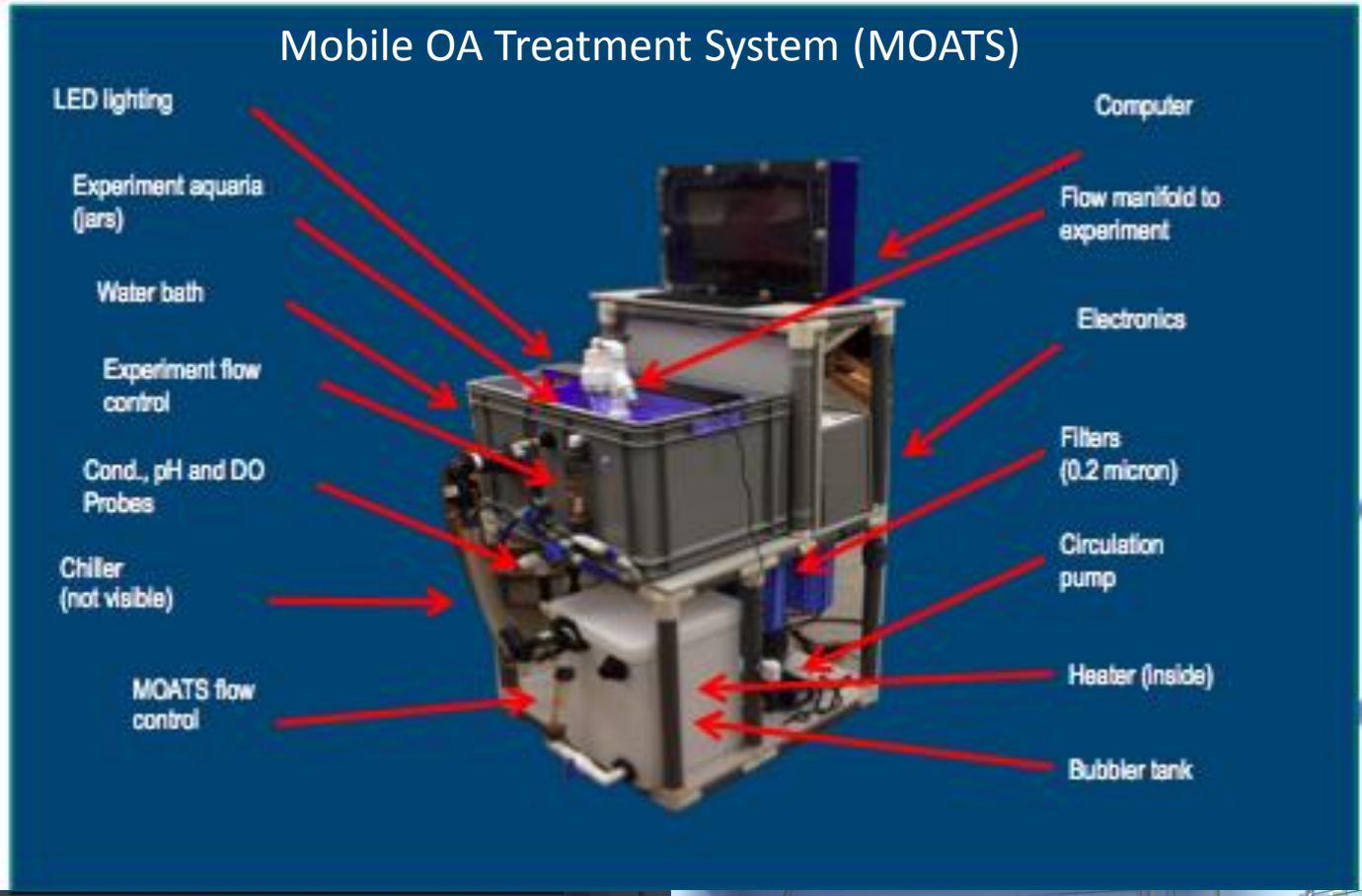
Adaptation Strategies

- In addition to CO_2 reduction, reduce other stressors that can be controlled
  - Reduce nutrient and chemical pollution
  - Manage fisheries
  - Control invasive

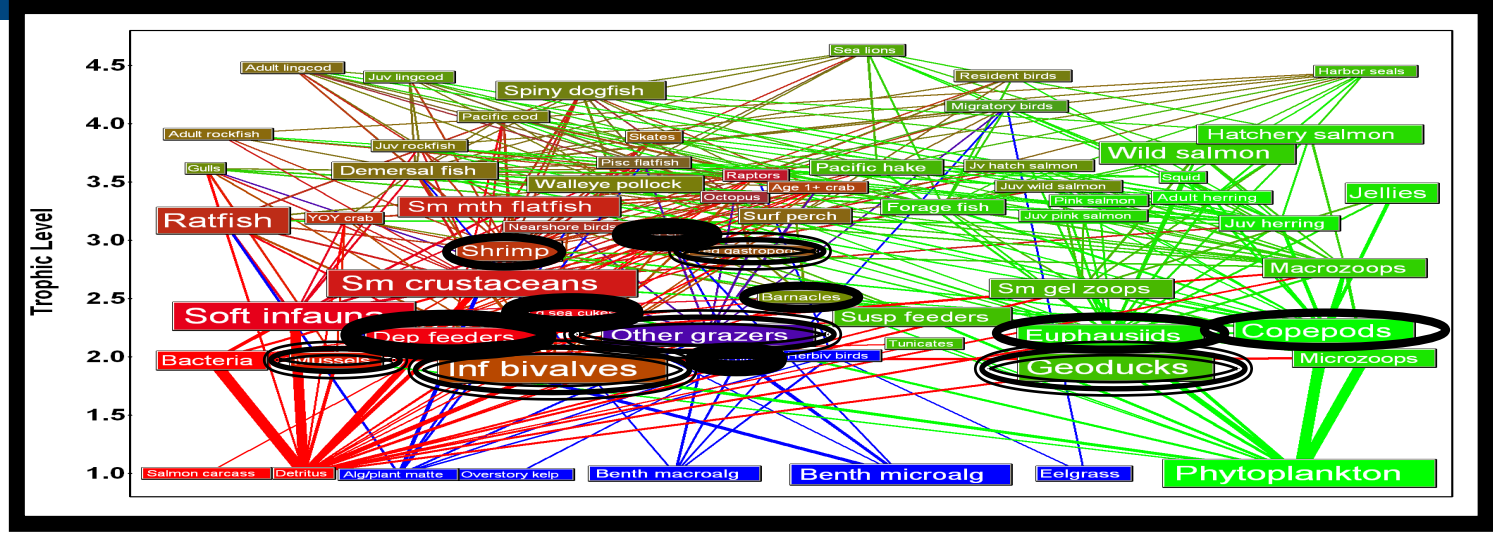
- Protect biodiversity and habitats to maximize likelihood of biological adaption

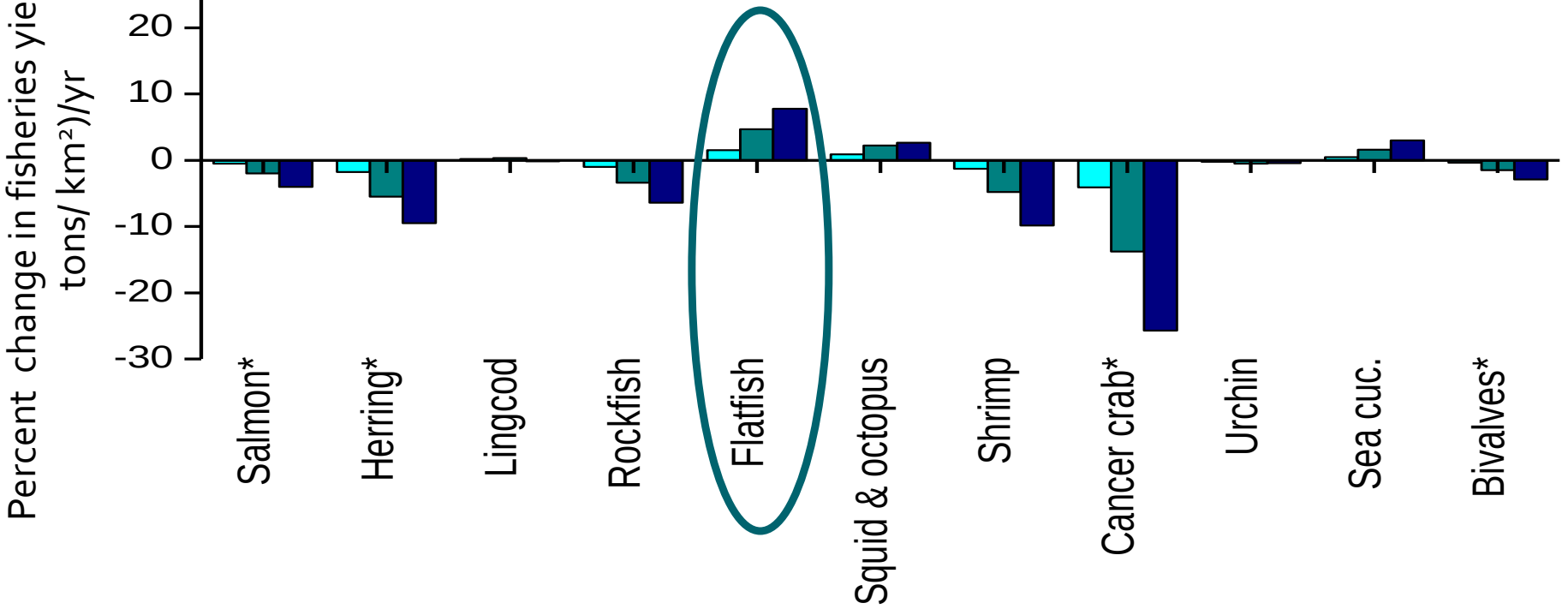
NOAA Science Support to Management

- ✓Observation network
- ✓Ecosystem models and lab
- ✓Spatial hazard assessment
- ✓Analyses to support management actions



Scenario Analysis: Change in Harvest in Puget Sound





Indirect effects of scenarios

Direct effects of scenarios

RIES

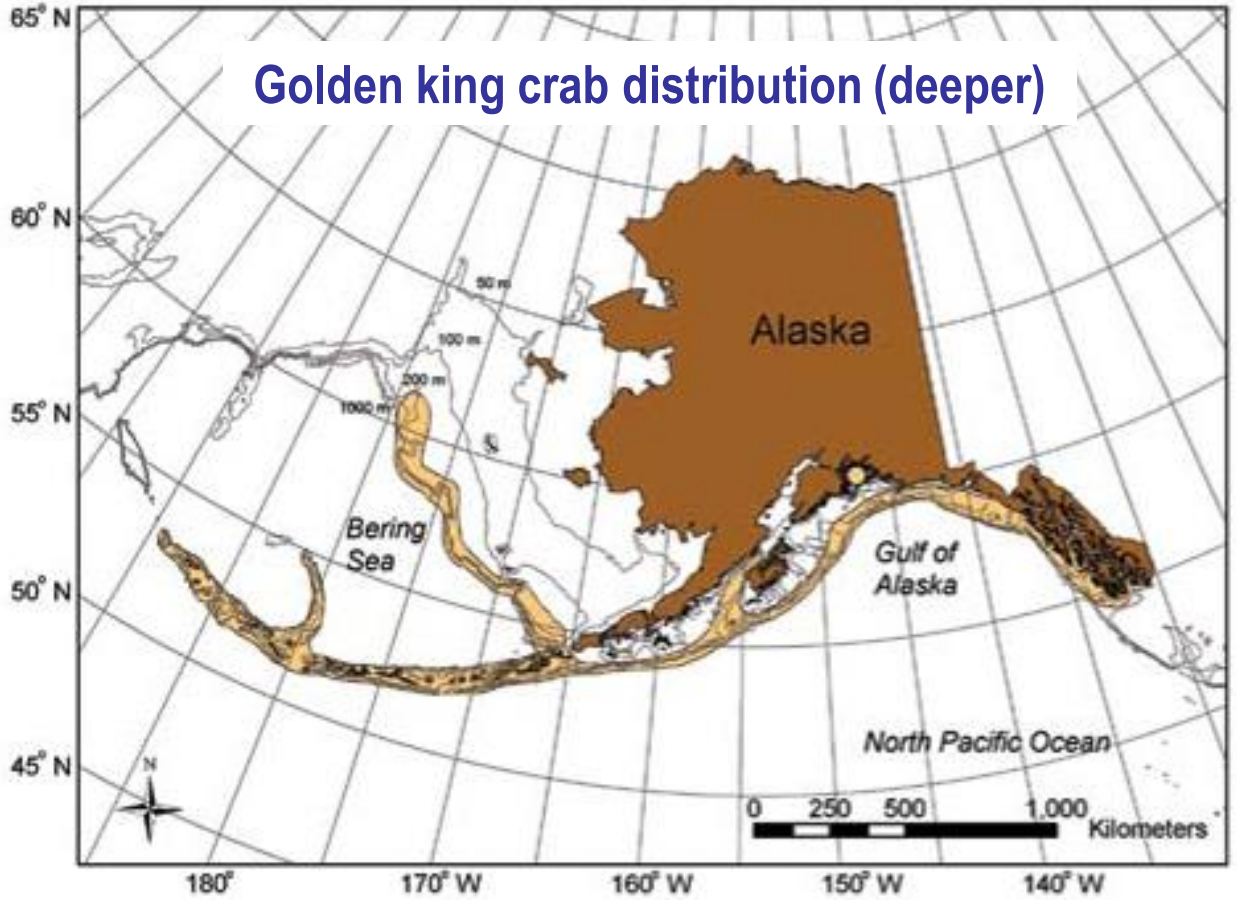
Note: Relative to baseline scenario

Busch et al. 2013

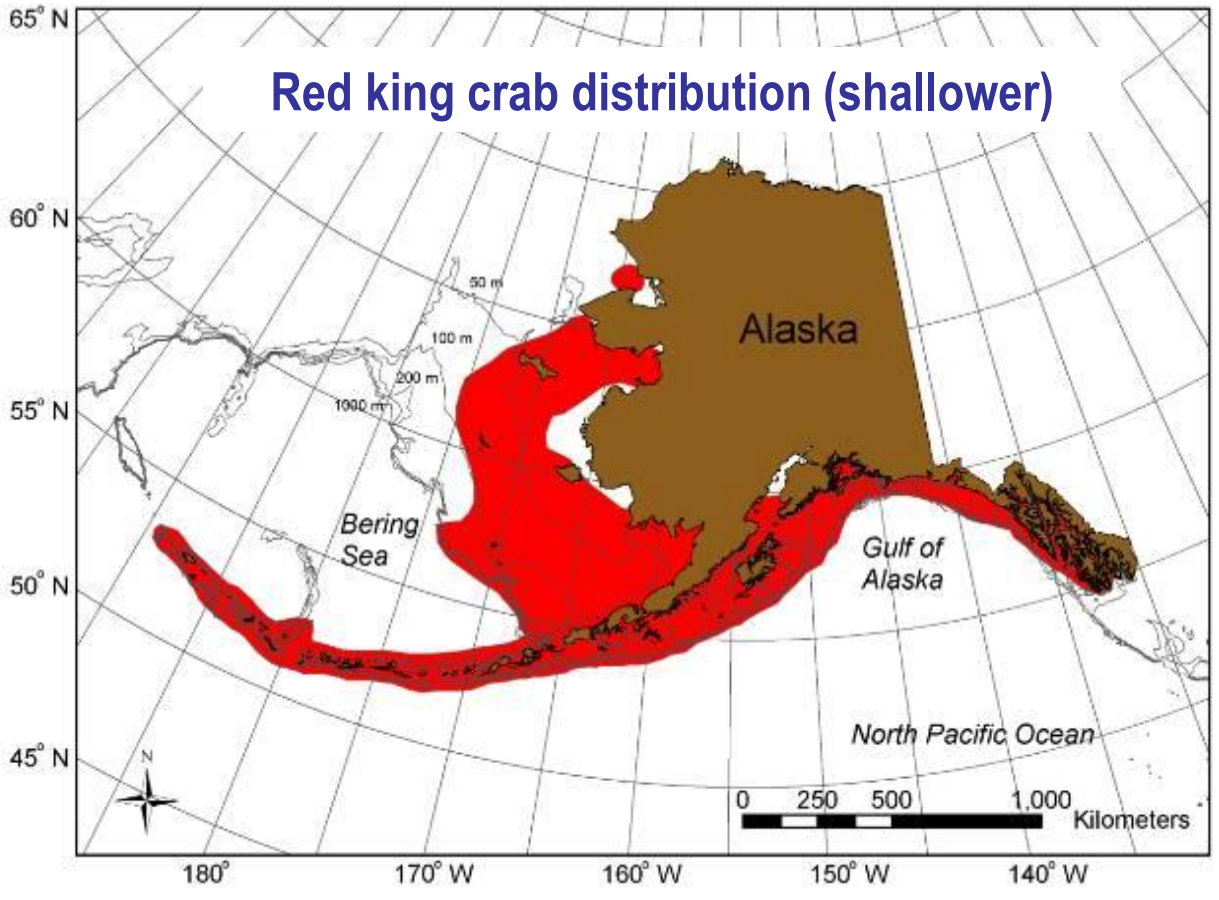
Ocean Acidification Effects on Alaska Crabs

EXPERIMENTS DIRECTED TOWARD UNDERSTANDING THIS DIFFERENCE AND FORECASTING ABUNDANCE

Inhabits **undersaturated** depths



Inhabits largely **saturated** depths



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Risk Assessment for Alaska's Fishery Sector

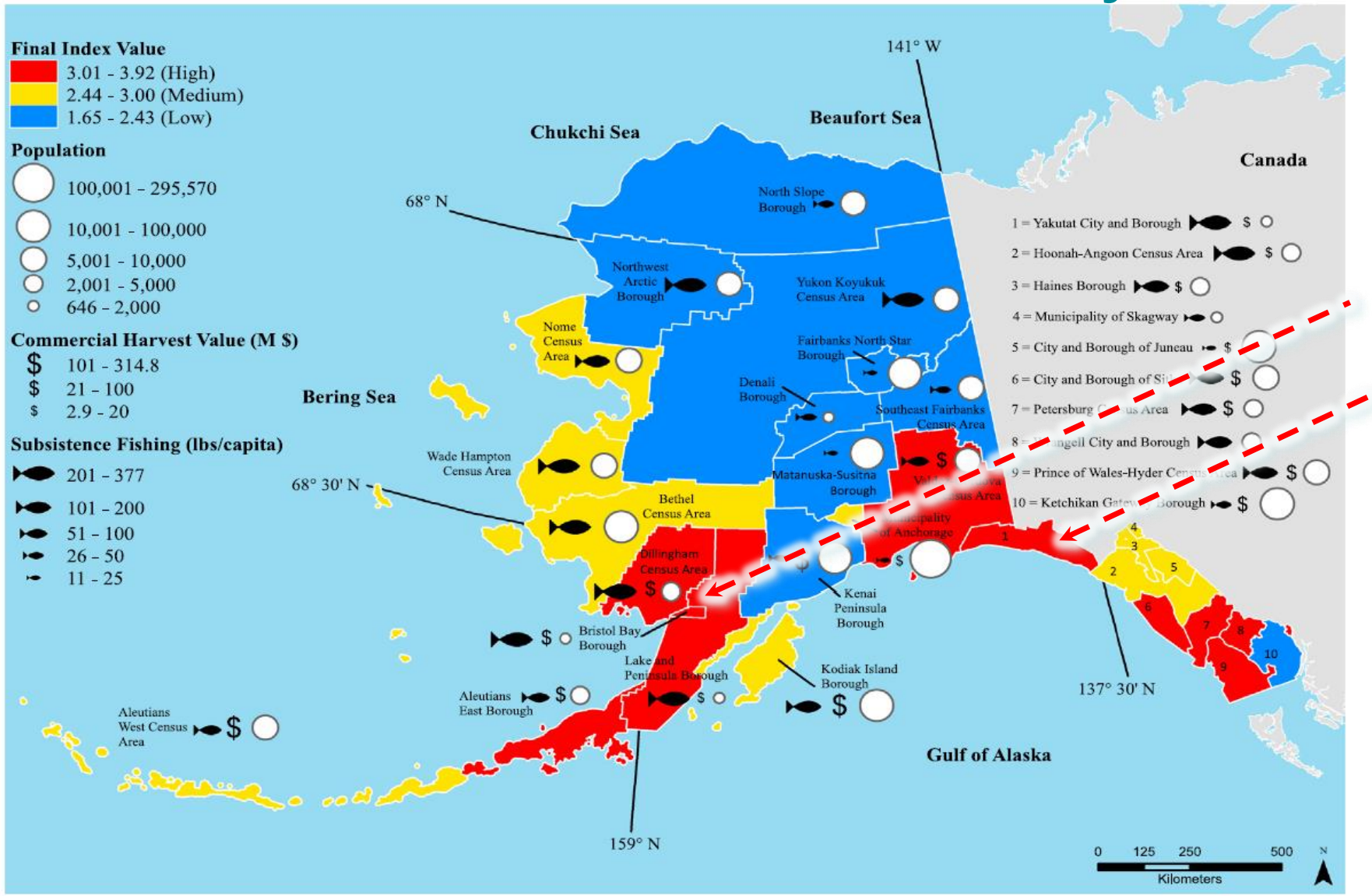

Fig. 11. Individual components of the final ocean acidification risk index for each census area.

Regions in **SW and SE Alaska** that are highly reliant on fishery harvests and have relatively lower incomes and employment alternatives likely face the highest risk from OA.

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Mathis, J.T., et al. Ocean acidification risk assessment for Alaska's fishery sector. Prog. Oceanogr. (2014), http://dx.doi.org/10.1016/j.pocean.2014.07.001

Summary

- Present conditions in the N. Pacific are anomalous and record warm SSTs, but are not all related to an El Niño (EN)
- Possible signals of a positive (warm) PDO evolving
- Models are predicting a moderate EN in the Fall and Winter of 2014-2015.
- Ocean Acidification impacts the North Pacific in different ways
- We are in a challenging position because of the unprecedented number of variables changing simultaneously and their rates of change

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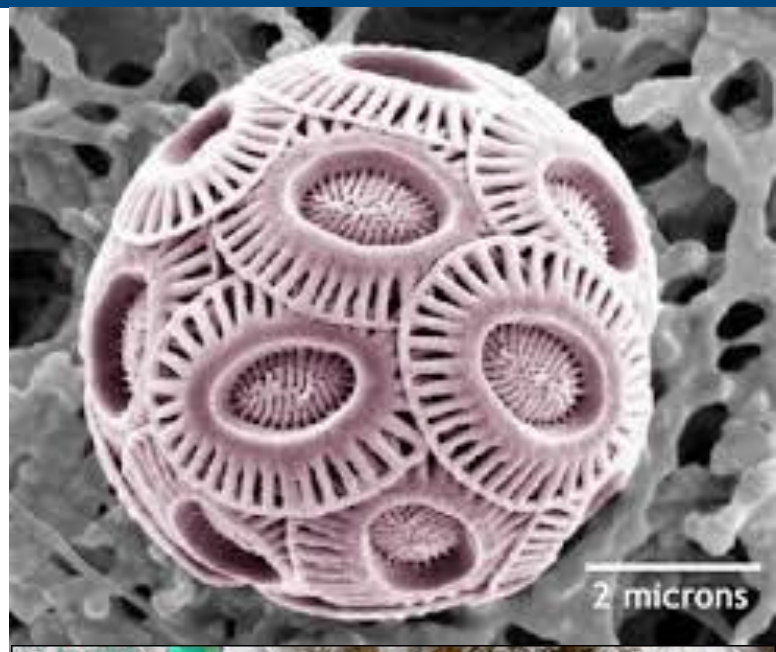
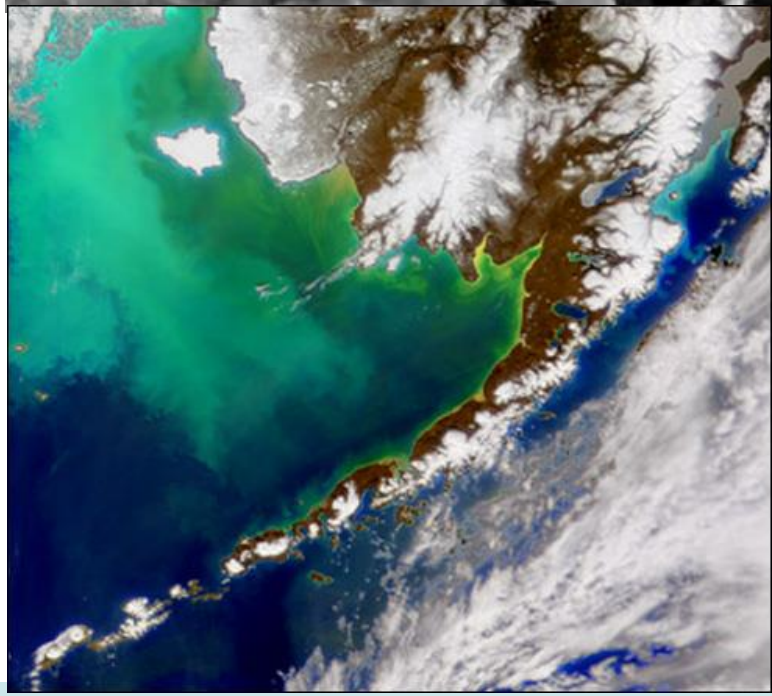
Questions?

Extra slides

El Niño's Effects: Eastern Bering Sea

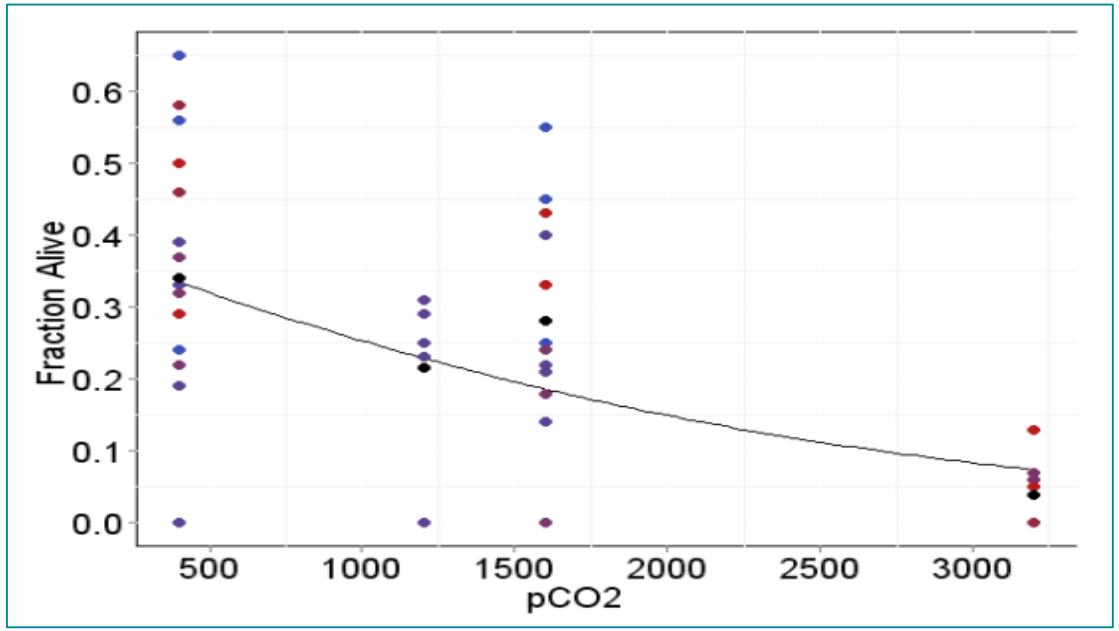
- Increased heat in surface waters
- Sustained algal (coccolithophore) blooms deplete nutrients
- Changes in ocean conditions (e.g., increased stratification) – affects apex predators' feeding
- High mortality in some species of plankton-feeding seabirds



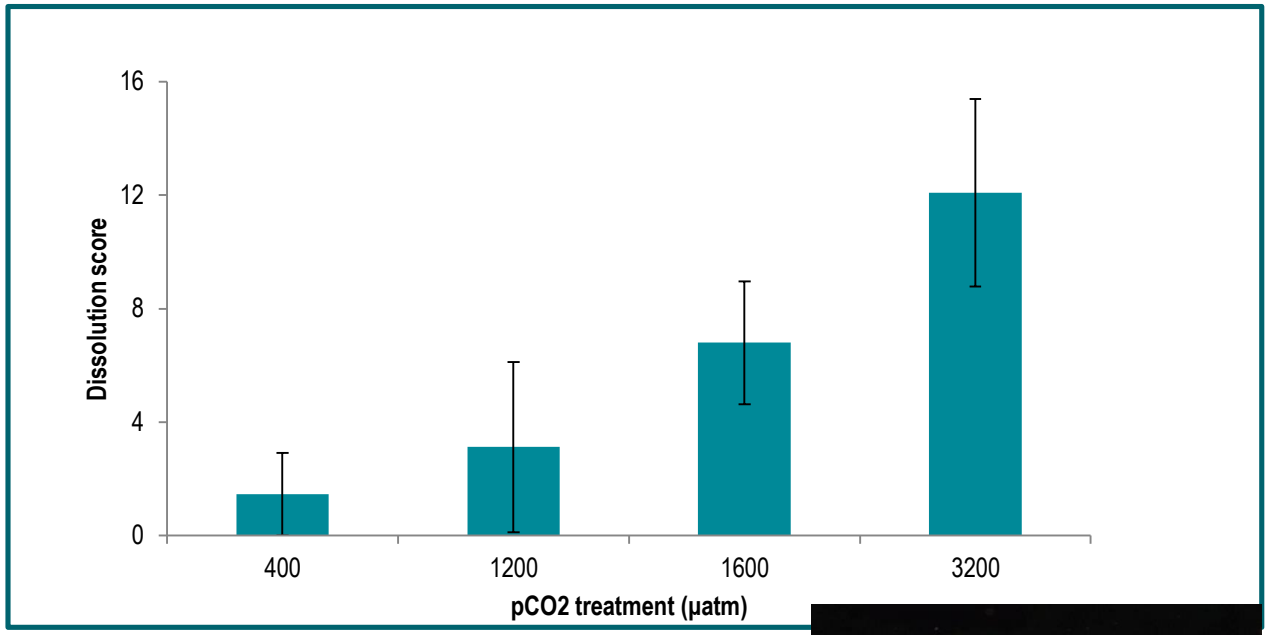


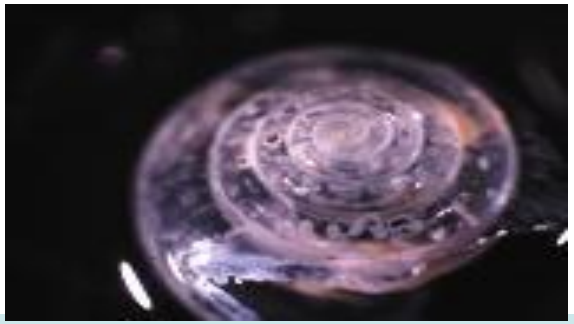
Lab Results: Pteropods

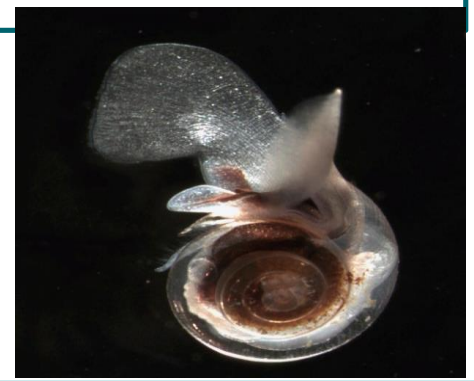
Pteropod Survival



Pteropod Shell Dissolution

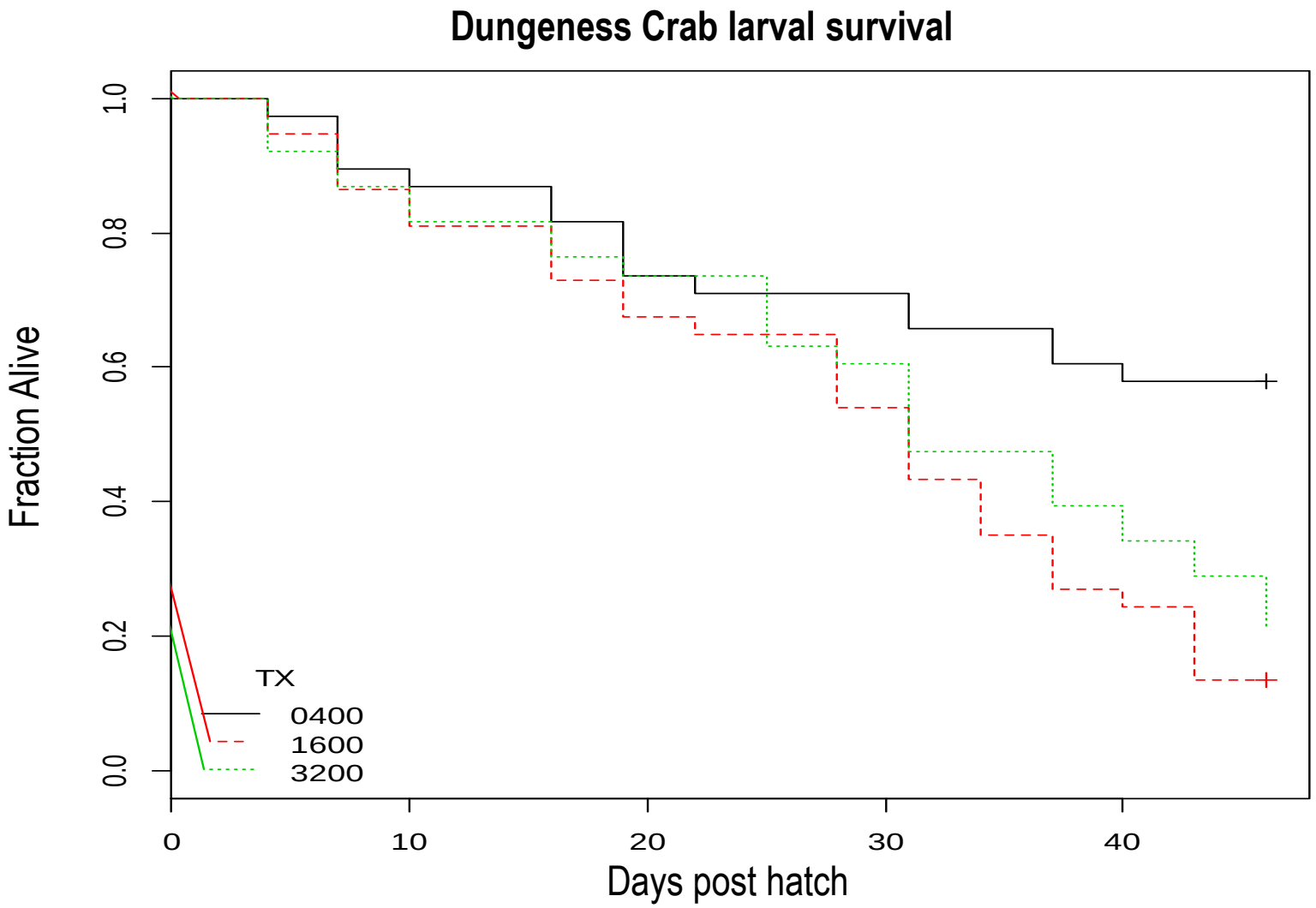






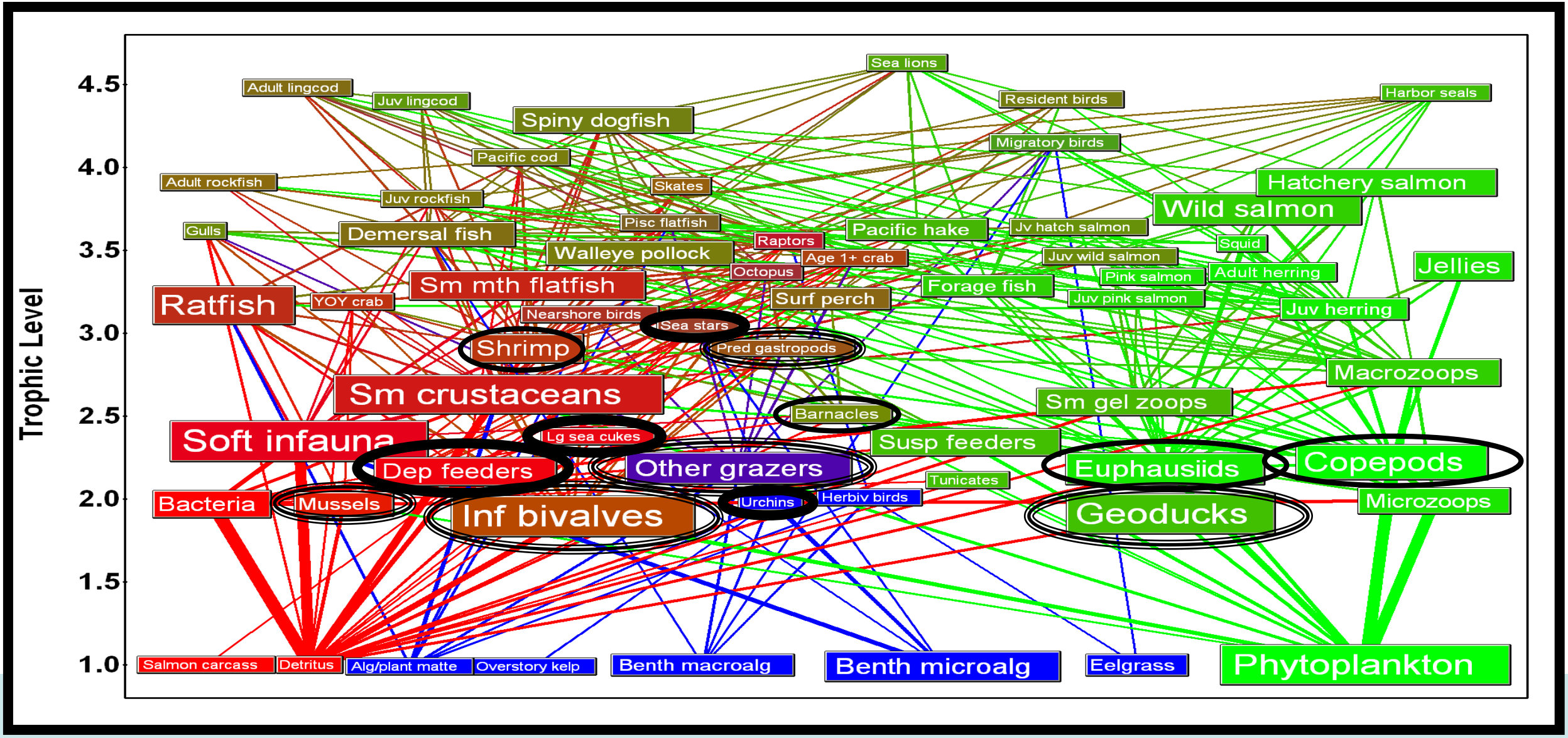
Busch et al. NWFSC

Lab Results: Dungeness Crab

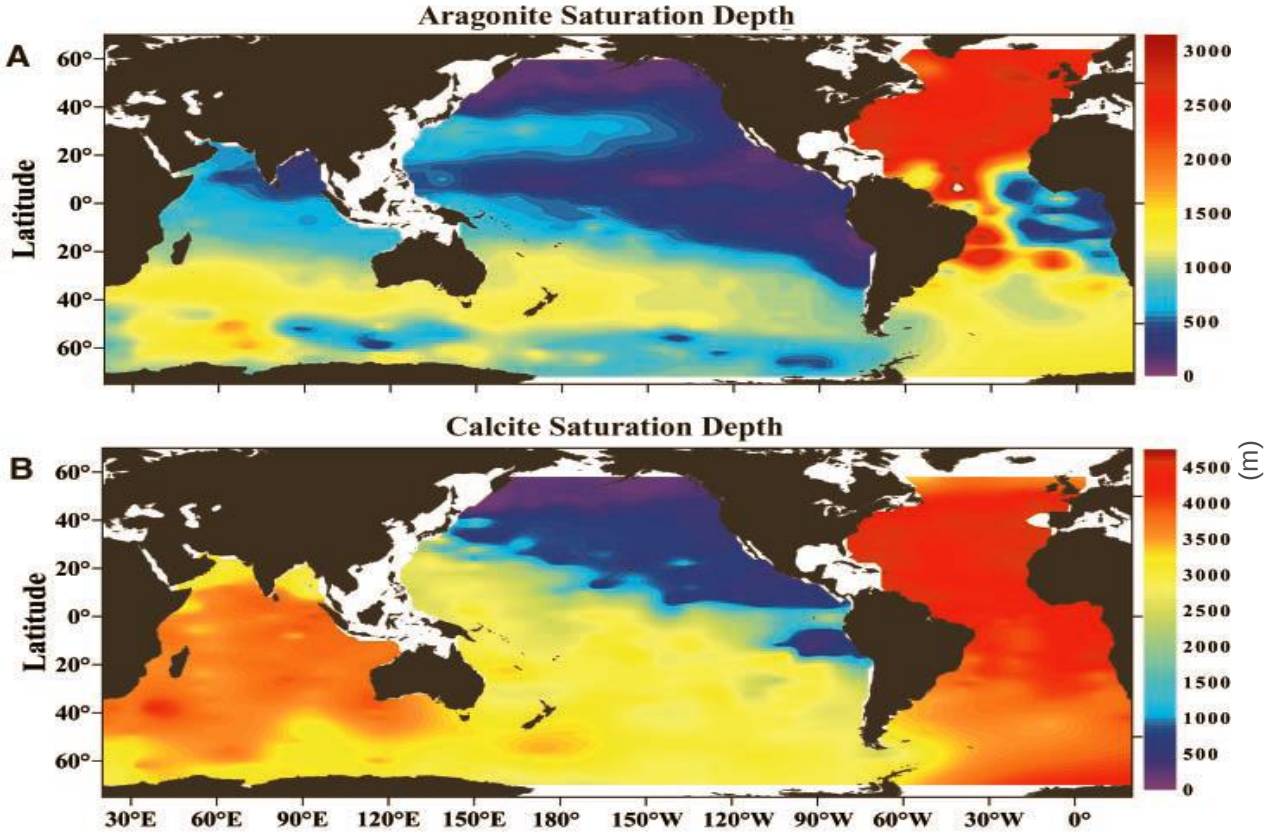


Miller et al. in review

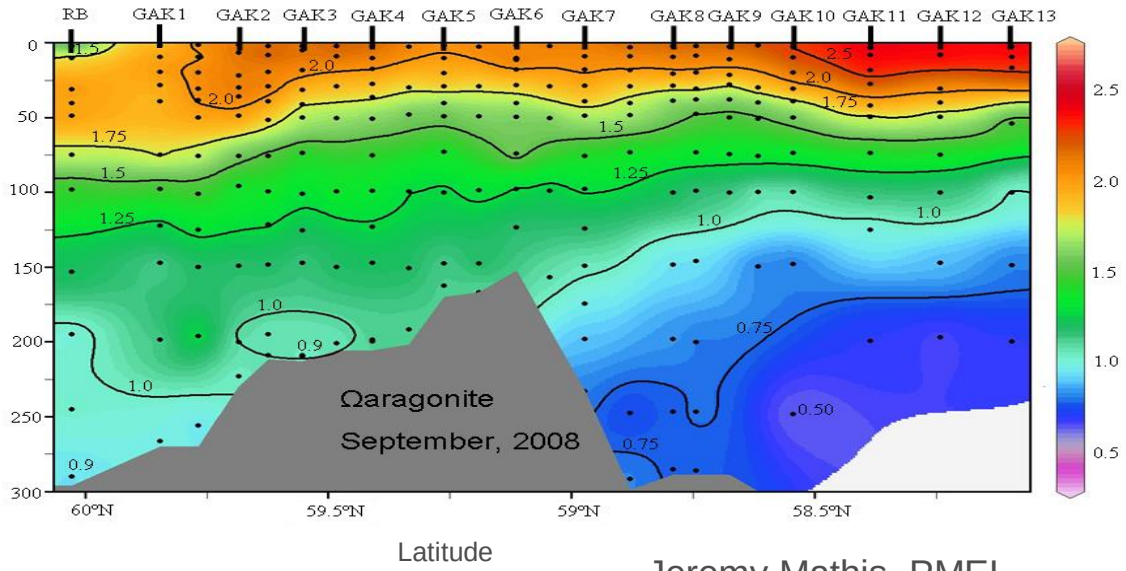
Food Web Modeling



North Pacific fisheries are at risk because calcium carbonate saturation horizons are relatively shallow



N-S transect located east of Kodiak Island



Jeremy Mathis, PMEL

Feely et al. 2004. Impact of anthropogenic CO_2 on the $CaCO_3$ in the oceans. Science 305: 362-366.