Projecting ecosystem consequences of climate variability and change:

PICES

R/V Sally Ride at SIO Nimitz Marine Facility

Aspirations for the next 25 years of PICES

UNIVERSITY OF SOUTH CAROLINA

Ryan R. Rykaczewski
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Nippon Foundation Nereus Program

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Steven Bograd, Elliott Hazen, Mike Jacox

U. South Carolina Lab
Casey Brayton, Michael Opiekun, Brendan Turley, Lev Looney

Opportunity to reflect on the past and dream of the future

International delegates endorsing the PICES Convention on December 12, 1990 in Ottawa, Ontario, Canada

<u>Purpose</u>—To promote the exchange of information and data, and to coordinate research concerning:

(a) the North Pacific marine environment and its interactions with land and atmosphere

(b) uses of the North Pacific and its living and non-living resources

(c) the effects of man's activities on the quality of the marine environment.

Prof. Wooster's opening question for the 1992 meeting:

> *"What is the nature of subarctic Pacific ecosystems, and how is it affected over periods of months to centuries by changes in the physical environment, by interactions among components of the ecosystem, and by human activities?"*

Opportunity to reflect on the past and dream of the future

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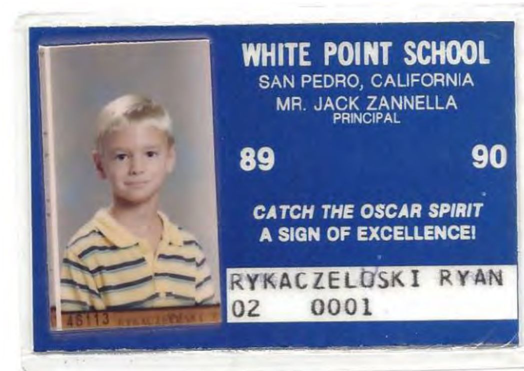

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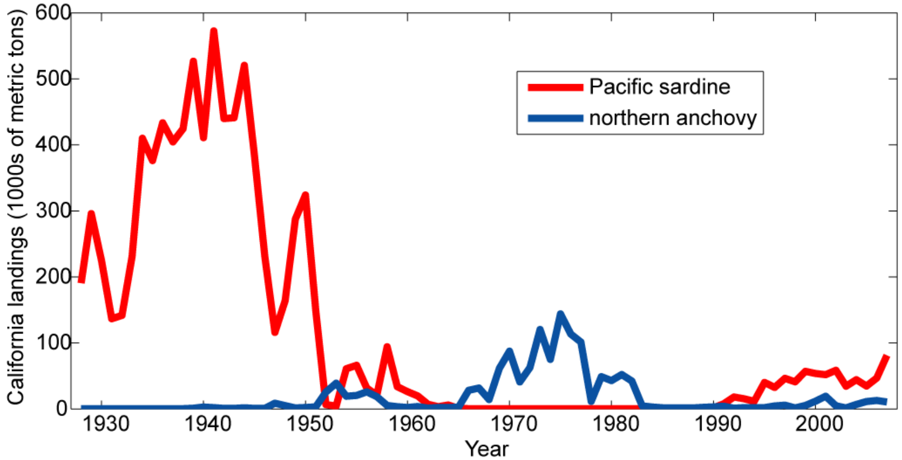
Opportunity to reflect upon the past and dream of the future

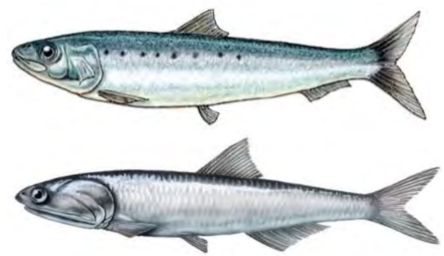
My initiation:
15th Annual Meeting—*Boundary Current Ecosystems*

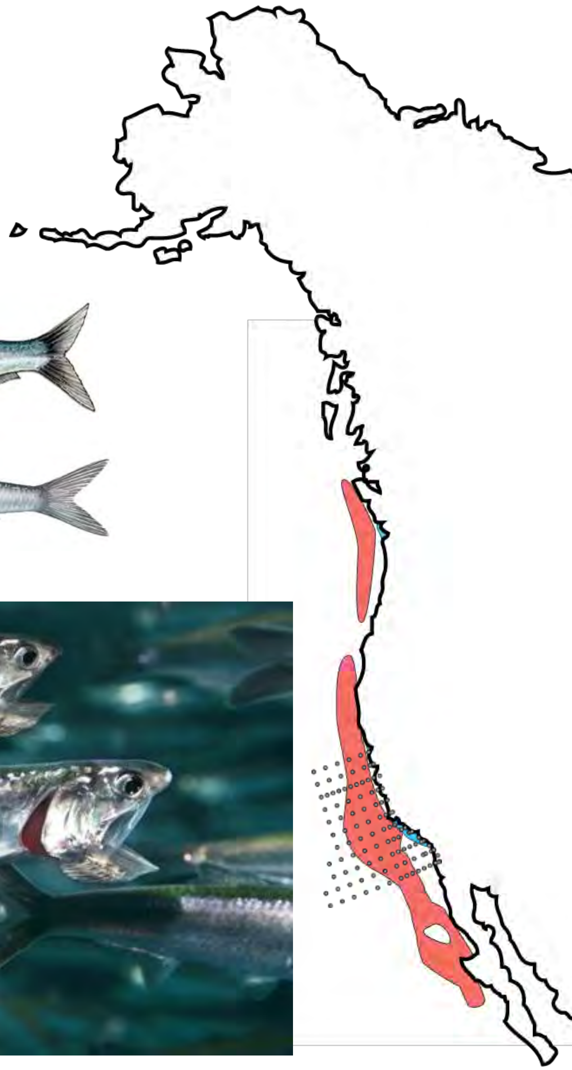
Mmmm, shirasu!

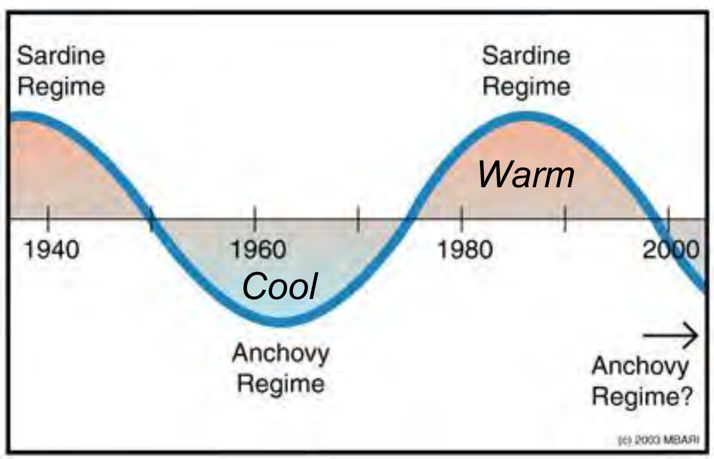
Variability of sardine and anchovy in the eastern N. Pacific

What drives changes in productivity of planktivorous fish populations?









Chavez *et al.* (2003)

Variability of sardine and anchovy in the eastern N. Pacific

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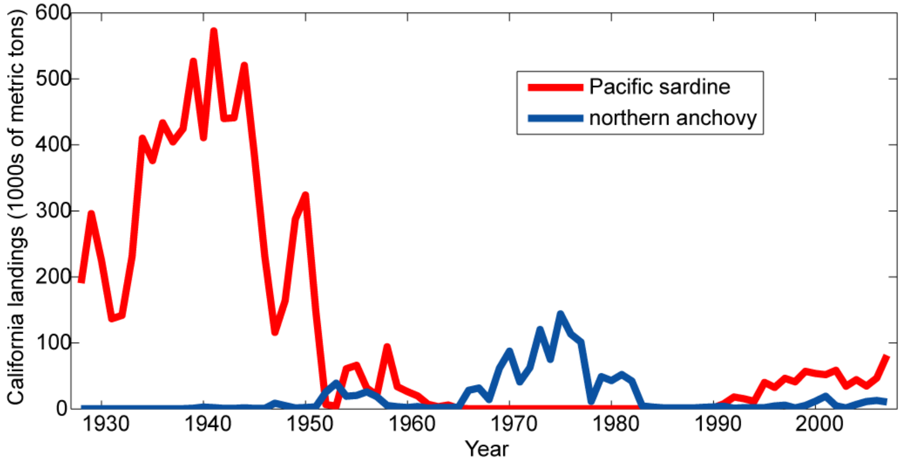

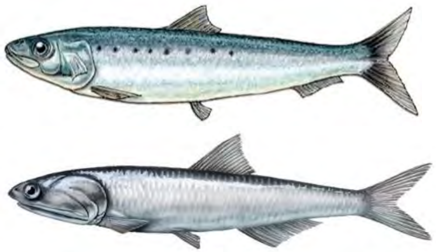

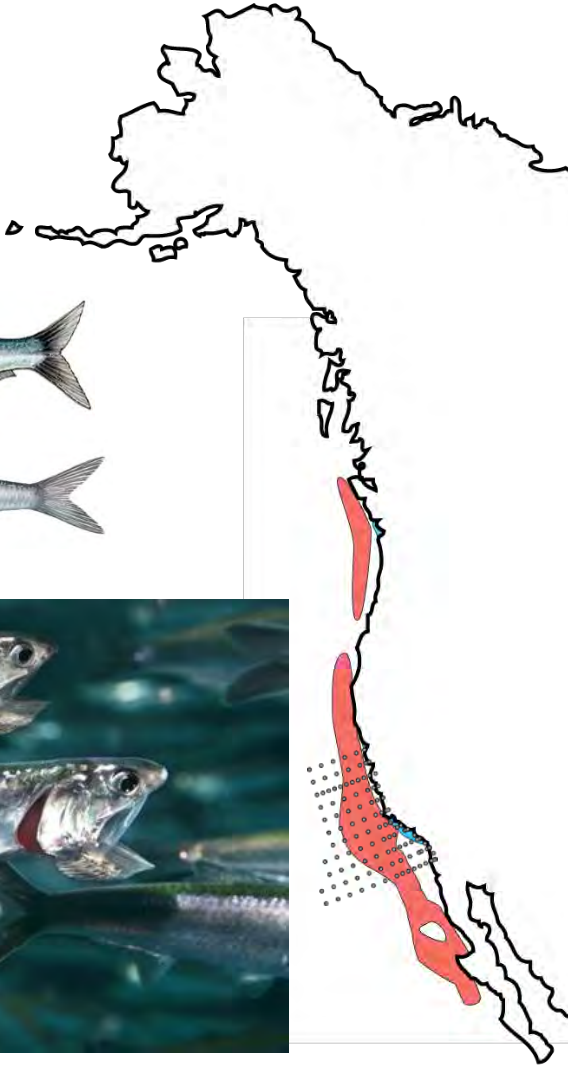

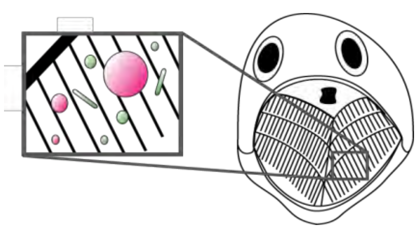

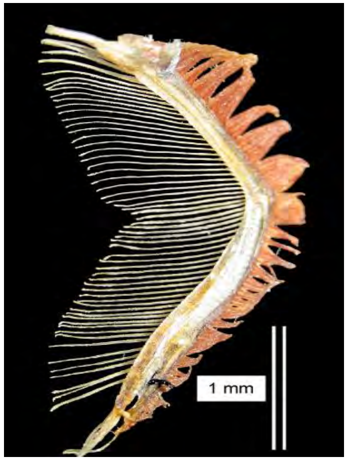

Variability of sardine and anchovy in the eastern N. Pacific

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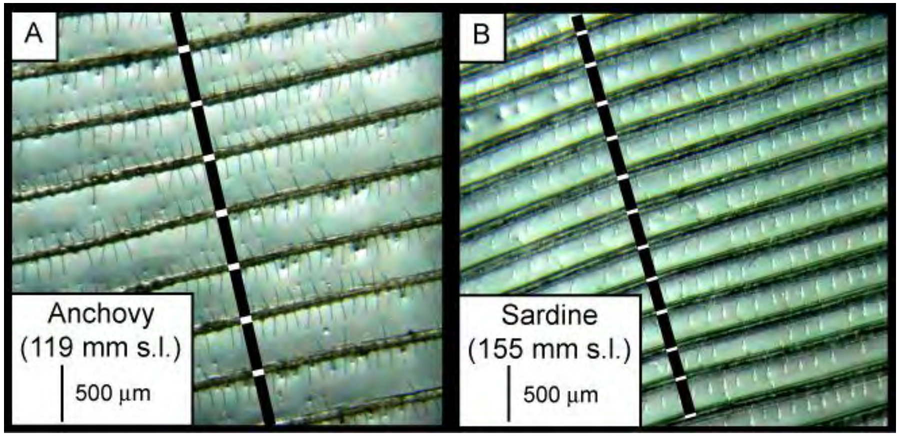

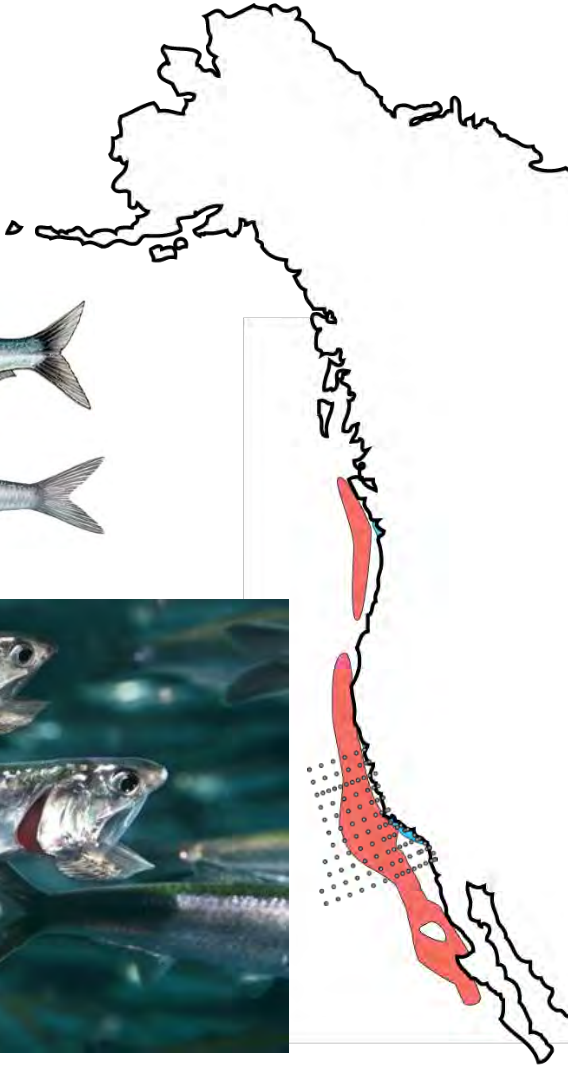

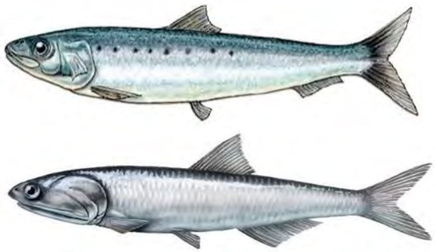

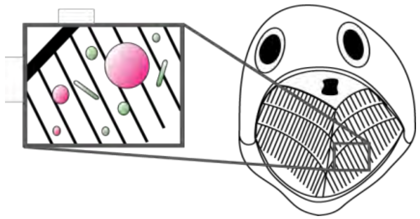

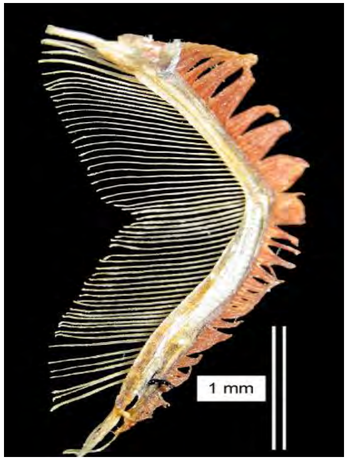

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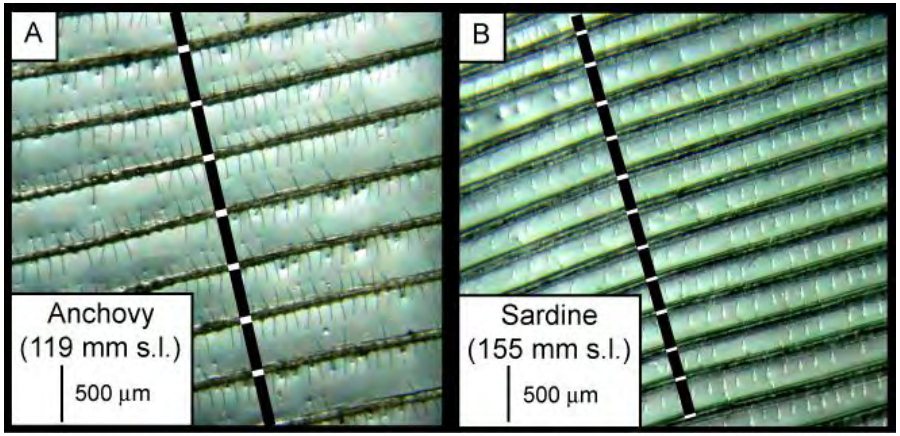
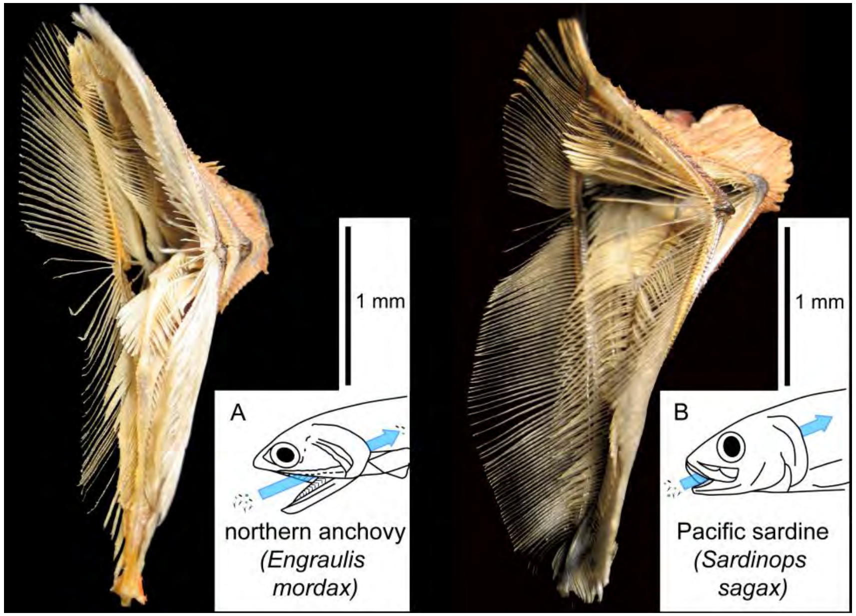
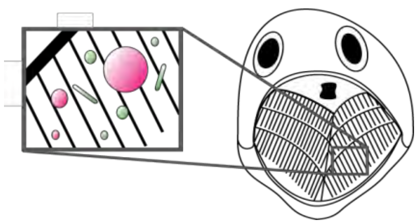
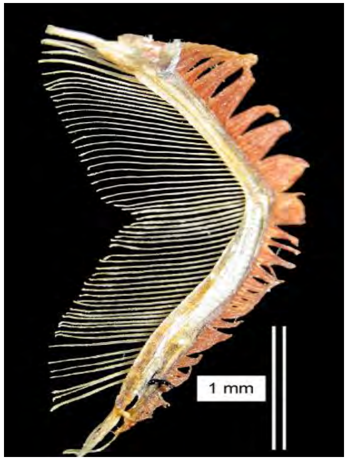




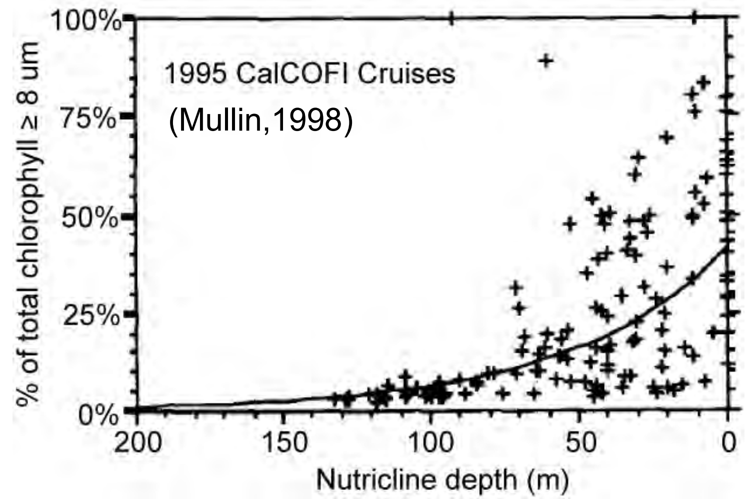


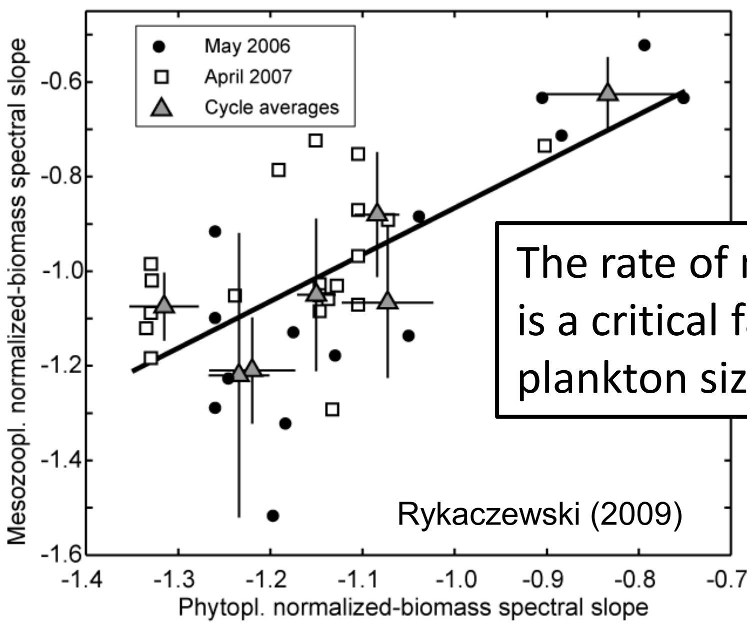


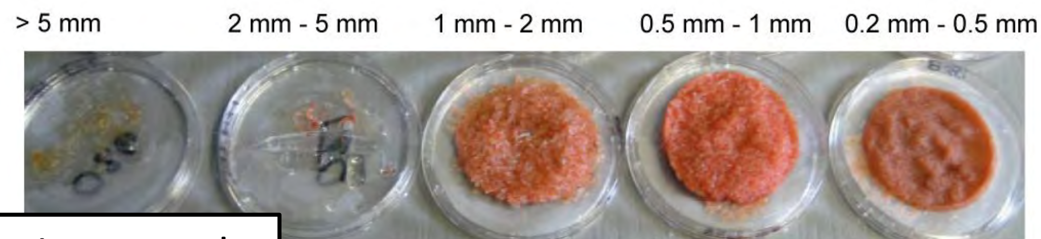
Rates of nutrient supply influence plankton composition

What drives changes in productivity of planktivorous fish populations?

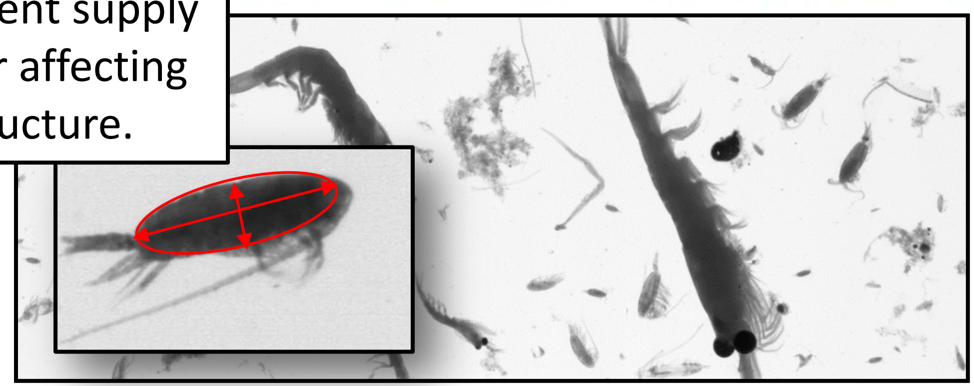
Hypothesis: Size structure of the plankton community in the California Current Ecosystem influences the productivities of small pelagic fishes.



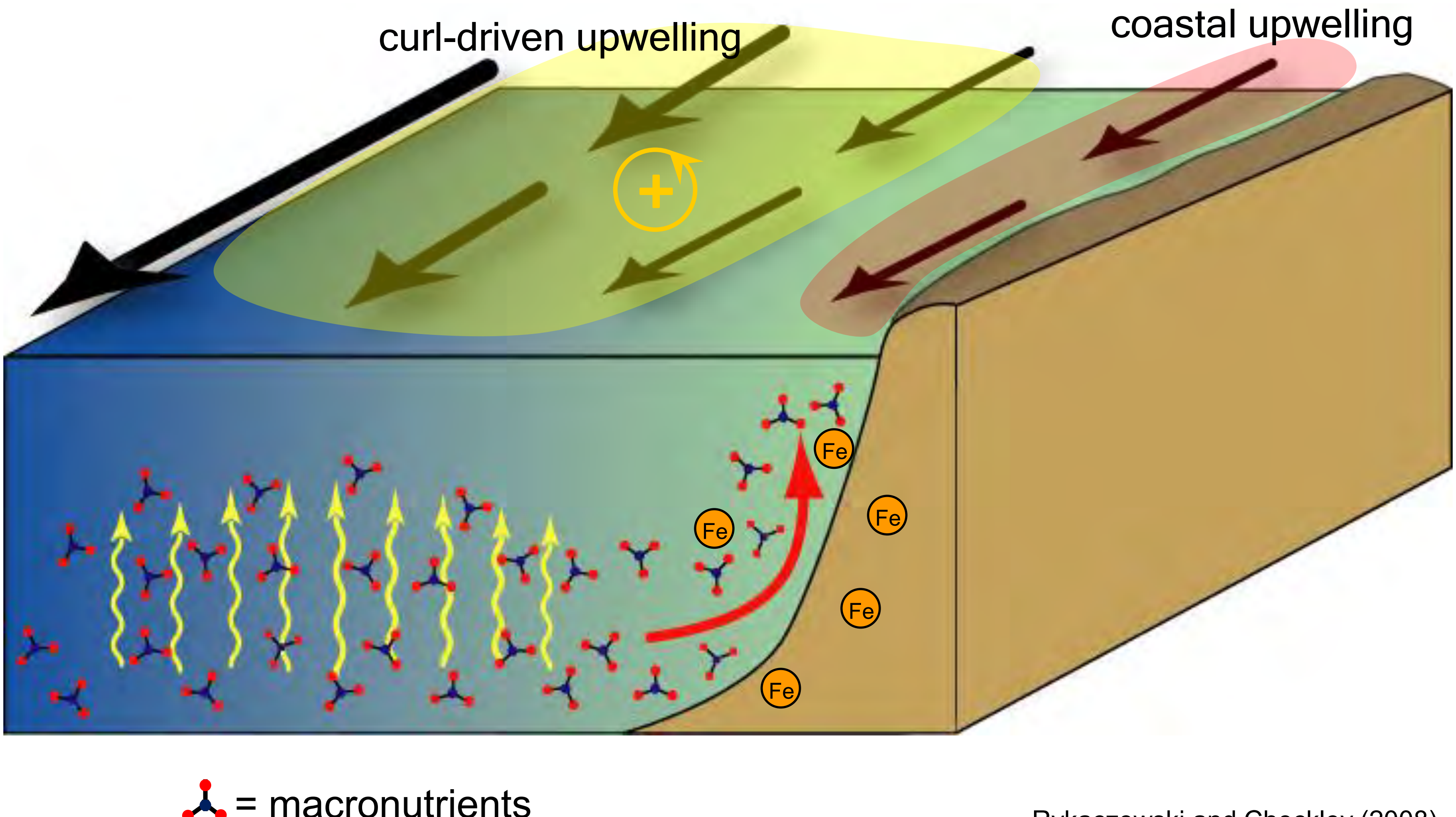




The rate of nutrient supply is a critical factor affecting plankton size structure.

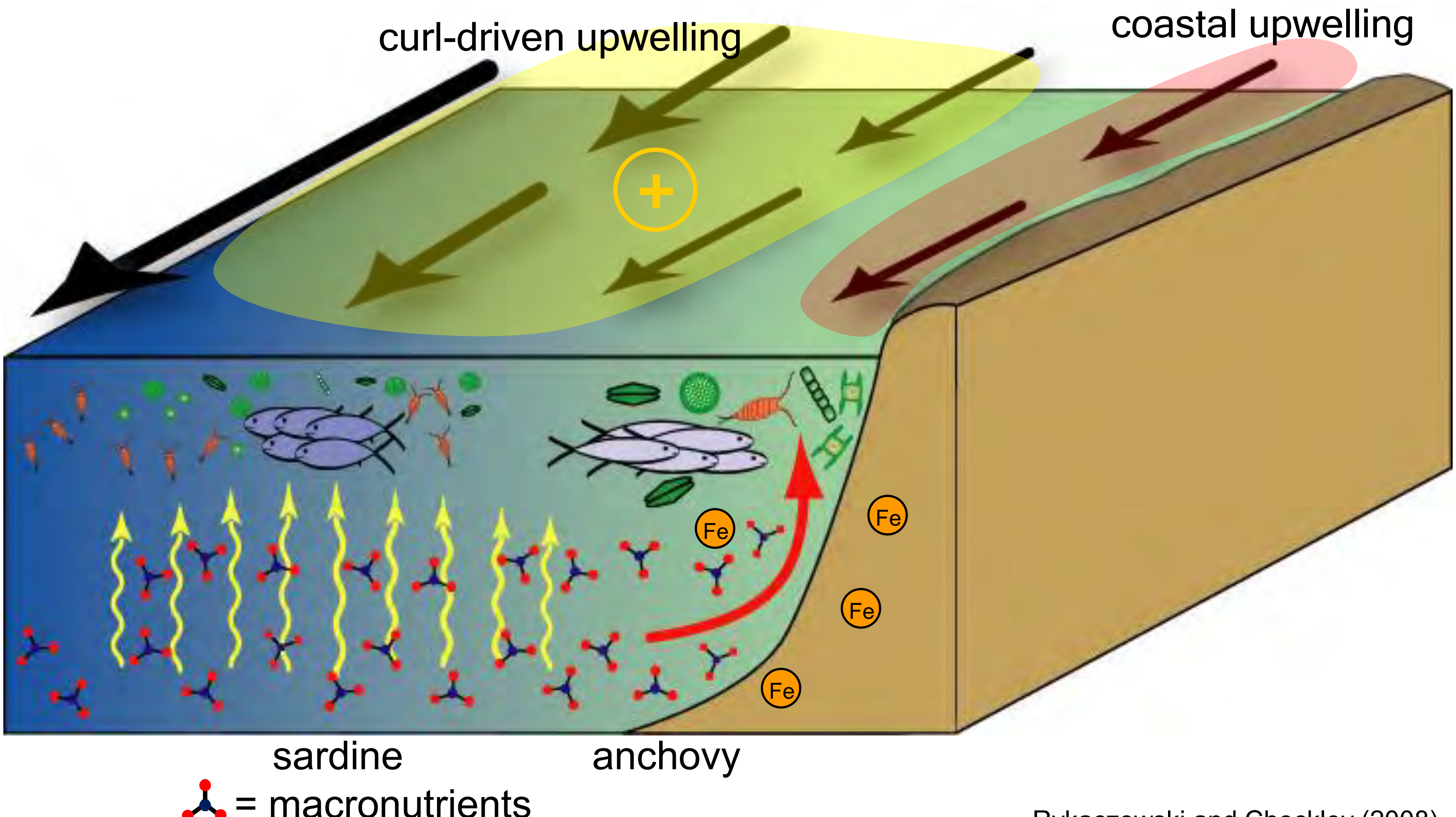


Wind-driven upwelling processes and the pelagic food web



Rykaczewski and Checkley (2008)

Wind-driven upwelling processes and the pelagic food web



Rykaczewski and Checkley (2008)

How will nitrate supply respond to long-term warming?

Prof. Wooster's opening question for the 1992 meeting:

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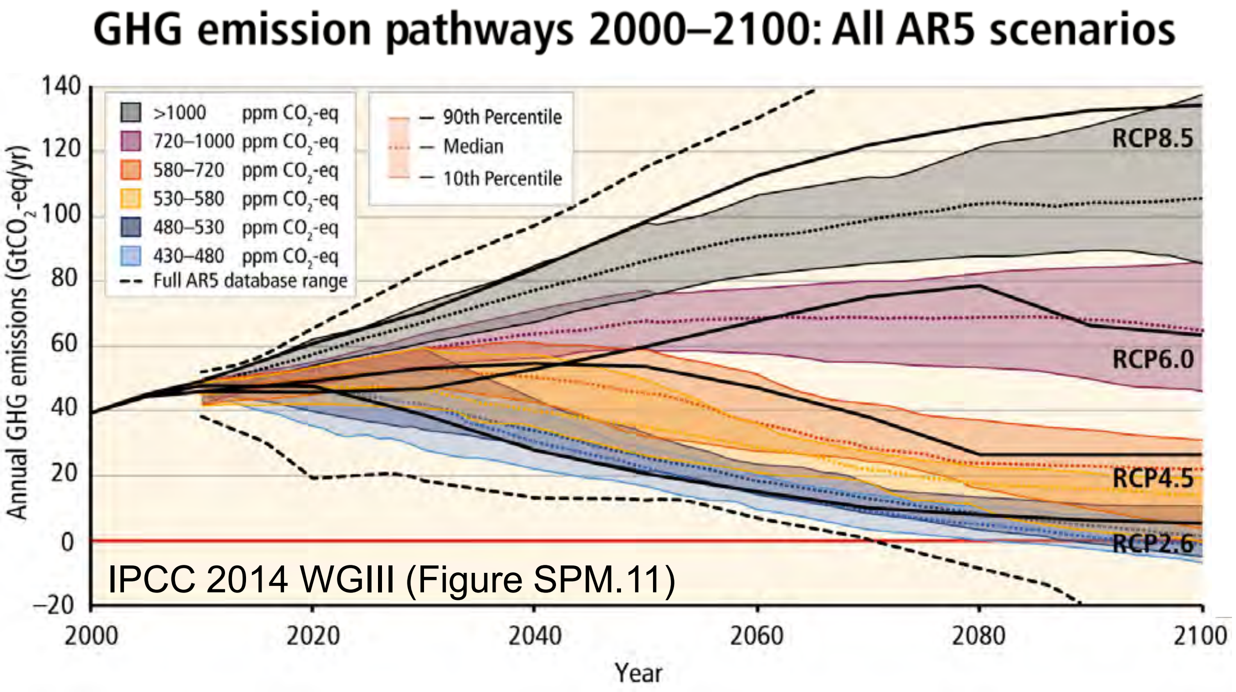
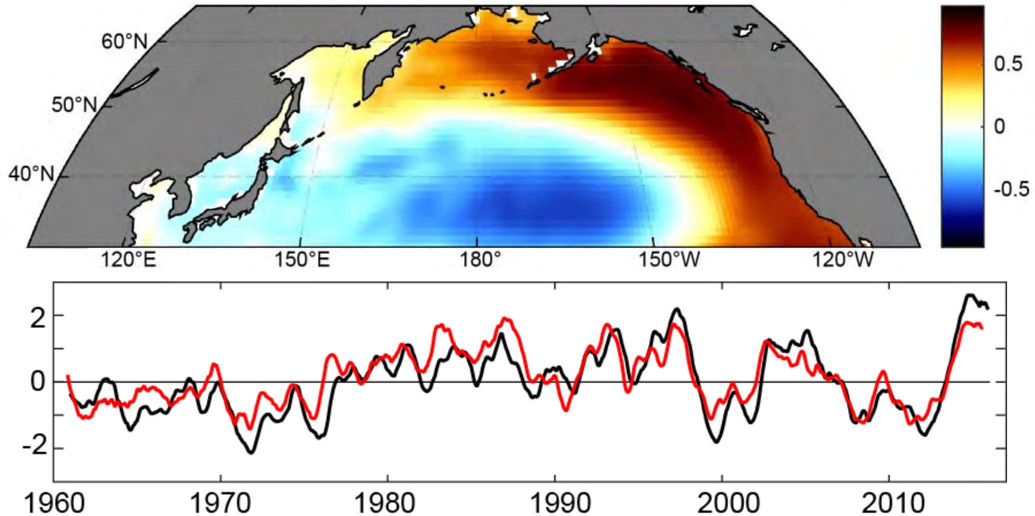


Ecosystems display prominent decadal scale variability

1st PC of SST anomaly from data assimilation model



— *1st PC of SST anomaly (not detrended) from GFDL Data Assimilation Model*

— *Pacific Decadal Oscillation (Mantua et al., 1997)*

Study of decadal ecosystem regime shifts has been one of the primary contributions of PICES.

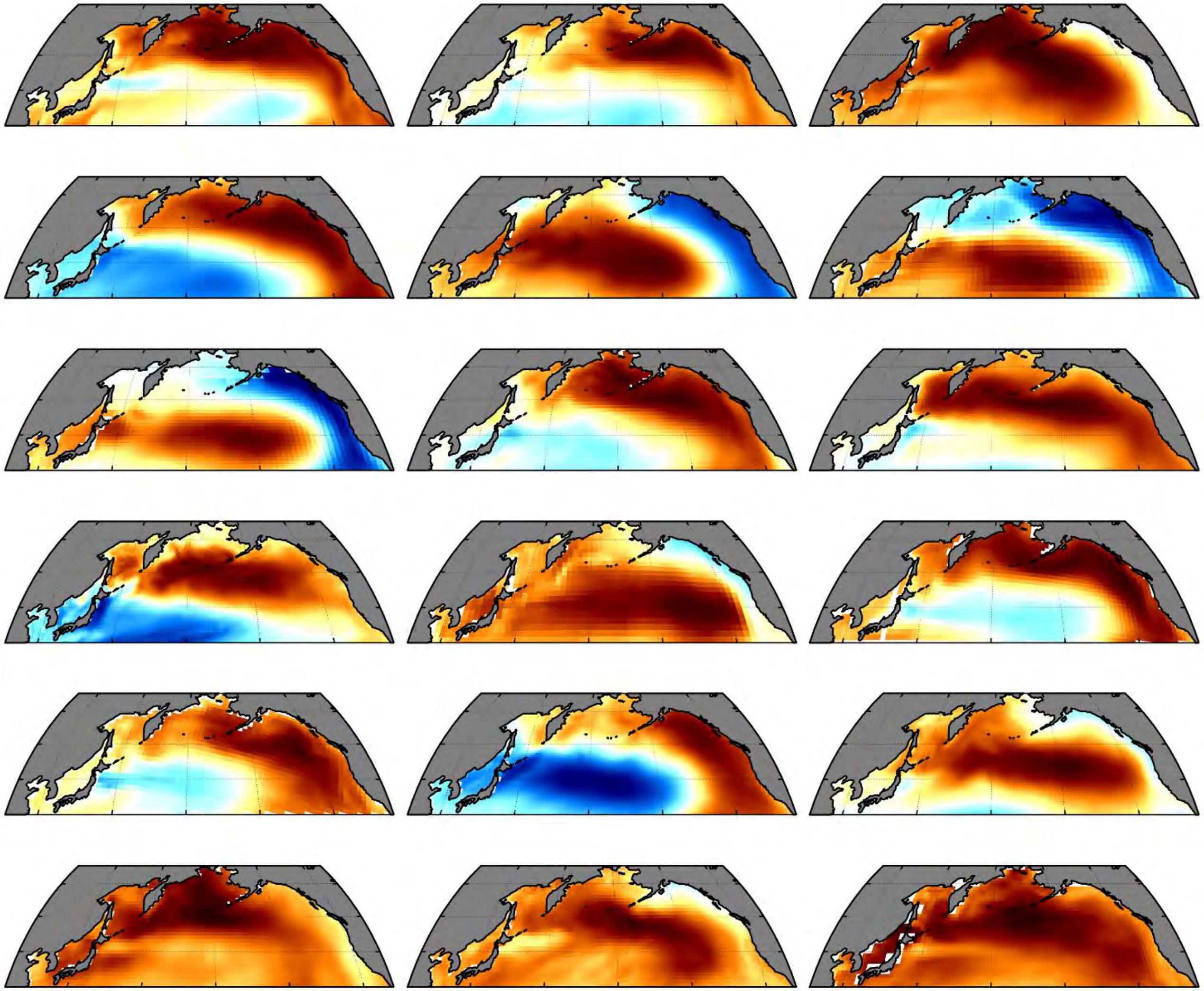
Understanding the impact of prominent decadal scale atmosphere-ocean variability on ecosystem structure and productivity continues to be a critical aim of fisheries oceanography and management worldwide.

Pattern of SST variability reasonably represented by IPCC-style models

1st PC of SST anomaly from 18 coupled climate models, 1961-2015:

Looking back at the previous 55 years, spatial oscillations are characteristic of most models.

How would this result change if we performed this exercise 25 years from now?

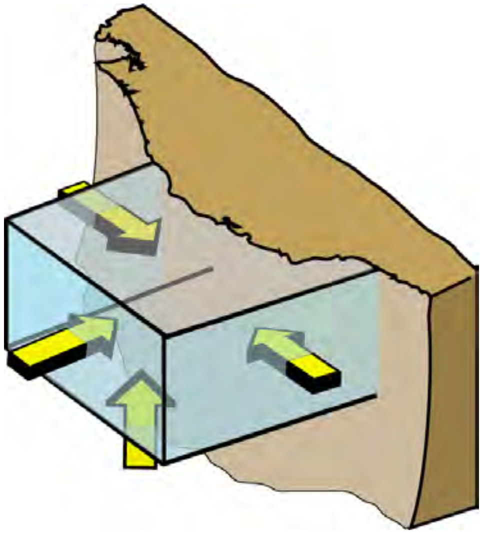


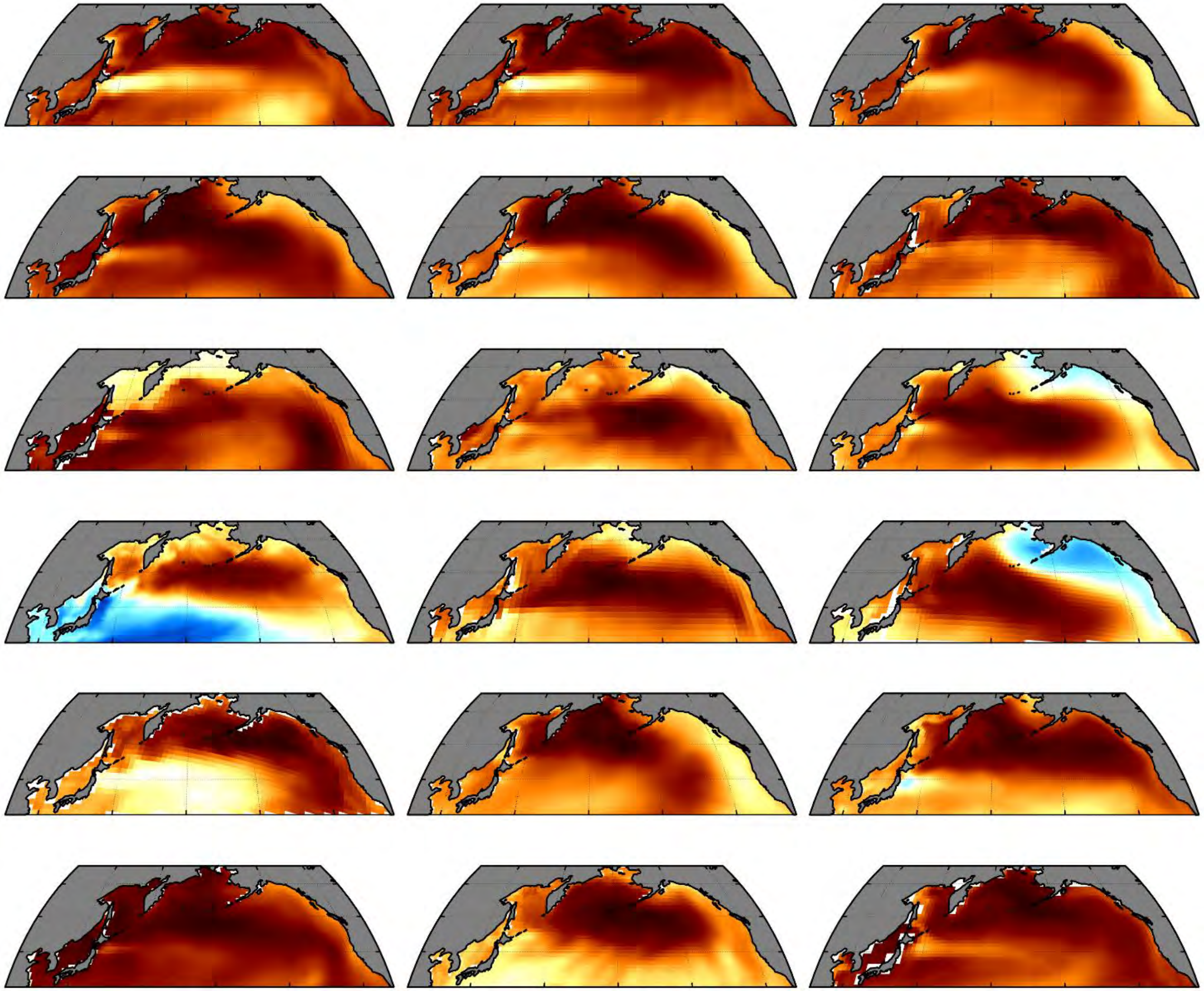
see also Furtado et al. (2011), Johnstone and Mantua (2014)

Characteristics of variability will change in the future

1st PC of SST anomaly from 18 coupled climate models, 1961-2015:

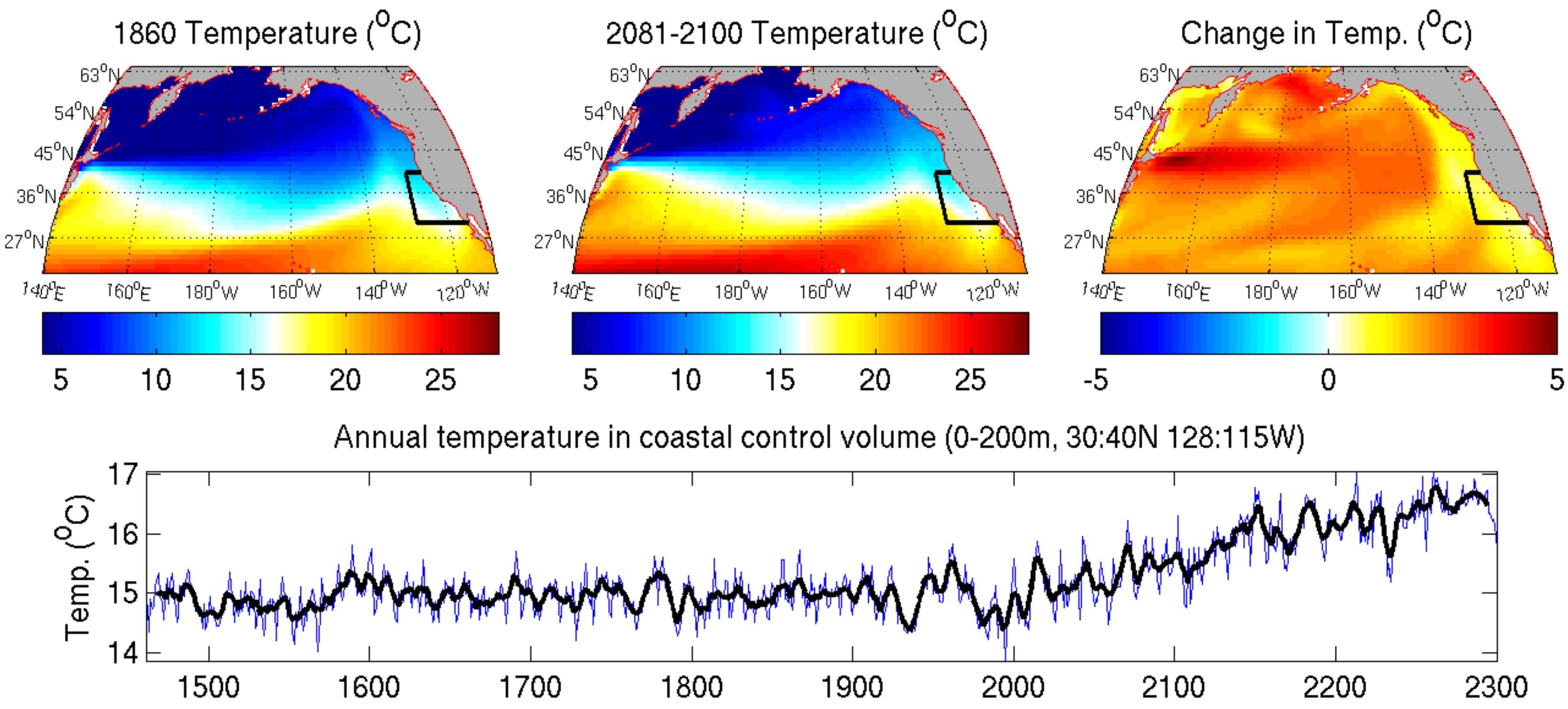
25 years from now, basin-scale warming is likely to be the dominant pattern of SST variability.





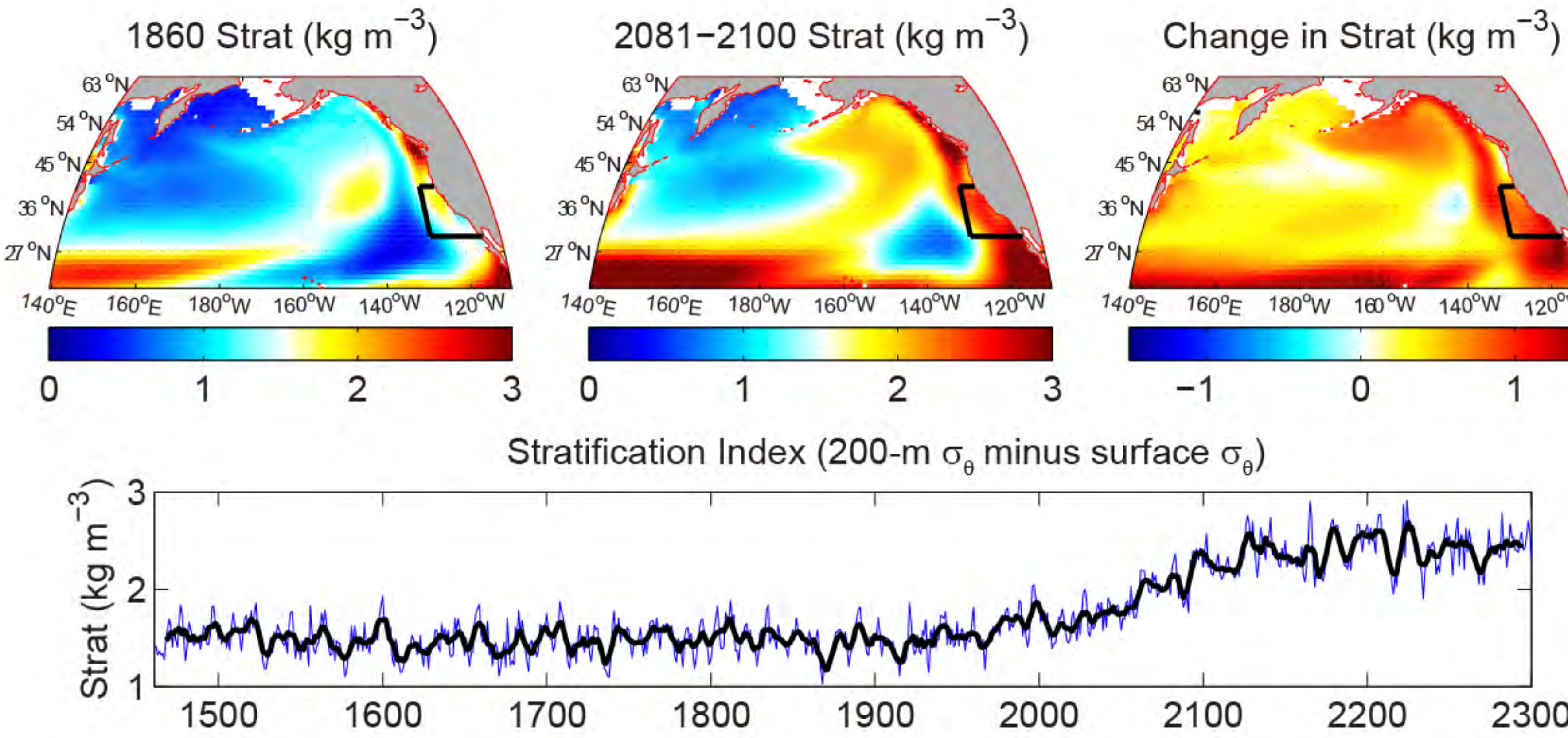
see also Furtado et al. (2011), Johnstone and Mantua (2014)

Temperature increases across the basin

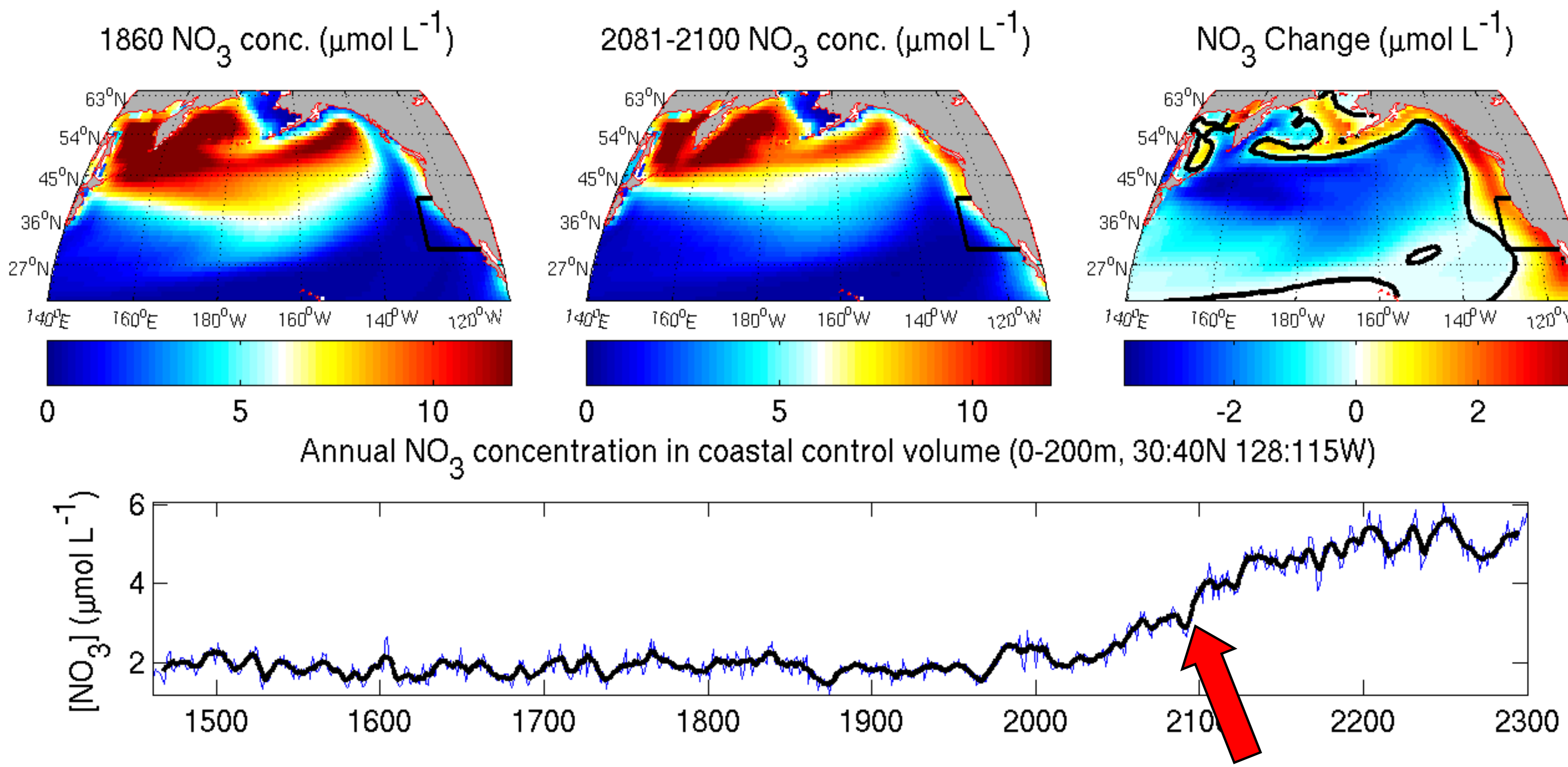


The magnitude of the upper-ocean temperature change varies, but the direction of the change is uniform: the whole Pacific becomes warmer at the surface.

Changes in local forcing suggest decreased nutrient supply



Surface-layer NO_3 increases despite stratification and winds



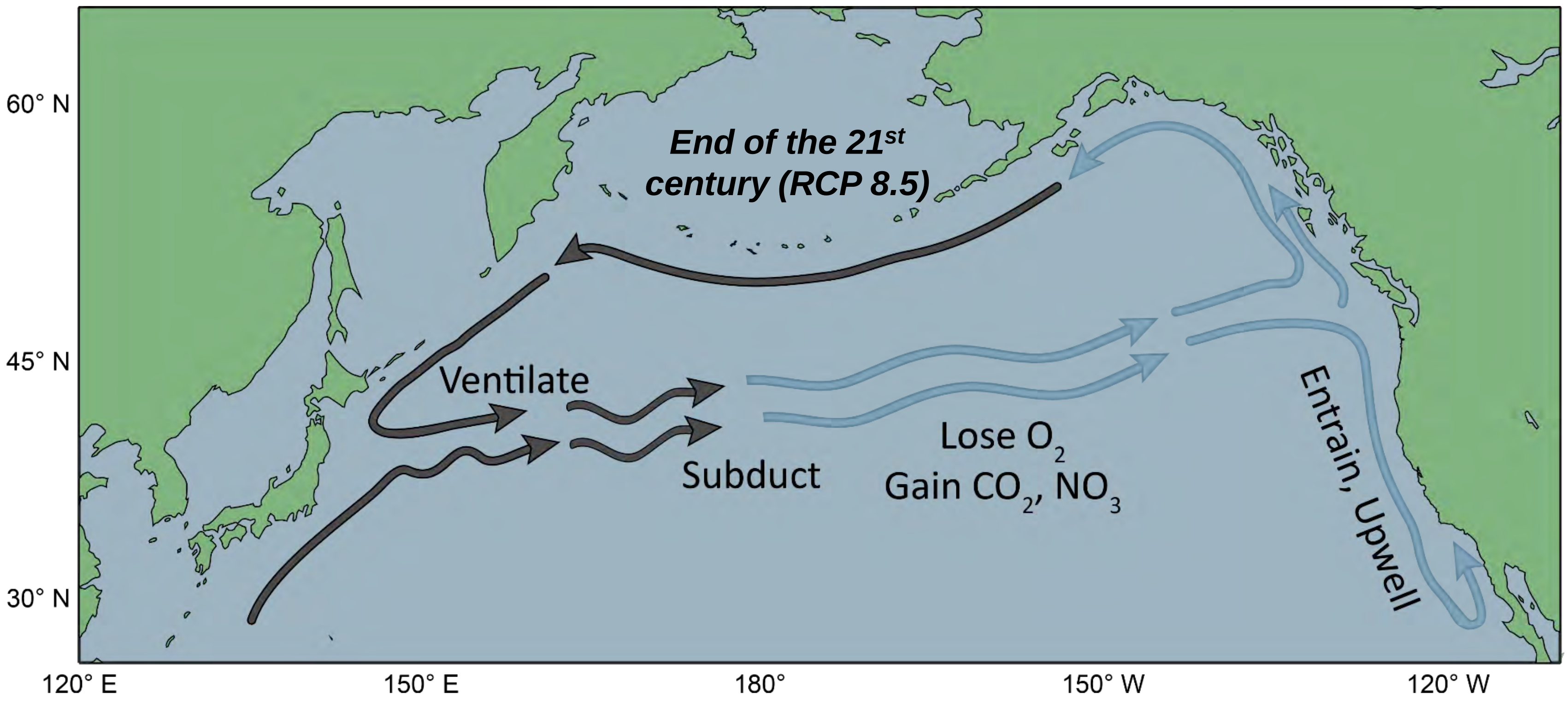
35% decrease in the average nitrate concentration in the North Pacific (20° N to 65° N).

85% increase in average nitrogen concentration between 2000 and 2100 along the US West Coast.

Rykaczewski and Dunne (2008)

Ventilation plays a dominant role at centennial scales

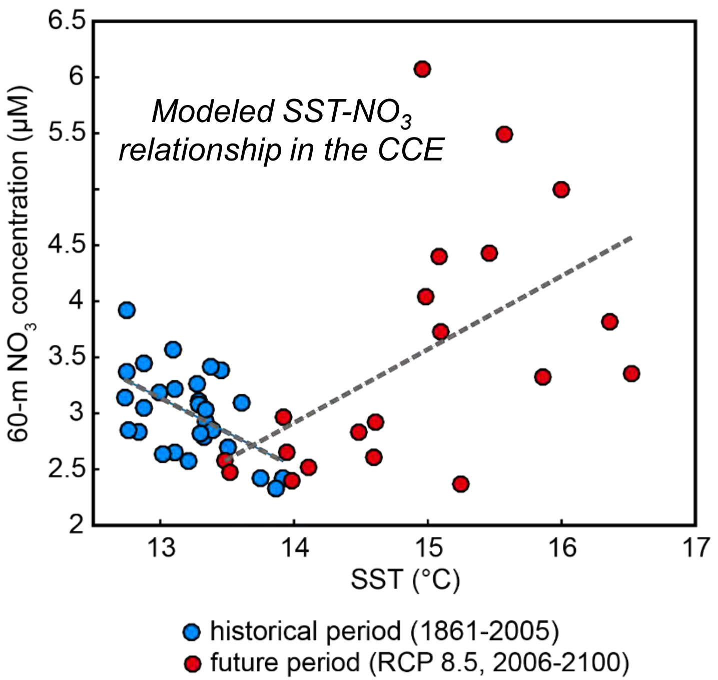
The dominant process influencing nutrient supply differs between the historical time period (with which we are accustomed) and the 21st century.



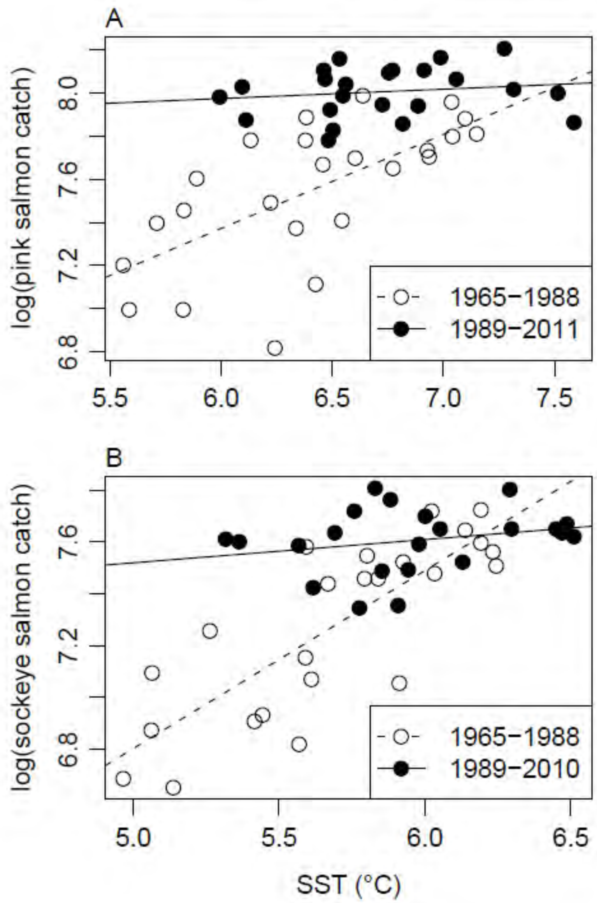
Reduced ventilation in the central and western North Pacific leads to increased accumulation of NO_3 and CO_2 and loss of O_2. This has significant implications for productivity, deoxygenation, and acidification in ecosystems of the eastern North Pacific.

Figure modified from PICES Special Publication Number 4

Key point: The mechanisms driving future ecosystem change may differ from those observed in the past



Empirical relationships derived from historical observations cannot necessarily be extrapolated to the future.

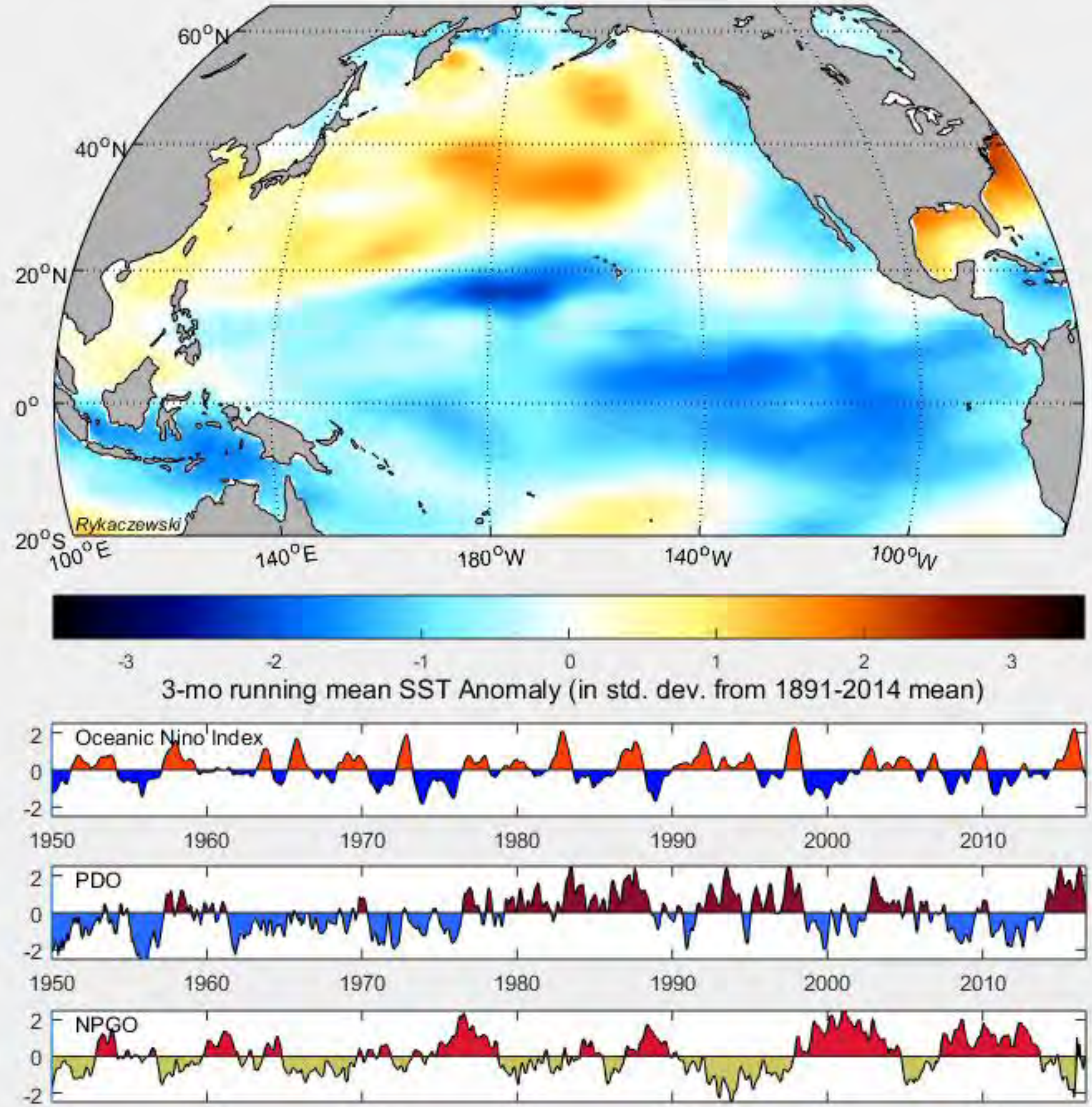


<u>Dr. Mike Litzow</u>
"Non-analogue ecosystem states in the Gulf of Alaska"

S10– Thursday, 9:40 AM

(We are fooling ourselves if we can expect empirical relationships to persist over time, even under conditions of natural variability.)

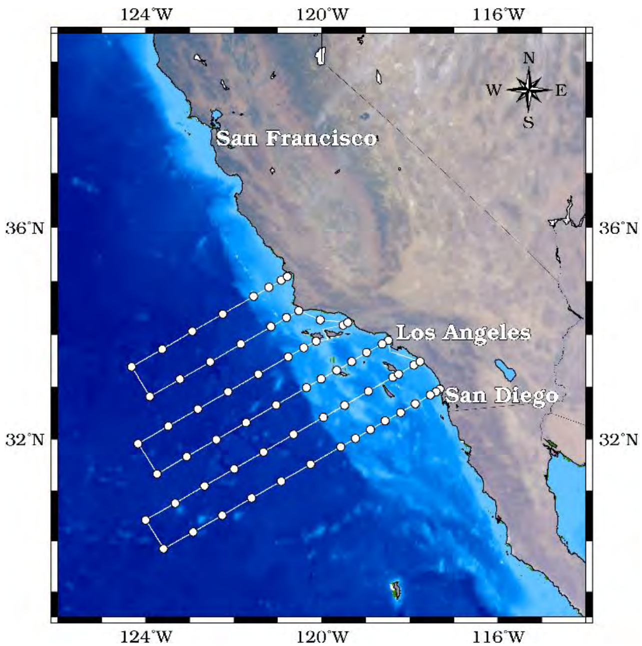
Jan 1950



SST from the COBE-SST Dataset
Japan Meteorological Agency

Ecosystem Oceanography Lab
University of South Carolina
Ryan Rykaczewski

Key point: Continuation and enhancement of long-term observing systems are essential



Detecting anomalous events and their impacts *requires* robust and consistent observational programs. Their value is obvious during unusual events; it is during "normal" years when motivation seems to ebb.

Computational improvements and model development offer an unparalleled view of ocean physics and biogeochemistry. Observational abilities of new platforms and techniques that offer novel perspectives are advancing.

However, sampling at the time and spatial scales relevant to the dominant periods of change remains challenging.

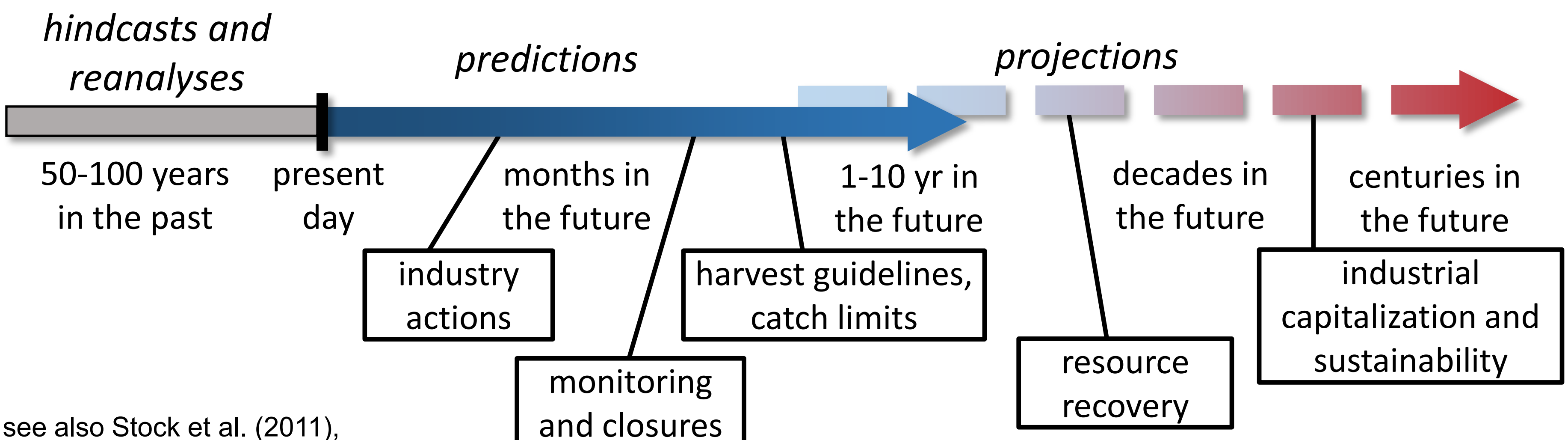
PICES scientists must continue to advocate for maintenance and enhancement of observational programs, particularly those that conduct synchronous sampling of physical, chemical, and biological conditions.

Scales of ecosystem scale predictions for management

"An important justification for creating PICES was that it could develop objective advice on scientific questions with great practical implications." - Prof. Wooster at the 1992 PICES Meeting

PICES, not limited to addressing the short-term needs management bodies, is uniquely positioned to investigate questions across the full spectrum of timescales.

This includes processes important for tactical decisions (seasons to interannual) as well as more strategic policies (that might be enacted over years to decades).

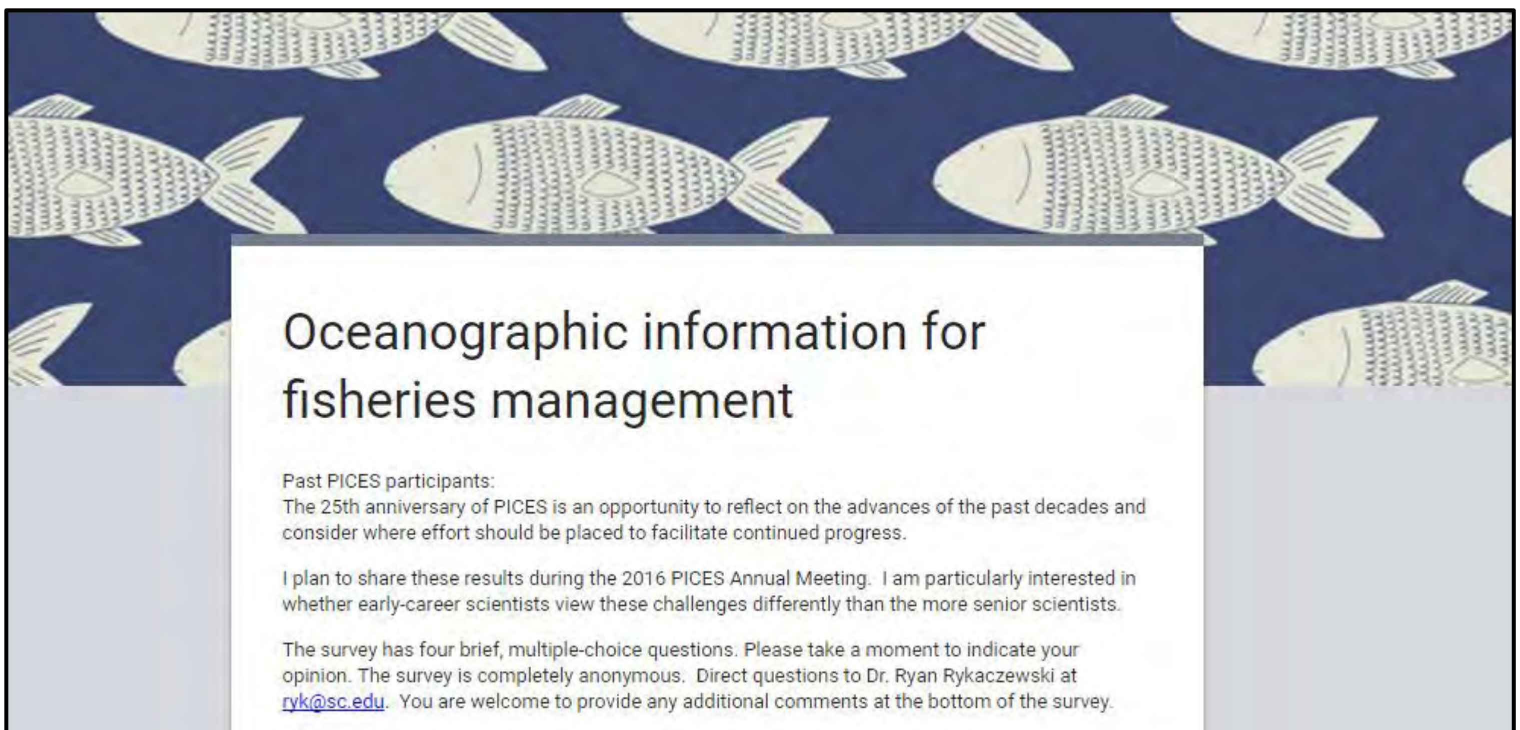


see also Stock et al. (2011), Tommasi et al. (2016)

Are we conducting "impactful" ecosystem research?

My naïve assumption (when I was drawn to oceanography) was that improved understanding of ecosystem process might permit use of environmental information in tactical management decisions.

With this concern on my mind, I emailed a survey to recent PICES participants with three questions. The only demographic data collected was "PICES early-career scientist" or not.



Oceanographic information for fisheries management

Past PICES participants:
The 25th anniversary of PICES is an opportunity to reflect on the advances of the past decades and consider where effort should be placed to facilitate continued progress.

I plan to share these results during the 2016 PICES Annual Meeting. I am particularly interested in whether early-career scientists view these challenges differently than the more senior scientists.

The survey has four brief, multiple-choice questions. Please take a moment to indicate your opinion. The survey is completely anonymous. Direct questions to Dr. Ryan Rykaczewski at ryk@sc.edu. You are welcome to provide any additional comments at the bottom of the survey.

161 responses: 36 from early-career scientists, 125 from our more mature colleagues

Currently, which factor is MOST important in limiting use of oceanographic, climate, and ecosystem information in the management and assessment of marine fisheries?

	Early Career	*More Mature*	
Scientific uncertainty regarding how physical processes influence fish populations.	25%	27%	
Low skill in predicting the future evolution of climate and oceanographic conditions at scales relevant for management decisions.	19%	19%	
Insufficient ability to represent ecosystem and multi-species factors into management plans and stock-assessment models in a useful manner.	28%	42%	
Political unwillingness to implement science-based management.	28%	12%	***

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Which area of marine science requires the MOST effort in coming decades to facilitate the use of oceanographic, climate, and ecosystem data in fisheries management?	Early Career	More Mature	
Increased process studies that examine mechanisms of physical-biological interactions in marine ecosystems.	29%	40%	
Improved models that better represent physical and biological processes and interactions at local-to-basin scales.	6%	19%	***
Improved observations of physical, chemical, and biological components of the ecosystem.	34%	14%	***
Increased testing and evaluation of the use of ecosystem data in fisheries management.	31%	26%	

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Twenty-five years from now, the use of oceanographic, climate, and ecosystem information for fisheries management will be:

	Early Career	*More Mature*
nearly the same as today, with limited use of oceanographic and climate information for management of very few fished stocks.	19%	14%
much more than today, with widespread use of oceanographic and climate information in management decisions for many fisheries.	81%	86%

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I also received an abundance of feedback in the "comments" section.

Common themes:

There is a scale mismatch between climate information and fisheries processes.

- see e.g. *Siedlecki et al. (2016)*

Simple models are oftentimes most useful and interpretable.

Relationships between stocks and oceanographic parameters deteriorate over time, and so more mechanistic understanding is needed. (E.g., understanding dynamics of zooplankton and non-commercial species remain critical missing links.)

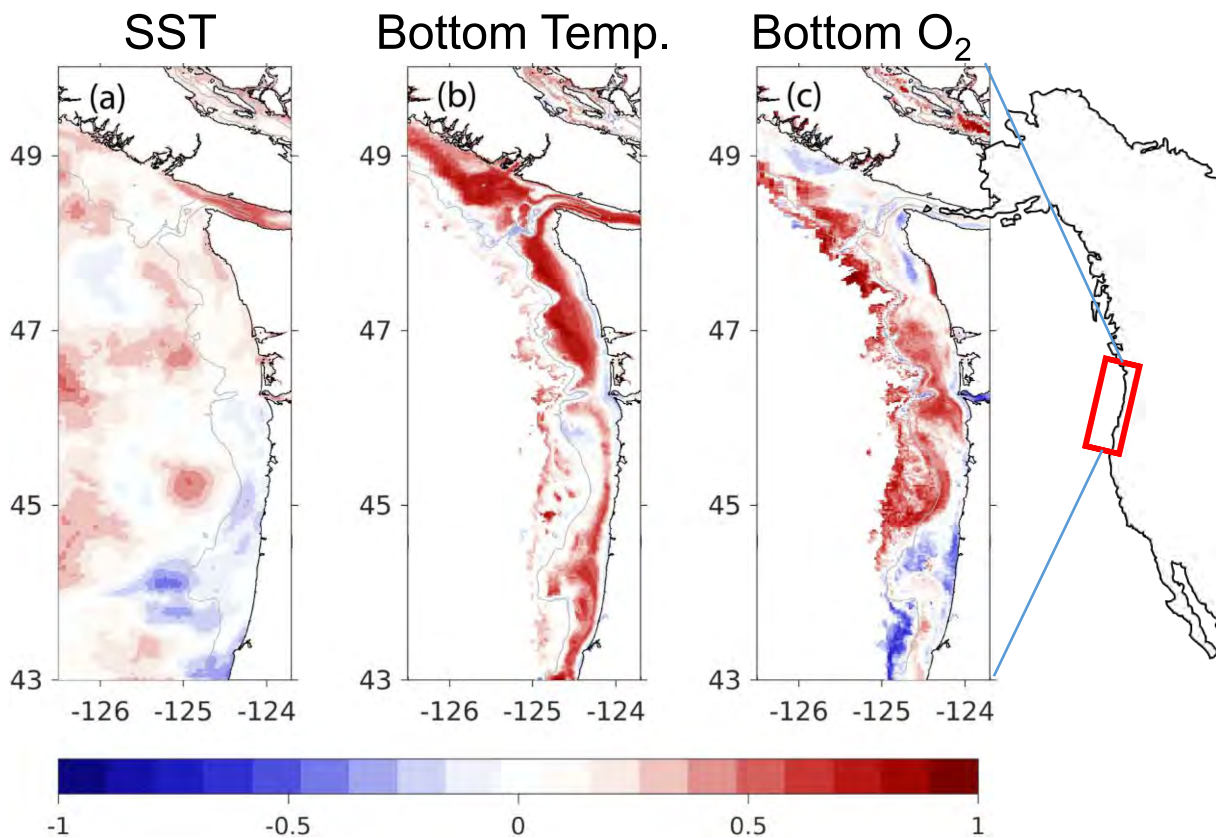
A permanent dialogue between the scientists and the managers in required. Communication among scientists, managers, policy makers, and the public is indispensable.

Downscaling of ocean forecasts

Siedlecki et al. (2016, *Scientific Reports*)

JISAO's Seasonal Coastal Ocean Prediction of the Ecosystem (J-SCOPE) team aims to produce high-resolution forecasts of regional ocean conditions relevant for fisheries and resource management.

This includes SST and bottom temperature, pH, aragonite saturation state, and bottom oxygen.



http://www.nanoos.org/products/j-scope/home.php

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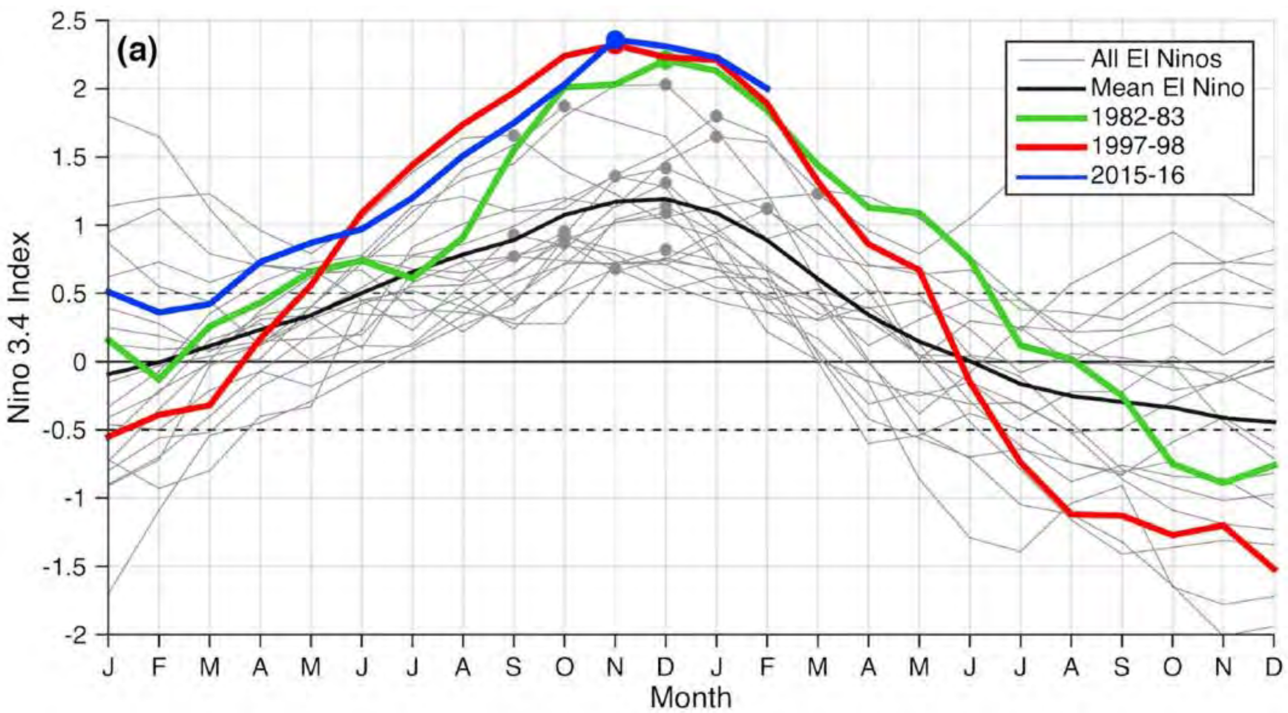
Predicted impact of the 2015-2016 El Niño on chlorophyll

Jacox et al. (2016, *Geophysical Research Letters*)

A combination of simple statistical models, glider observations, satellite data, and a regional circulation model was used to offer a prediction El Niño's impact on summer chlorophyll anomaly.



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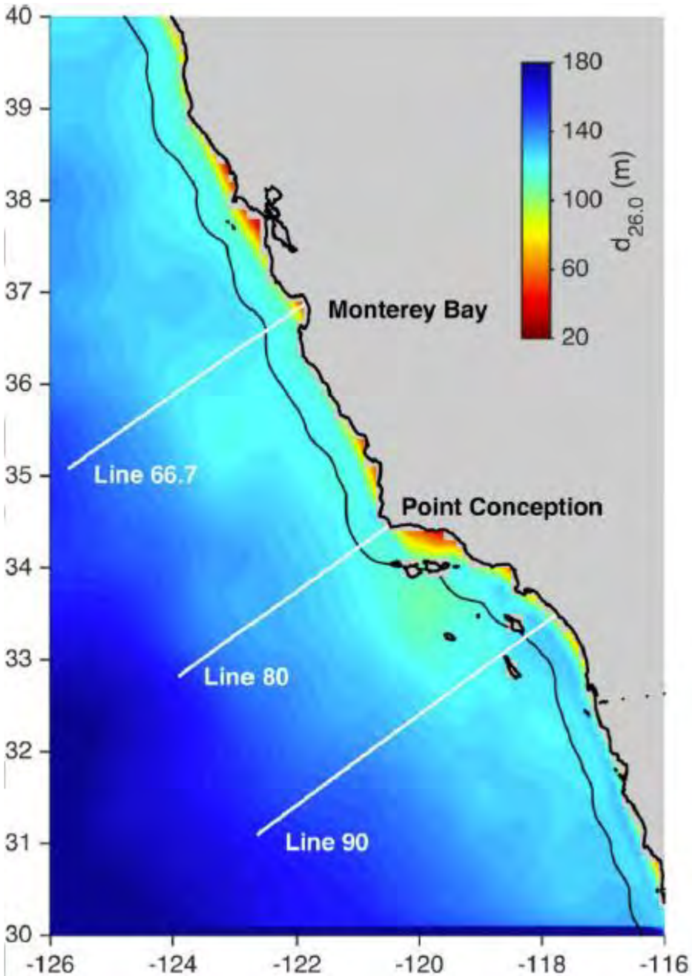

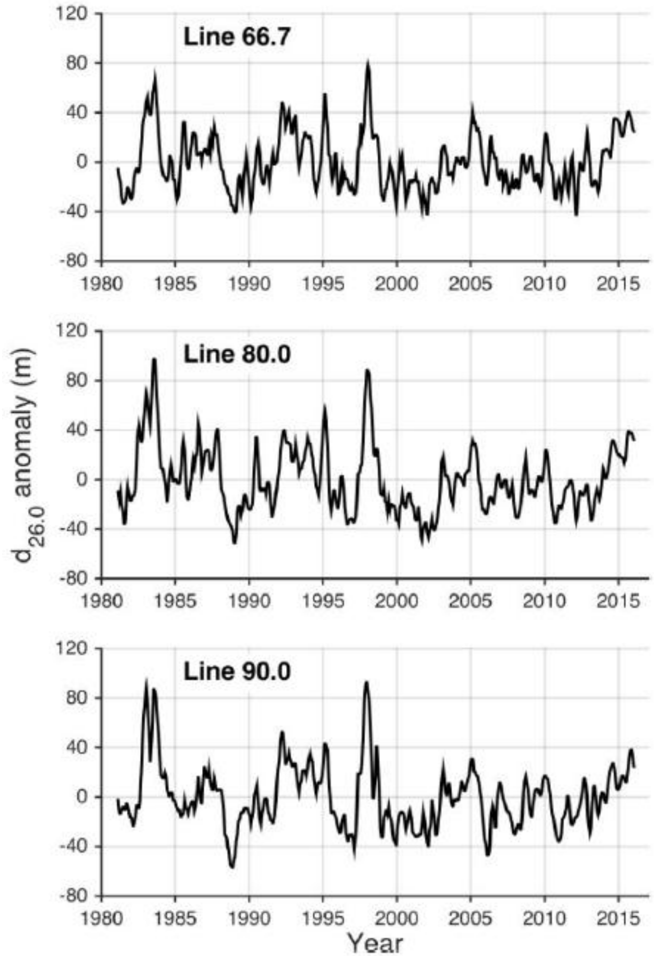

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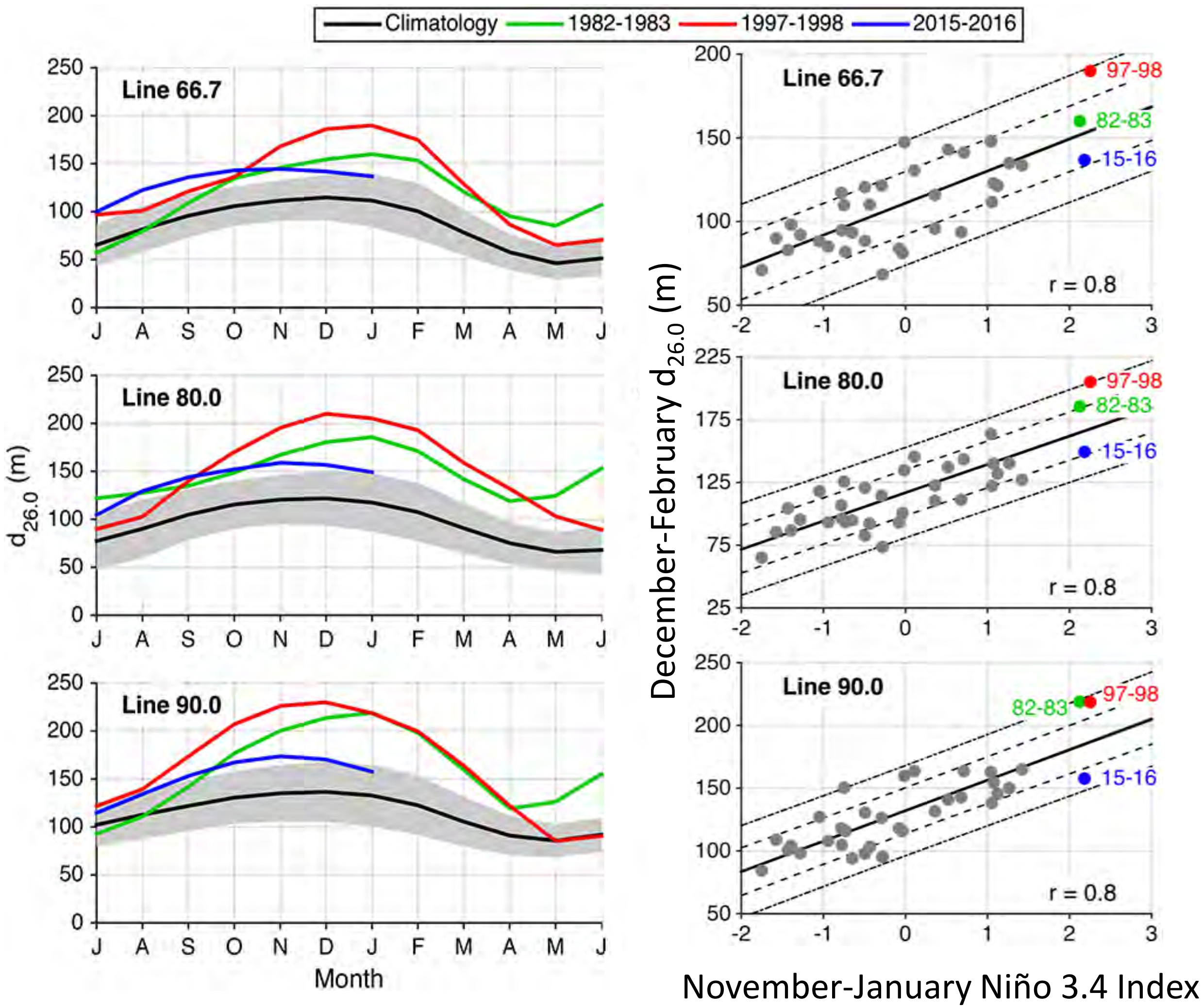

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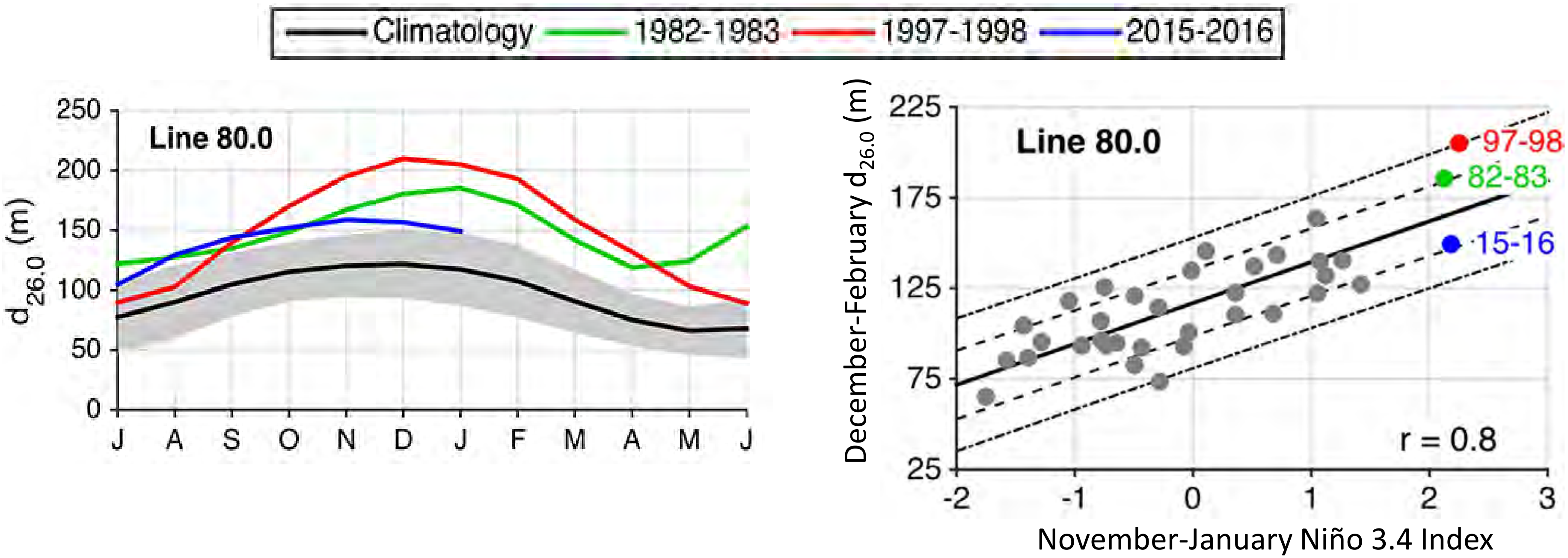

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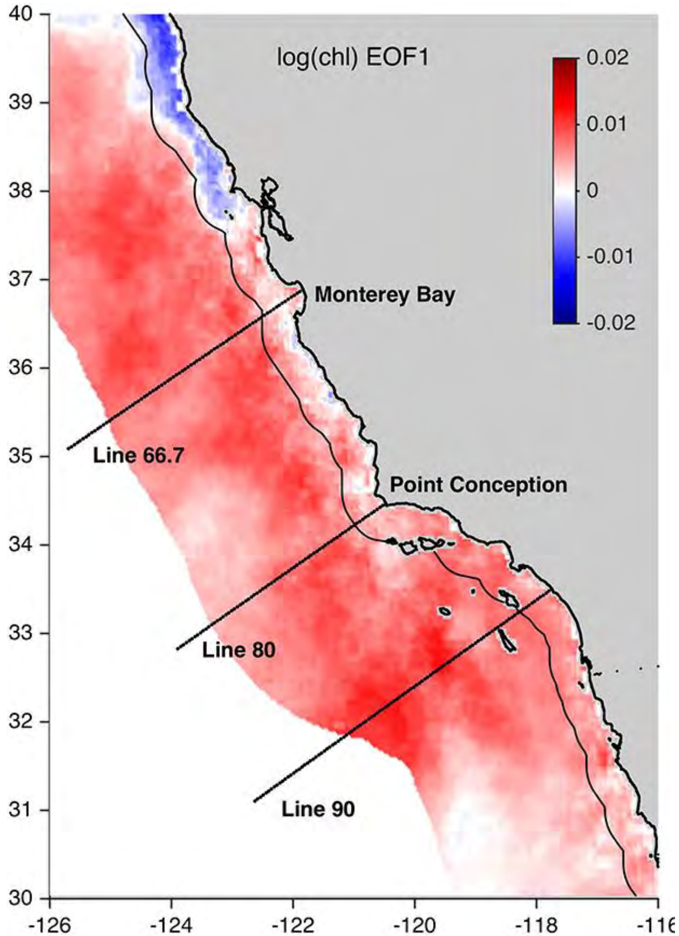

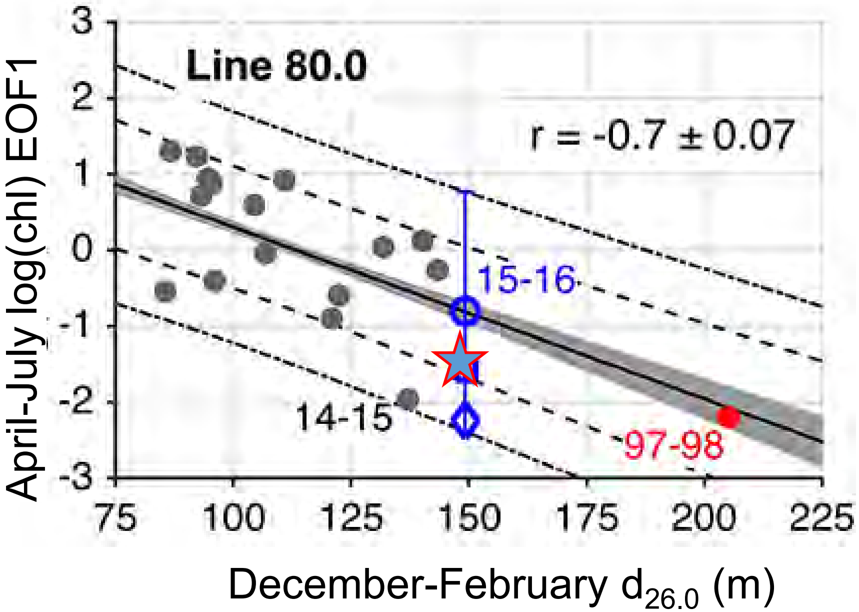

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Relationships between stocks and oceanographic parameters deteriorate over time, and so more mechanistic understanding is needed. (E.g., understanding dynamics of zooplankton and non-commercial species remain critical missing links.)

A permanent dialogue between the scientists and the managers in required. Communication among scientists, managers, policy makers, and the public is indispensable.

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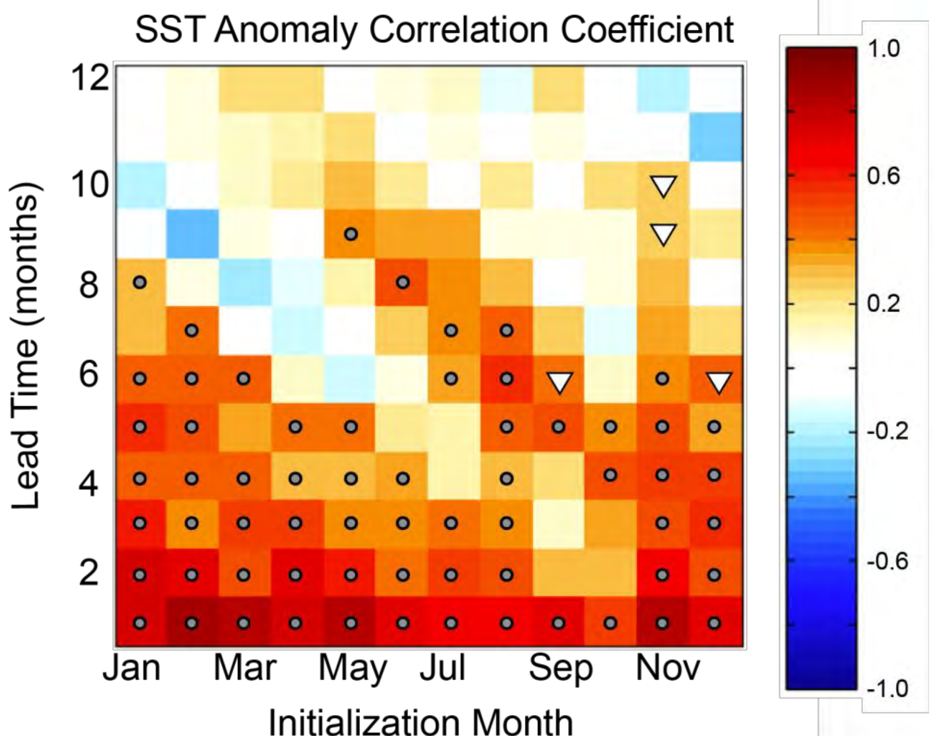
Evaluating changes to management strategies

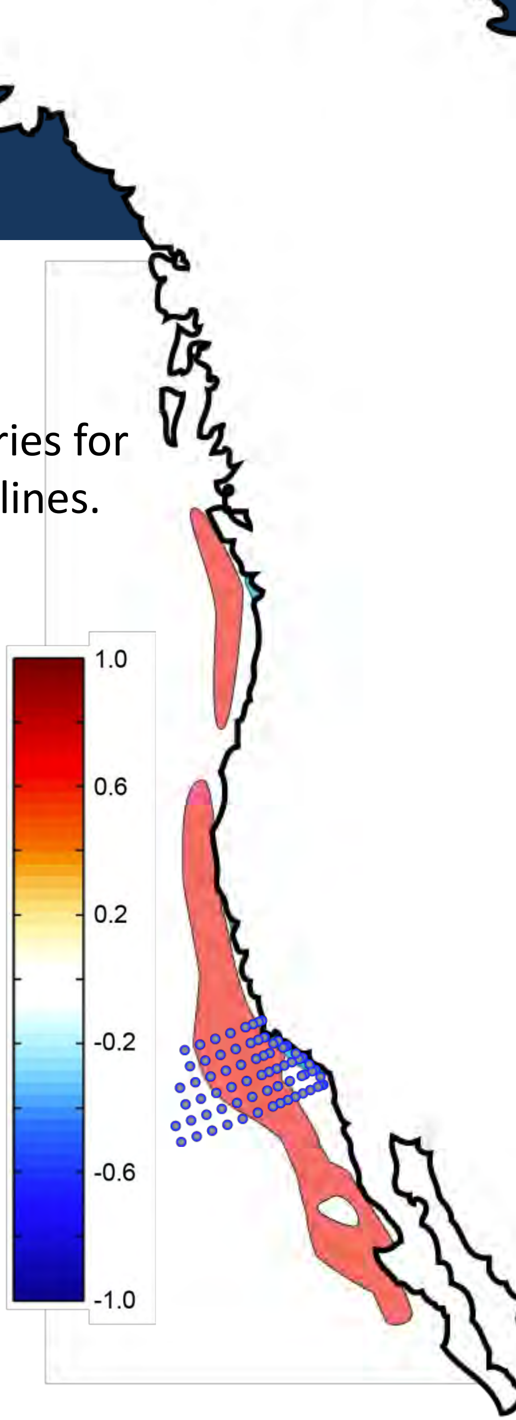
Tommasi et al. (in press at *Ecological Applications*)

The Pacific sardine stock in the eastern Pacific is one of the few fisheries for which environmental information is included in setting harvest guidelines.

Advances in dynamic global climate forecasts raise prospects of improved, forecast-informed resource management.

GFDL CM 2.5-FLOR allows forecasts of SST several months in advance.





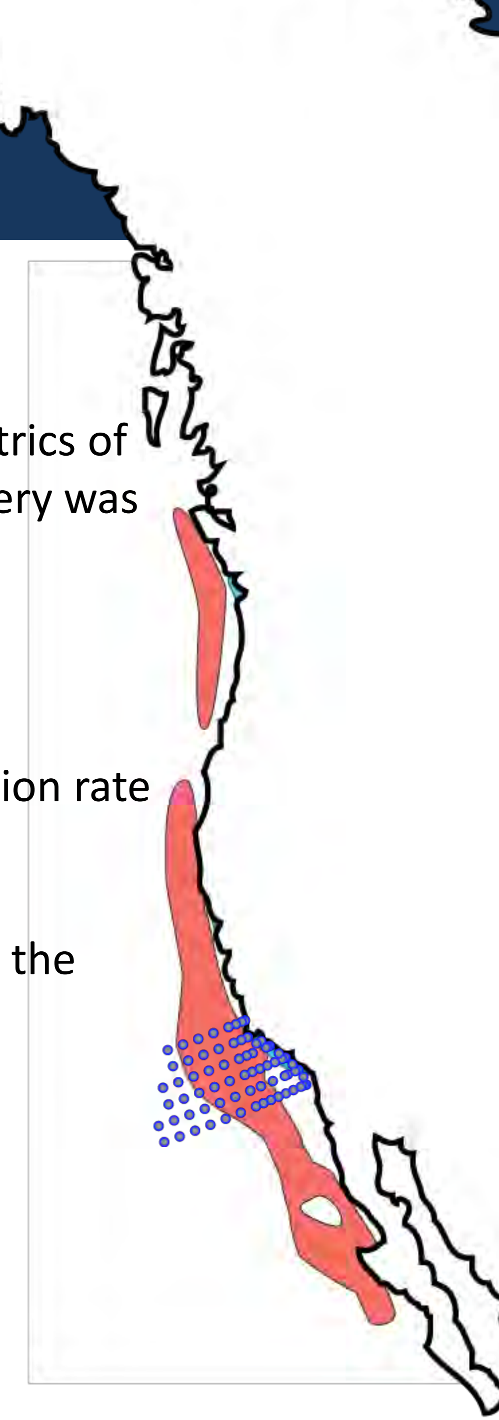
Evaluating changes to management strategies

Tommasi et al. (in press at *Ecological Applications*)

The influence of use of SST information and forecasts on different metrics of fishery performance that included stock biomass and yield to the fishery was assessed.

Four different "Harvest Guideline" (HG) strategies were tested:

- HG1) no SST information (constant exploitation rate)
- HG2) SST anomalies over the past three years influence exploitation rate
- HG3) Observations from two previous years are combined with a forecast of SST for the coming year to vary exploitation rate
- HG4) an estimate of future sardine biomass is included in setting the exploitation rate



Evaluating changes to management strategies

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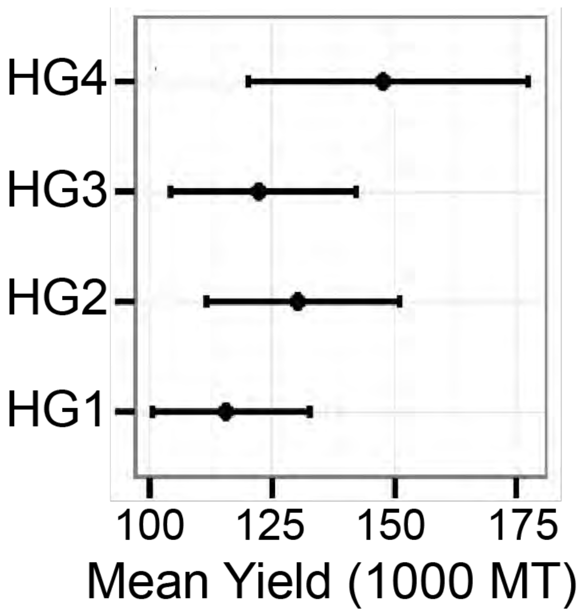

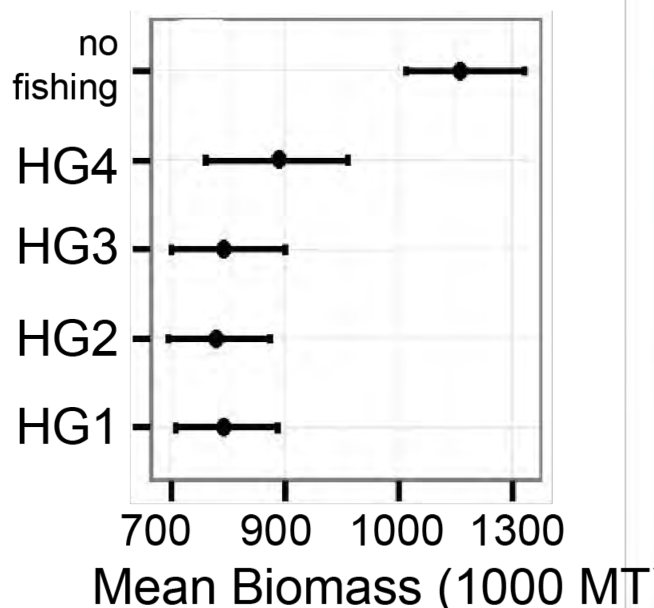

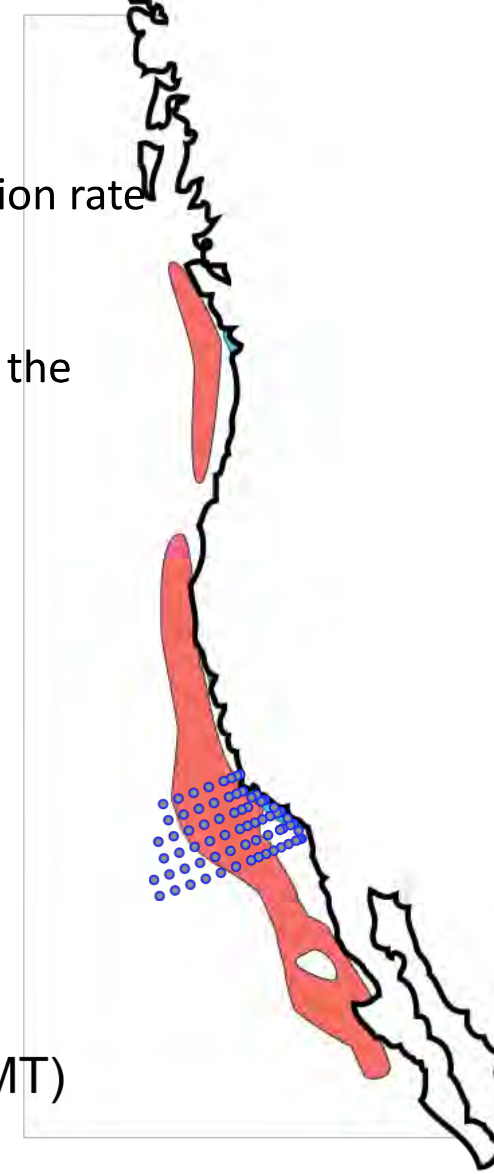

161 responses: *36 from early-career scientists, 125 from our more mature colleagues*

I also received an abundance of feedback in the "comments" section.

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Lack of funding inhibits maintenance of oceanographic time series needed for tactical management decisions. Management plans will not include environmental data if the consistent availability of those data is questioned. Coincident observation of oceanographic and biological information is important.

Points to keep in mind this week (and after we return home)

1. Past ecosystem responses to climate variability may be insufficient to project future conditions. We need to continue to strive to understand mechanisms.

2. Long-term observations remain critical. Models are necessary for testing hypotheses and exploring dynamics, but are ineffective without observations for comparison. New techniques are promising, but we remain challenged by our need to assess plankton and fishes at appropriate scales.

3. We need to keep the motivations of PICES' founders in mind. Interaction across national and disciplinary boundaries is the strength of our organization.
   a) Engagement with resource managers is critical. Passing knowledge by osmosis is not enough.
   b) The political climate seems more divisive and nationalistic now than it has in decades. We should embrace the fact that PICES science fosters internationalism!

4. **What are we doing now so that in 25 years, we are not asking the same questions that we are asking today?**

Thank you for your attention!