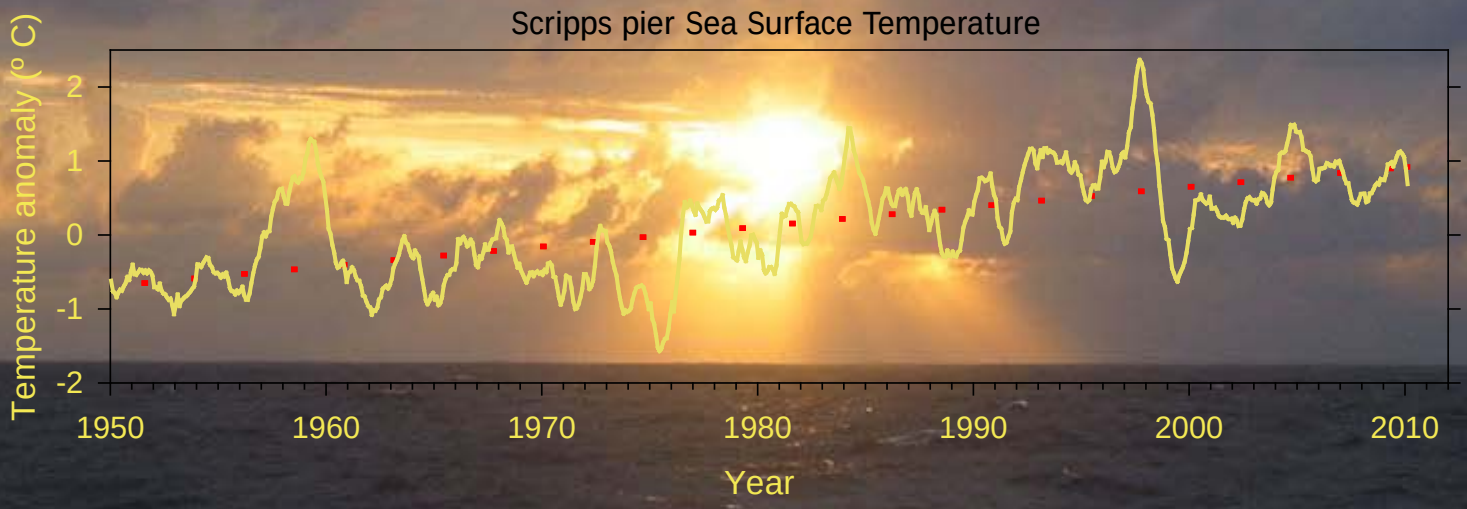
Pelagic ecosystem responses to climate forcing: Linear tracking or threshold dynamics?

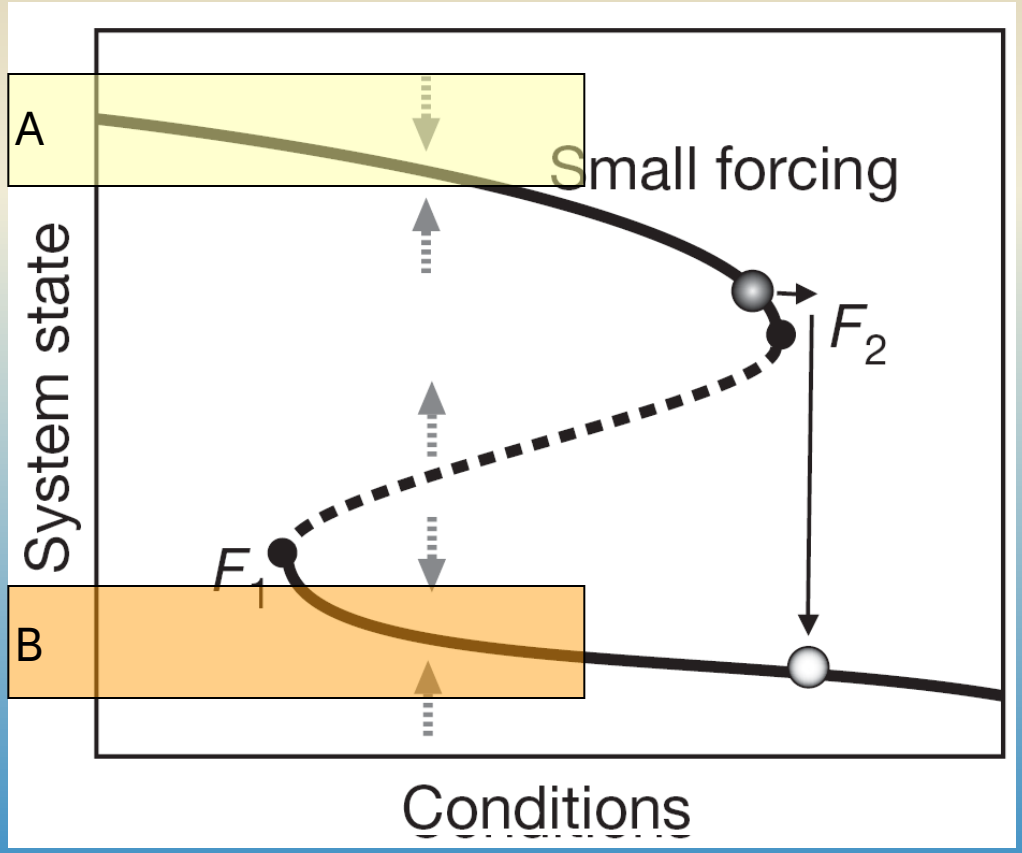


Mark D. Ohman
Scripps Institution of Oceanography
University of California, San Diego

U.S. LTER Network - 26 sites

including terrestrial, aquatic, & human-dominated ecosystems

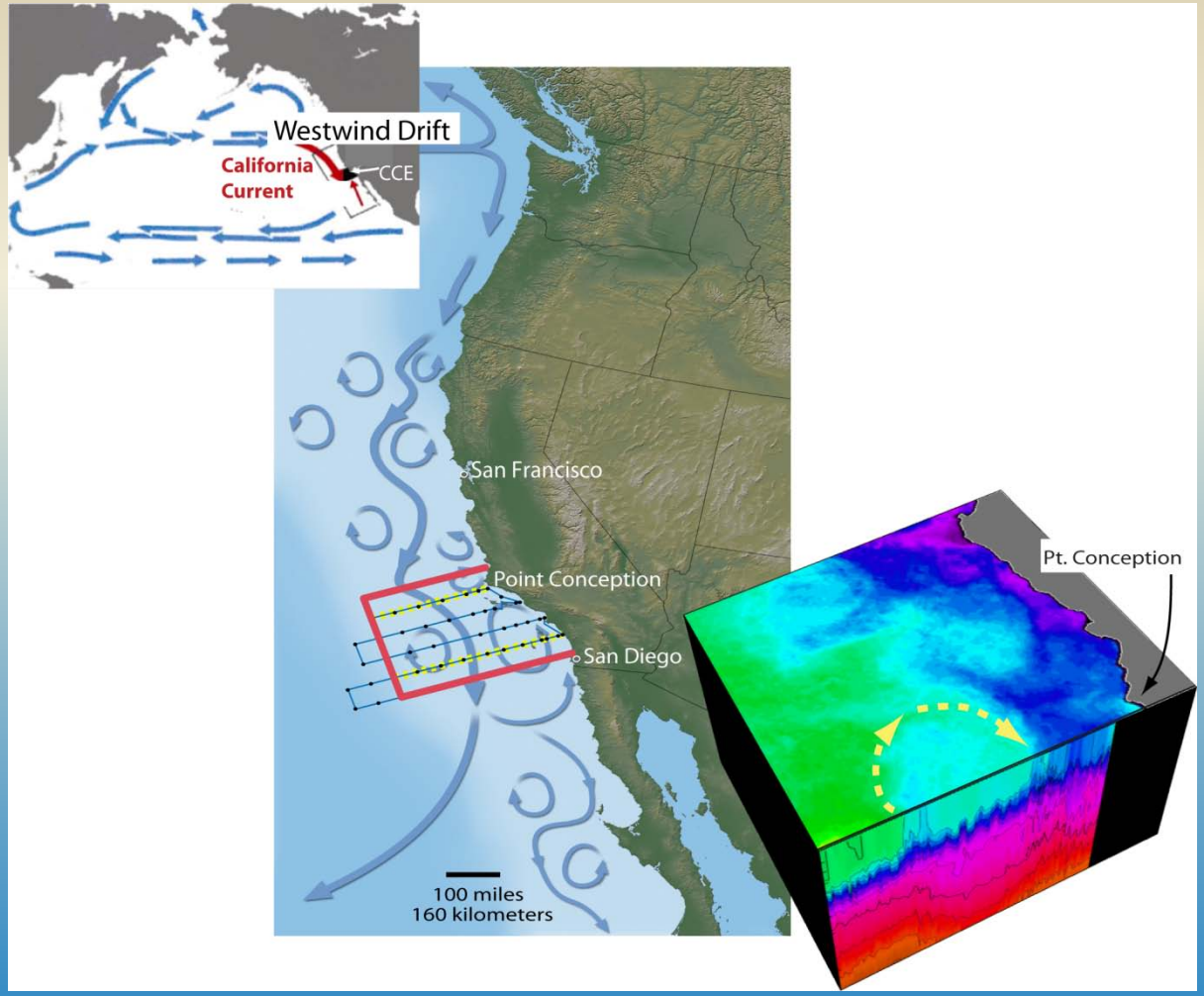
Fold Bifurcation



Scheffer et al. 2009, Nature

California Current Ecosystem LTER

A Coastal Upwelling Biome



CCE: leverages 62-yr CalCOFI time series

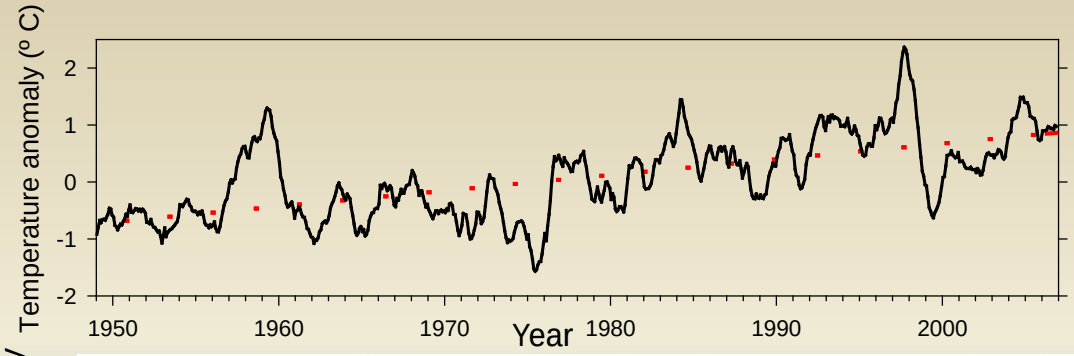
Multiple, interacting time scales

of ecosystem change

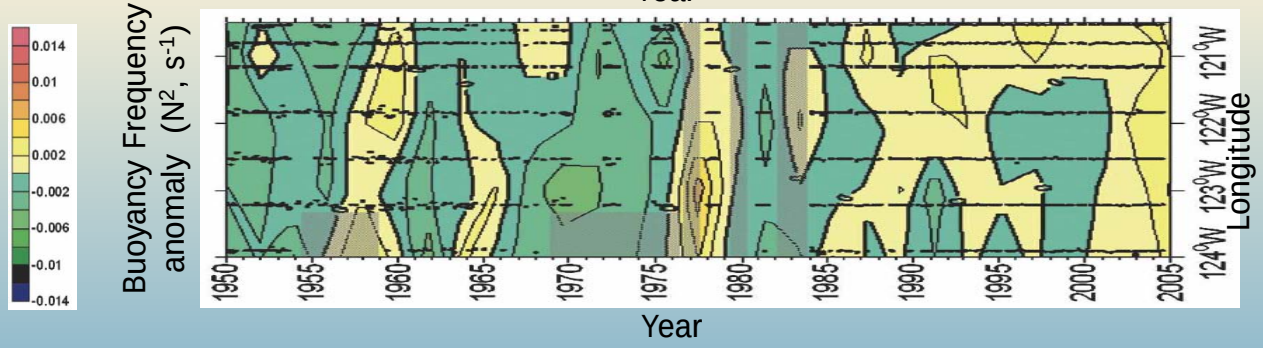
Progressive, long-term changes

in the California Current Ecosystem

Long-term Changes in Vertical Stratification



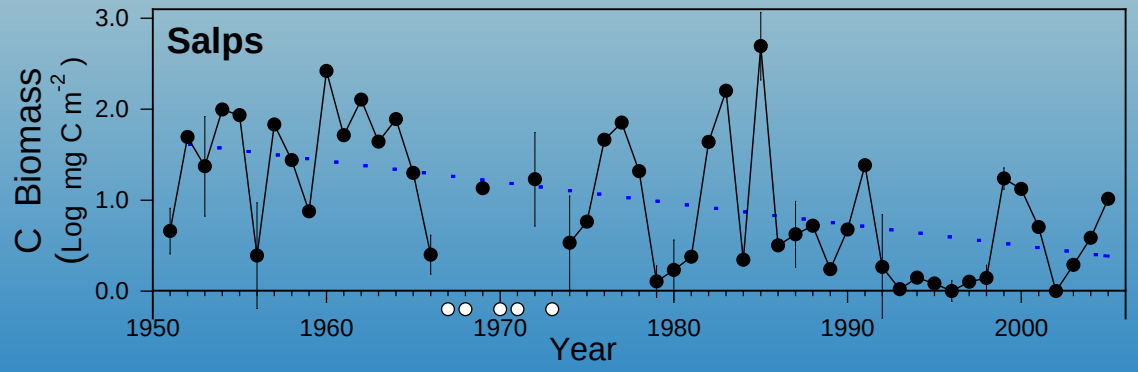
Scripps Pier Temperature



Density Stratification

N^2

CalCOFI line 80



Salp biomass

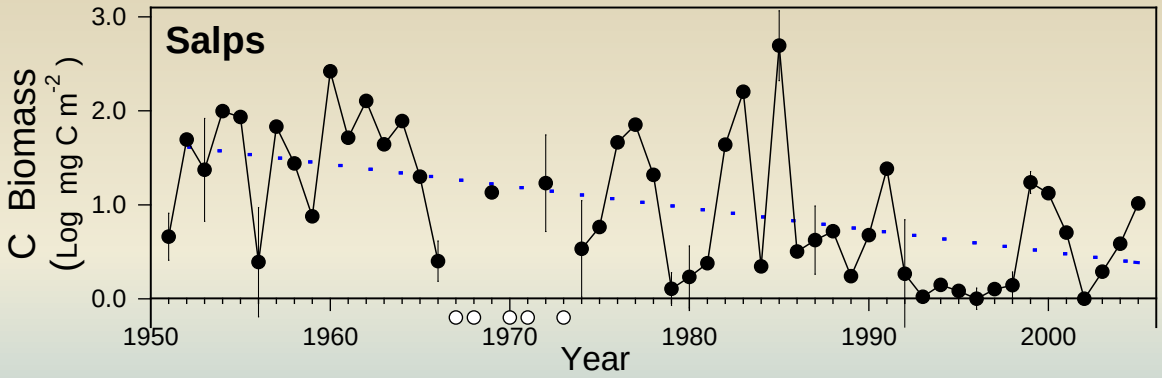
photo: D.Wrobel

Lavaniegos & Ohman (2007) *Progress in Oceanography*

Kim and Miller (2007) *J. Physical Oceanography*

Links to Biogeochemistry

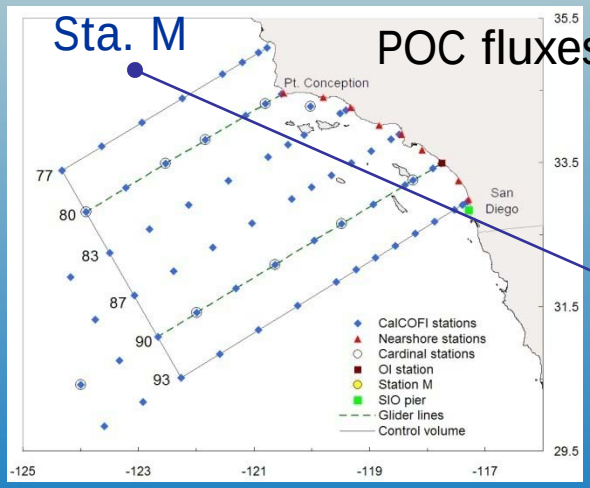
Deep Sea C fluxes?



Ocean Surface waters

Sta. M deep-sea benthic observatory

export fluxes



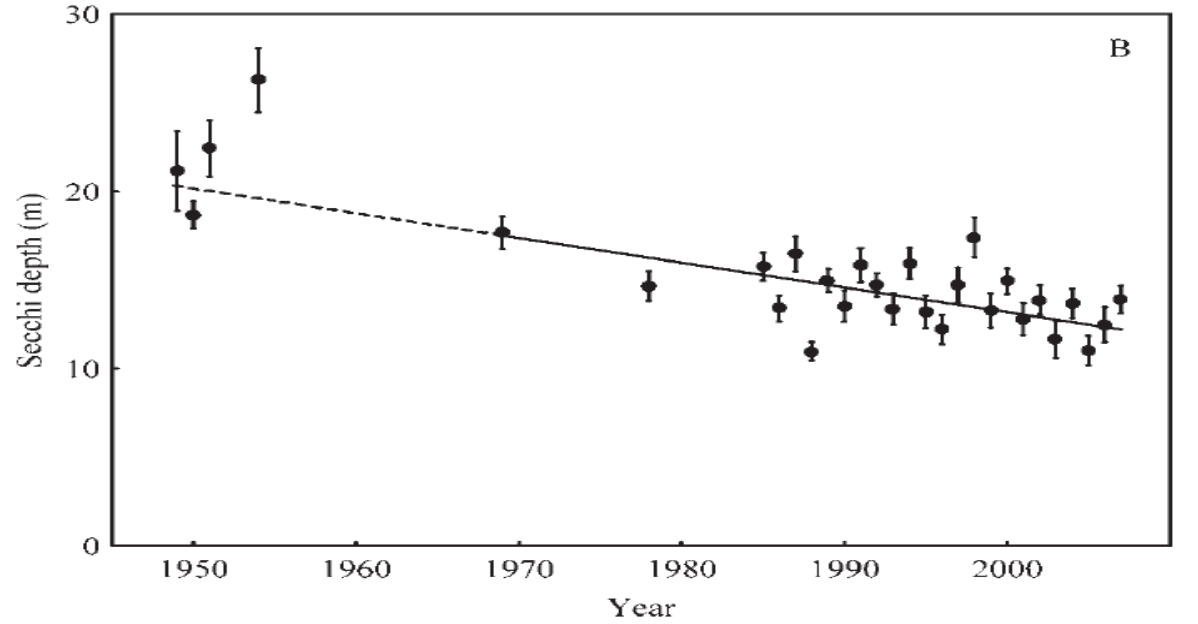
K. Smith

POC fluxes, SCOD, benthic macrofauna interactions

4100 m deep

Long-Term Decrease in Ocean Transparency

(Secchi disk depth)



CalCOFI region

annual averages
inshore region

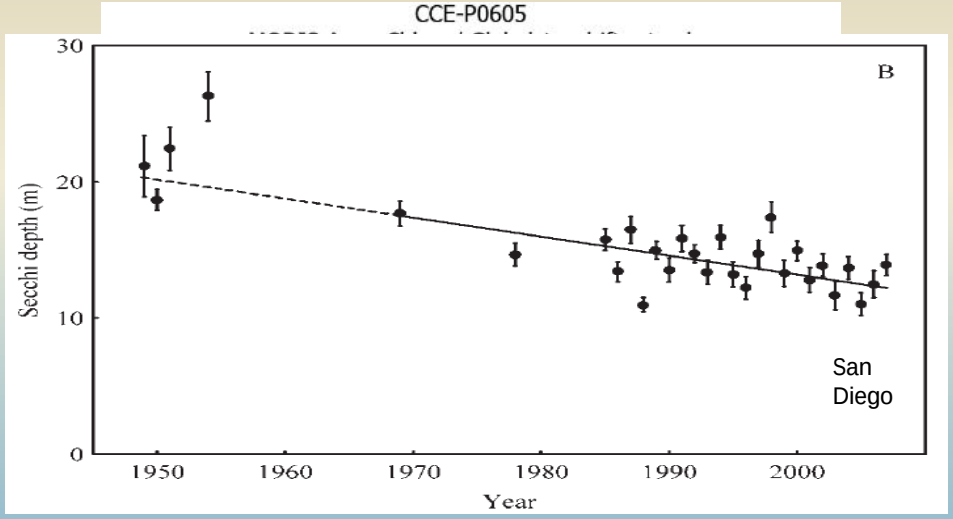
Aksnes and Ohman 2009

Exchanging Space for Time:

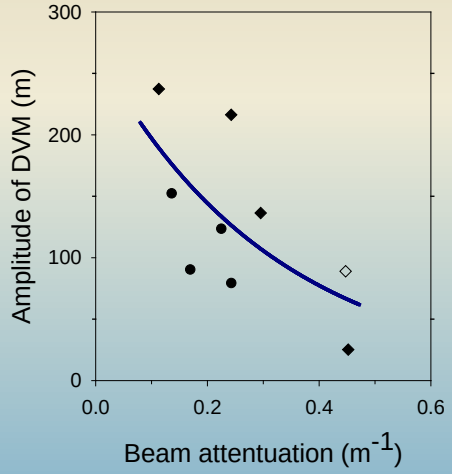
Spatial differences as an analog of temporal change

Spatial differences in transparency affect zooplankton vertical distributions

Changes in transparency over time



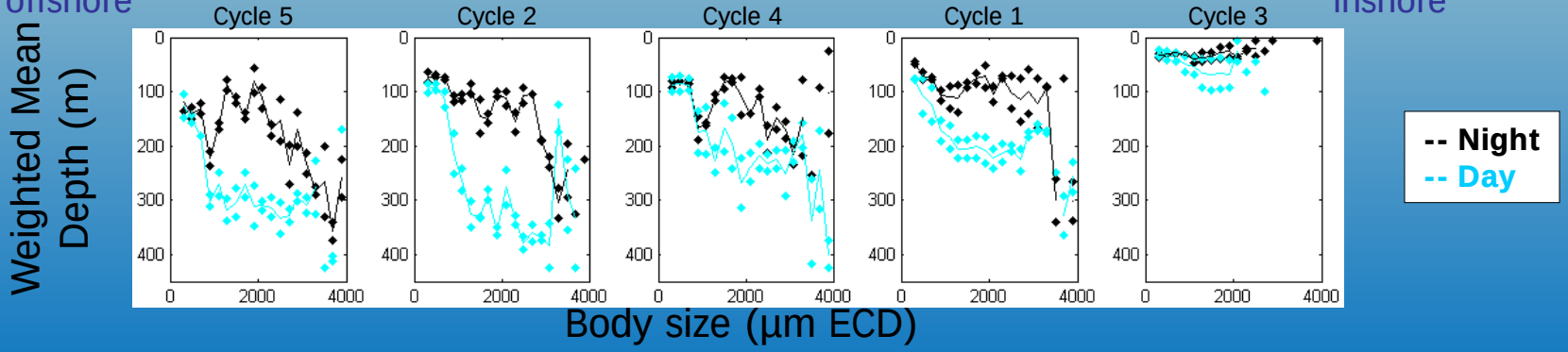
Copepod Diel Vertical Migration vs. water column transparency



Planktonic Copepods

offshore

inshore

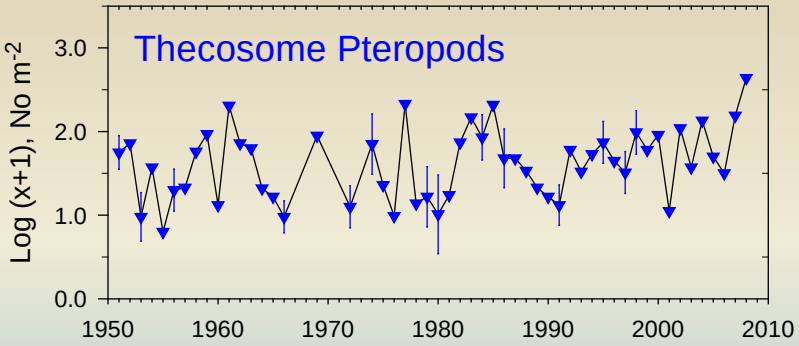


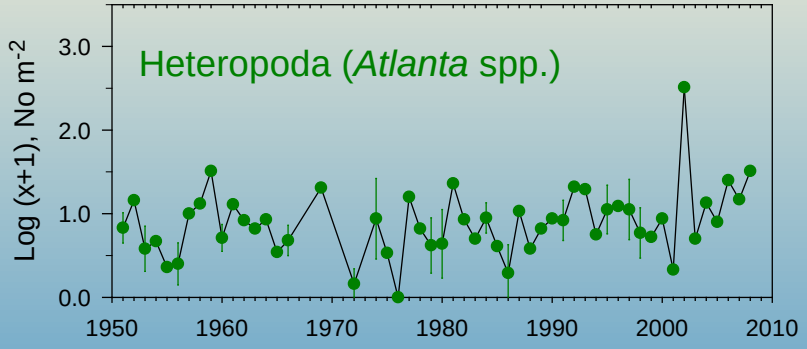
Ohman & Romagnan (in prep)

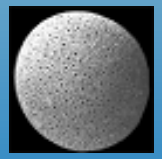
Importance of long term research:

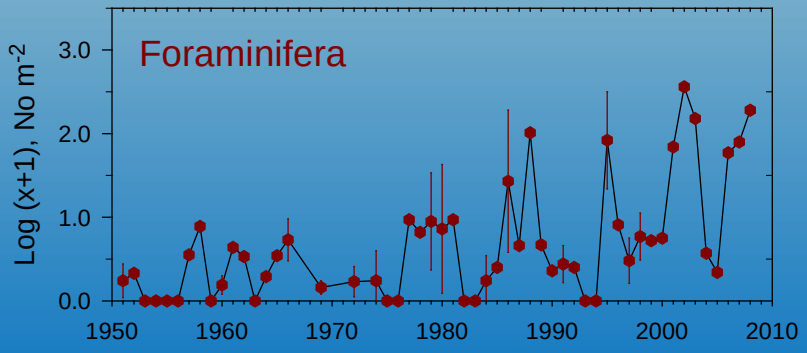
detecting thresholds of change

Southern California









Spring cruises

Year

Consequences of lowered seawater pH and undersaturation w.r.t. aragonite in the CA Current System ?

(cf. Feely et al. 2008)

Ohman et al. (2009) GRL

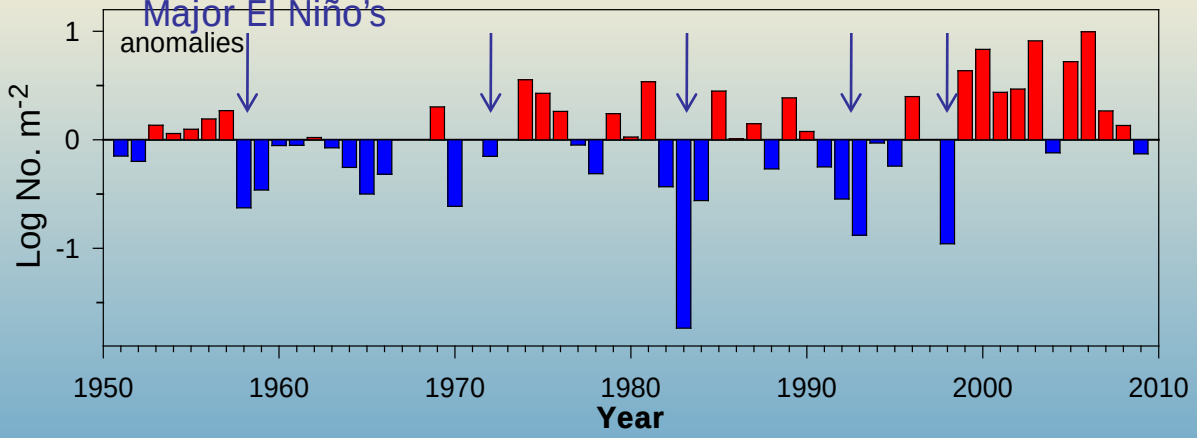
Natural modes of climate variability:

interannual and interdecadal changes

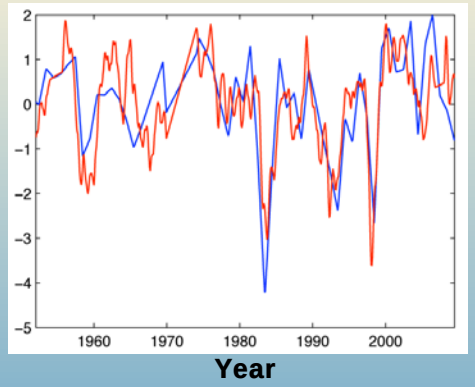
in the California Current Ecosystem

Interannual variability

Euphausia pacifica



***E.p.*$_{recon}$ vs. *E.p.*$_{obs}$**



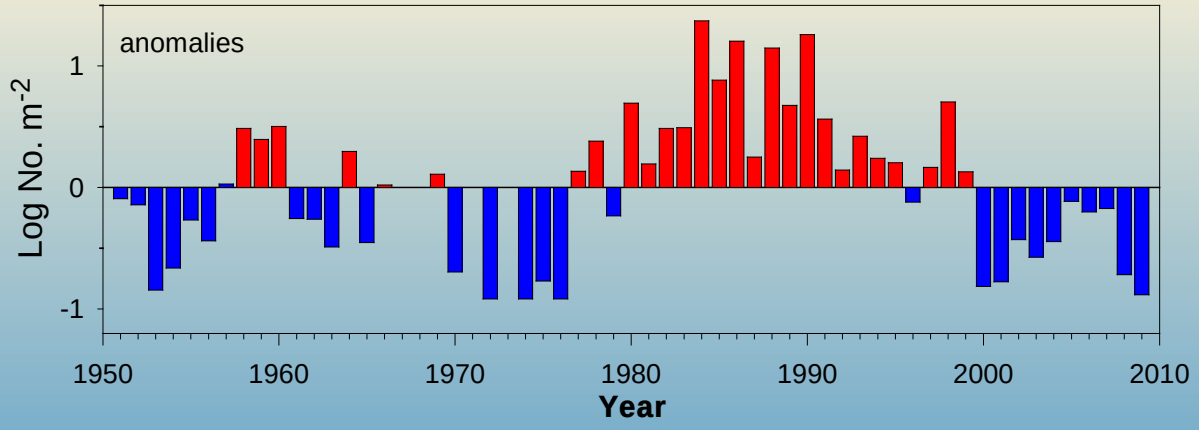
Sea Surface Height
AR1 model

Ohman and Di Lorenzo (in prep)

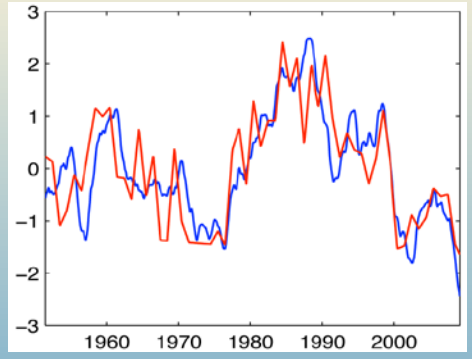
Brinton data source - CalCOFI

Interdecadal variability
PDO

Nyctiphanes simplex



***N.s.*$_{recon}$ vs. *N.s.*$_{obs}$**



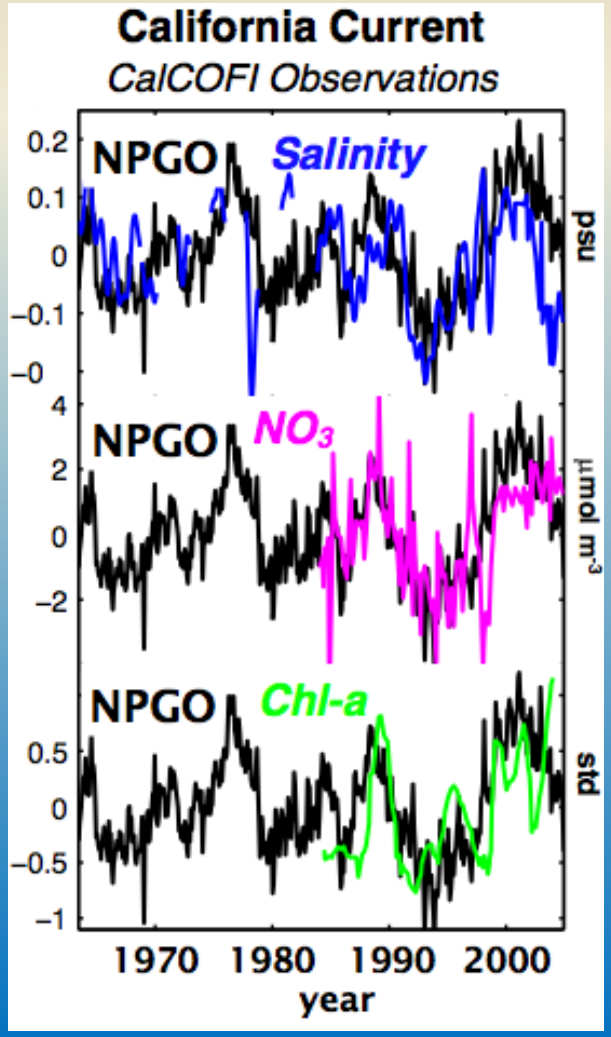
PDO
AR1 model

Ohman and Di Lorenzo (in prep)

Brinton data source - CalCOFI

Interdecadal variability

North Pacific Gyre Oscillation (NPGO)



NPGO initially diagnosed from a ROMs model

Di Lorenzo et al. 2008, GRL

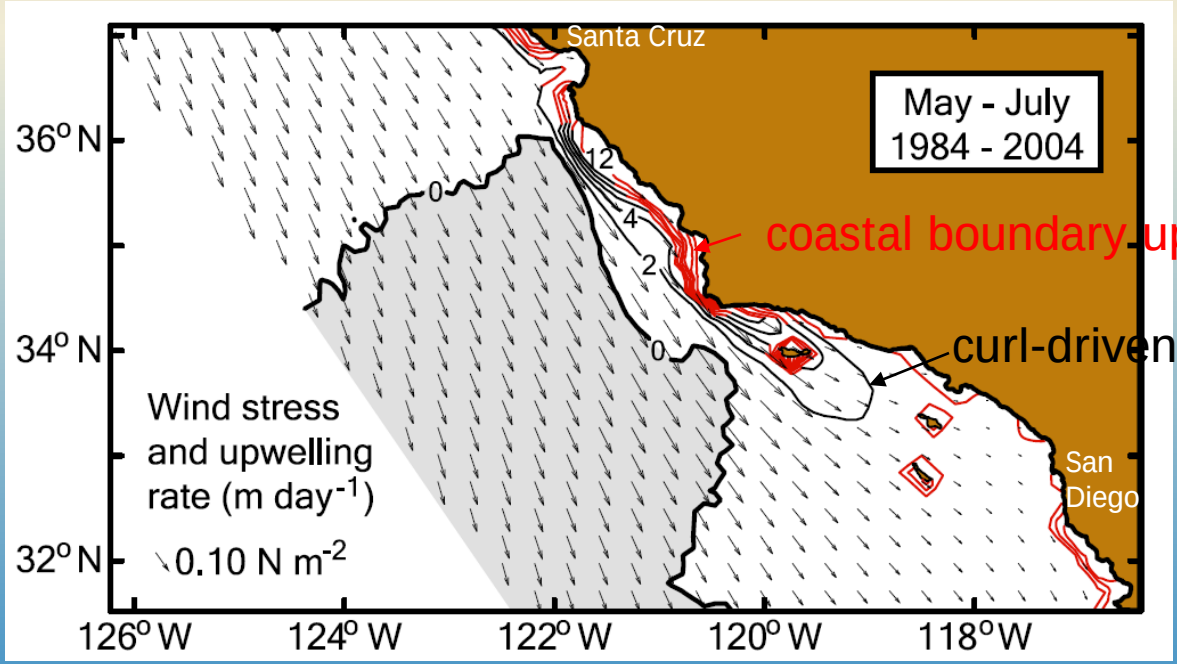
Spatial dimensions of climate forcing:

differential effects on co-occurring species

Distinction between:

Coastal boundary upwelling

Wind-stress curl upwelling



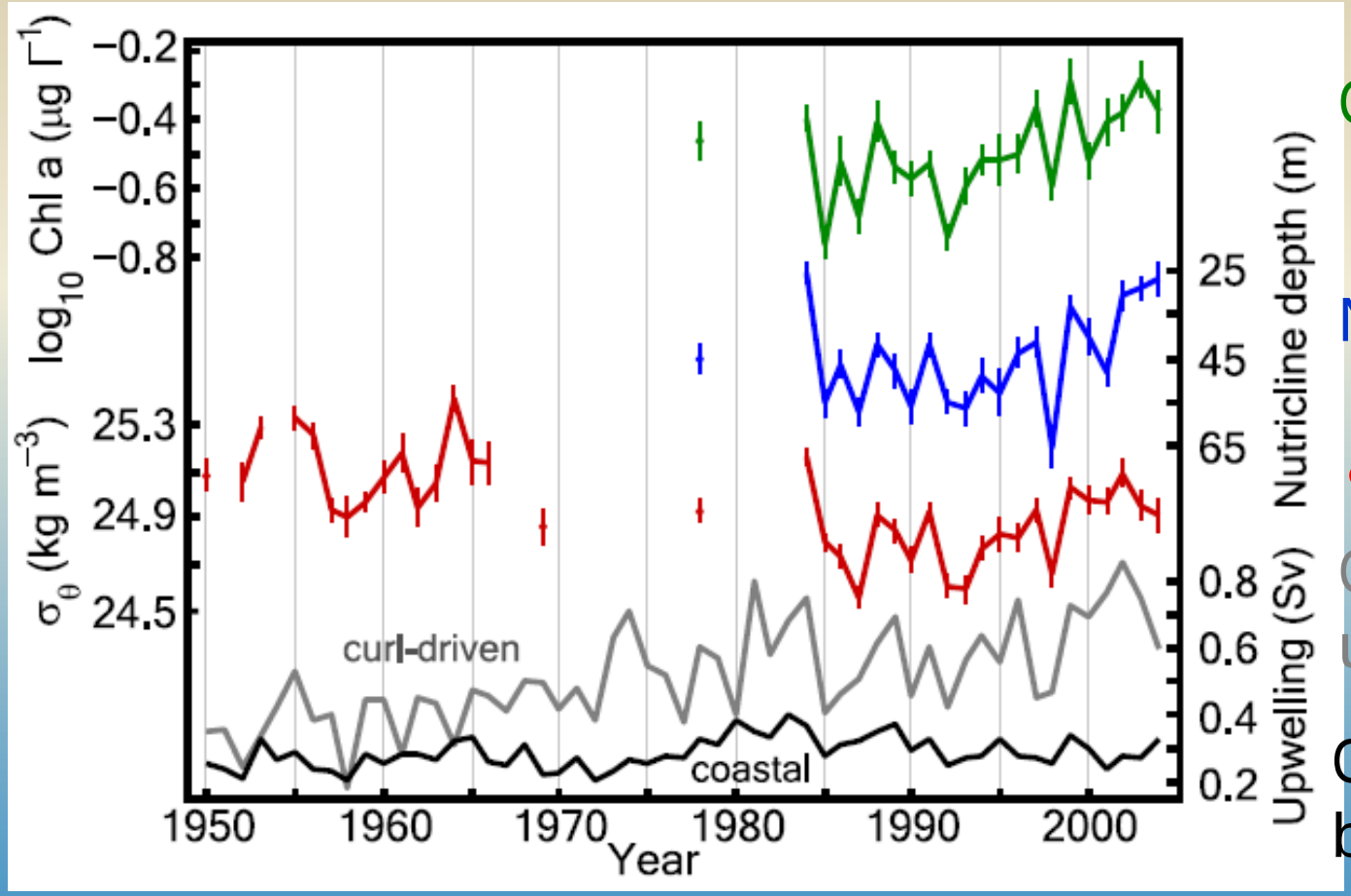
Typical Vertical Velocity
(m day^{-1})

coastal boundary upwelling 7-12

curl-driven upwelling 0-1

Rykaczewski and Checkley (2008) PNAS

Long-term increase in curl-driven upwelling



Chl*a*

Nutricline depth

σ_θ

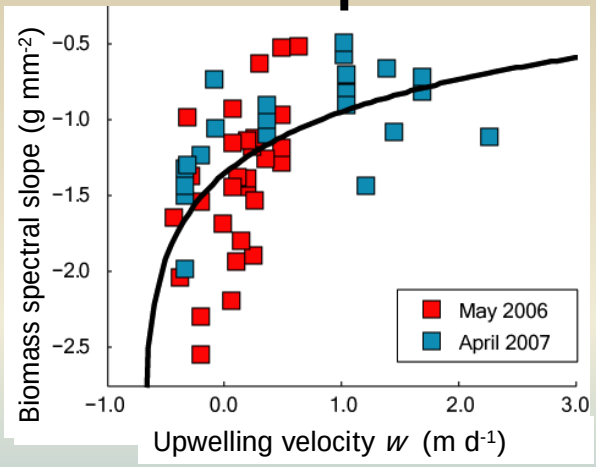
Curl-driven upwelling

Coastal boundary upwelling

Rykaczewski and Checkley (2008) PNAS

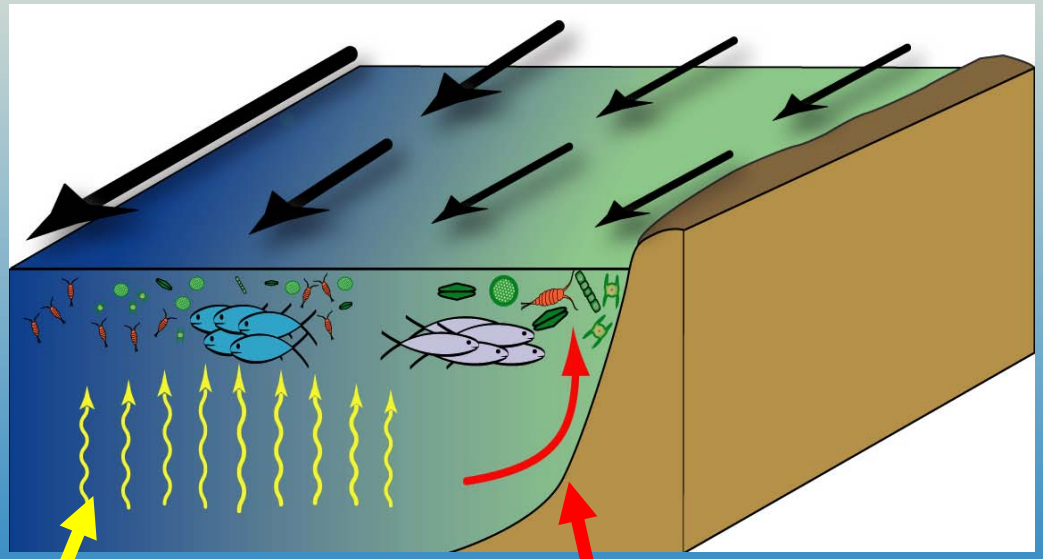
Zooplankton body size is proportional to upwelling velocity

CCE-LTER process cruises



Rykaczewski & Checkley 2008

PNAS



Wind stress curl driven upwelling: sardine

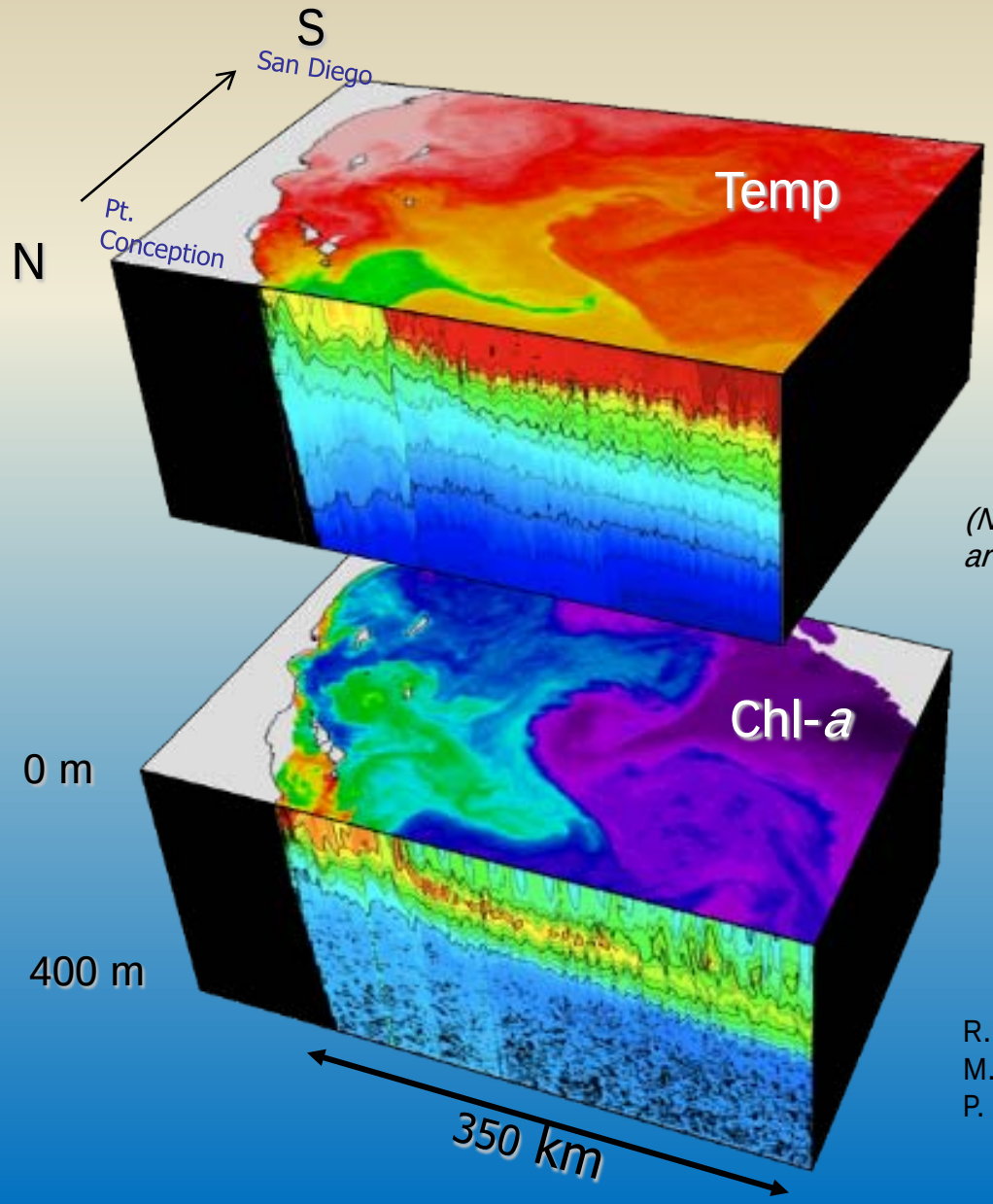
Coastal boundary upwelling: anchovy

Spatial dimensions of climate forcing:

Climate change may act at the

mesoscale and sub-mesoscale

Mesoscale & sub-mesoscale ocean features



(N.B. glider and SeaWifs images are on different color scales)

R. Davis, M. Ohman - glider image
M. Kahru – satellite images
P. Franks - composition

Biophysical gradients at ocean fronts

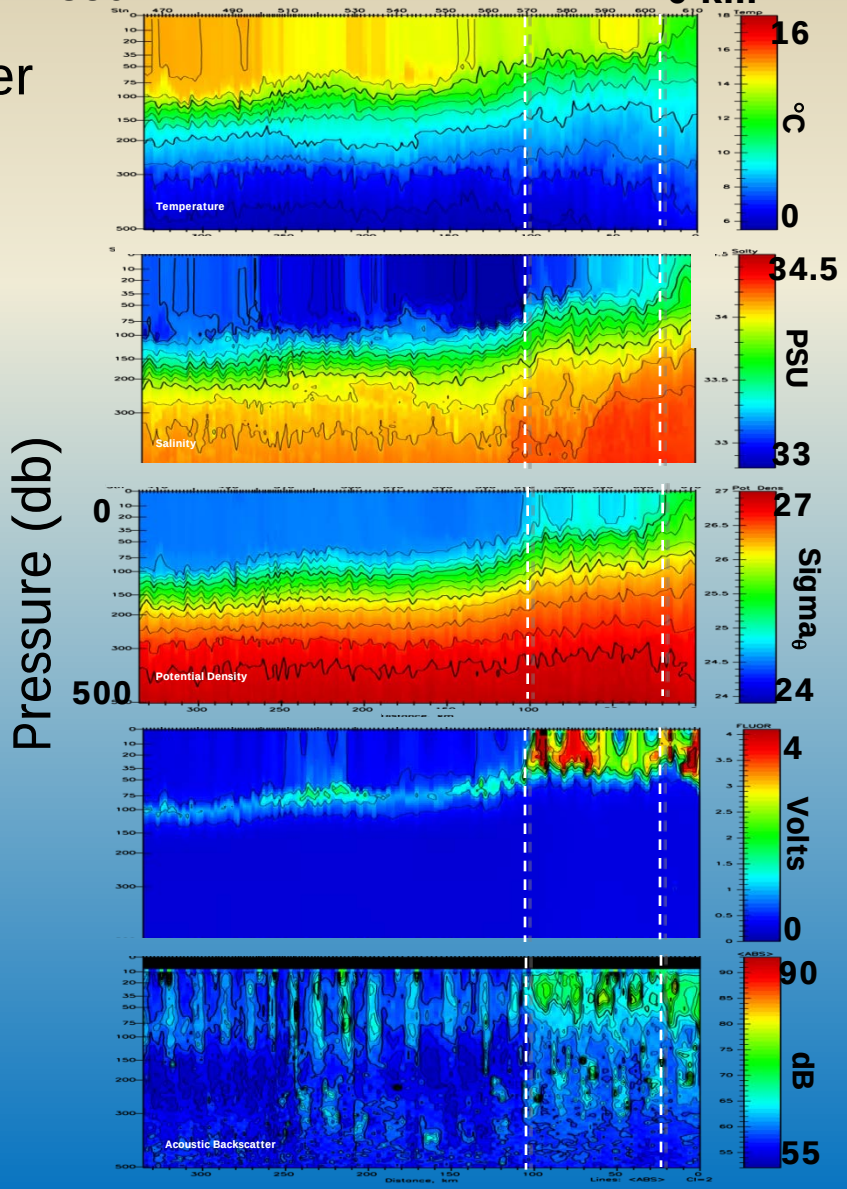
offshore — **Line 80 Section** — nearshore (off Pt. Conception)

350 km ◄ 0 km

Spray ocean glider

Russ Davis,
Dan Rudnick,
Mark Ohman

Jesse Powell
Scripps, CCE
graduate student



Temperature

Salinity

Potential Density

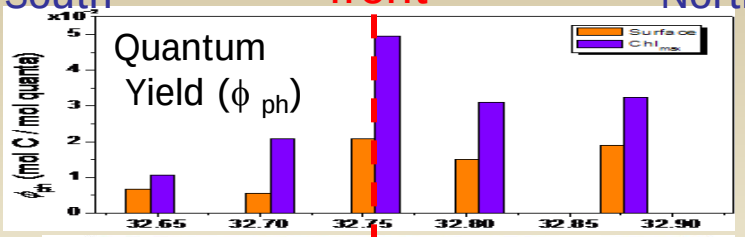
Chlorophyll-*a*

Acoustic Backscatter
(750 kHz)

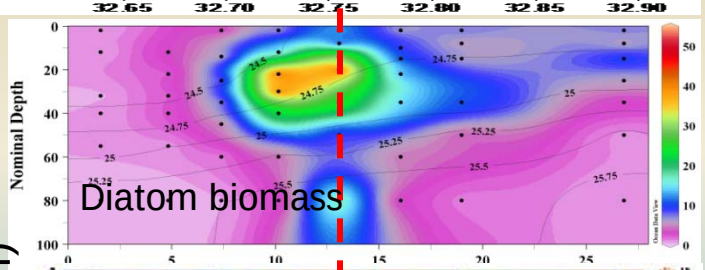
Sections across the “A-Front”

South front North

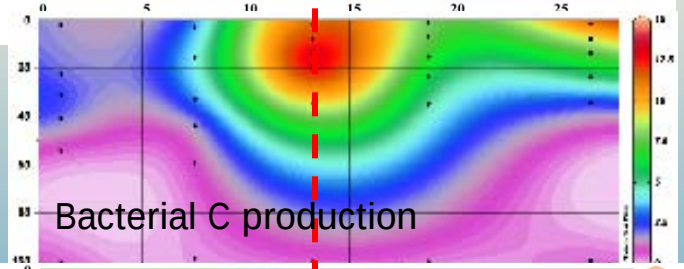
Wang



Taylor, Landry

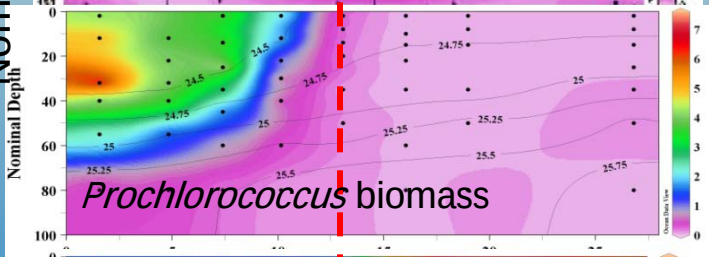


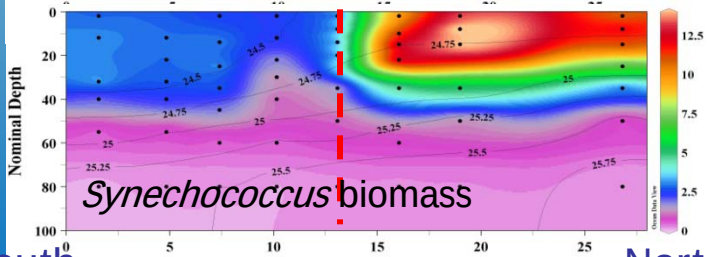
Symo, Azam



Nominal depth (m)

Taylor, Landry

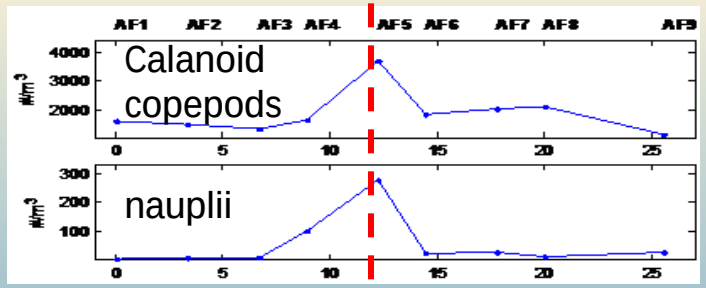




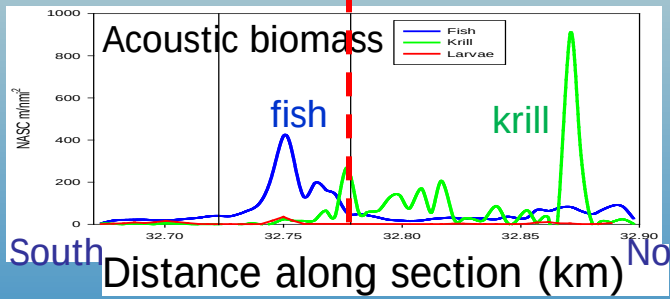
South Distance along section (km) North

Ocean hotspots

Total Biomass > 202 µm



Ohman



Koslow, Lara-Lopez

(offshore, Southern CA Current)

Coda:

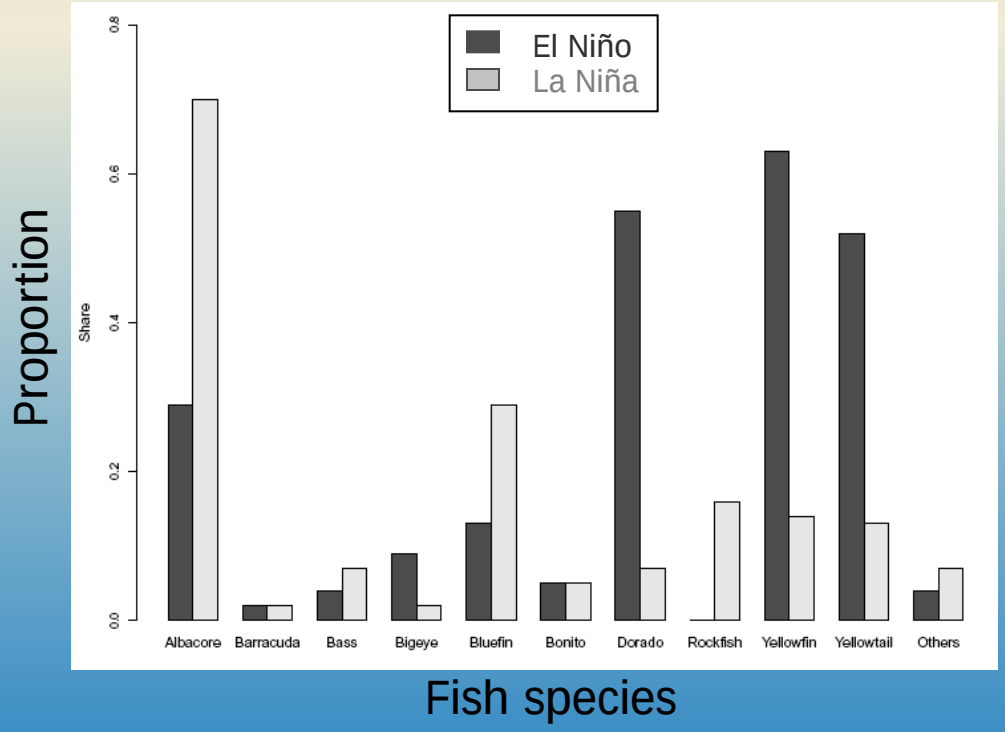
Human perceptions of

(and responses to) Climate Change

Part of the

LTER Maps and Locals (MALS) project:

Fish species landed in San Diego during El Niño or La Niña



Zhang et al. (in review) *Fishermens' perspectives on climate variability*

Interviews with captains of commercial passenger fishing vessels (CPFVs)

Only 12.9 % of these respondents unambiguously agreed that climate change is a possibility

The broader American public, in 2010:

71% (Yale) 74.5% (Stanford)

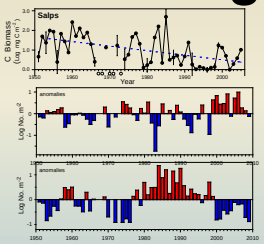
Time frame: April to July 2010
Locations: Mission Bay and Point Loma
Total effective samples: 62 (total number of CPFVs in these two locations in 2009: 83)

Summary

Examples of climate influences on the California Current Ecosystem LTER site:

Processes operate on multiple, interacting time scales

- Progressive, long-term changes
- Interannual
- Interdecadal

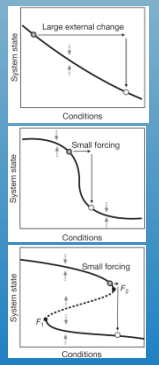


Importance of the spatial dimension in climate responses

- Wind stress curl vs. coastal boundary upwelling
- Possible nonlinear effects of ocean “hot spots”

Best conceptual model for biotic responses ?

- Linear tracking of the physical environment
- Thresholds
- Fold bifurcation with stabilizing mechanisms

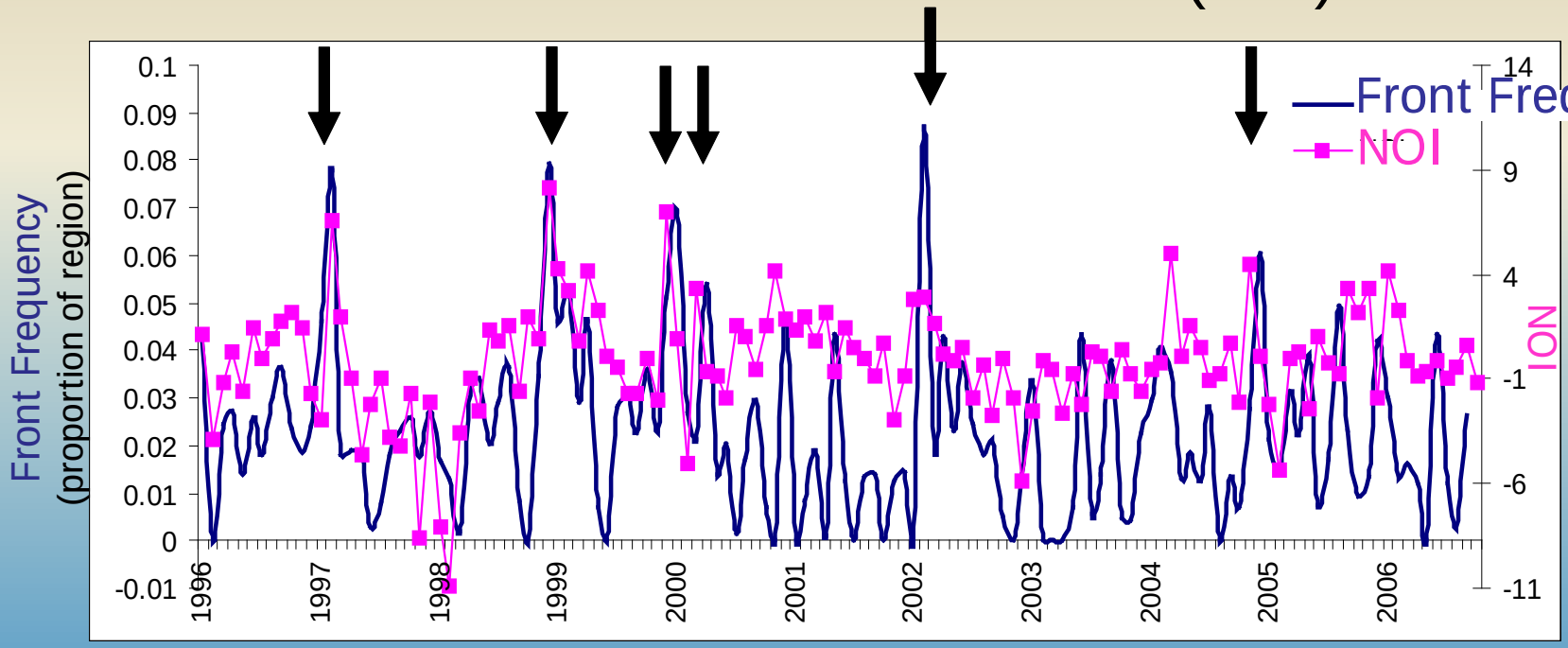


fin

Long-Term Variability in Front Frequency

satellite SST imagery

Related to variation in climate (NOI)



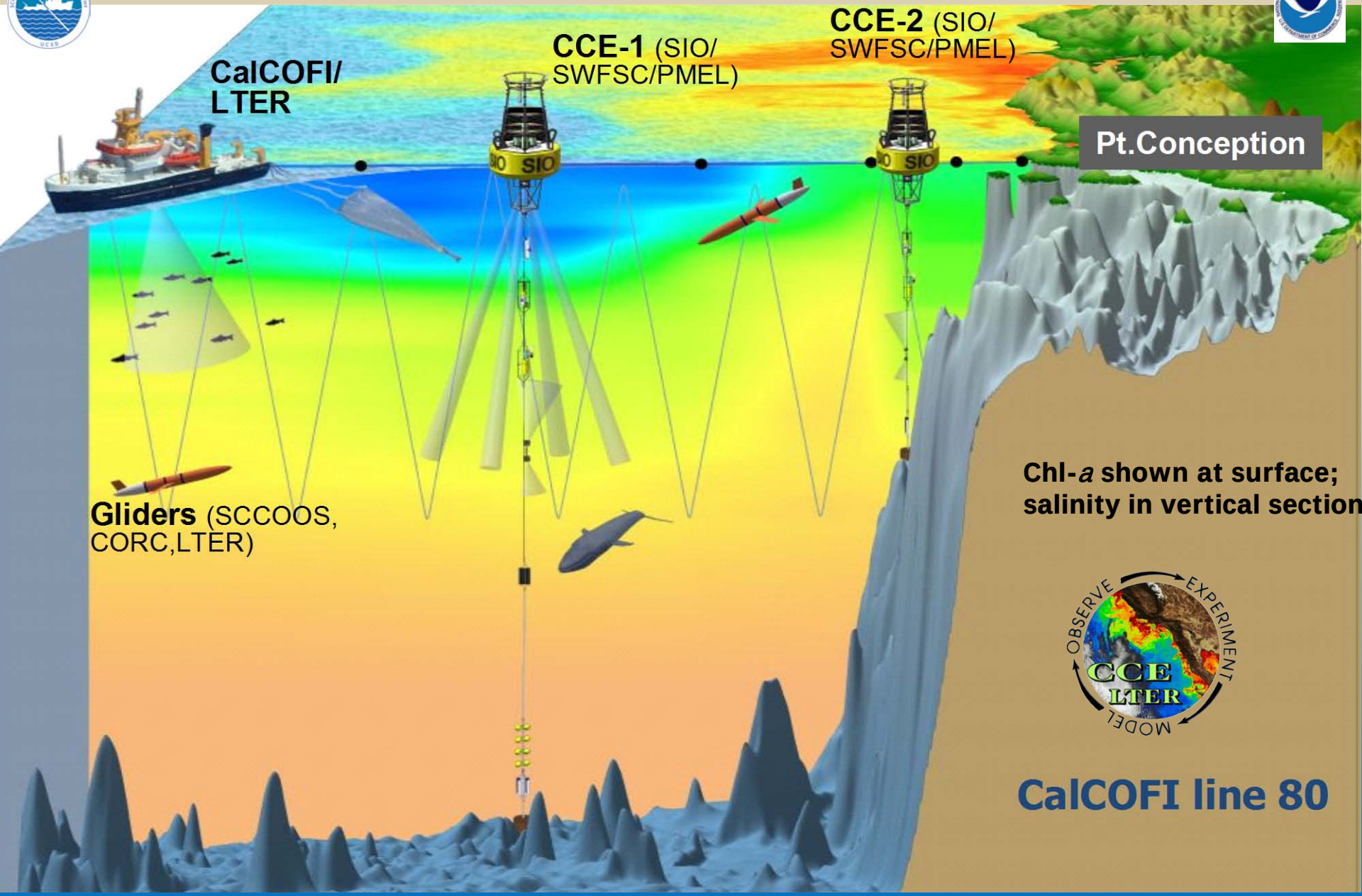
Southern California Current

Arrows indicate coincident peaks

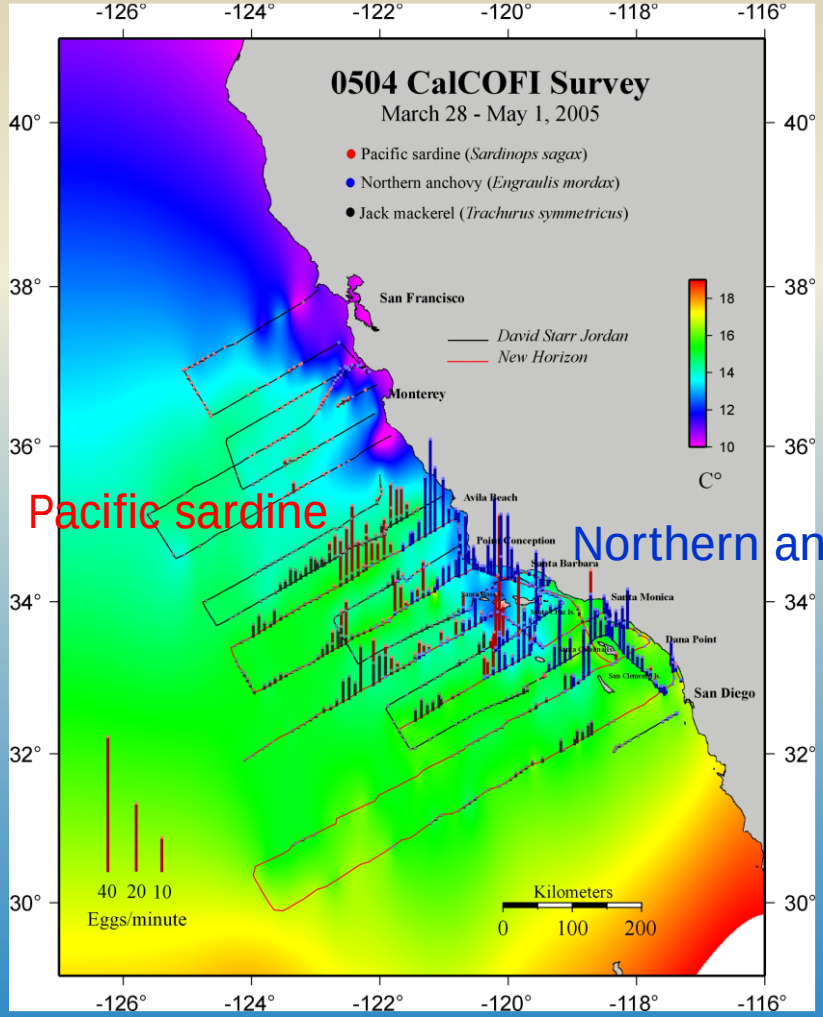
Kahru and Manzano (in prep.).

End-to-end Observing System – Southern California Current System

pCO_2 to marine mammals, integrated with 4D ocean modeling



Spawning of small pelagic fishes
CalCOFI egg survey (CUFES)



Southwest Fisheries Science Center
National Marine Fisheries Service

Preliminary study of an Oceanic Front