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

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U.S. LTER Network - 26 sites
including terrestrial, aquatic, & human-dominated ecosystems
Preferred state A

Preferred state B

System state

Conditions

Small forcing

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

- Temperature
- Density
- Stratification

Lavaniegos & Ohman (2007) *Progress in Oceanography*
Kim and Miller (2007) *J. Physical Oceanography*
Sta. M deep-sea benthic observatory

K. Smith
POC fluxes, SCOD, benthic macrofauna interactions
4100 m deep

Sta. M

Ocean Surface waters

Links to Biogeochemistry
Deep Sea C fluxes?

Salps

C Biomass (Log mg C m$^{-2}$)

Year


0.0 1.0 2.0 3.0

Export fluxes
Long-Term Decrease in Ocean Transparency

(Secchi disk depth)

Aksnes and Ohman 2009
Exchanging Space for Time
Spatial differences in Transparency affect zooplankton vertical distributions

Changes in transparency over time

Copepod Diel Vertical Migration vs. water column transparency

Planktonic Copepods

Ohman & Romagnan (in prep)
Importance of long term research: detecting thresholds of change
Southern California

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
Ohman and Di Lorenzo (in prep)

Brinton data source - CalCOFI
Interdecadal variability
PDO

Nyctiphanes simplex

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

Rykaczewski and Checkley (2008) PNAS
Zooplankton body size is proportional to upwelling velocity.

Wind stress curl driven upwelling: sardine

Coastal boundary upwelling: anchovy

Rykaczewski & Checkley 2008 PNAS
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

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"

Quantum Yield (φ_{ph})

Latitude 32.70 32.75 32.80 32.85 32.90

NASC m/nmi^2

0 200 400 600 800 1000

Fish Krill Larvae Calanoid copepods nauplii

Synechococcus biomass Bacterial C production Prochlorococcus biomass

Wang Taylor, Landry Symo, Azam Taylor, Landry

Ocean hotspots

Total Biomass > 202 µm

Calanoid copepods nauplii

Acoustic biomass

Distance along section (km)

( 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

Related to variation in climate (NOI)

Arrows indicate coincident peaks

Kahru and Manzano (in prep.).
End-to-end Observing System - Southern California Current System

pCO₂ to marine mammals, integrated with 4D ocean modeling

CalCOFI/LTER

CCE-1 (SIO/SWFSC/PMEL)

CCE-2 (SIO/SWFSC/PMEL)

Pt. Conception

Chl-α shown at surface; salinity in vertical section

CalCOFI line 80
Spawning of small pelagic fishes
CalCOFI egg survey (CUFES)
Preliminary study of an Oceanic Front

"A-front" study

SST (°C)