The State of the Central California Ecosystem

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Roadmap

• What is an ecosystem?
• The ocean is much more changeable than we thought
• Changes are not uniformly distributed
• Strong coupling between physical environment and biological populations
• Global physics, local or regional ecosystem responses
• Last few years upwelling favorable winds
• have been weak/delayed and ocean has been more stratified
Ecosystem

- a functional unit consisting of all the living organisms (plants, animals, and microbes) in a given area, and all the non-living physical and chemical factors of their environment, linked together through nutrient cycling and energy flow. An ecosystem can be of any size—a log, pond, field, forest, or the earth's biosphere—but it always functions as a whole unit
What determines the state?

- The physical and chemical environment
- Biotic interactions (competition and predation) – not covered here

What determines the environment?

- Natural cycles
- Humans
Model of the Pacific at 12.5 km resolution – Sea Surface Temperature (SST)

Yi Chao, JPL
Environment varies at many scales

- Global
- Basin
- Local
An Introduction to Anomalies

Temperature

Chlorophyll

1989 to 2007

2004
2005
2006

1989 to 2007

2004
2005
2006
International Panel on Climate Change indicates with 90% certainty that recent warming caused by fossil fuel emissions.
Strong Northern Hemisphere Bias in Recent Warming

Reynolds and Smith, 1981-2006
Regime shifts
It is a familiar story

El Niño | Child | La Niña
--- | --- | ---
El Viejo | Parent | La Vieja

1900 to 2000

MBARI time series
Let's focus on our local system
A major difference between terrestrial and marine ecosystems is that on land the primary producers can be seen with the naked eye while in the ocean powerful microscopes are needed.
The Central California Ecosystem – Study Beyond the Scope of Single Program
What was responsible for greening of California coastal waters?

- **Monterey Bay primary production**
- **Monterey Bay chlorophyll**
- **Southern California chlorophyll**
- **San Francisco Bay chlorophyll**

**Graphs:**
- A. Monterey Bay
- B. Monterey Bay
- C. CaKOFI
- D. San Francisco

Greening correlated with cooling and increase of nutrients at depth

Monterey Bay Temperature at Depth

Monterey Bay Nitrate at Depth

Monterey Bay Surface Chlorophyll

1984 to 2005
A large Humboldt squid caught offshore from Sitka in October 2004 is among numerous sightings of a species seen for the first time in waters of the Far North.
Ocean Temperature Cycles Impact Maternal and Pup Condition of Seals
Burney J. Le Boeuf, Daniel E. Crocker and Patricia Morris
Shifts in Deep-Sea Community Structure Linked to Climate and Food Supply

Henry A. Ruhl* and Kenneth L. Smith Jr.

www.sciencemag.org  SCIENCE  VOL 305  23 JULY 2004
Monterey Bay Time Series
- El Niños during 92-93 and 97-98
- Transition from El Viejo to La Vieja
- The age of dinoflagellates?

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A. Temperature, 0m

B. Water column stratification, 0-20 m

C. Nitrate, 60m

D. Chlorophyll, 0m

E. Dinoflagellates

The Age of Dinoflagellates?
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The Paleocene

- Dinoflagellates were prominent globally along coastal margins 55 million years ago when there was a rapid carbon release into the atmosphere and oceans, rivaling the present anthropogenic release of CO$_2$, and the world was significantly warmer.
Harmful Algae

Pseudo-nitzschia

Alexandrium

Diatom

Dinoflagellate

Mary Silver - UCSC/CIMT
PRBO Seabird Time Series

- measurements through time (abundance of birds, breeding success, food habits, etc.)
  - Farallones, Ano Nuevo, Alcatraz, etc.

![Point Reyes](image)

Farallon Island Field Station, USFWS & PRBO
2005: Unprecedented Breeding Failure

Cassin’s auklet (*Ptychoramphus aleuticus*)

Mean breeding success = 0.70

Sydeman et al. (2006)
2005, not a blip; 2006, the same

Blue Whales also absent in 2005 and 2006 (Don Croll – UCSC/CIMT)

Leatherback turtles also show unusual distribution (Scott Benson – NOAA/CIMT)
Questions:

- What will happen to coastal upwelling ecosystems under global warming?
- Will they stratify as seen recently with a predominance of dinoflagellates?
- Or will coastal upwelling intensify?
The northwest African margin is a coastal upwelling system. Sea surface temperature (SST) records from Moroccan sediment cores, extending back 2500 years, reveal anomalous and unprecedented cooling during the 20th century, which is consistent with increased upwelling. Upwelling-driven SSTs vary out of phase with millennial-scale changes in Northern Hemisphere temperature anomalies (NHTAs) and show relatively warm conditions during the Little Ice Age and relatively cool conditions during the Medieval Warm Period. These results suggest that coastal upwelling may continue to intensify as global warming and atmospheric CO2 levels increase.

McGregor, Dima, Fischer, Mulitza Science, 2/2/2007
Fish Scale Record from a core off Peru

Paleopeces (unpub. data)

Little Ice Age

Year (AD)

Mean percent Callao

62.8

31.0

Paleopeces (unpub. data)
A developing Paradox

- Observations from the modern record show that the entire globe warms during El Niño and El Viejo (see Science paper) and in coastal upwelling systems (at least in the Pacific) temperature goes up and biological productivity goes down. The opposite seems to happen during the Little Ice Age when the coastal upwelling system off NW Africa warmed and the coast of Peru became less productive. We must be looking at very different mechanisms ...

- Will there be more fish in a warmer world? Who knows but we will be in for many surprises. Our ocean observing, management and teaching need to “adapt” to this realization
Conclusions

- The State of the Ecosystem is strongly impacted by environmental variability.
- The last few years have seen a shallow thermocline and weak/delayed upwelling favorable winds.
- These changes could be the result of natural variability or human impacts or a combination of both.
- Current observing programs will provide the answer and must be continued.
Next Steps

• Formalize the integration process
• Identify and fill gaps – while MB/Central California among the most observed ecosystems there is still a formidable challenge ahead
• Look more carefully at land-sea fluxes
• Look more carefully at biotic interactions and introduced species
• Be adaptive