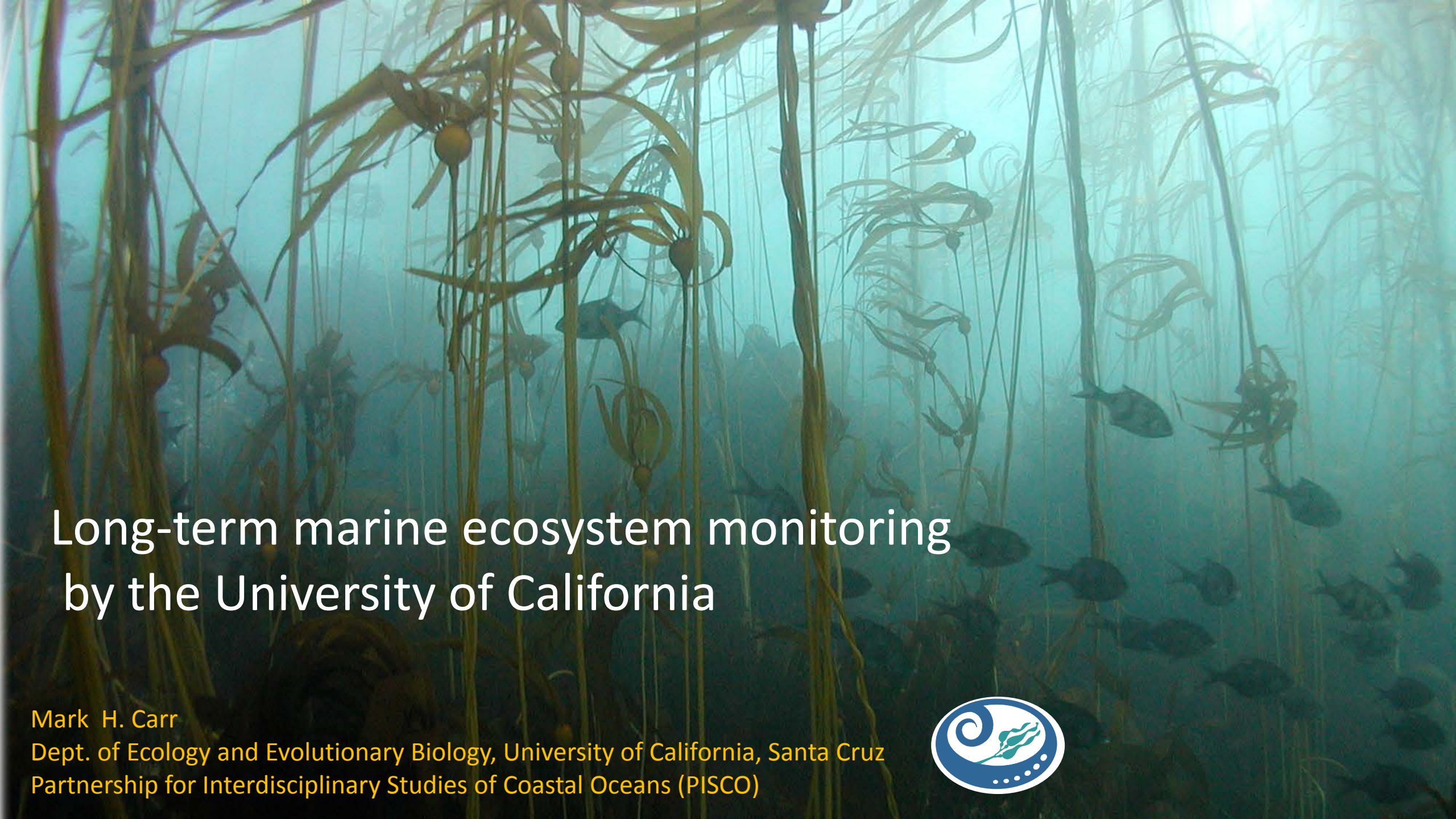


Long-term marine ecosystem monitoring by the University of California

Mark H. Carr
Dept. of Ecology and Evolutionary Biology, University of California, Santa Cruz
Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO)

Characteristics of UC Long-term Monitoring Programs

- Diversity of programs… generate a variety of solutions
- Each program informs multiple management and policy issues
- Reflects the value of long time series for interpreting change
- Reflects the value of real-time information to identify and explain change
- Maintained by creative blend of multiple funding sources

Examples of diverse applications

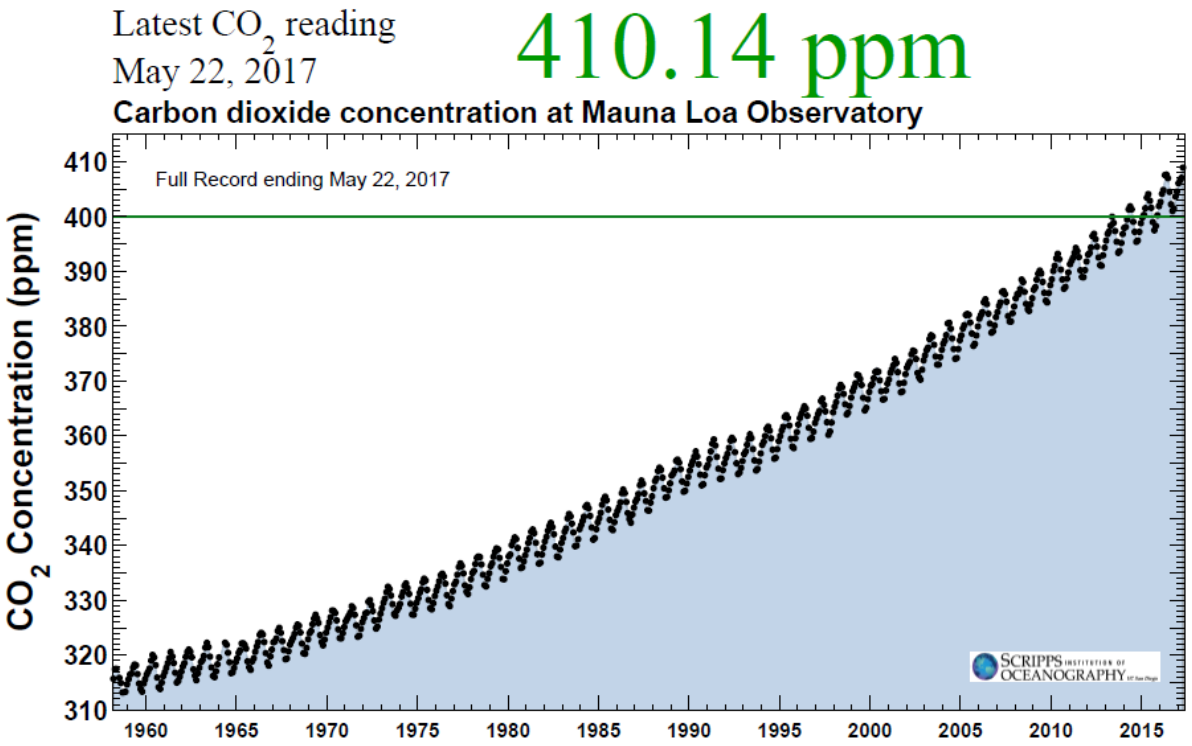
- Climate change
  - documenting
  - coastal vulnerability and climate adaptation
- Fisheries management
- Pollution
  - forecasting spatial patterns of impact
  - harmful algal blooms
- Emerging issues
  - climatic perturbations and epidemics
- Marine protected area networks
  - evaluation

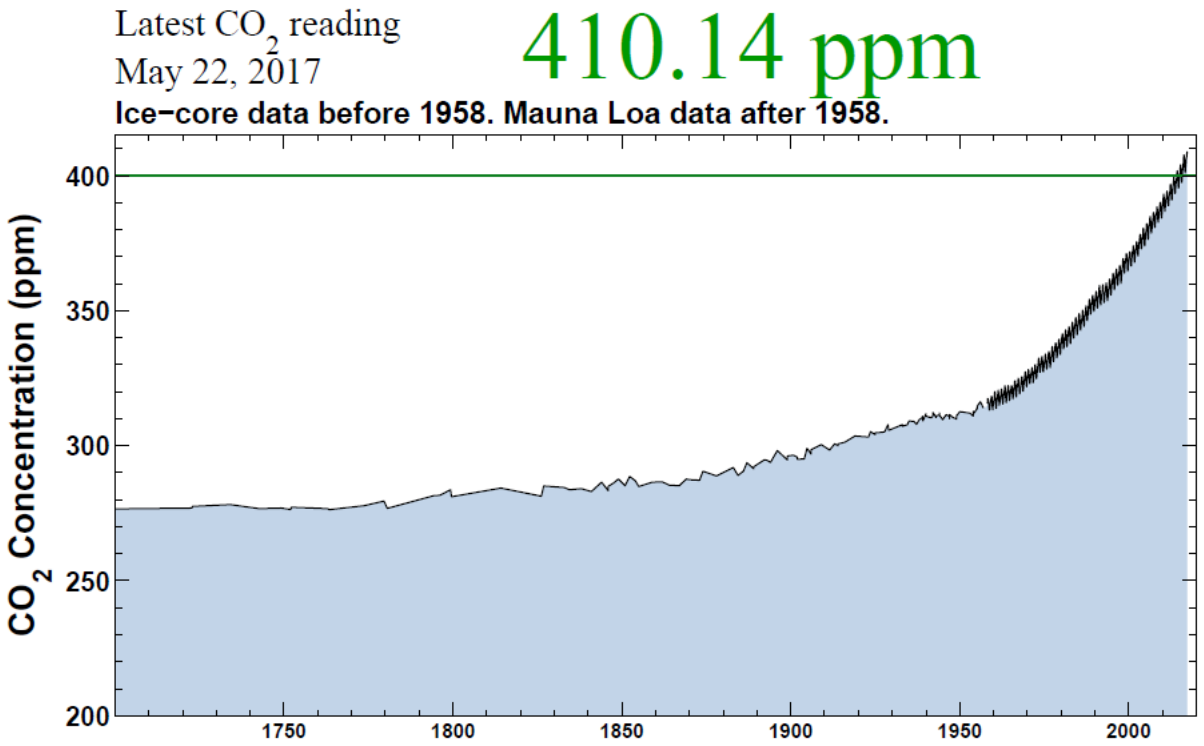
Climate Change – The Keeling Curve

(https://scripps.ucsd.edu/programs/keelingcurve/)

Researchers: Charles David Keeling and (son) Ralph Keeling - Scripps Institute of Oceanography

Purpose: To describe change in concentration of carbon dioxide in the atmosphere





Climate change - informing climate adaptation

Santa Barbara Coastal Long-Term Ecological Research program (http://sbc.lternet.edu)

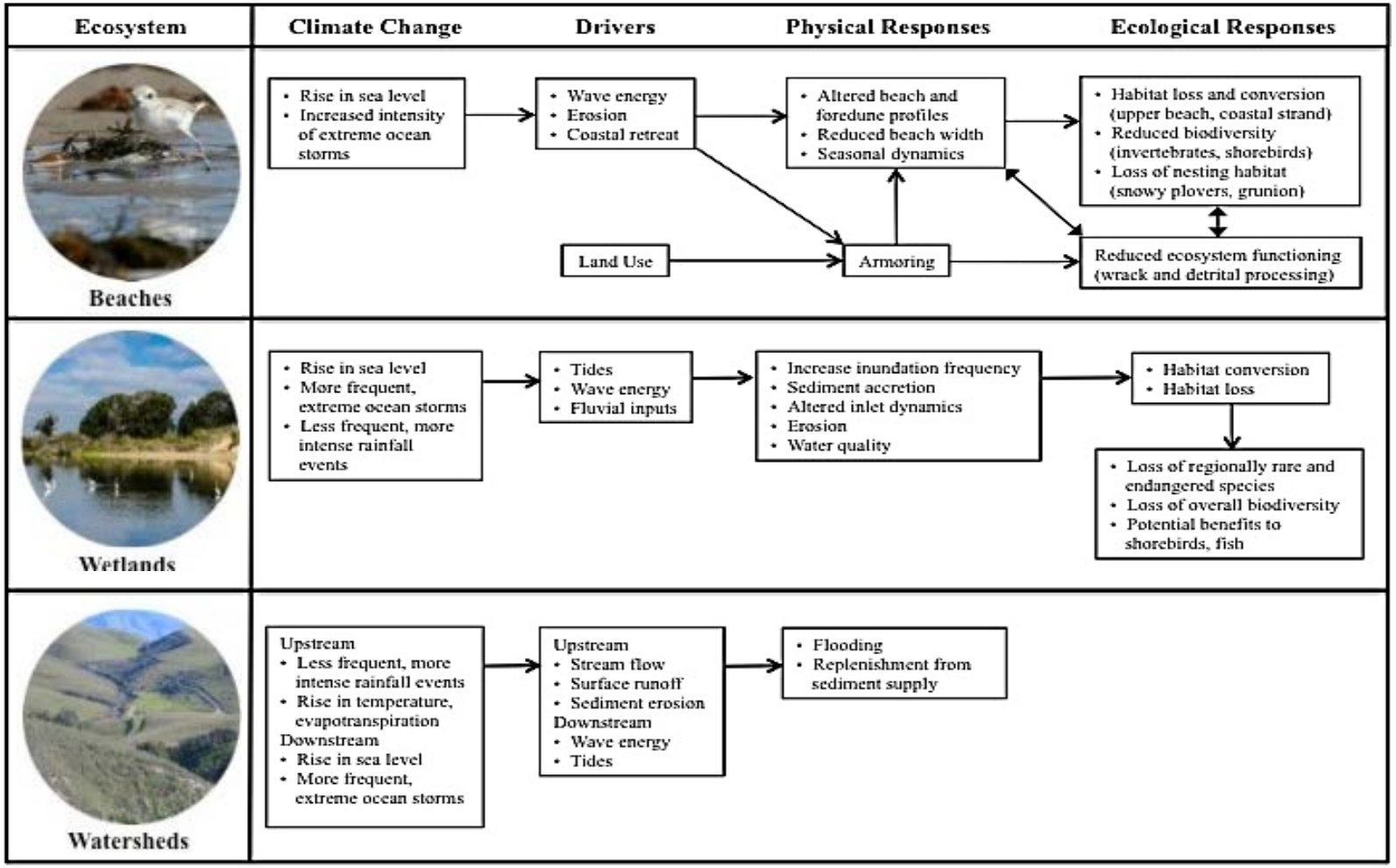
Researchers: Dan Reed (UC Santa Barbara) and others

History: seasonally; 2000 to present

Purpose: How kelp forests and their interaction with adjacent land and ocean ecosystems are altered by disturbance and climate

Climate adaptation planning

in collaboration with coastal planners



SBC LTER time series data are being used to investigate future changes in beaches, wetlands and coastal watersheds in response to predicted changes in climate and sea level rise

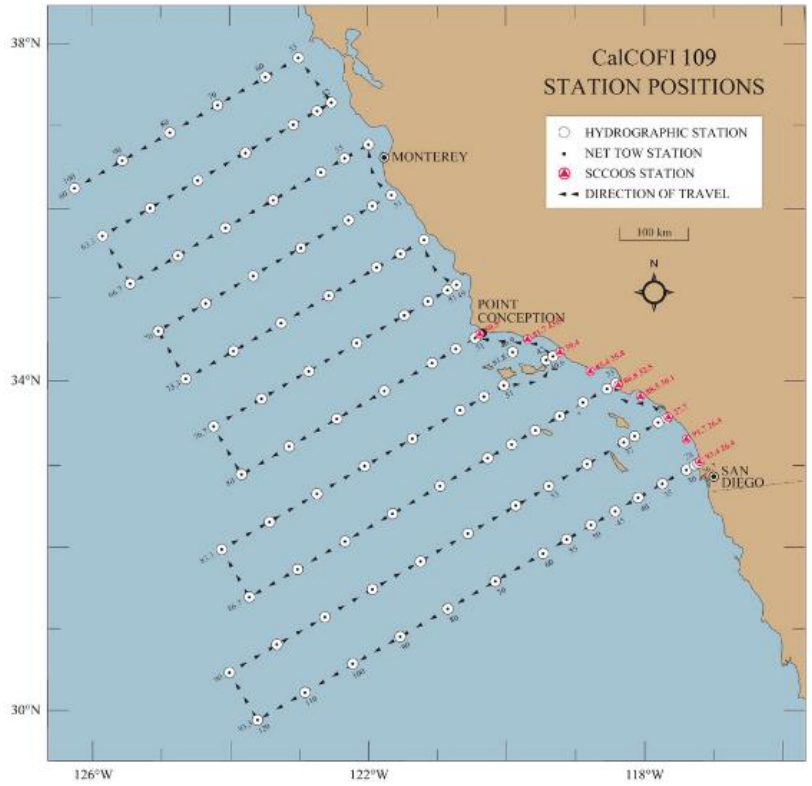
Fisheries, MPAs, Climate Change – CalCOFI

California Cooperative Oceanic Fisheries Investigation: http://calcofi.org

Researchers: David Checkley, Jr. (SIO) in partnership with CDFW & NOAA Fisheries Service

History: quarterly; 1949 to present

Purpose: To understand the southern California Current Ecosystem in support of living marine resource management



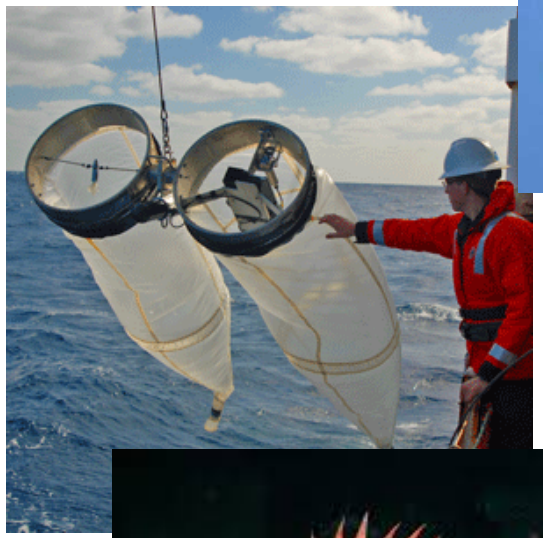
Fisheries, MPAs, Climate Change – CalCOFI

California Cooperative Oceanic Fisheries Investigation: http://calcofi.org

Fisheries management - Larval abundances (sardine, anchovy, market squid, spiny lobster, Dungeness crab) used to forecast and set fishing quota.

Marine protected areas - Efficacy of federal rockfish conservation areas (RCAs) by comparing larval production inside and outside of protected area.

Long-term change - Detecting and distinguishing long-term ocean variability (e.g., Pacific Decadal Oscillation) and climate change effects.



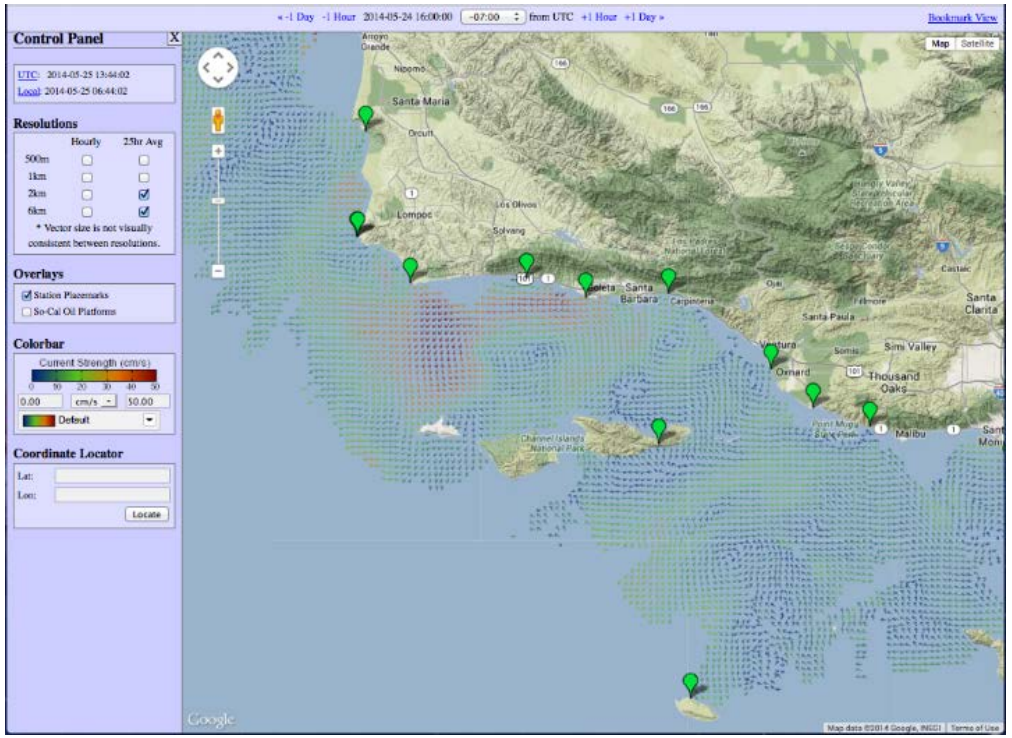
Pollution: Continuous Surveys of Ocean Currents - HF Radar Program

SCCOOS, CenCOOS (www.sccoos.org/; www.cencoos.org/)

Researchers: John Largier (UC D), Libe Washburne (UCSB)

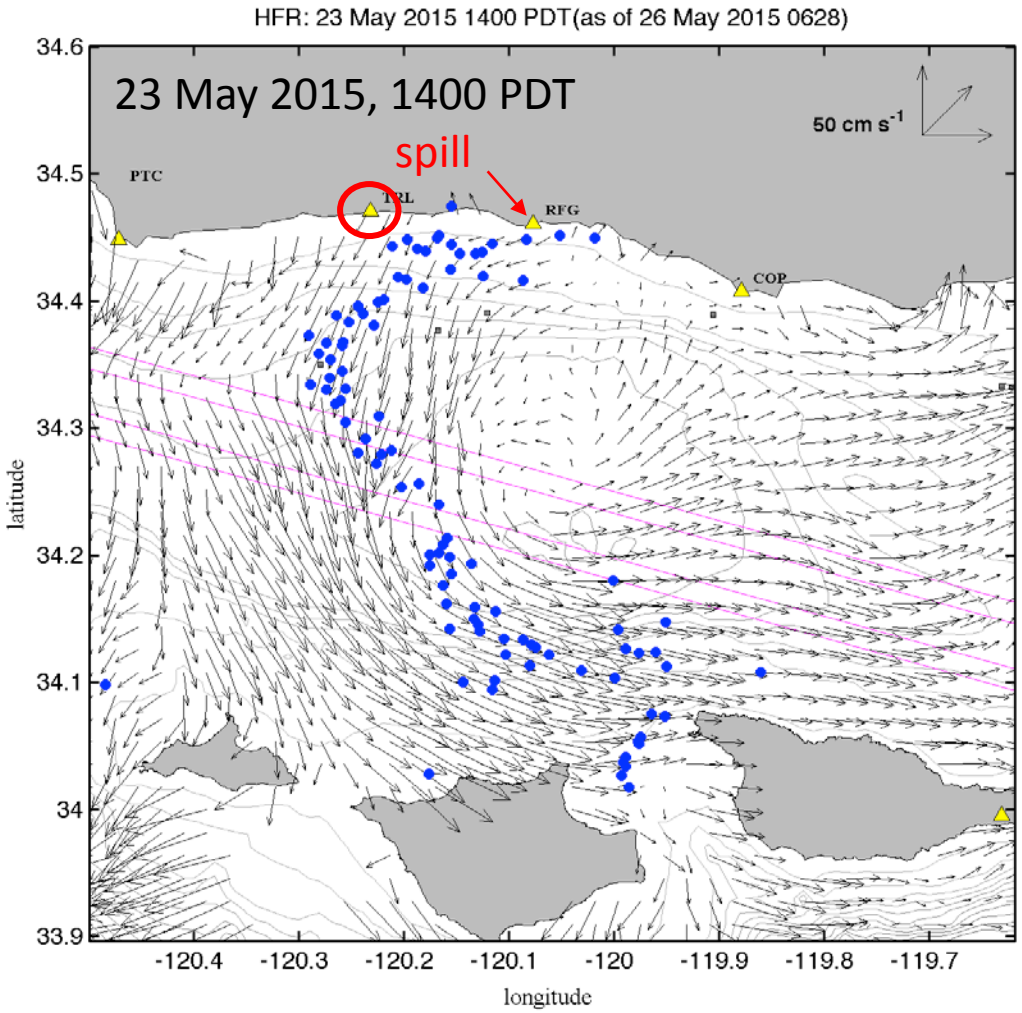
History: continuous in real time; 2005 to present

Purpose: Provide real-time estimates of surface currents to describe and predict the fate of anything transported by surface currents



Pollution: Continuous Surveys of Ocean Currents - HF Radar Program

SCCOOS, CenCOOS (www.sccoos.org/; www.cencoos.org/)



Also, predicts the movement of people who have fallen off boats to direct Coast Guard in real time. Estimated to have saved 50 lives.

Pollution: Harmful Algal Blooms – CalHABMAP

California Harmful Algal Bloom Monitoring and Alert Program - http://www.sccoos.org/data/habs/

Researchers: Raphael Kudela - UC Santa Cruz

History: @ 8 piers since 1990

Purpose: To predict, document and explain harmful algal bloom outbreaks and their ecological and human impacts

HAB Timeline

1987: Domoic Acid first identified, but linked to previous events

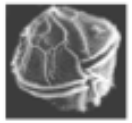
1991: DA discovered in Monterey Bay, Major bird mortality event

1995: L. polyedrum Red Tide (extending from Baja to Monterey, CA)

1998: P-n bloom along much of the US West Coast
Severe bird and marine mammal mortality

2002: More than 500 sea lion, 20 dolphin Seizures in Southern California

1987 1990 1992 1994 1996 1998 2000 2002



2000: Highest recorded DA values in Monterey Bay
Relatively few impacts on higher trophic levels

2003: Pseudo-nitzschia bloom in Santa Barbara, Massive DA concentrations

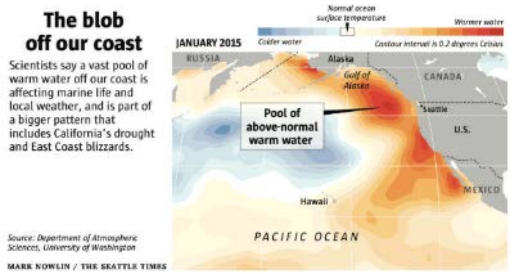
2015: The "warm blob" triggers Unprecedented west coast bloom

2006: Pelicans poisoned in Southern California; Linked to contaminated shellfish

AP Photo/Krista Niles

2007: Highest ever recorded DA in shellfish, Santa Barbara; DA poisoning from Los Angeles to Monterey

2012: most toxic shellfish in a decade



2004 2006 2008 2010 2012 2014 2016 The Future?

2006: Massive red tides in Monterey--shift to "Age of Dinoflagellates?"—causes bird stranding event

2009: Mass bird stranding linked to red tides in the Pacific Northwest

2011: Abalone die off in Sonoma Linked to red tide

2016: Return of massive red tides

Ecosystem responses to epidemic and climatic perturbation

Program: PISCO (www.piscoweb.org)

Researchers: Mark Carr

Institution: UC Santa Cruz

History: Yearly, since 1998

Purpose: To determine population and ecosystem responses to climatic events

Sampling methods: SCUBA surveys

sea star epidemic

"Blob" and El Nino

Ecosystem responses to epidemic and climatic perturbation

Program: CDFW and UC Davis
https://www.wildlife.ca.gov/Conservation/Marine/Invertebrates/Survey-Assessment-Project

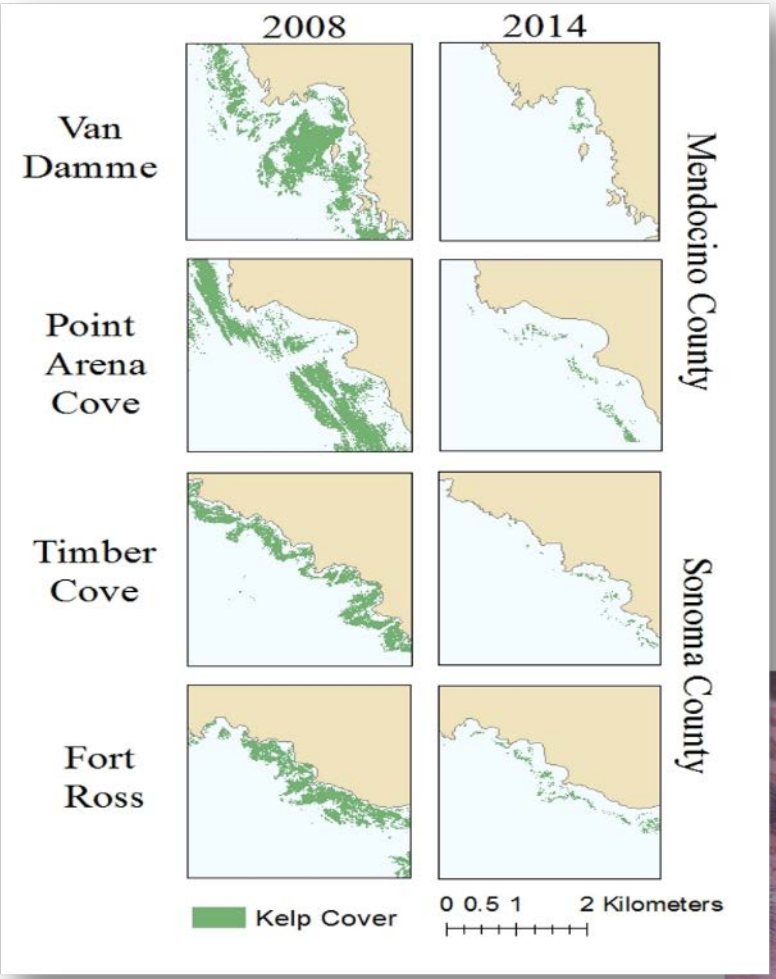
Researchers: Laura Rogers-Bennett and Cynthia Catton

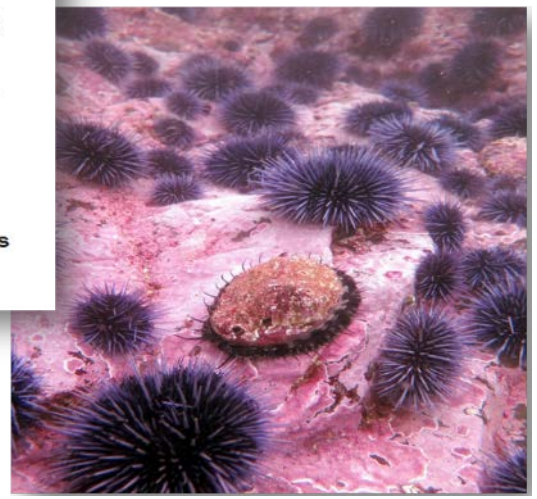
Institution: UC Davis Bodega Marine Lab

History: Yearly, since 1999

Purpose: To describe and explain kelp forest ecosystem dynamics and inform management of commercial sea urchin and recreational abalone fisheries

Sampling methods: SCUBA surveys





MPAs: Network Evaluation

Program: Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) (www.piscoweb.org)

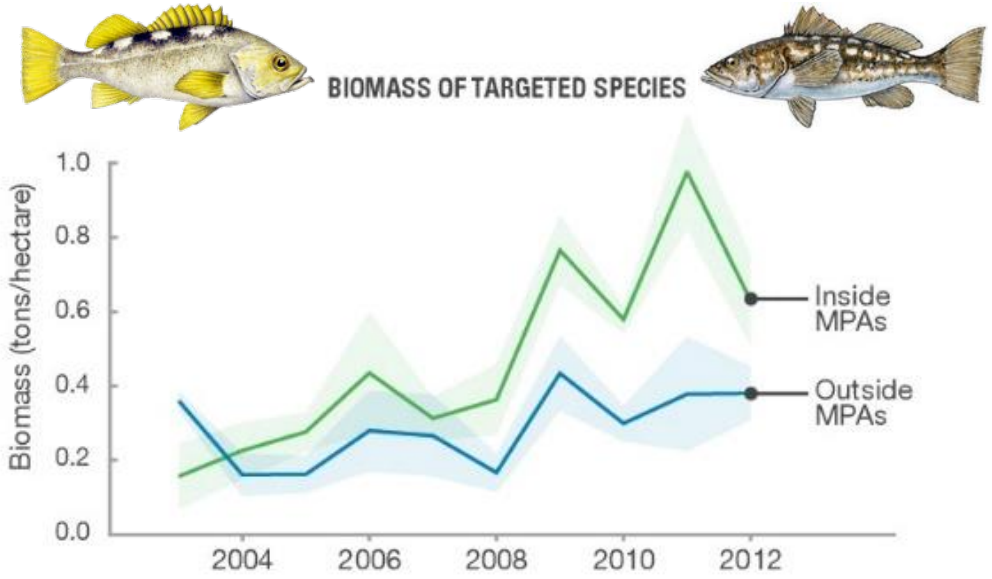
Researchers: Jennifer Caselle

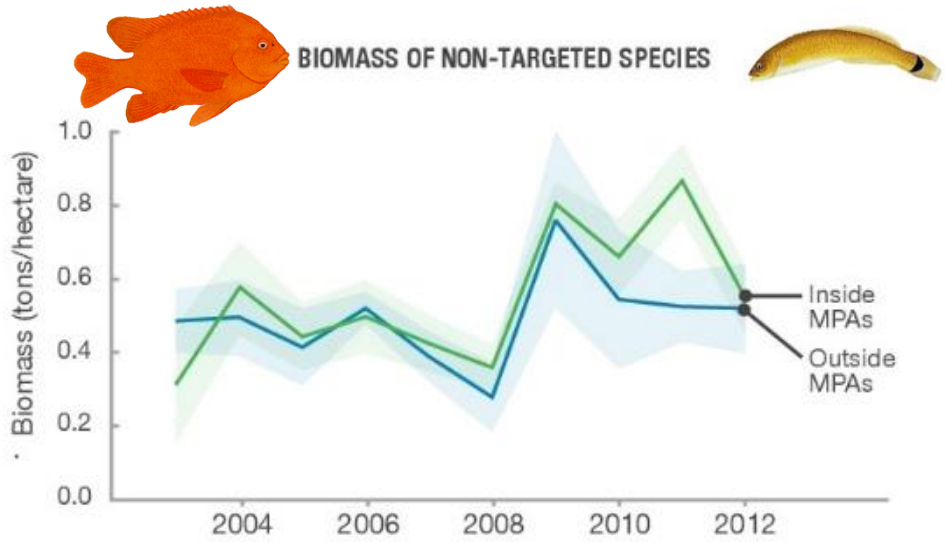
Institution: UC Santa Barbara (w/ UCSC, Stanford, Oregon State Univ)

History: Yearly, since 1998

Purpose: To determine population and ecosystem responses to MPA establishment

Sampling methods: SCUBA surveys





Caselle et al. 2015, Scientific Reports

Contributions of UC Long-term Monitoring Programs

- Diversity of programs… generate a variety of solutions
- Each program informs multiple management and policy issues
- Reflects the value of long time series for interpreting change
- Reflects the value of real-time information to catch and explain change
- Maintained by creative blend of multiple funding sources

Following are back-up slides, not for the talk

Long-term Continuous Monitoring of Ocean Temperature Informs Fisheries Management

Program: Scripps Institute of Oceanography Pier (https://scripps.ucsd.edu/programs/shorestations/)

Researchers: Aquarists and volunteers from the Birch Aquarium

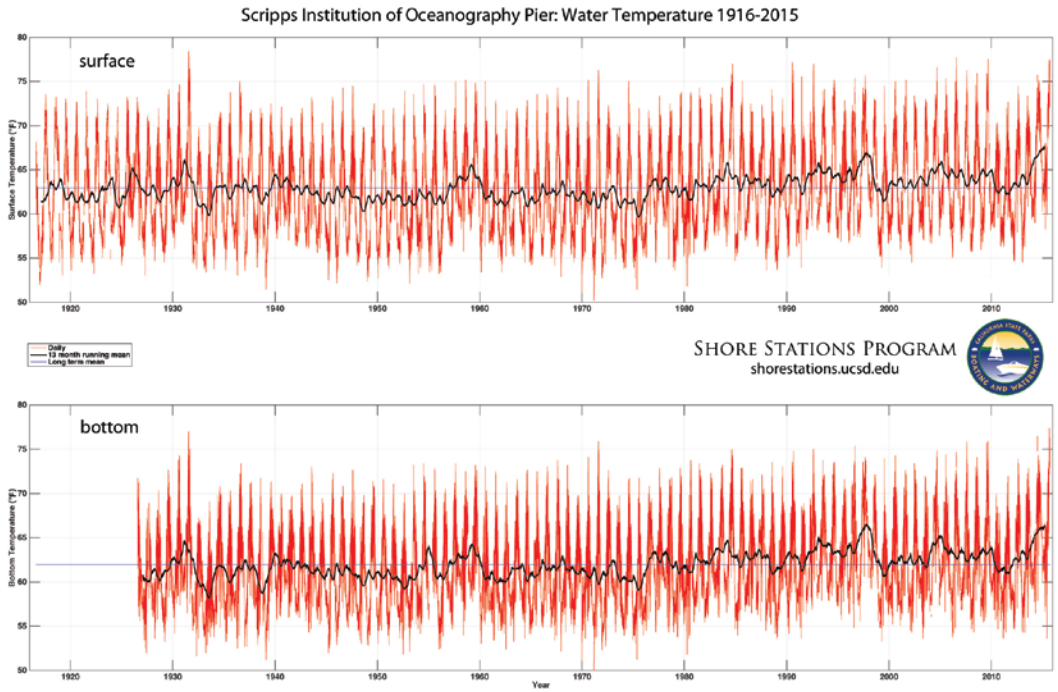
Institution: Scripps Institute of Oceanography

History: daily; 1916-present (surface), 1925-present (bottom)

one of the world's longest ocean time series, and the longest on the Pacific Rim

Purpose: To describe ocean temperature change

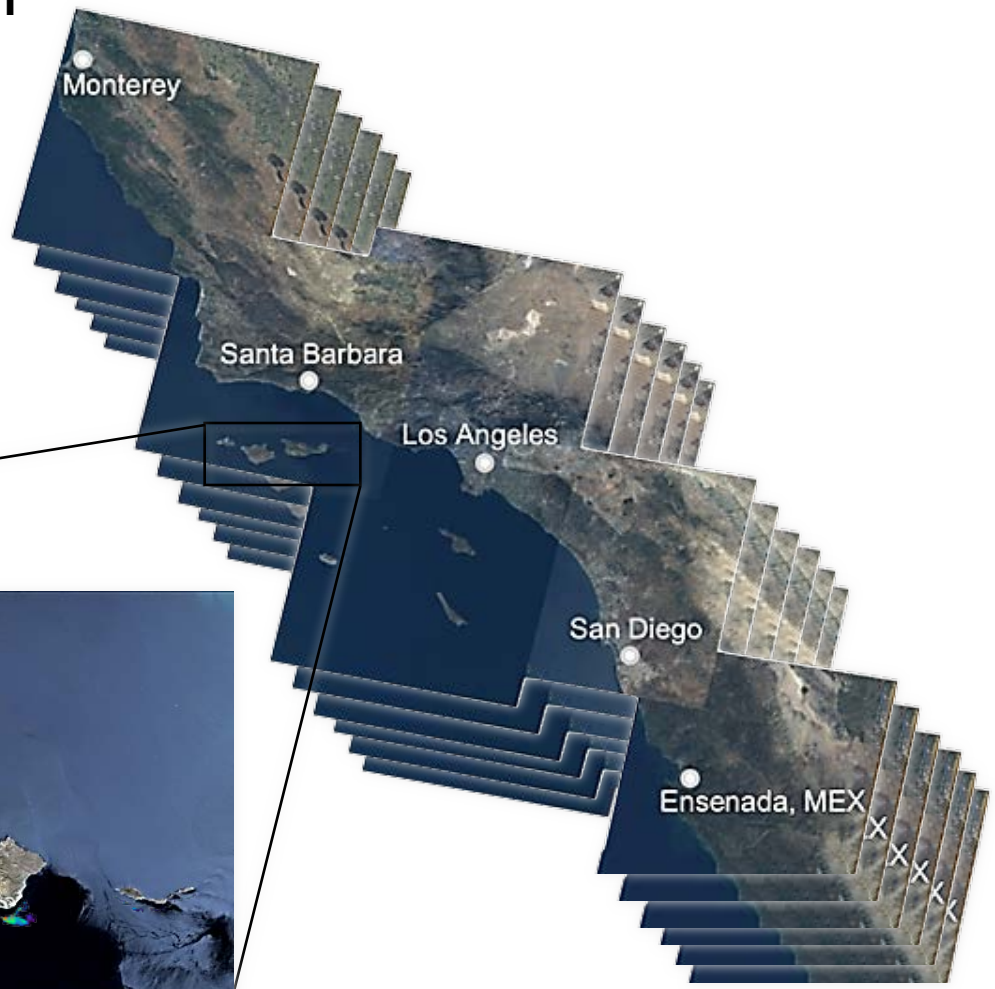
Sampling methods: Hand-held instruments



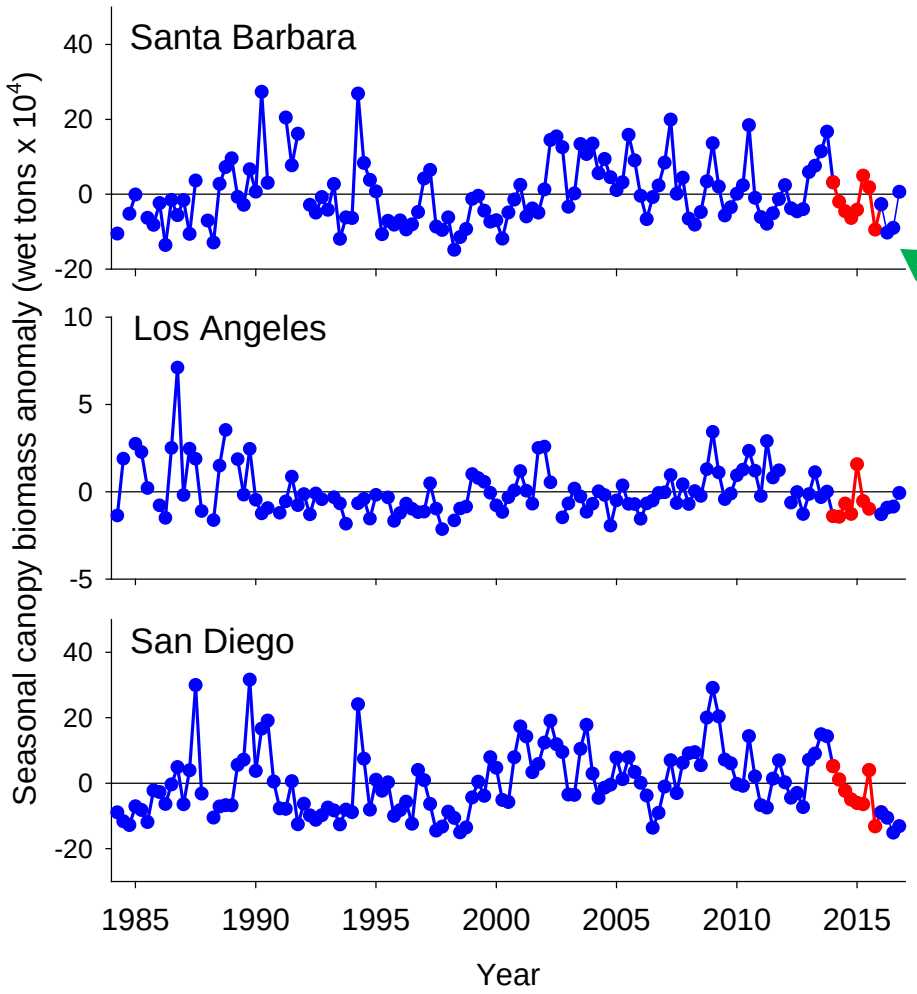
For decades, used in harvest control rule for Pacific sardine fishery (allowable take is reduced in cool periods unfavorable for sardine production).

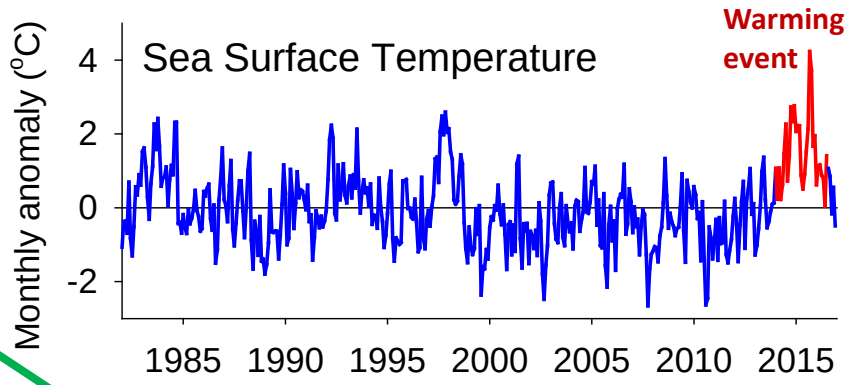
Novel SBC LTER data set uses Landsat ™ imaging to monitor giant kelp canopy biomass

- 30 m resolution imagery
- Spatially continuous coverage from Monterey to Magdalena Bay
- 1984 - present every 1-2 months
- Reflectance calibrated to biomass using long-term diver plots
- Useful for marine spatial planning, resource assessment and climate response



Landsat data show unremarkable response by giant kelp to extreme ocean warming event





The "Blob"
El Nino

Seasonal kelp anomalies during 2014-2016 were within the range observed during the 33-y time series despite unprecedented positive anomalies in ocean temperatures

The importance of California Current to Trans-Pacific Species

Program: Tagging of Pelagic Predators (TOPP); (gtopp.org)

Researchers: Dan Costa (UCSC) and Barbara Block (Stanford)

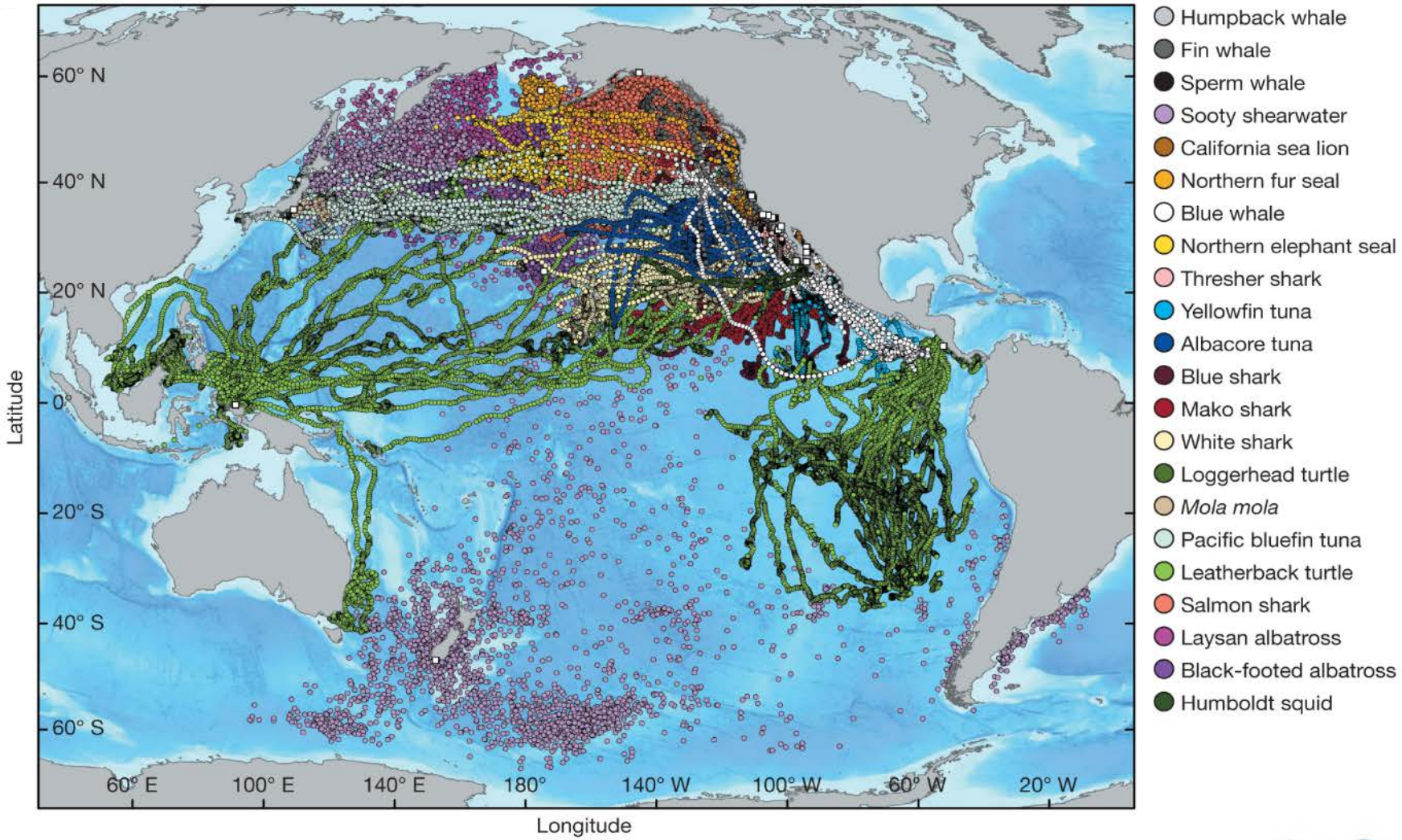
Institution: UCSC, Stanford and non-academic partners

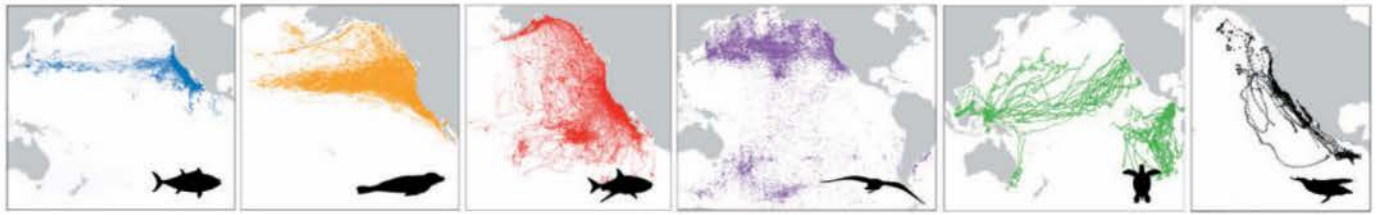
History: Continuous, 2000 - 2010

Purpose: To describe and explain movement patterns and habitat use of wide-ranging pelagic predators (sharks, tuna, swordfish, marine mammals, turtles, seabirds)

Sampling methods: remote-sensed telemetry instruments installed on animals

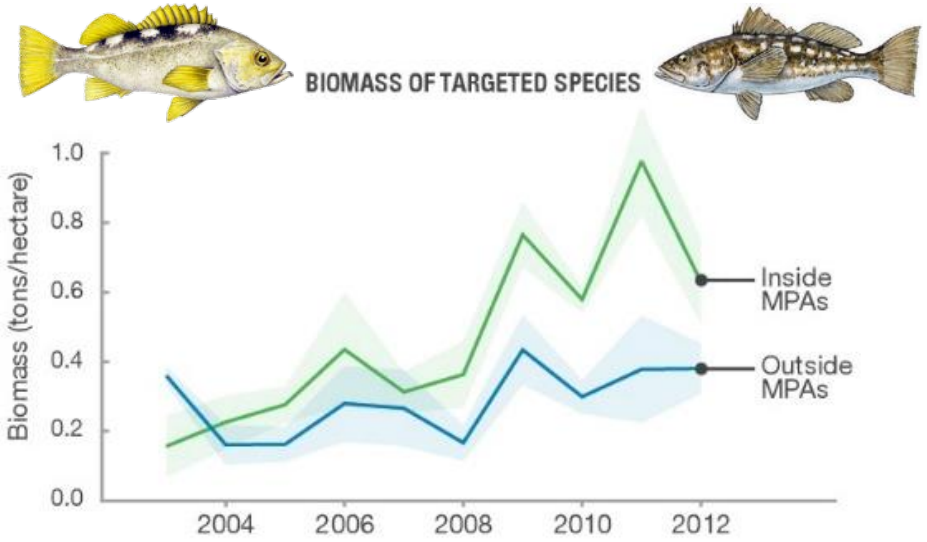
The importance of California Current to Trans-Pacific Species

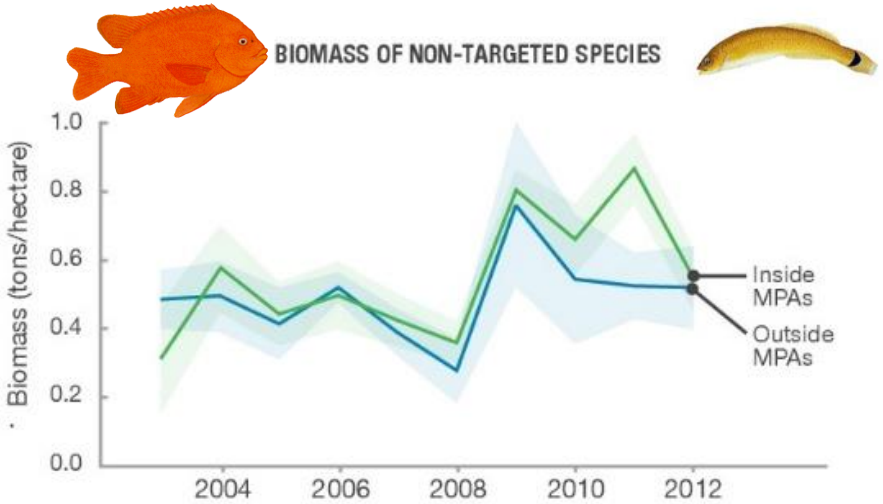


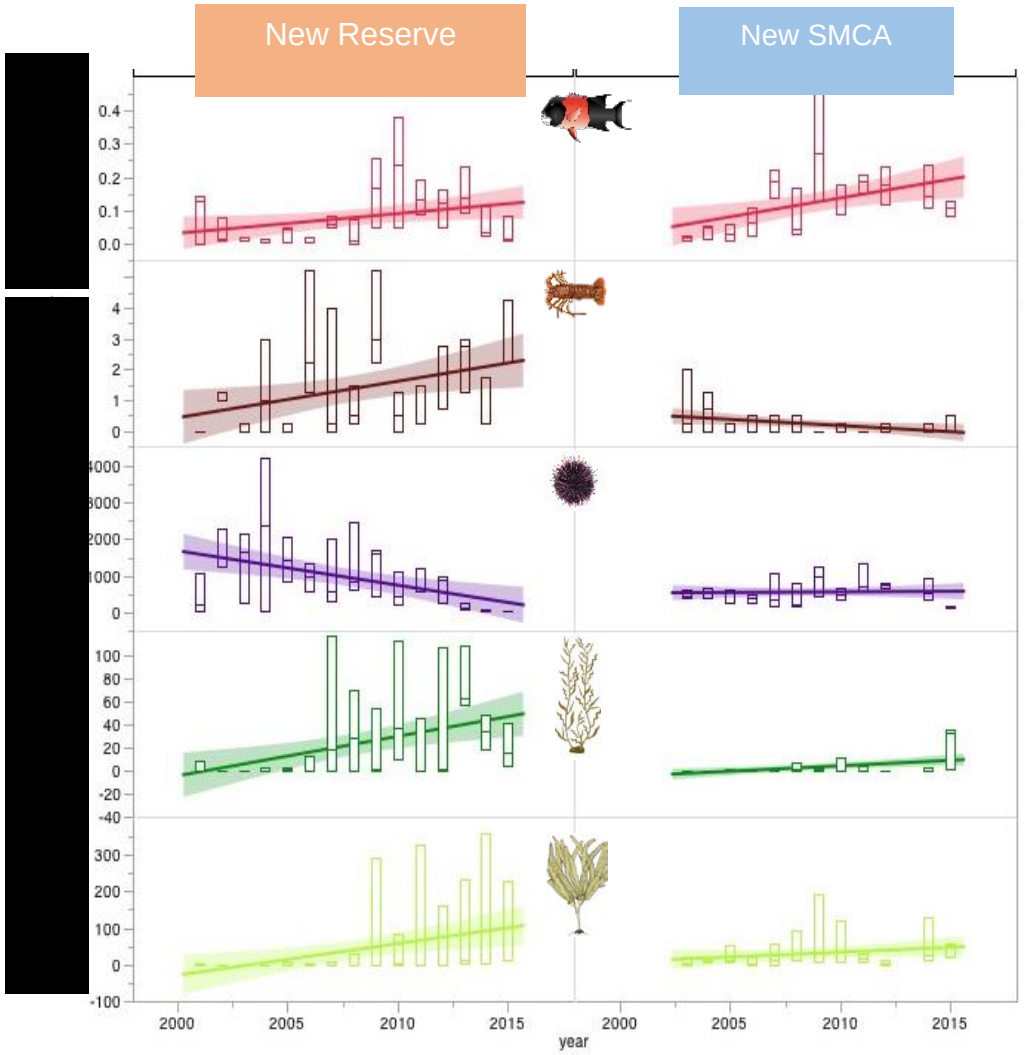


TOPP
Tagging Of Pacific Pelagics

Trajectories of fish biomass across Channel Islands MPAs over 10 years of protection



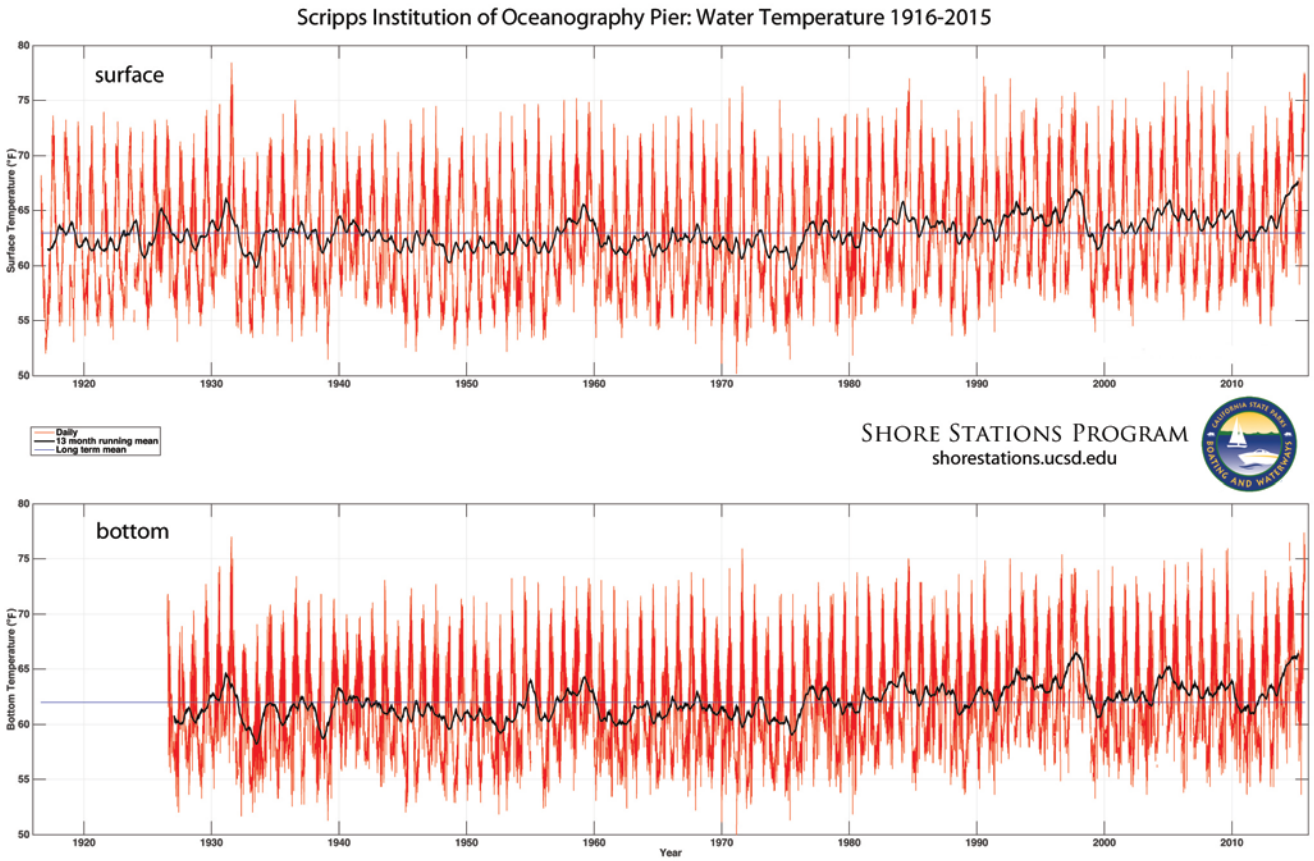




Caselle et al. 2015, Scientific Reports

Long-term Continuous Monitoring of Ocean Temperature Informs Fisheries Management

For decades, SIO Pier surface temperature used in harvest control rule for Pacific sardine fishery (cool temperature unfavorable for sardine and thus a smaller fraction of available sardine biomass allowed to be caught).



Examples of diverse applications

- Climate change
- Fisheries management
- Climatic perturbations
- Coastal vulnerability and climate adaptation
- Marine protected area networks
- Characterizing ecosystem responses to epidemics
- Harmful algal blooms (HABs)
- Importance of California Current to wide-ranging species