Santa Barbara Coastal LTER
Field Trip Booklet

Prepared for the National Science Foundation Site Review Team

October 20-22, 2015
Santa Barbara, CA

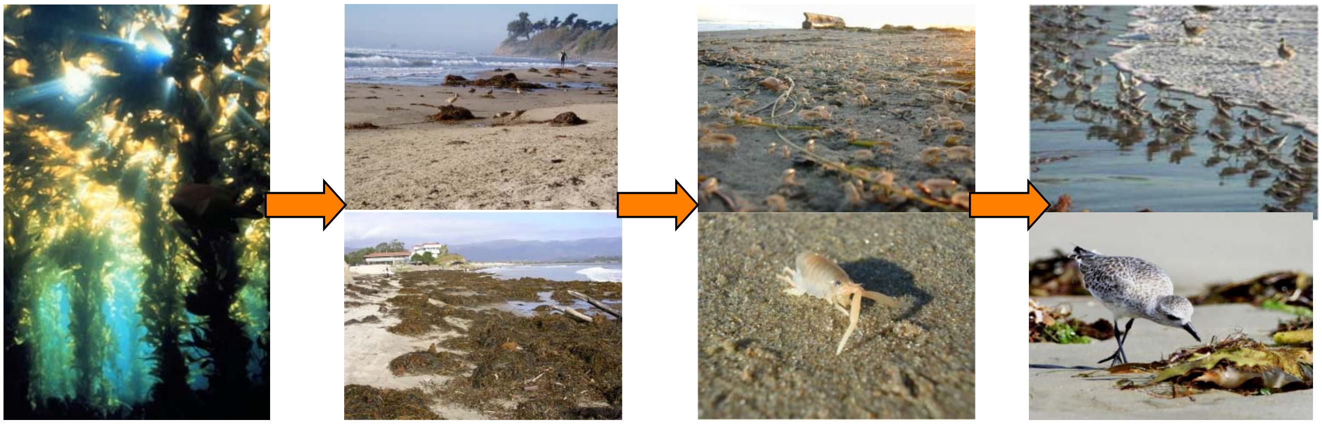
Santa Barbara Coastal
Long-Term Ecological Research

SBC III Field Trip Presentations

Kelp Forest Subsidies to Sandy Beach Ecosystems

Jenny Dugan, Mark Page, Dave Hubbard, Nicholas Schooler

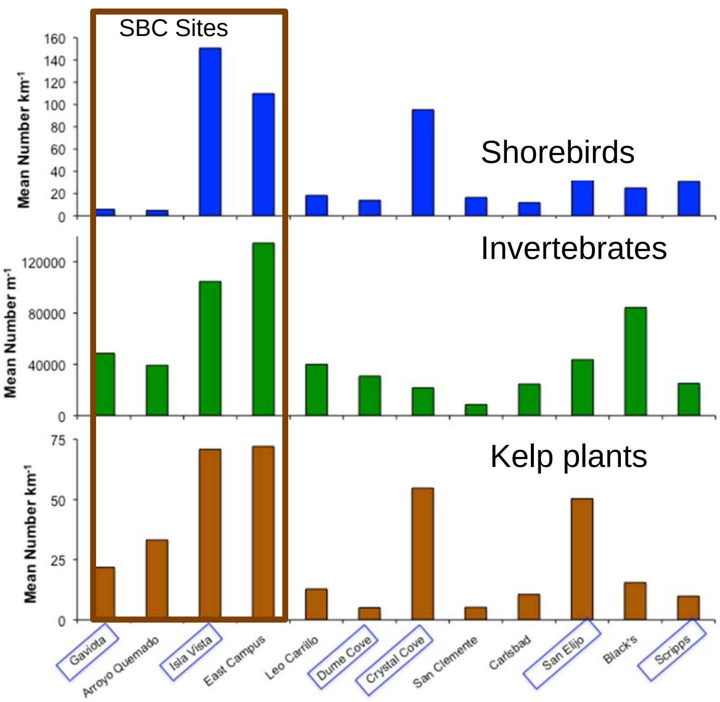
Kelp Forests | **Wrack Subsidies** | **Food Webs** | **Shorebirds**



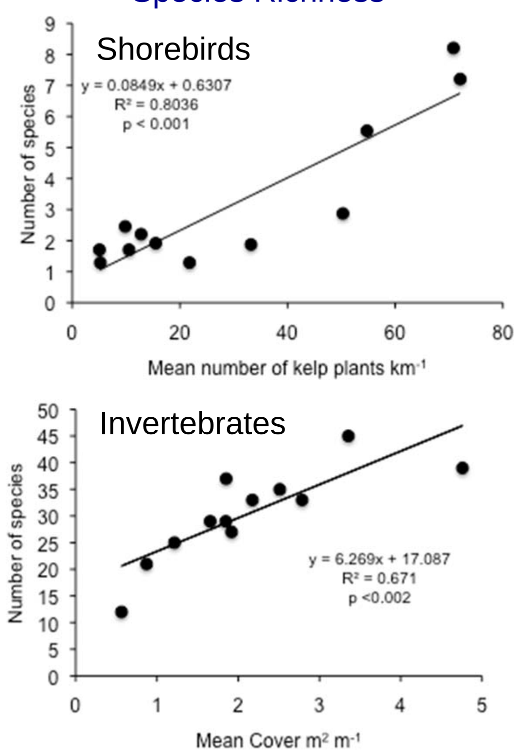
Kelp Forests	Wrack Subsidies	Food Webs	Shorebirds
High NPP Most is exported	High inputs to shoreline > 540 kg kelp m^{-1} year	Intertidal species ~40% associated with wrack	Wintering & Migration >28 species, 127 birds km^{-1}

Strong responses to kelp subsidies across trophic levels

Abundance



Species Richness



Subsidies from kelp forests support food webs and critical ecosystem functions on sandy beaches

Intertidal consumers can process kelp subsidies rapidly

Adult on kelp float

Kelp after 1 night

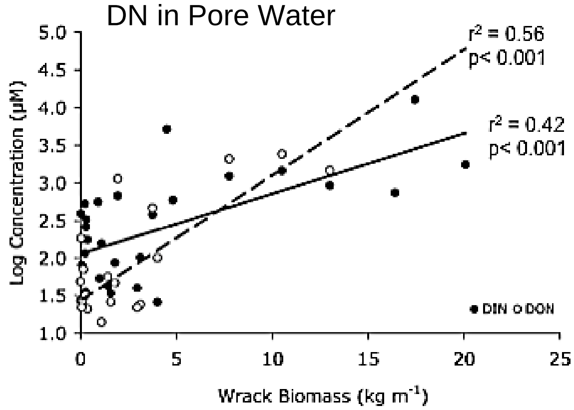
Juveniles on kelp

Abundant talitrid amphipod populations can eat up to 18 kg of kelp m^{-1} $month^{-1}$ in the summer

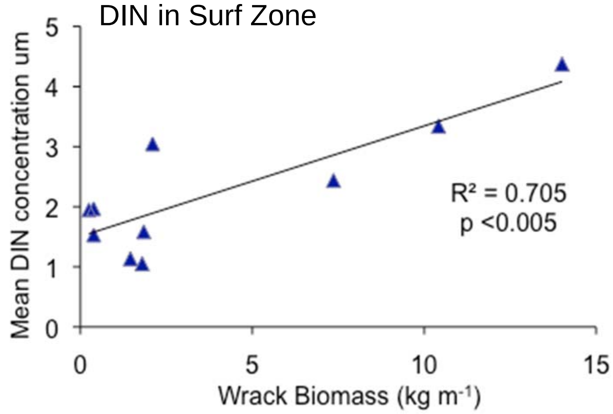
Subsidies of kelp wrack and intertidal nutrients

Dissolved nitrogen concentrations in saline intertidal pore water and in surf zone water were correlated with wrack biomass on the beach

DN in Pore Water

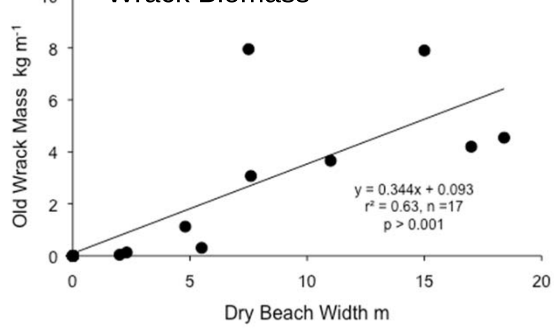


DIN in Surf Zone

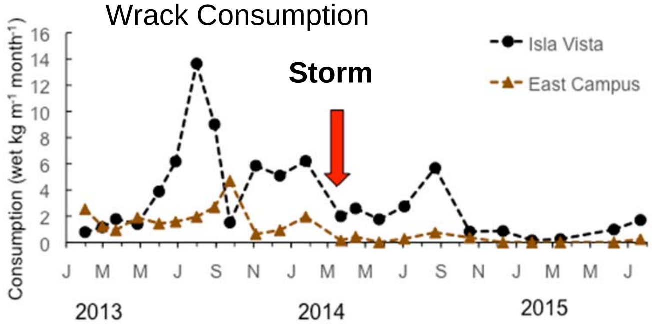


Beach conditions affect subsidies, consumption & DIN

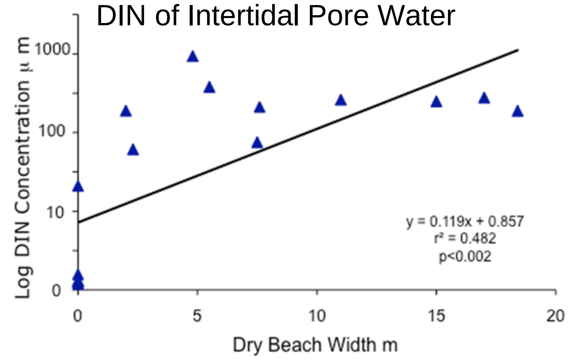
Wrack Biomass



Wrack Consumption



DIN of Intertidal Pore Water

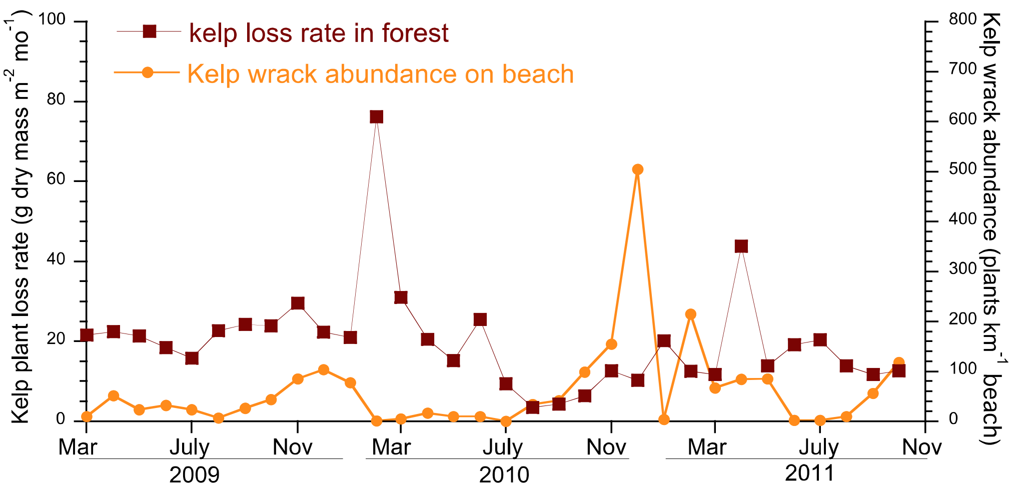


Patterns and processes affecting transport and retention of kelp subsidies

Bob Miller, Jenny Dugan, Carter Ohlmann, Dave Hubbard

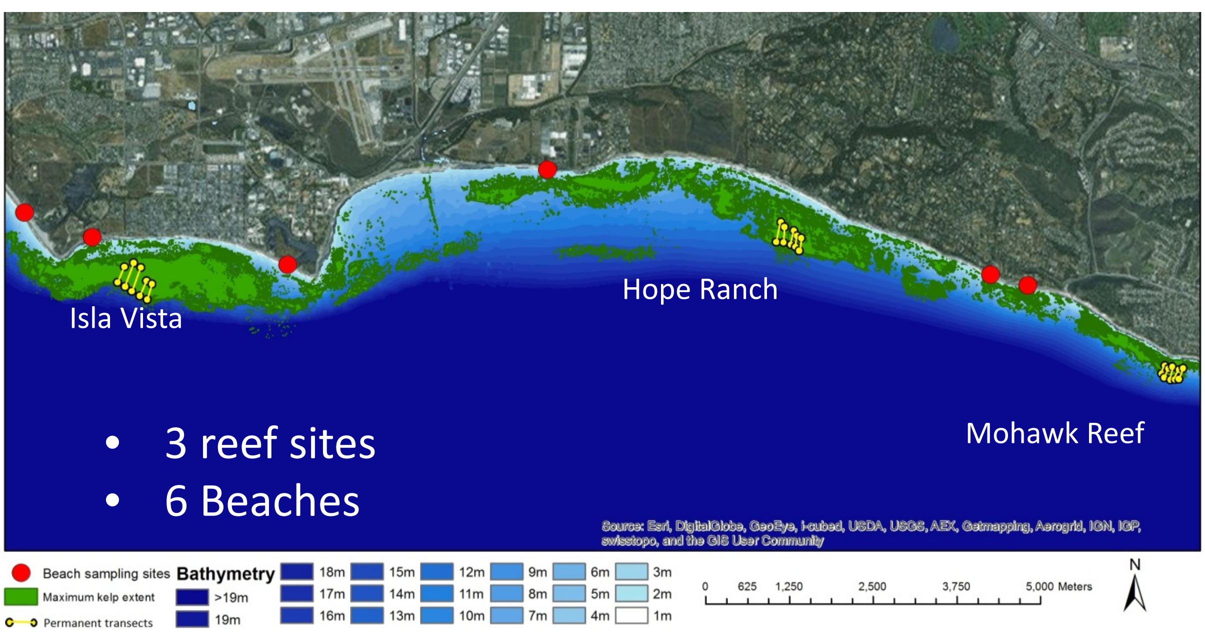
- Most kelp NPP is exported out of the forest
- Sandy beaches have low autochthonous production but kelp fuels a productive ecosystem on beaches
- Little is known about the variability and scale of trophic connectivity between kelp forests and the intertidal

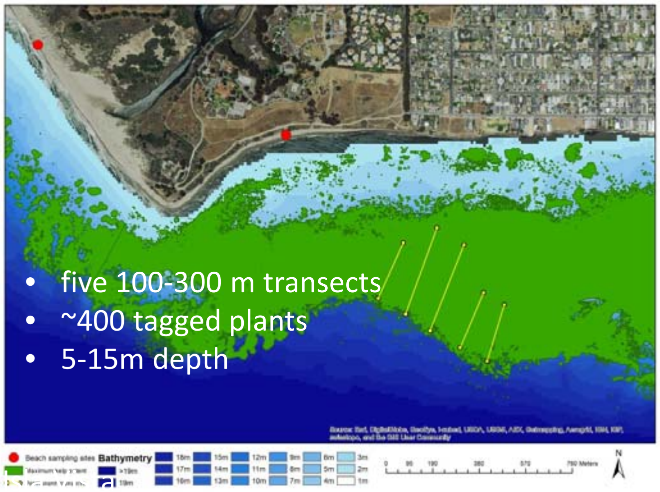
Mismatch between timing of kelp losses and wrack abundance



Wrack abundance on beach inshore of Mohawk vs. loss rate of *Macrocystis* biomass from the kelp forest at Mohawk. Peaks in loss generally occur in winter/early spring while peaks in wrack abundance are often in autumn

Creating a picture of kelp transport from reef to shore





On the Reef

- Tagged ~1200 growing kelp plants on cross-shore transects at the 3 sites
- Measured plant and holdfast size, depth, and substrate type to determine what variables lead to plant loss
- Deployed ADCPs to measure waves and currents

On the Beach

- Surveying 25 km of beach monthly to locate tags and measure wrack abundance
- Citizen scientists report tags
- Deployed ADCPs to measure waves and currents

In Transit

- Monthly drifter releases at all 3 sites
- Satellite tracked drifters deployed on drifting kelp plants
- Data combined with tag results to create a model of kelp delivery along the coastline

HELP WANTED!

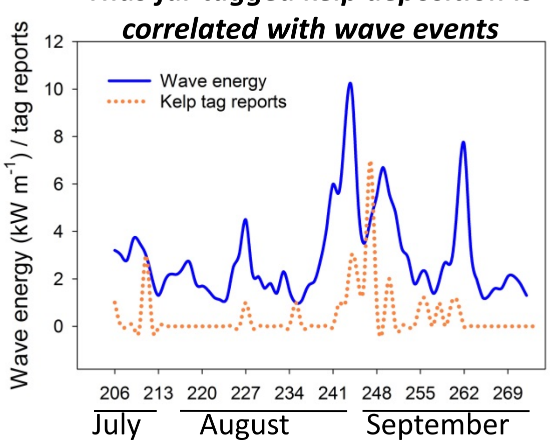
Want to help with a coastal ecosystem study? Like to walk on the beach?

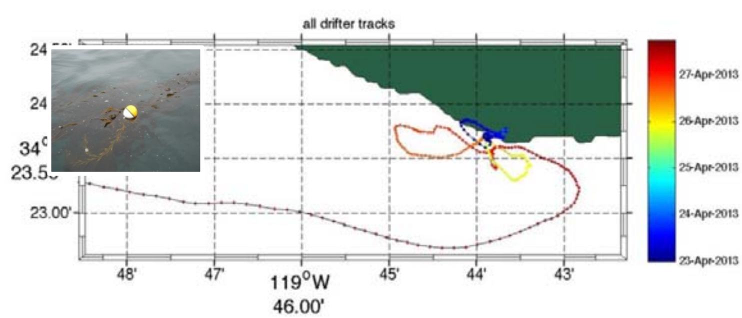
Watch for BRIGHT ORANGE plywood cards attached to kelp plants. For more info on participating in a study of the fate of giant kelp plants go to:

http://kelp.ucsb.edu

NSF UCSB msi Marine Science Institute ERI Earth Research Institute

Thus far tagged kelp deposition is correlated with wave events





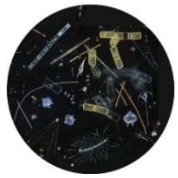
Tracks of kelp tagged with drifters, color coded by time. Small dots show position every 10 minutes. All tagged plants emanate from the offshore edge of the Mohawk reef kelp forest at the same time.

Dissolved inorganic nitrogen dynamics of beach pore water

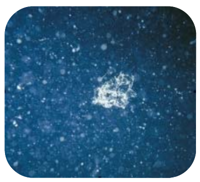
Blair Goodridge and John Melack

Beaches as biogeochemical reactors

Giant kelp

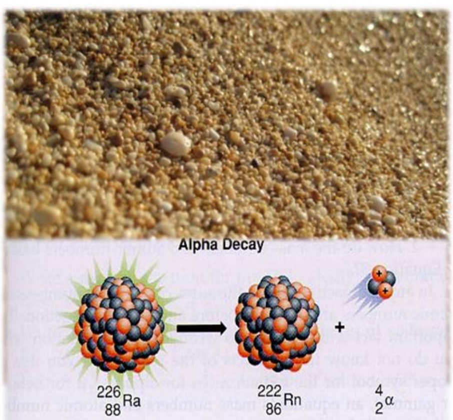


Phytoplankton

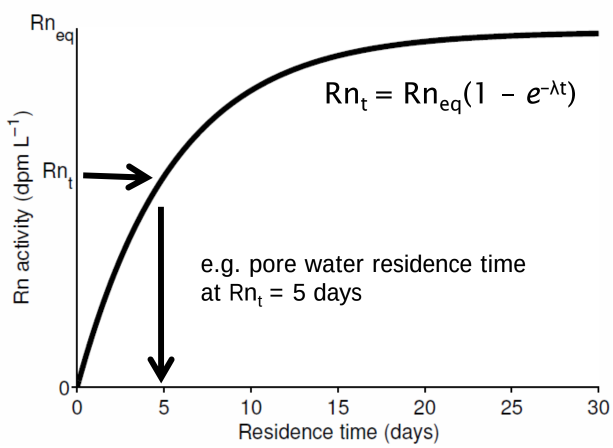


Detrital

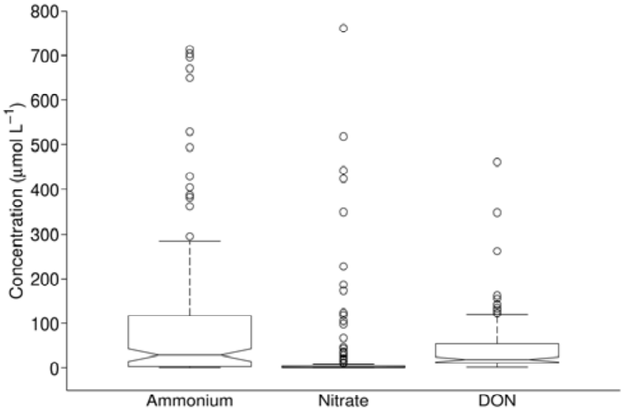
Radon residence times: linking pore water chemical and hydrologic temporal variability



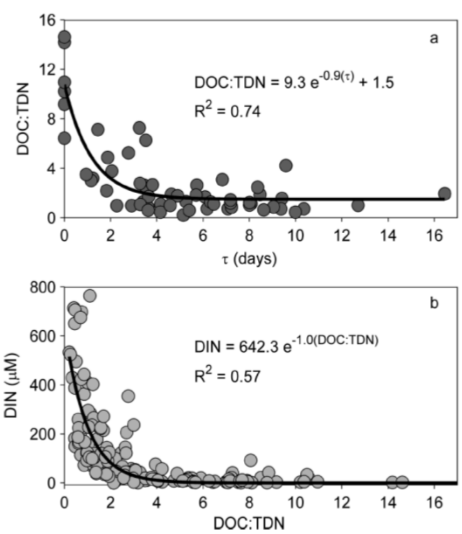
Prentice-Hall 4th ed.; kabooski.com



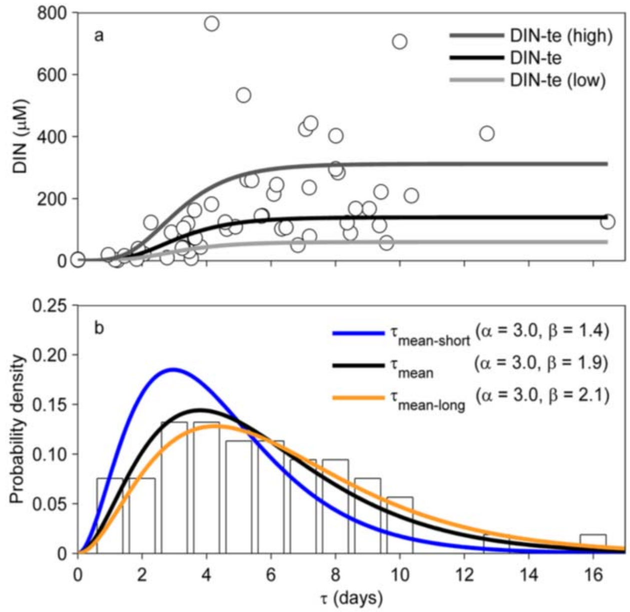
Ammonium dominant form TDN



DOC:TDN correlated with residence time



Volume-weighted mean DIN concentrations

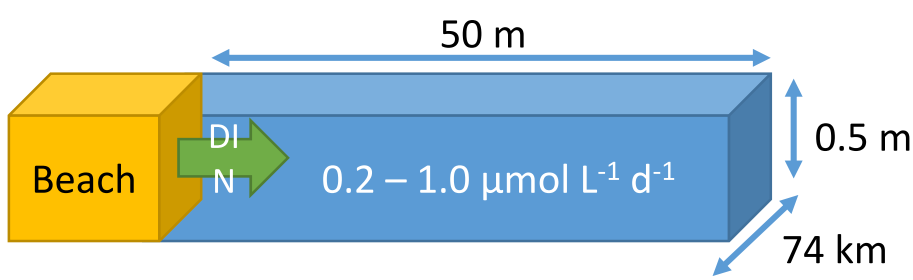


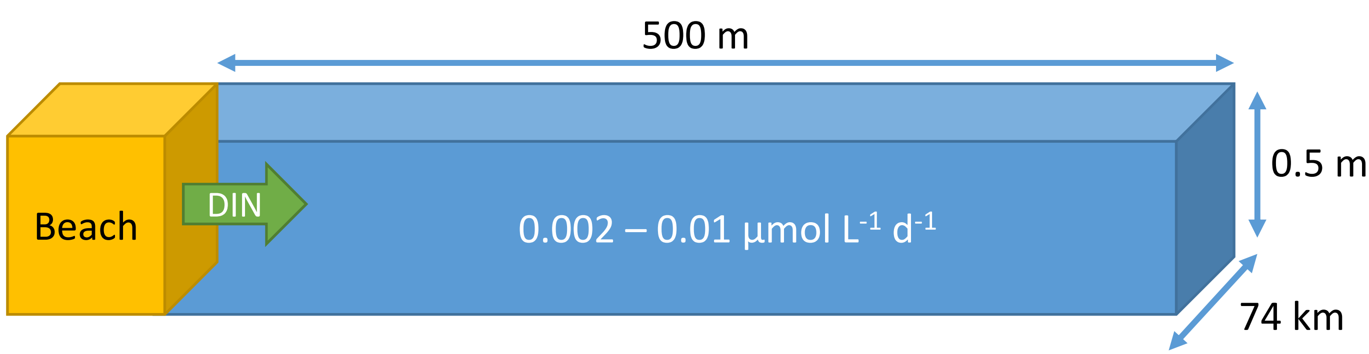
	DIN-te low	DIN-te	DIN-te high
Mean τ short (4.4 days)	37	87	194
Mean τ (5.7 days)	44	102	227
Mean τ long (6.4 days)	46	107	238

Beach contribution to nearshore DIN supply

	Exposure (µmol L^{-1} d^{-1})
Winter upwelling:	1.0
Spring upwelling:	1.9
Internal waves:	0.3
Terrestrial runoff:	0.3 - 1.5

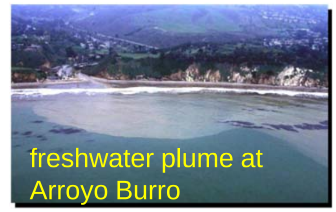
McPhee-Shaw et al. 2007 *Limnology & Oceanography*

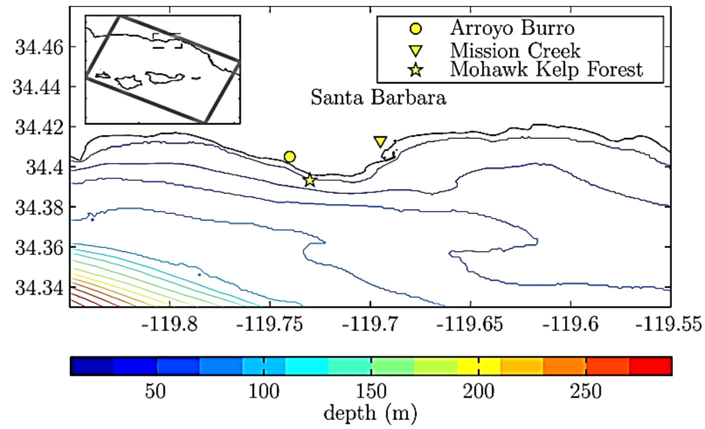




Characterizing Dispersion and Dilution from Small Coastal Streams

Leonel Romero, Dave A. Siegel, James C. McWilliams, Yusuke Uchiyama, and Charles Jones

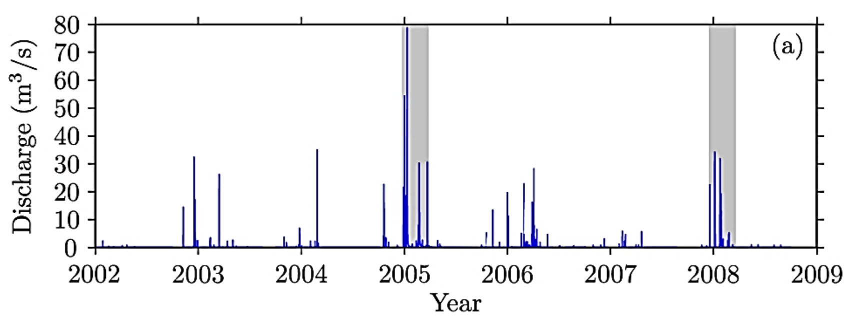


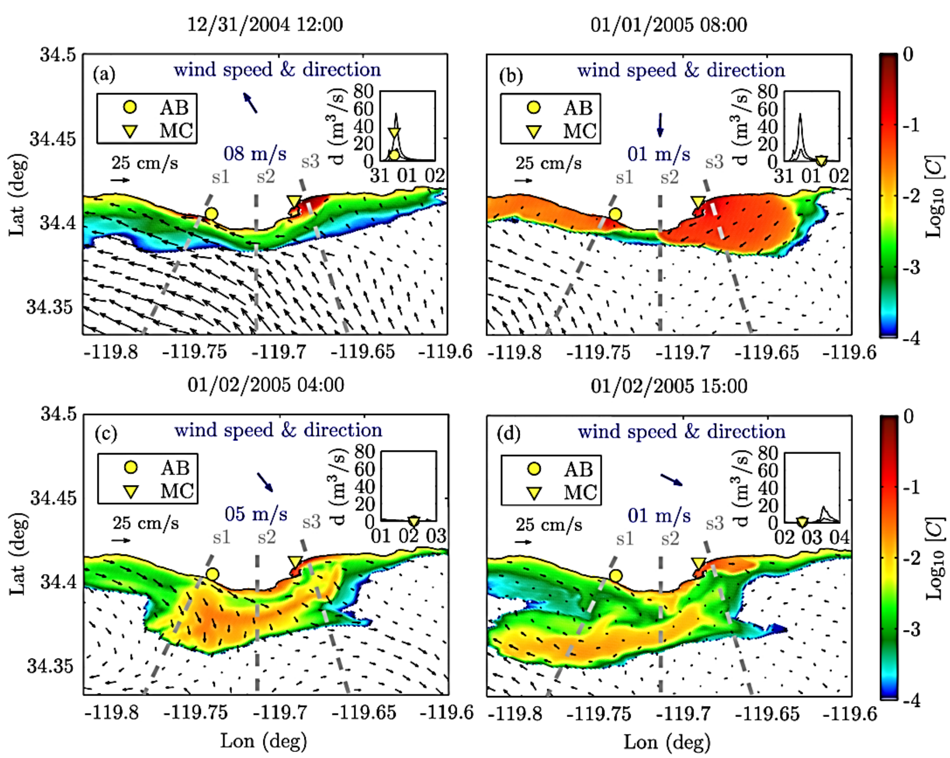


- Study region and model domain
- 100 m ROMS simulations
- Arroyo Burro (AB) & Mission Creek (MC)

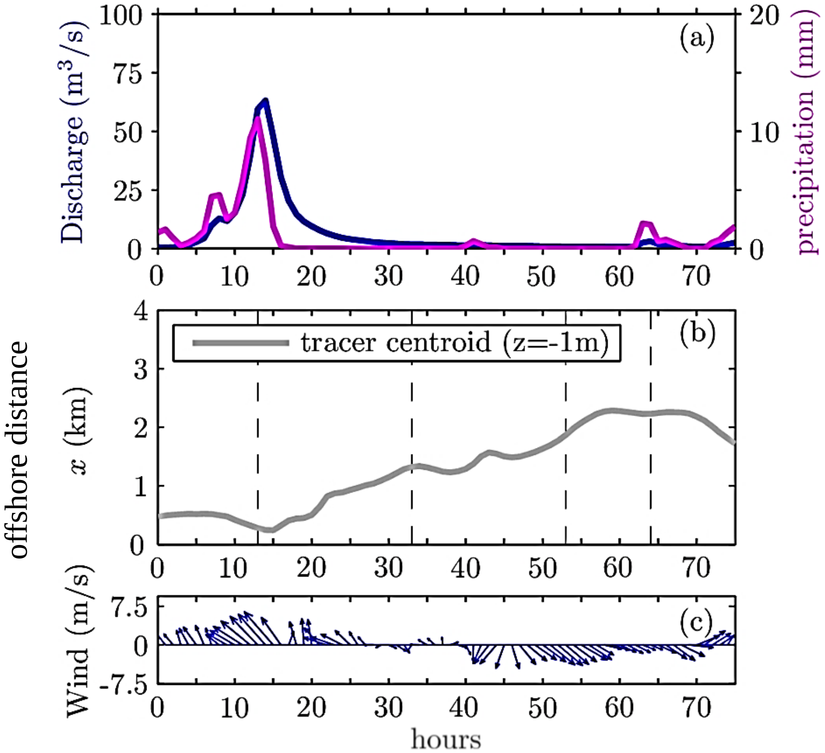
Romero et al. in review

- Measured discharge at Mission Creek
- Gray periods are study foci

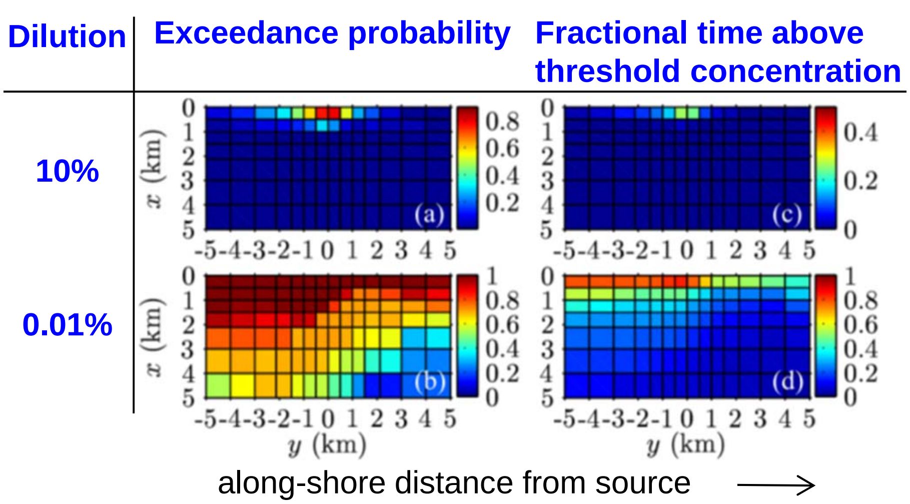




- Evolution of simulated plumes during the first storm of Winter 2004/2005
- As rain passes, winds transition from downwelling to upwelling favorable
- Dilutes & pushes plume offshore



- Discharge and precipitation are tightly coupled
- Passive plume initially within inner km but is pushed offshore as the winds shift to upwelling favorable



- For 10% dilution, plume is near coast and near source
- For 0.01%, plume still has strong cross-shore gradients but weak alongshore ones
- Exceedance times are almost always short over the event

Conclusions:

1. Tight coupling is found among precipitation, hydrologic discharge and wind forcing which all contribute to plume evolution
2. Plume dilution is rapid and anisotropic with strong cross-shelf gradients
3. Plume dispersion results are consistent with the particle-pair results of Romero et al. (2013) providing a path for using simple dispersal models for assessing ecological impacts

Ocean transport and fate of phytoplankton

Libe Washburn, Mark Brzezinski, Dave Siegel, Leonel Romero, Fernanda Freitas, Carter Ohlmann, Melanie Fewings, María Aristizabal

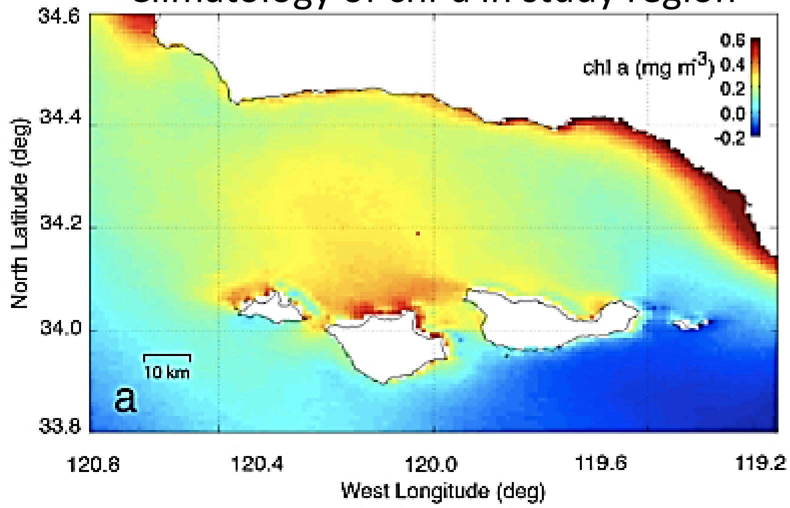
Background

- Phytoplankton primary productivity (PPP) controlled by light, nutrients, consumption, and physical transport processes
- PPP is an important subsidy for kelp forest ecosystems

SBC LTER research questions:

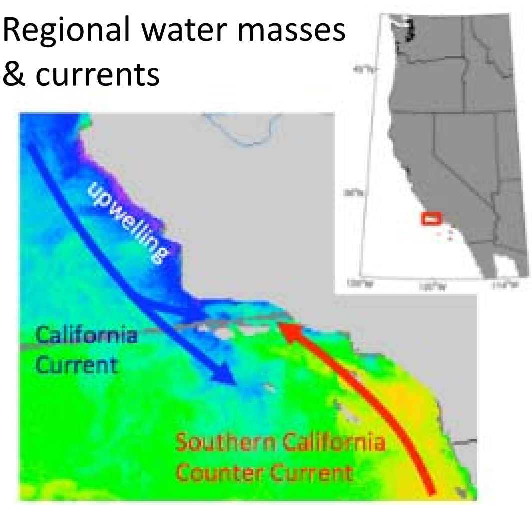
1. What is the fate of phytoplankton PPP?
2. What processes transport phytoplankton to nearshore habitats?

Climatology of chl-a in study region

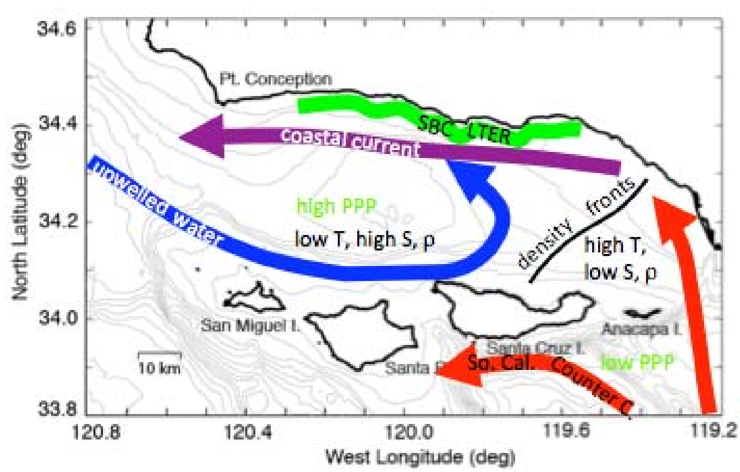


Phytoplankton transported by processes acting on a wide range of space & time scales

Regional water masses & currents

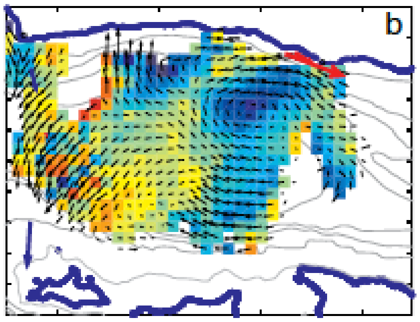


Current patterns in SB Channel

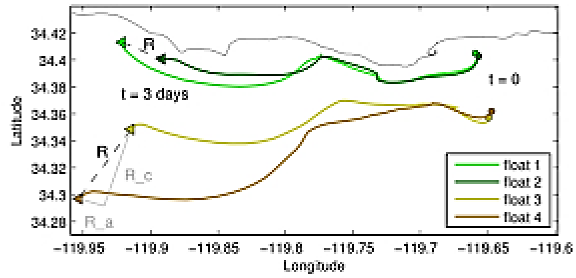


SBC research has identified several processes that transport phytoplankton

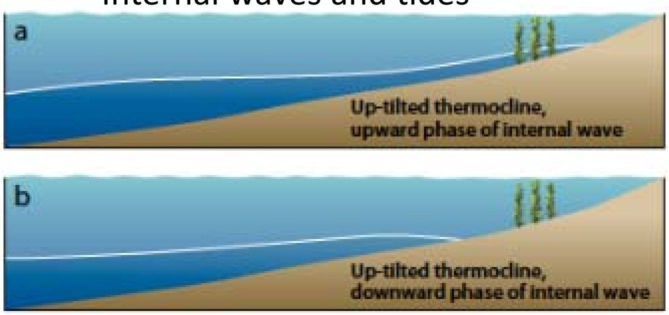
Coastal eddies



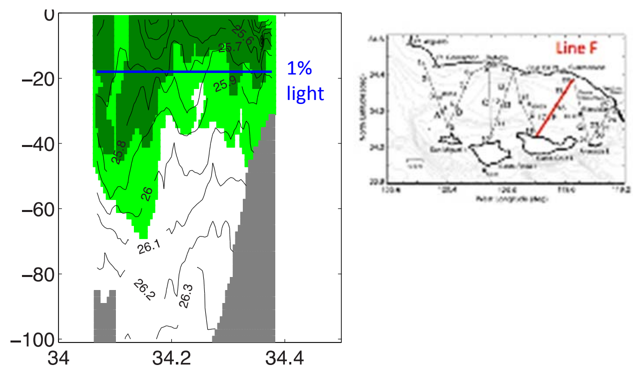
Turbulent dispersion



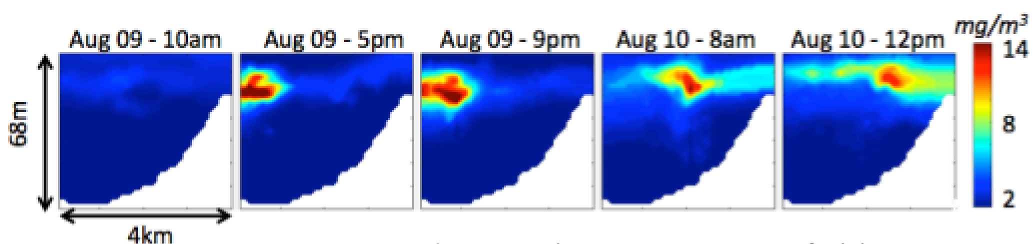
Internal waves and tides



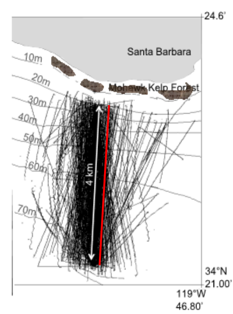
Water mass subduction



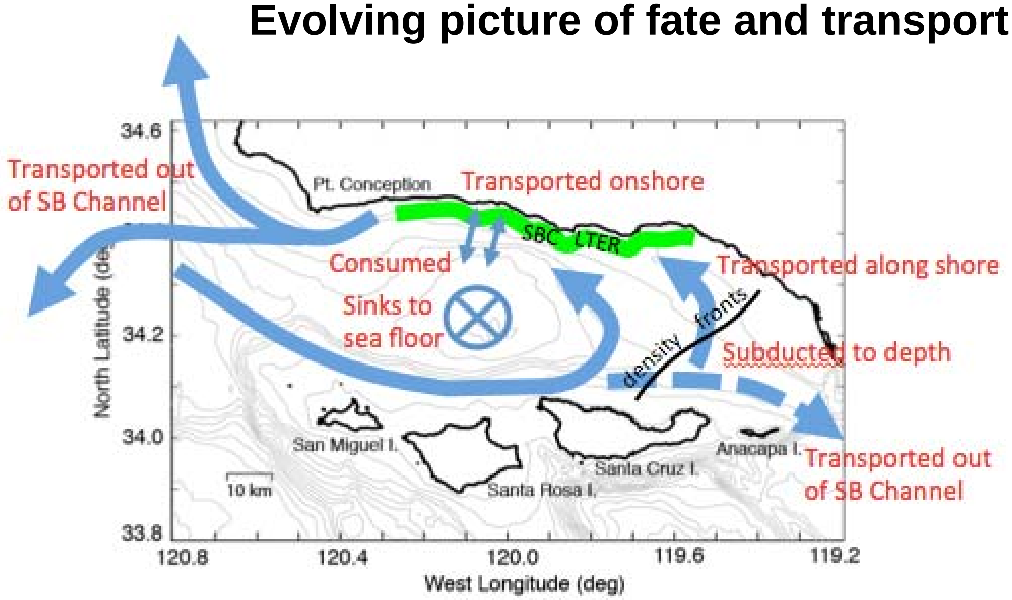
Other transport processes remain to be identified



Rapid cross-shore transport of chl-a



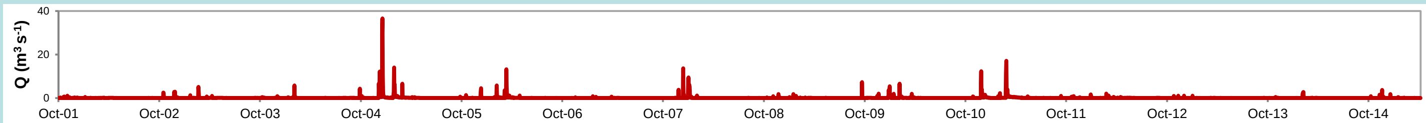
Evolving picture of fate and transport of PPP



Terrestrial Runoff from Coastal California Watersheds

Ed Beighley, Dongmei Feng, Xiaoli Chen, Naomi Tague, John Melack

Mediterranean Climate: long dry season (Apr-Nov) and short rainy season (Dec-Mar)



Hydrologic Characteristics

- ***Event Dominance:*** System is event driven with 10 to 20 events in a typical year and over 50% of annual water export in a single event
- ***Uplands vs. Lowlands:*** Large variations between coastal plain and mountains
- ***Non-linear Response:*** Streamflow highly sensitive to land cover, initial moisture conditions and rainfall (total and intensity)

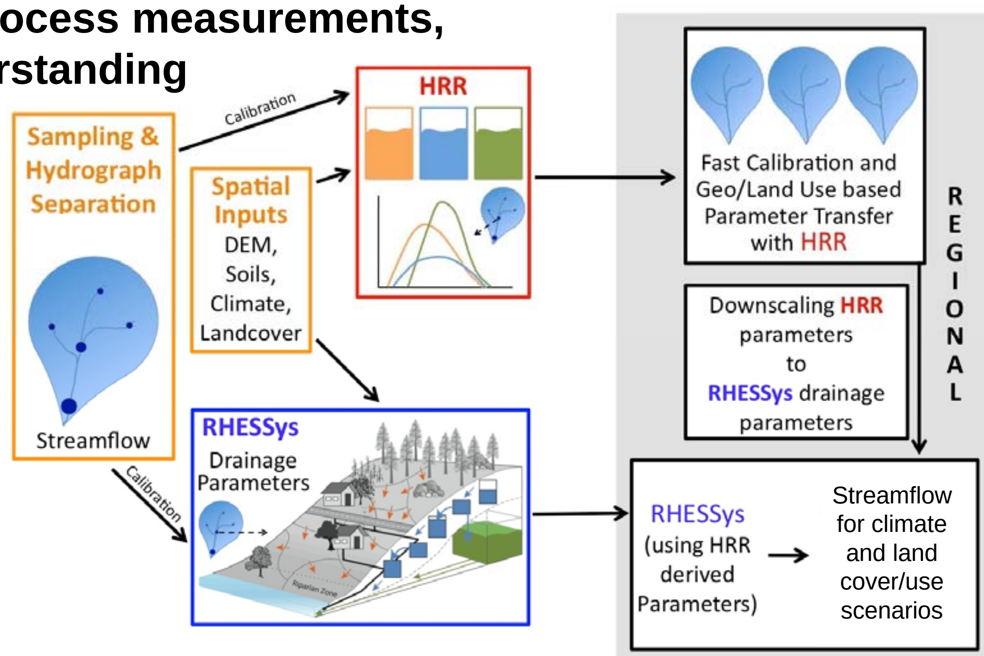
Impacts on terrestrial export of water, nutrients and sediment?

- Disturbances to terrestrial environments (wild fires or land cover change)
- Non-stationary and altered climate conditions (trends and future conditions)

Empirical challenges		SBC LTER solutions
1. Dynamic land cover	→	AVIRIS based land cover
2. Study region scale	→	Multi-model approach
3. Model/parameter uncertainty	→	Multi-model ensemble approach
4. Non-stationary climate conditions	→	Downscaled CIMP5 climatology

Multi-model, multi-process measurements, calibration and understanding

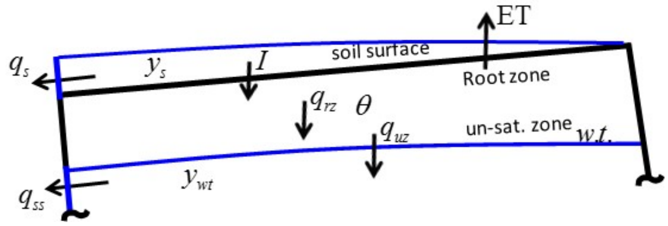
Combining watershed-scale rainfall-runoff model (HRR) with finer-scale hydroecological model (RHESSys) that incorporates vegetation water-use, regrowth and hydrologic processes

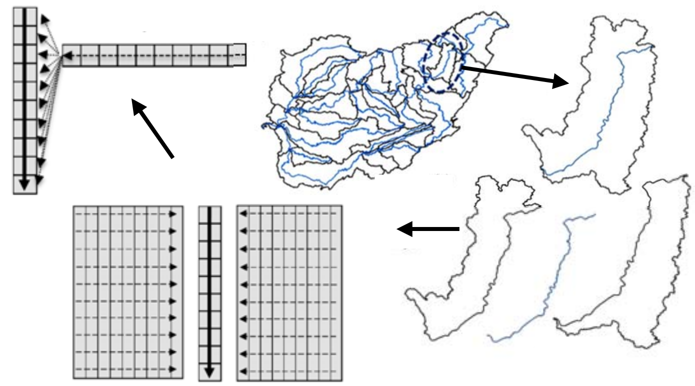


(1) HRR Model: Study Region Watersheds → Catchment-scale

Hillslope River Routing (HRR) Model

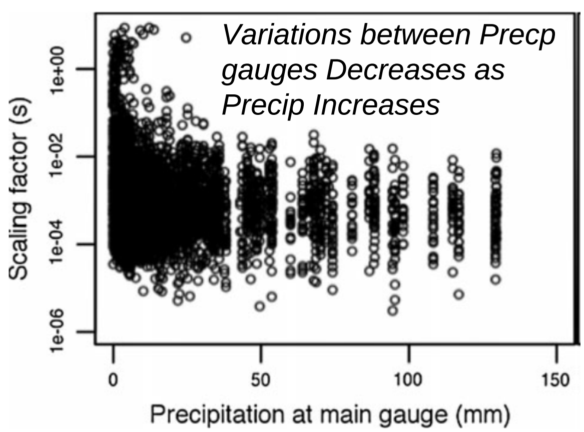
- Combines hydrologic and hydraulic processes
- SBC → 3089 catchments w/ 179 watersheds

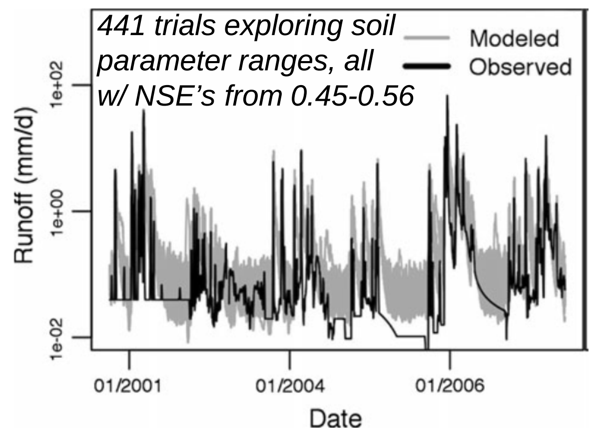




(2) RHESSys Model: Mission Creek Watershed → Patch-scale

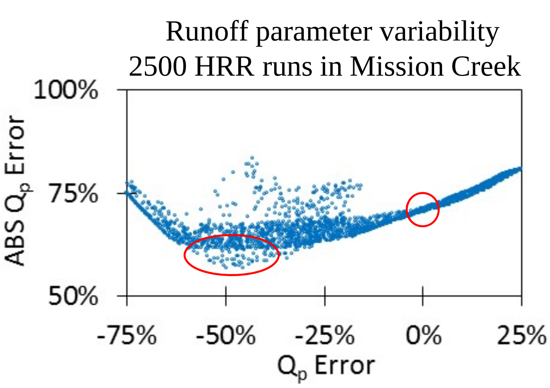
Shields & Tague 2012



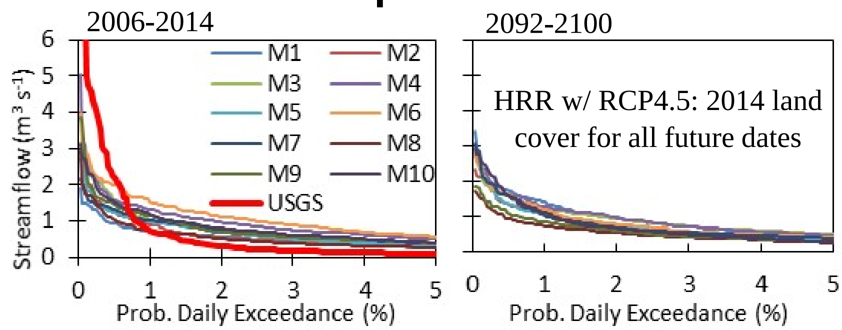


Downscaled (6 km, daily) climate forecasts for precip. & temp. (min/max)

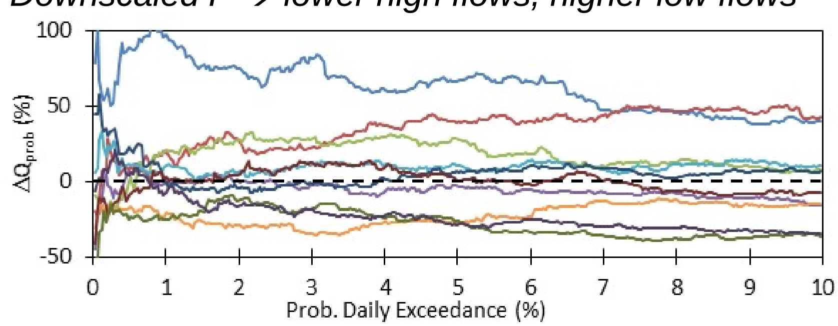
- IPCC CMIP5 models (10 used) with 2 emission scenarios for 1950-2005 & 2006-2100
- *HRR calibration results in varying performance between storm events → min absolute event streamflow (ABS Q_p) error results in larger negative relative (Q_p) errors*



Future climate impacts event streamflow



Downscaled P → lower high flows, higher low flows

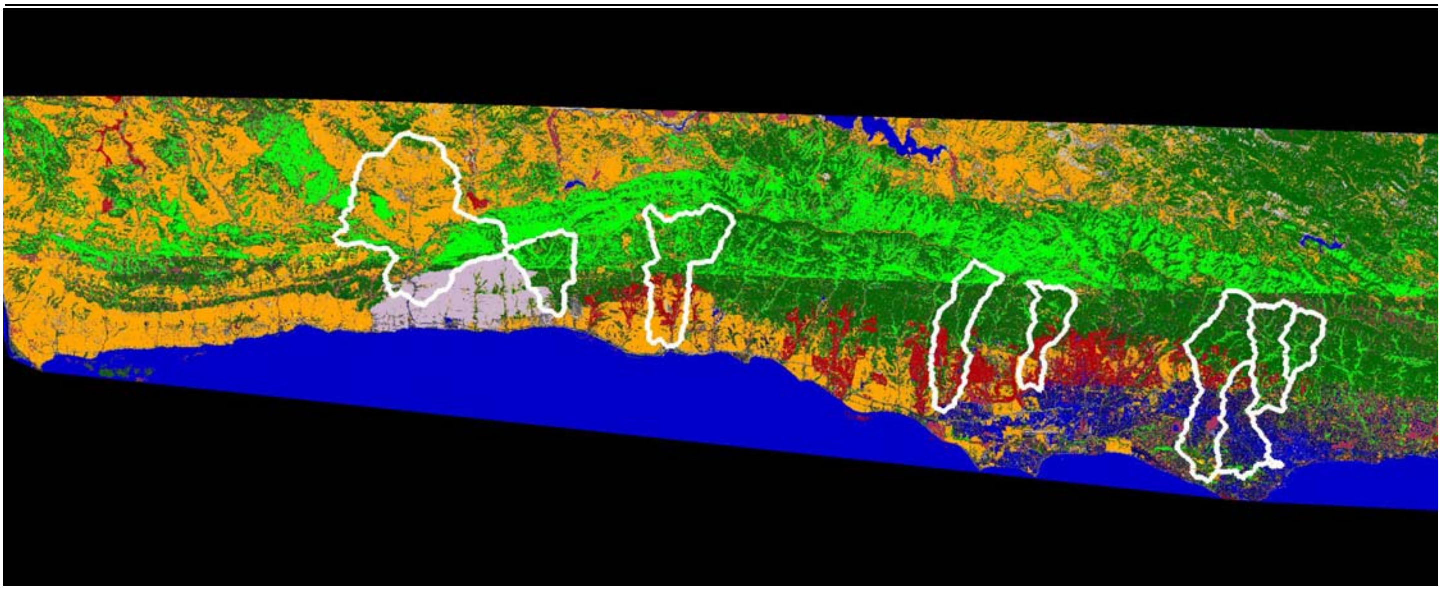


Change in streamflow distribution for 2006-2014 to 2092-2100 time periods (ΔQ_{prob}) shows large uncertainty in event streamflow changes (±40%)

Watershed characteristics and nutrient fluxes

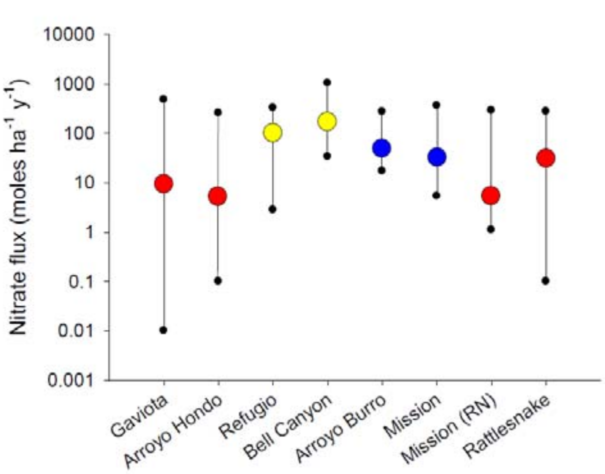
**John Melack, Blair Goodridge, Matt Meyerhof, Helen Chen,
Rosana Aguilera, Dar Roberts**

Watersheds range from undeveloped to agricultural to urban along coast and with elevation

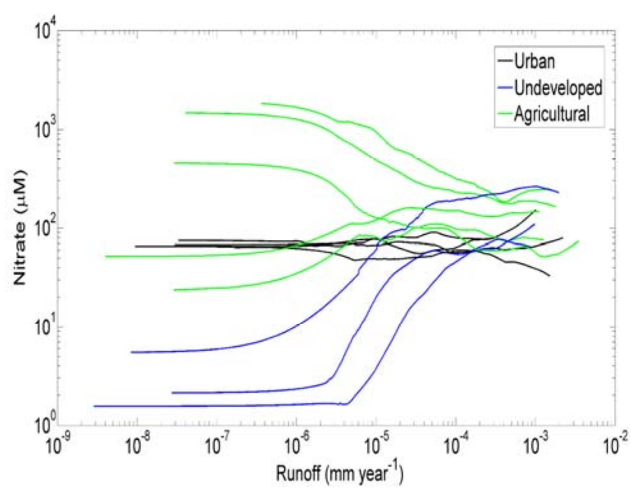


AVIRIS derived land use/land cover: Blue – Urban/suburban; green – shrubs; tan – grasses; red – orchards; grey – burn scar; white outlines of Gaviota, Arroyo Hondo, Bell Canyon, San Pedro, Arroyo Burro, Mission (upper and lower) and Rattlesnake watersheds (west to east)

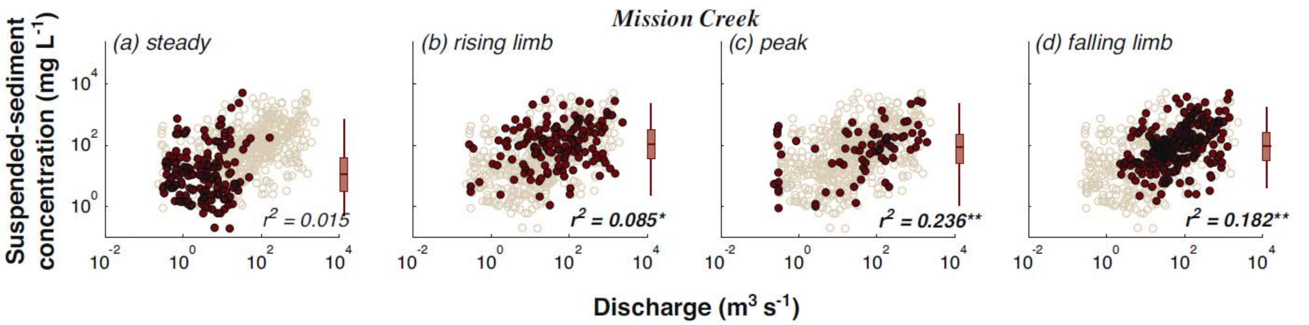
Annual nitrate fluxes for eight coastal watersheds (2002 to 2014) Dots, medians (red, burned; yellow, agriculture; blue, urban) and range, black lines



Nitrate concentrations versus runoff varies as a function of land use



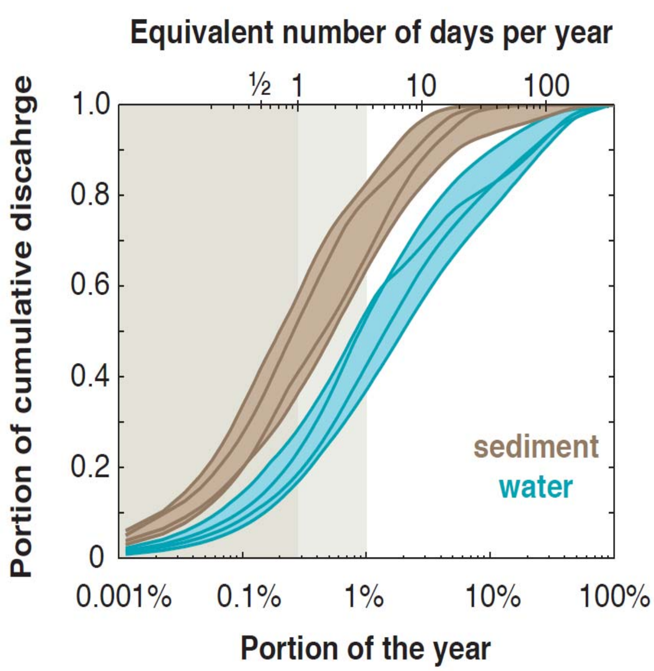
TSS versus discharge for Mission Creek



Suspended sediments contain high concentrations of N and P:

Particulate N: 12 to 220 micromolar
Particulate P: 0.2 to 66 micromolar

Half of suspended sediment transport occurs in ~ one day per year



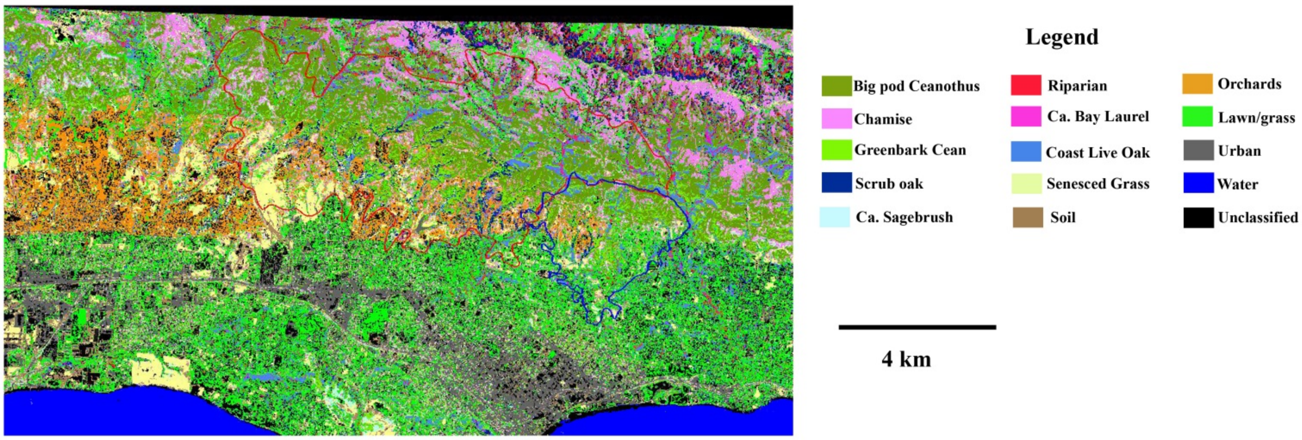
Pre-Fire Fuels, Fire Severity and Post-fire Recovery

Dar Roberts, Erin Wetherley, Mingquan Chen, Bodo Bookhagen, John Potapenko

Fire severity depends on fuel type, fuel moisture and meteorology
Fire severity impacts post-fire recovery, and nutrient and sediment outputs

1) *Three wildfires burned in close progression along the Santa Barbara Front Range between 2008 and 2009*

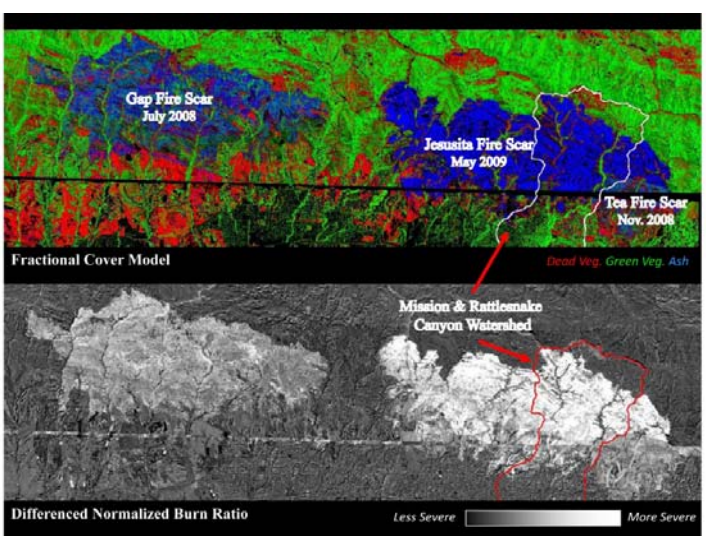
Pre-fire fuel types had little impact on fire spread except in orchards, lawns and riparian areas



- Pre-fire fuels map from August 2004 AVIRIS imagery. Image subset shows the Jesusita (Red: May 2009) and Tea (Blue: Nov 2008) fire perimeters

2) *Fire severity was mapped via fractional cover of dead plant material (red), green vegetation (green) and ash (blue) and Difference Normalized Burn Ratio*

The Jesusita Fire was a high severity fire. Lower severity occurred in the Gap Fire. Dead vegetation in the Tea Fire scar is due to senesced annual regrowth.



Spectral mixture model of dead vegetation (red), green vegetation (green) and ash (blue) for August 2009

Difference Normalized Burn Ratio from same image

3) *Post-fire recovery was monitored using mixture models from 2009 to 2013*

Pre-fire, the watershed is dominated by green vegetation and ~22% senesced material. Following the Jesusita Fire the watershed is modeled as mostly ash, which rapidly declines in 2010 and 2011 and is absent by 2013. High levels of bare soil and senesced material in 2013 reflect poor recovery due to persistent drought. Crown mortality in riparian areas is higher in Mission Creek than Rattlesnake in August 2009, indicating higher severity.

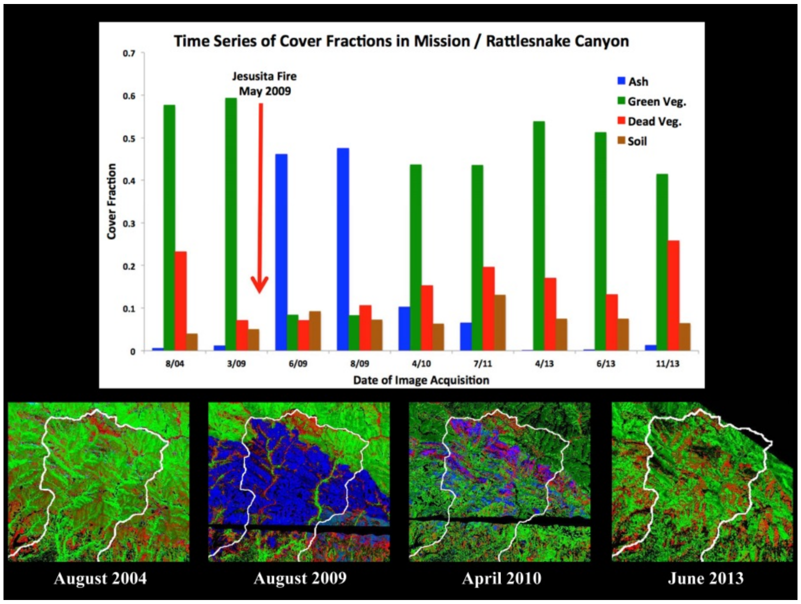


Figure showing changes in ash, green and dead vegetation and ash in the watersheds from 2004 to 2013. A subset of images are shown below the bar plots.

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4) *Lidar provides additional discrimination in high severity burns*

Lidar-derived canopy height models show relict tall woody vegetation in areas mapped as high severity by dNBR and in areas mapped only as ash by AVIRIS. Mixture models and Lidar provide complementary information

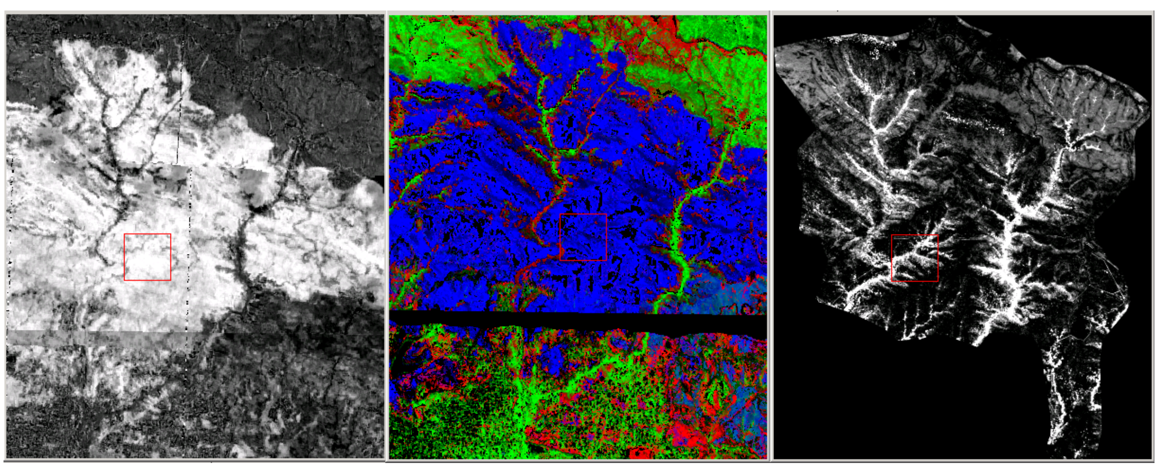
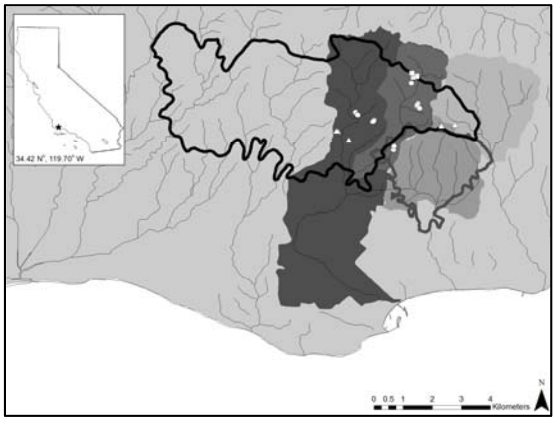


Figure showing three different measures of severity, dNBR (left), mixture model (center) and digital height model (right). The mixing model clearly discriminates riparian areas that were burned but retain dead vegetation from unburned vegetation. Lidar canopy height models show areas retaining standing woody biomass modeled as ash by a mixing model.

Biogeochemical responses to fire in coastal chaparral ecosystems

Erin Hanan, Carla D'Antonio, Naomi Tague, Joshua Schimel

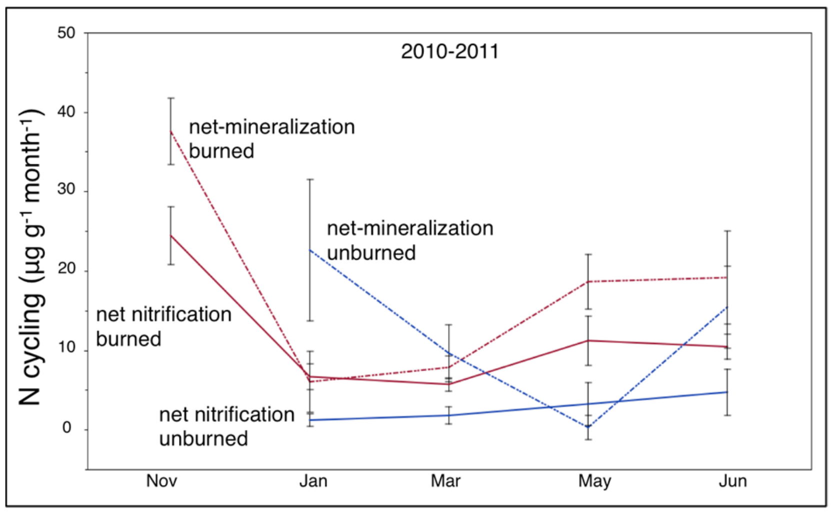


What factors influence nitrogen cycling and retention as chaparral ecosystems recover from fire?

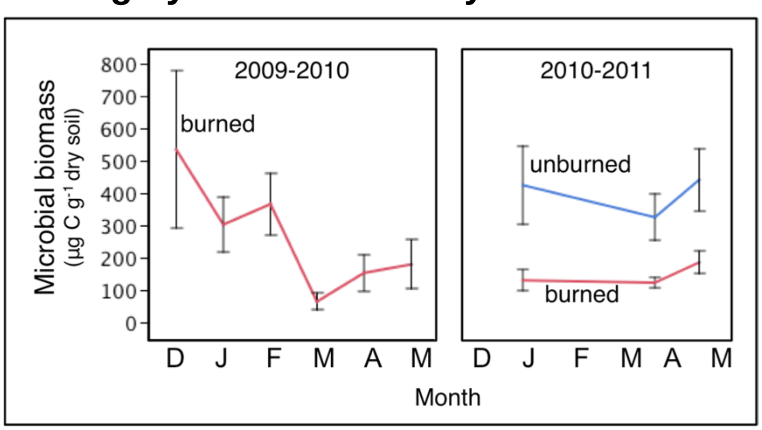
- Jesusita Fire boundary
- Tea Fire boundary
- Mission Canyon
- Rattlesnake Canyon
- Sycamore Canyon
- Coldspring Canyon
- Sampling locations

Nitrification was enhanced following fire

Burned
Unburned

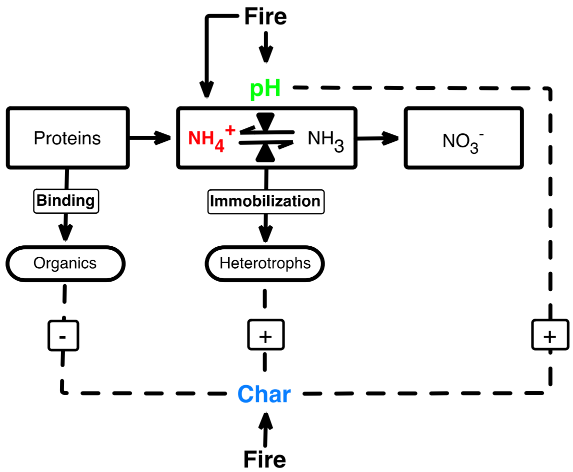


Microbial biomass was high right after fire, then declined and stayed low through year 2 of recovery



Plants took up N commensurate with net-mineralization fluxes

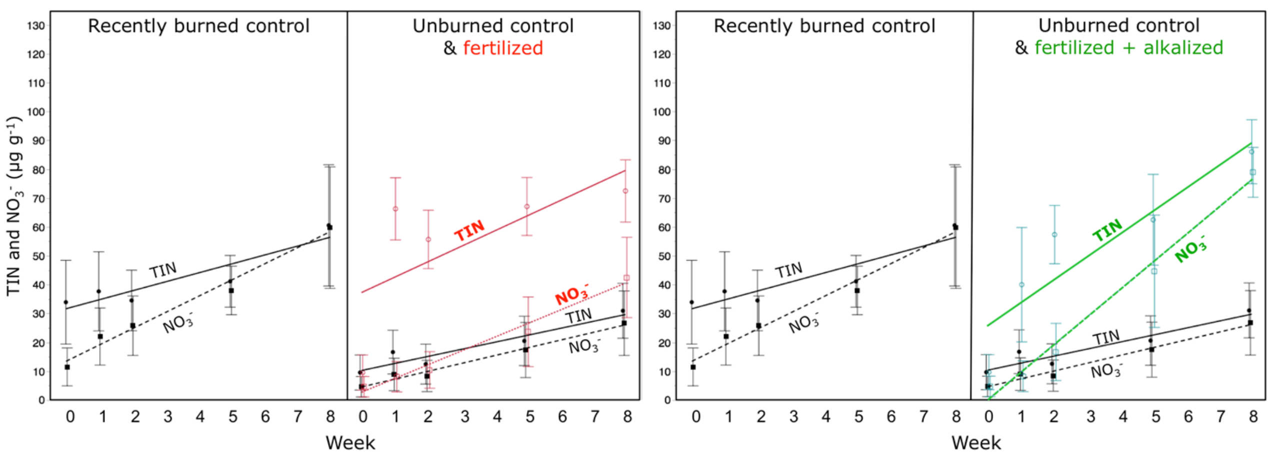
How do substrate, pH, and char influence net mineralization, nitrification, and microbial dynamics in chaparral ecosystems?



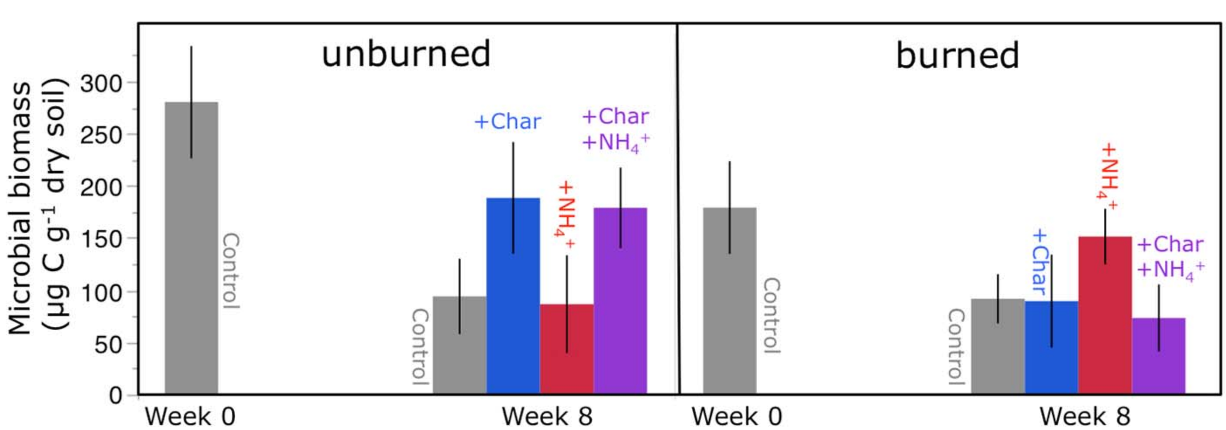
Factors driving nitrification in fire-prone ecosystems.

Evaluated the effects of these factors using a factorial design

Total inorganic N and nitrate increased when unburned soils were fertilized. Nitrate increased much more rapidly when soils were both fertilized and alkalized



Microbial biomass C at the beginning and end of incubation for all treatments. Char provided C to microbes in unburned soils



Records of Disturbance along the Santa Barbara Channel

Alexander Simms, Laura Reynolds, Michael Bentz, Michael Truong

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Key Point:

Delivery of sediment and environmental changes are driven by low-frequency, high magnitude disturbance events

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Disturbances include:

1) Tectonic Processes: Earthquakes, tsunamis, subsidence
2) Climatic and weather-related phenomena
3) Land-use changes associated with European colonization

Question: *How do we find a record of disturbances with return periods longer than LTER observations?*

Solution: Sediments within estuaries and coastal lakes

Approach: Cores at Carpinteria Slough, Goleta Slough, Dune Pond

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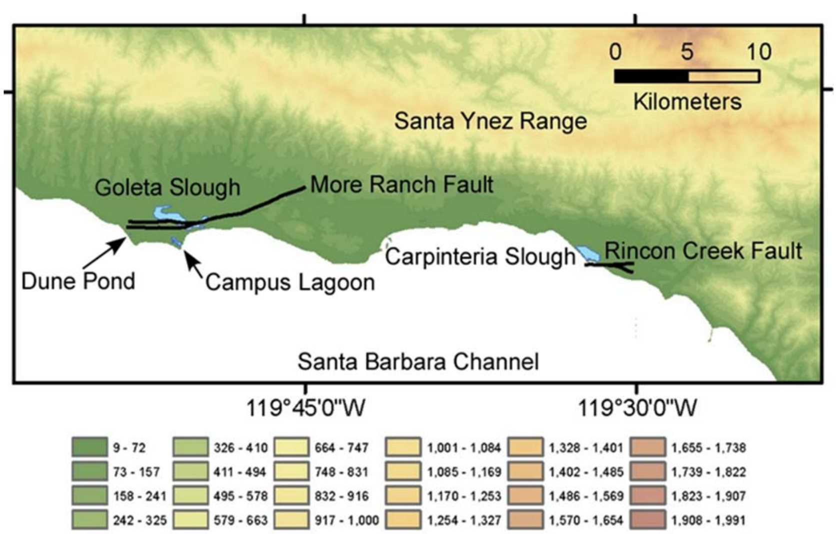
Tectonic Processes



- Faults and folds throughout area
- Faults control the location of estuaries

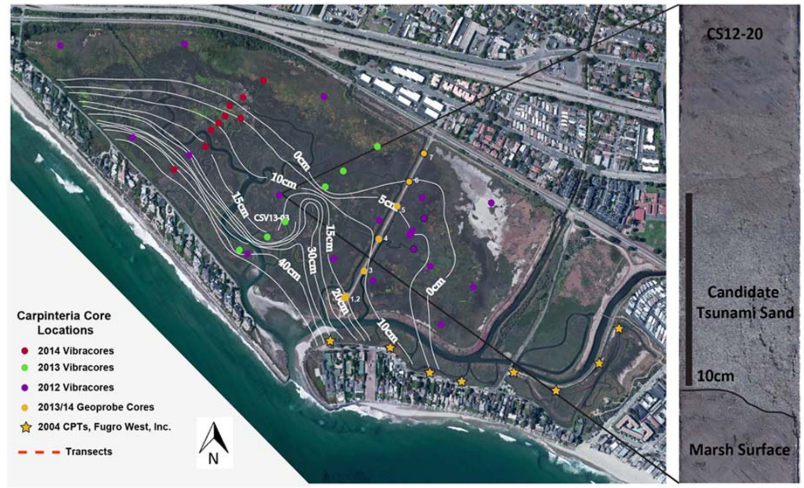
Sediments record:

1. Tsunamis
2. Subsidence

1812 Historical Tsunami

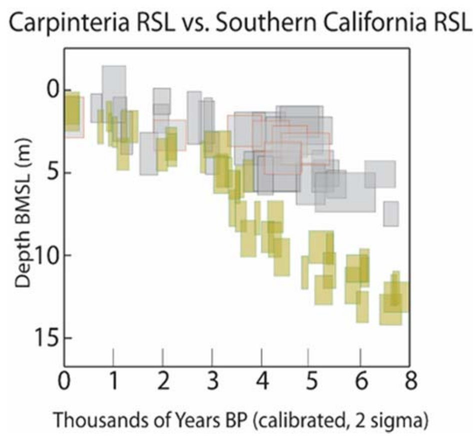
First physical evidence
Carpinteria Slough

- Sand sheet up to 50 cm
- Marine sand
- Thins landward



Subsidence

- Sloughs are sinking at ~1.0 mm/yr
- Episodic or gradual?
- Long-term balance with sedimentation

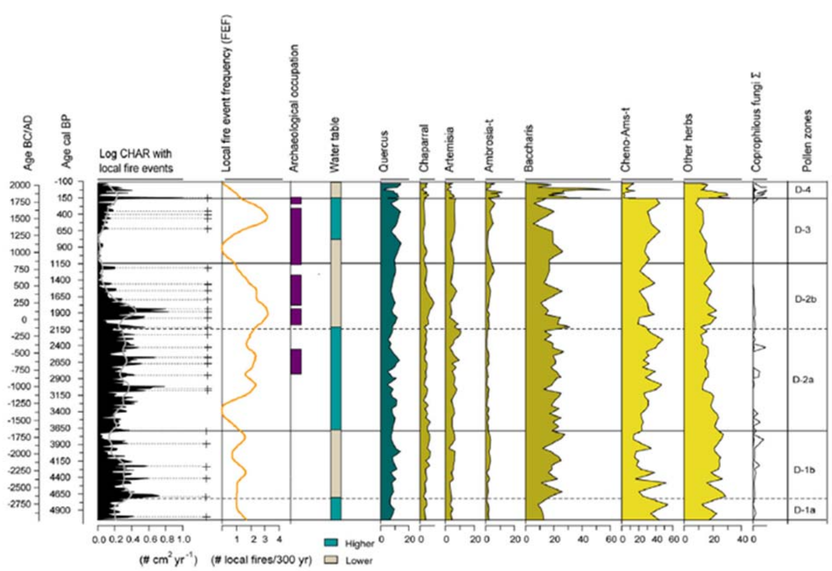


Flooding

- Periods of rapid infilling of Carpinteria Slough

Land-use changes

- Order of magnitude increase in sedimentation rates
- Changes in vegetation
- Decrease in fire frequency

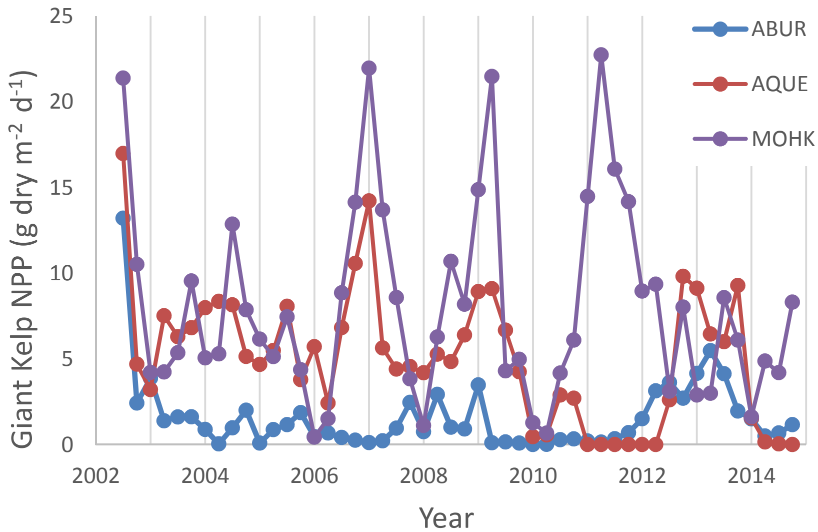


Primary production on nearshore reefs

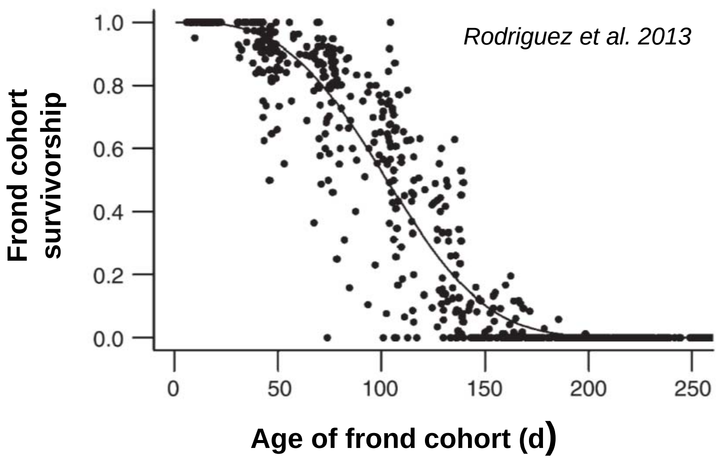
Andrew Rassweiler, Dan Reed, Bob Miller, Craig Carlson, Ellie Halewood, Gabe Rodriquez, Christy Yorke, Shannon Harrer, Clint Nelson

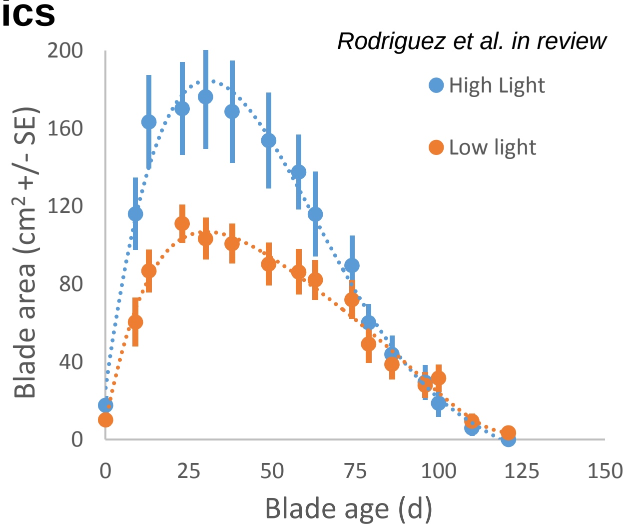
Giant kelp NPP

Rassweiler et al. 2008

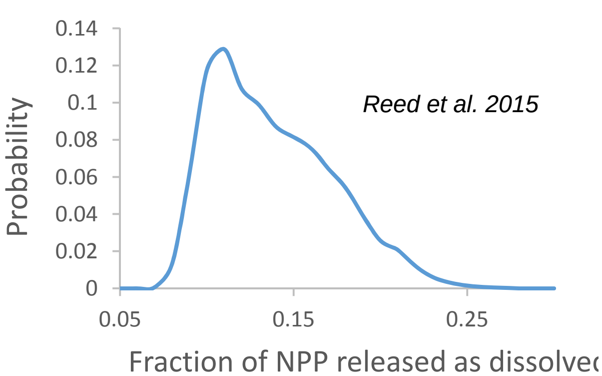


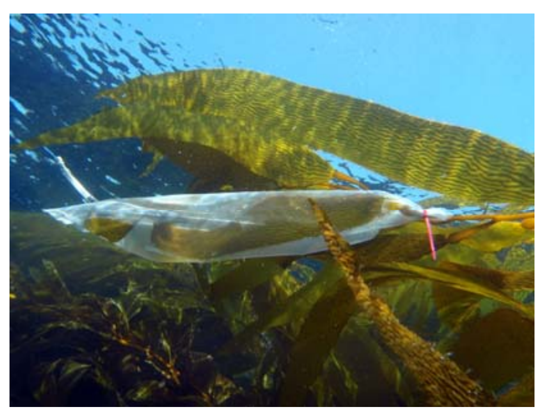
Frond and blade lifespans affect dynamics



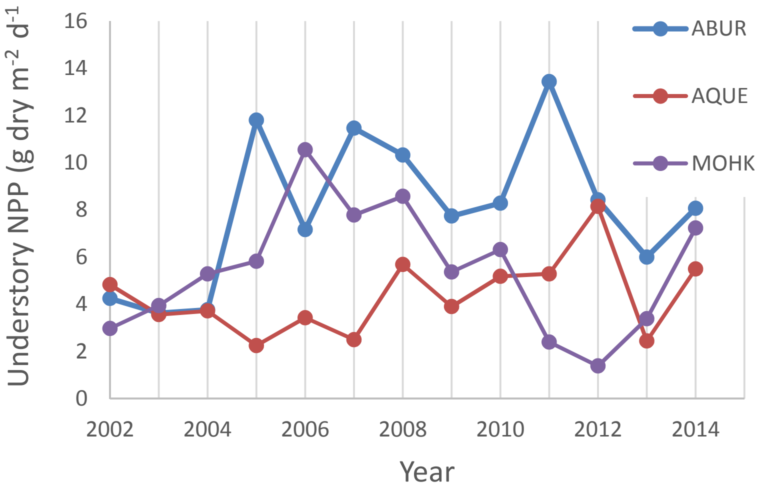


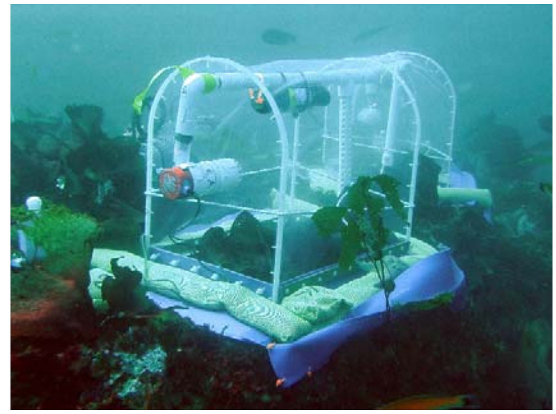
Dissolved component of giant kelp NPP





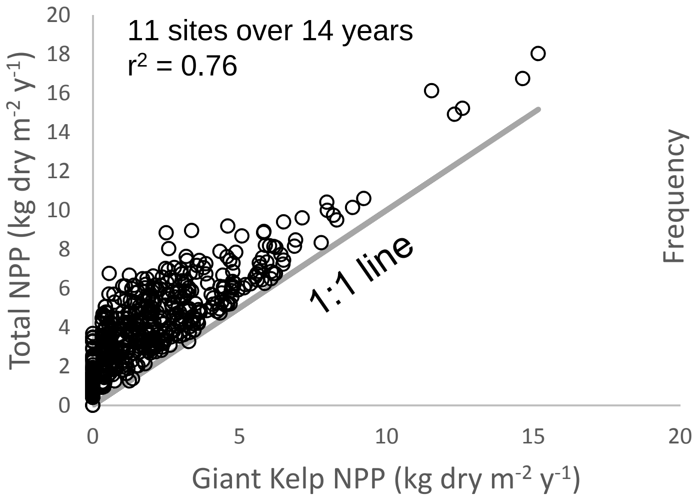
Understory NPP can be comparable in magnitude to giant kelp NPP

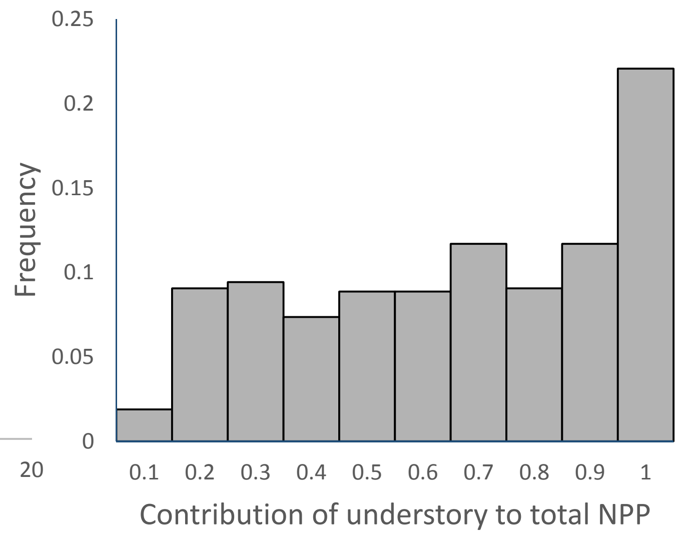




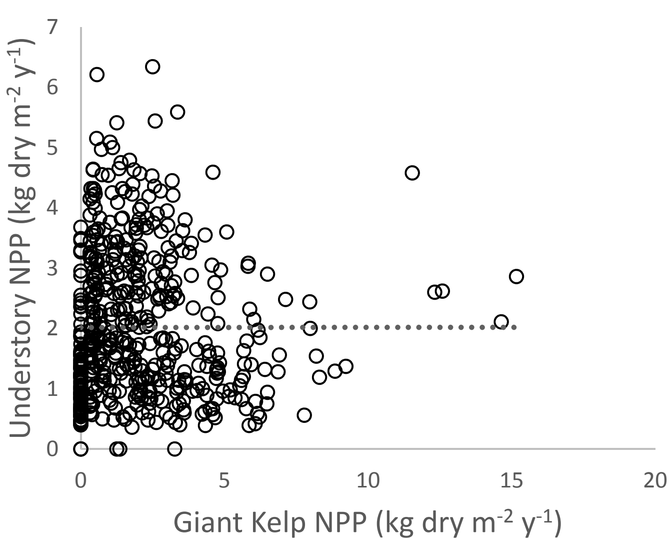
Miller et al. 2011, Harrer et al. 2013

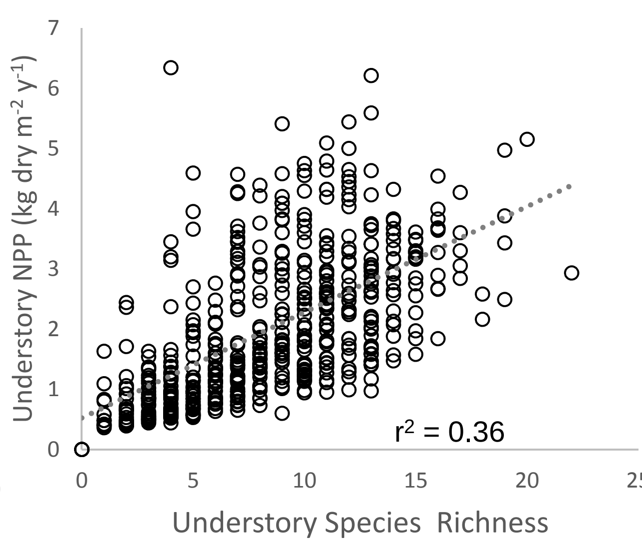
Giant kelp dominates variation in NPP, but understory is locally important





Understory NPP not correlated with giant kelp, but is related to diversity





Wave disturbance and kelp forest structure and function

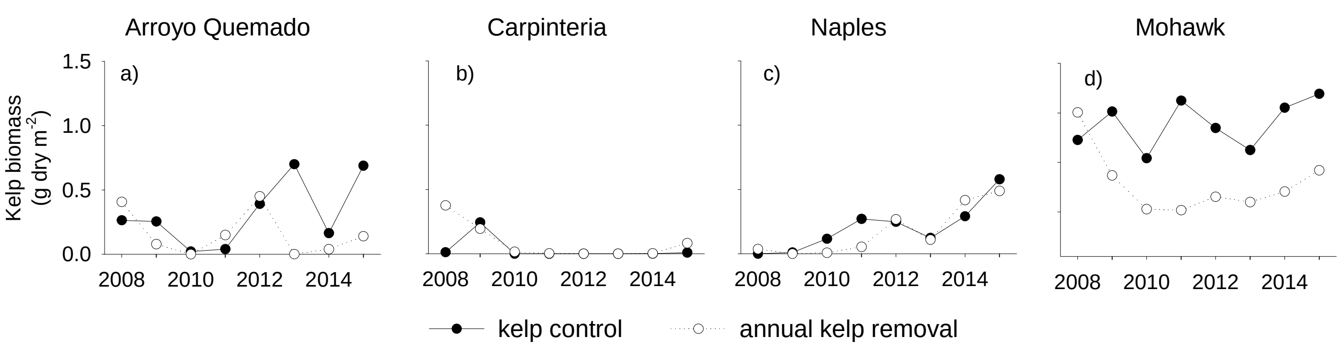
Bob Miller, Andrew Rassweiler, Dan Reed, Sally Holbrook

- The wave and storm climate is predicted to change in the NE Pacific as a result of climate change
- Wave disturbance disproportionately removes giant kelp, *Macrocystis*
- Results from simulations and a short-term experiment by SBC researchers suggest that an increase in the frequency of severe wave disturbance will change the structure and diversity of the kelp forest but not overall NPP

Long-term disturbance experiment

- **Initiated 2008**
- **Remove *Macrocystis* from 40 m x 40 m plots at 4 sites once per year in winter to simulate wave disturbance**
- **Adjacent undisturbed plots serve as controls**

Difference between treatment plots depends on site



At three sites, natural processes remove kelp in both treatment and control plots

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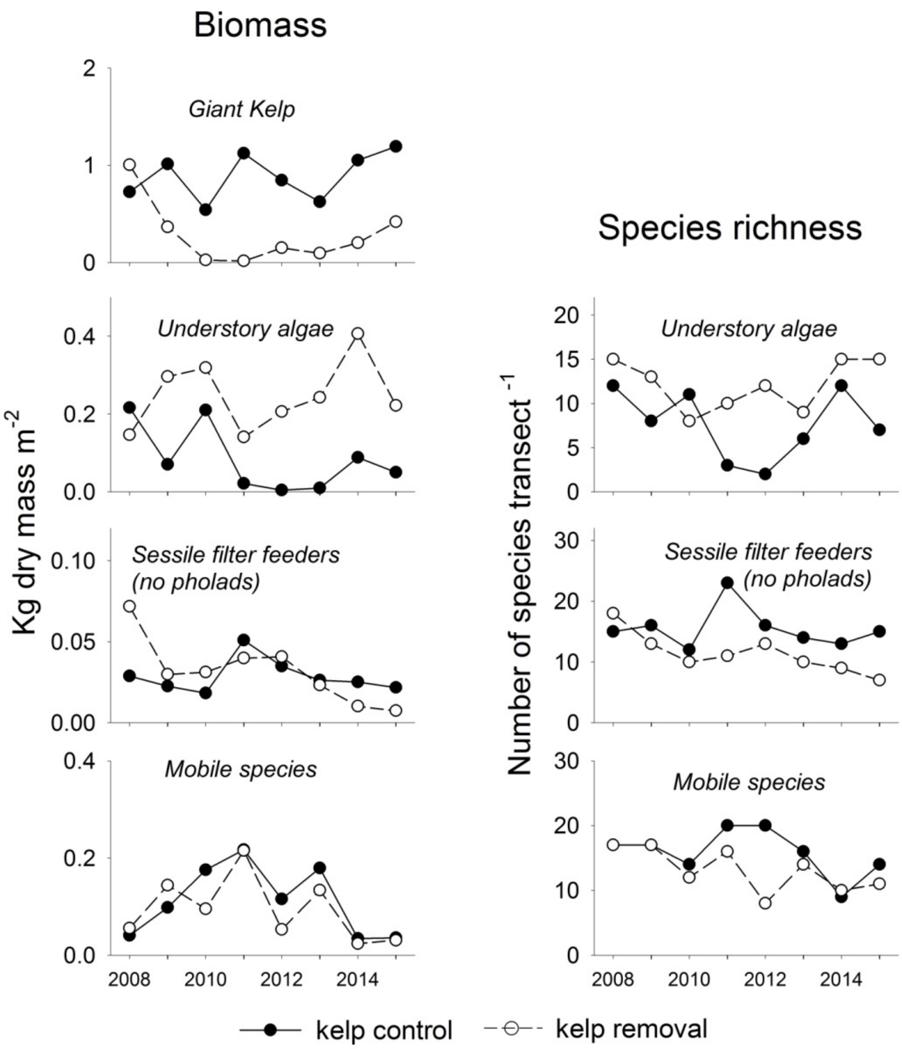
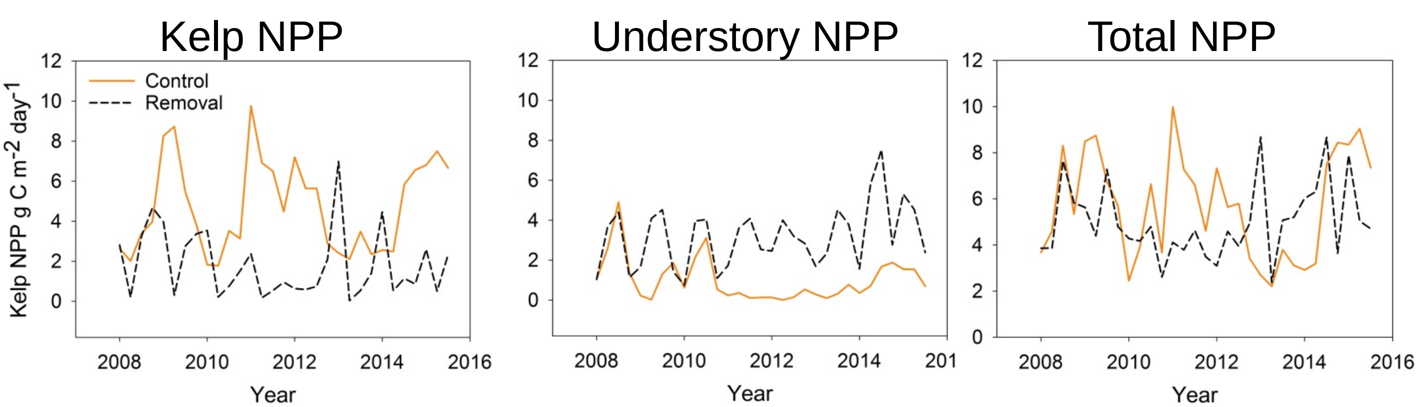
Mohawk Reef results

Understory algae and sessile invertebrates respond to kelp removal



Understory NPP helps compensate for kelp loss



Mean Total NPP is indistinguishable between control and removal (5.7 +/- 0.4 vs. 5.0,+/- 0.3; $p = 0.2$)

Nitrogen Supplies Sustaining Year-round Kelp Growth

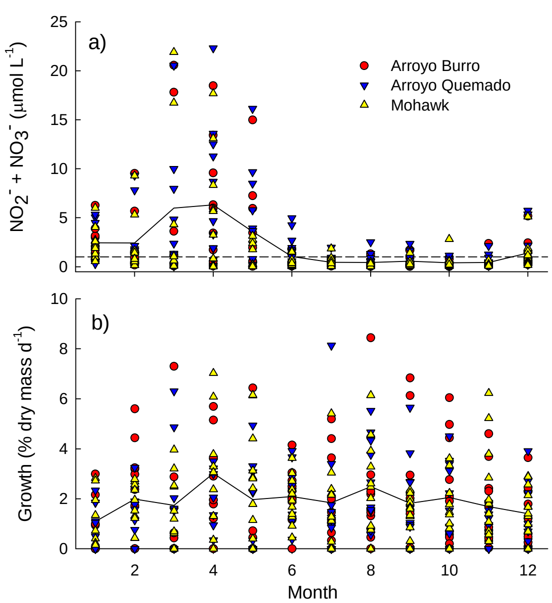
Mark Brzezinski, Dan Reed, Andrew Rassweiler, John Melack, Blair Goodridge, Jenny Dugan

N Supply Challenges:

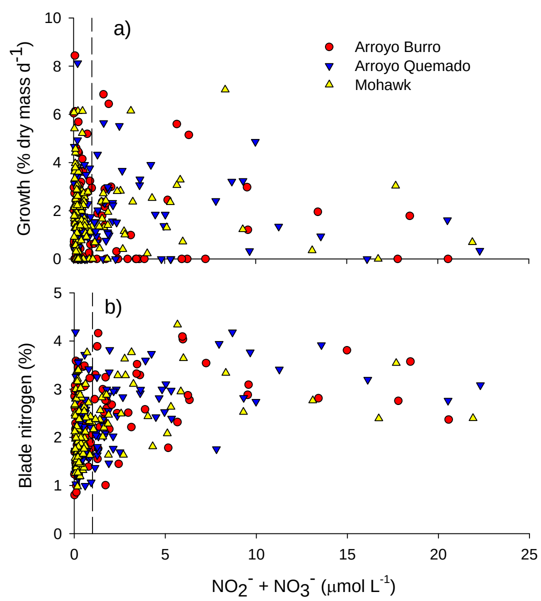
1. Substantial kelp growth throughout the year
2. Minimal N storage in kelp forests necessitates a continuous supply of DIN

Challenges		LTER Solution:
Biological Demand	→	Time series of biomass, kelp tissue N
NO_3 Sources	→	Moorings, stream monitoring,
NO_3 Supply	→	Modeling

Time Series of NO_3 and Kelp Growth

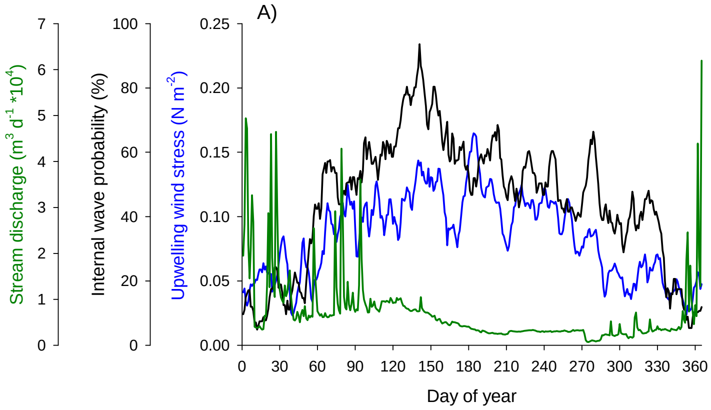


- Seasonality in nitrate not reflected in growth rate

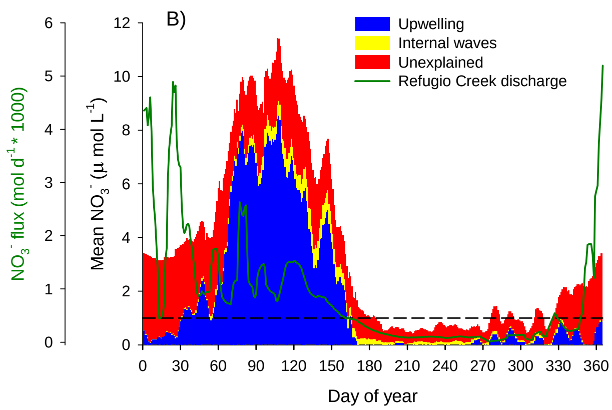


- Growth and N content often high when nitrate low

Diversity, Timing and Magnitude of Nitrate Supply

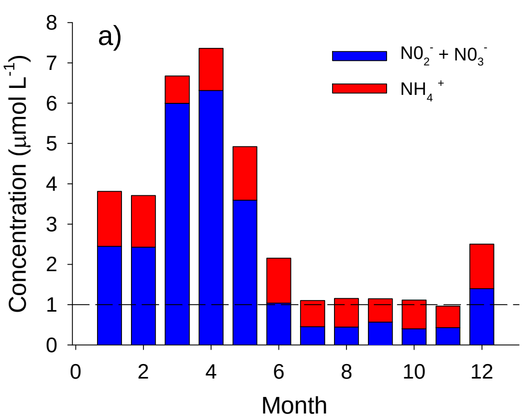


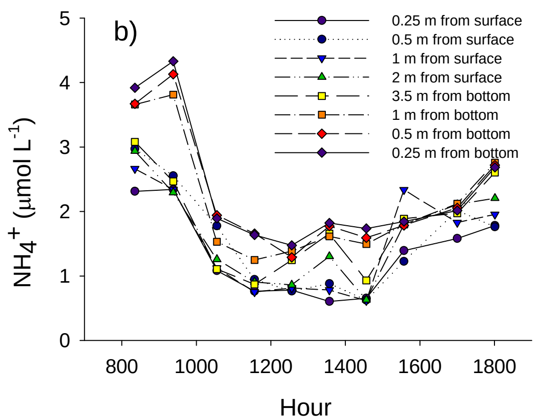
- One or more delivery mechanisms present throughout the year



- Nitrate delivery meets kelp N demand except during summer

Ammonium as the "Missing DIN"





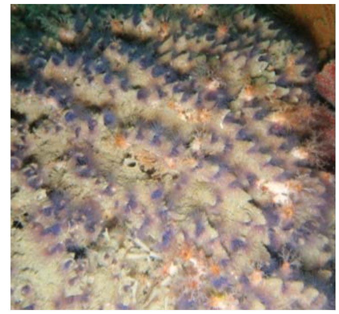
- Considering ammonium brings summer total DIN above growth threshold
- High resolution temporal profiling suggests a benthic source
- New campaign will address benthic efflux as potential DIN supply

Trophic interactions and energy flow in the kelp forest food web

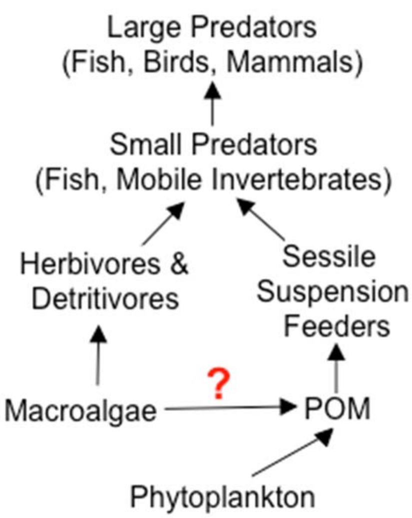
Mark Page, Bob Miller, Christie Yorke, Craig Koenigs, Dan Reed, Mark Brzezinski

Sources of organic matter to kelp forest suspension feeders

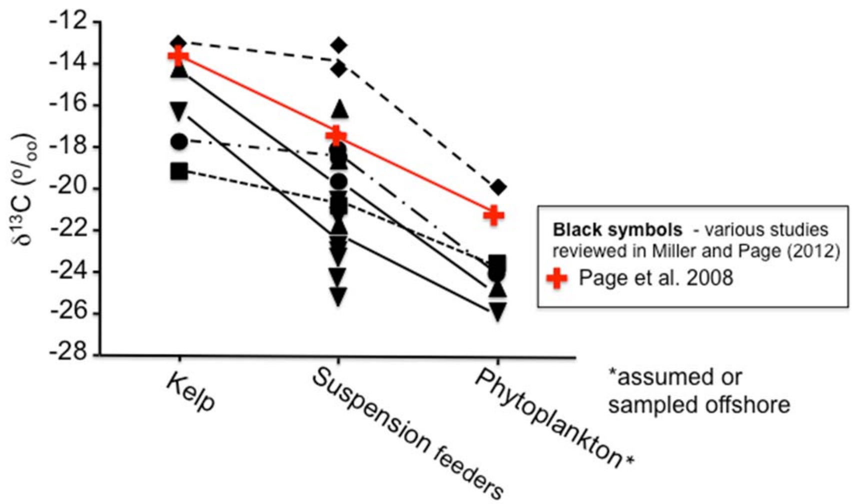


Kelp forest food web

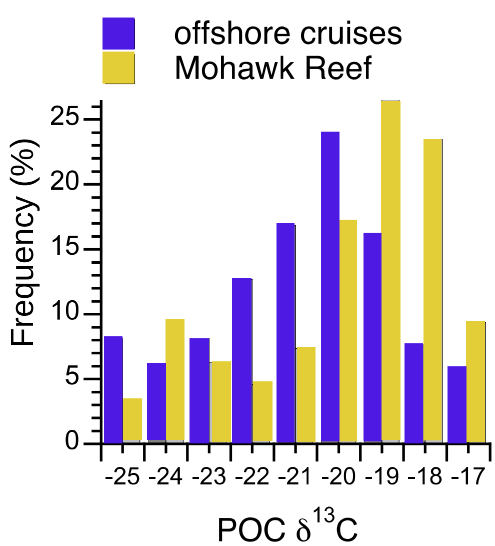


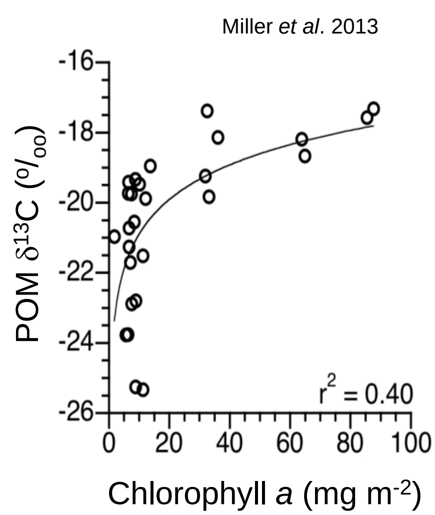
The kelp detritus hypothesis (KDH)



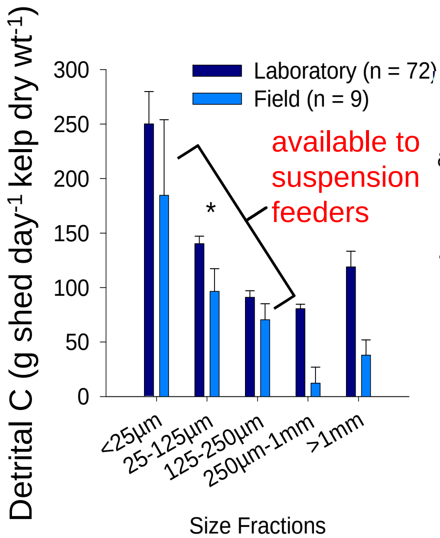
- Kelp detritus asserted to be important source of dietary carbon to benthic suspension feeders
- Nearshore POM is generally assumed composed of a mixture of kelp detritus and phytoplankton

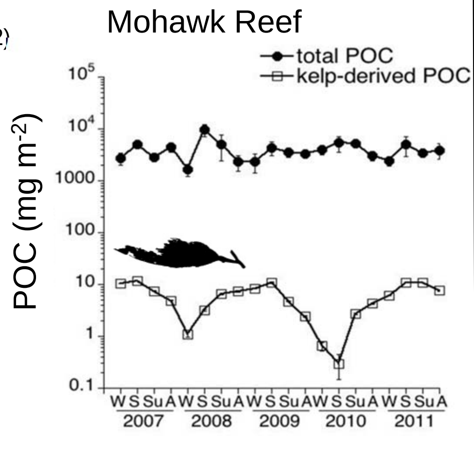
Reef and offshore phytoplankton differ in isotope composition





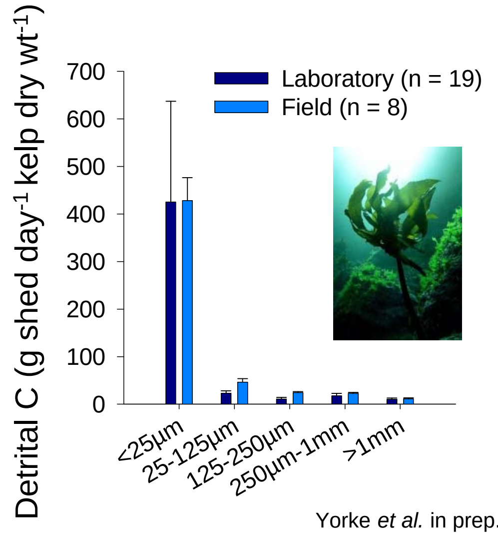
Detrital kelp carbon is a very small fraction (<0.2%) of total suspended reef POC





Yorke *et al.* 2013

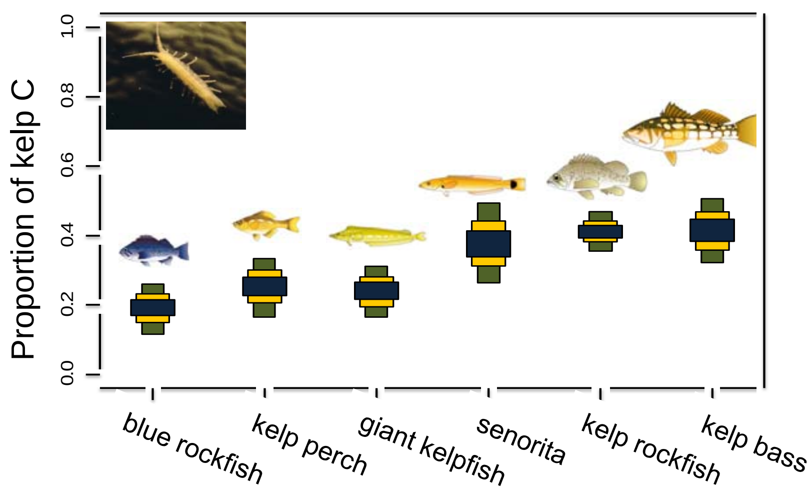
Detrital kelp a larger fraction of reef POC in New Zealand?



Yorke *et al.* in prep.

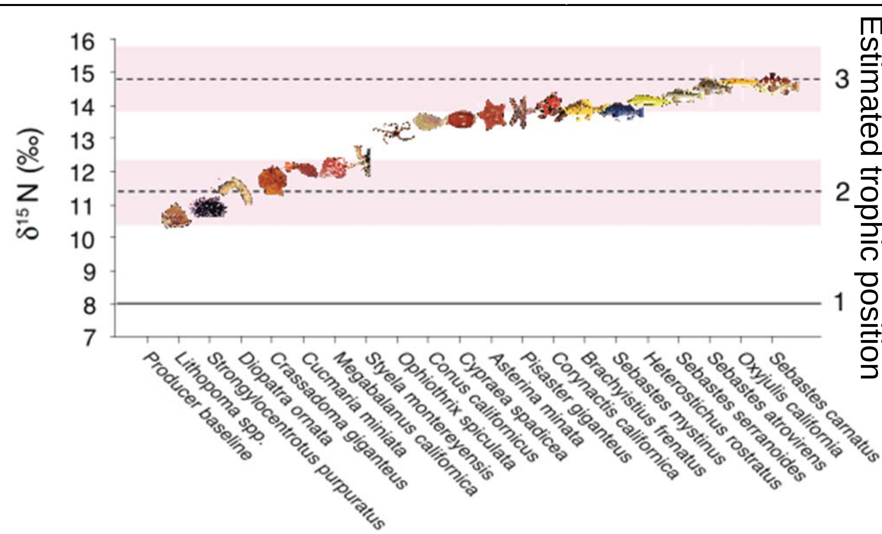
Giant kelp provides significant trophic support to fishes living in the canopy of the kelp forest

Koenigs *et al*. in press



Nitrogen isotope analysis complemented gut content studies in revealing that some predatory fish were feeding largely on lower-level invertebrates

Page *et al*. 2013



SBC LTER Schoolyard: Education and Outreach

Scott Simon, Carol Blanchette, Jenny Dugan

UCSB *AS* THE SCHOOLYARD

Aligns SBC LTER science with Next Generation Science Standards and Practices

Transforms science content knowledge at multiple levels

- Strategic Pre-service & In-service teacher training
- Undergraduate/graduate student training,
- Teacher professional development

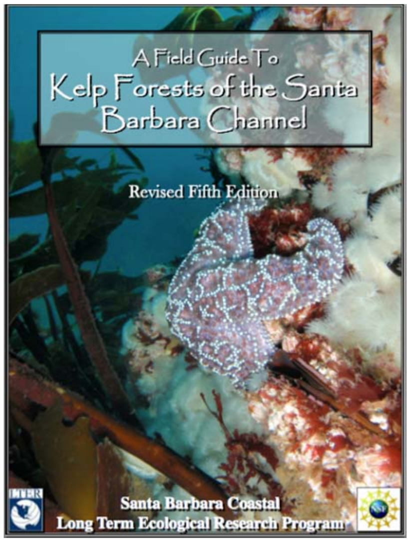
Optimizes project-based & place-based experiential learning for P-20 students across 3 south coast counties

SBC SCHOOLYARD BY THE NUMBERS

- ~60 schools/year
- 98% are within 15 miles of an accessible beach
- >50% of students polled had never been to the beach
- "All the science these kids will get"-SB Co. K-12 Teachers

- Coastal location
- Supports strategic on/off campus partnerships and collaborations
- Provides P-20 and the community an ocean view of the SBC LTER

UCSB *AS* the SCHOOLYARD

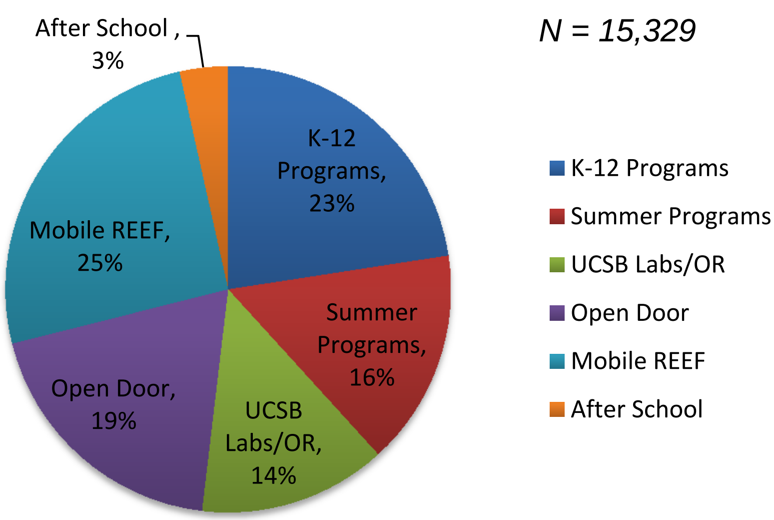


Use of SBC resources to support science and pedagogical content knowledge

- Field Guide/Apps
- Researchers
- Professional Education Staff
- Data

<u>Outcome:</u>
Engaging experiences with place-based STEM content

Percentage of On Campus and Off Campus community learning about SBC Science



- Kelp forest ecology
- Press / Pulse disturbances
- Ocean circulation / climate
- Plankton diversity
- Food web interactions

ON CAMPUS PARTNERSHIPS

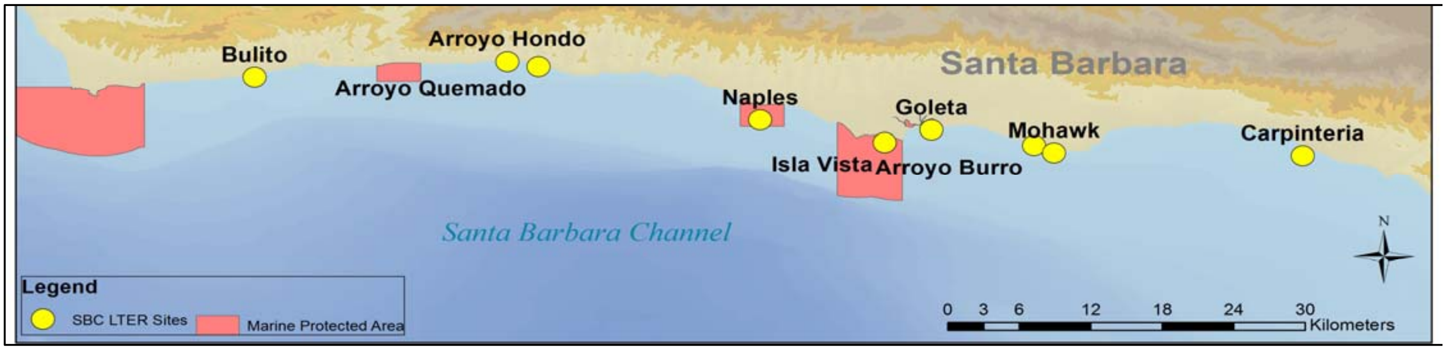
OFFICE OF EDUCATION PARTNERSHIPS
EARLY ACADEMIC OUTREACH PROGRAM
GIVERTZ GRADUATE SCHOOL OF EDUCATION

OFF CAMPUS PARTNERSHIPS

NOAA-SB CHANNEL ISLANDS NATIONAL MARINE SANCTUARY
AM. ASSOC. OF UNIVERSITY WOMEN (AAUW) TECH TREK
SANTA BARBARA UNIFIED SCHOOL DISTRICT

Effects of fishing on kelp forest community structure

Sally Holbrook, Hunter Lenihan, Andrew Rassweiler, Dan Reed,
Carla Guenther, Lindsay Marks



Marine Protected Areas (MPAs)

- Locations that restrict or prohibit fishing
- Provide a large scale manipulation
  - Assess effects of fishing
  - Understand ecosystem dynamics
- Coastal MPAs established in 2012 include 2 SBC long-term sites

Fishing can trigger a trophic cascade

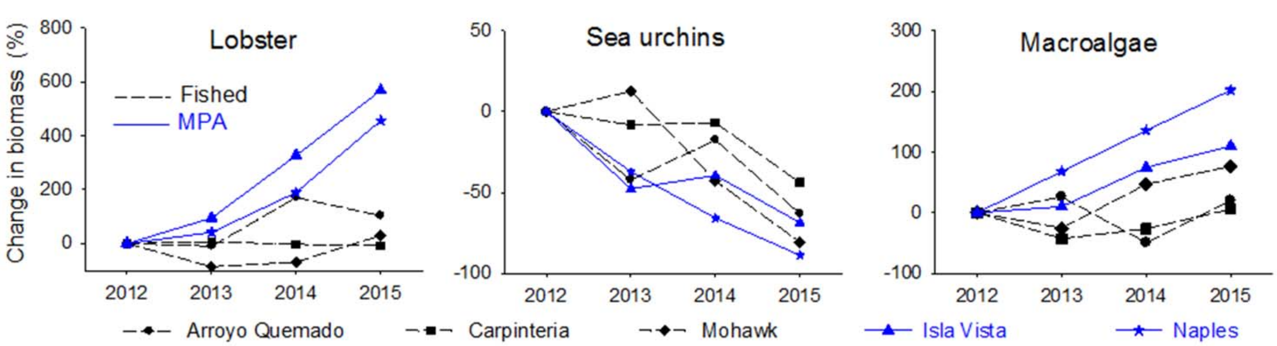
Spiny lobster

Sea urchin

Giant kelp

Guenther et al. 2012

- Use SBC time series data and fishery data
- Lobsters biomass increased dramatically
  - Lower trophic levels also responding
  - We expect changes to continue over decades



MPAs affect behavior of fishers

LTER researcher co-fishing with local lobstermen

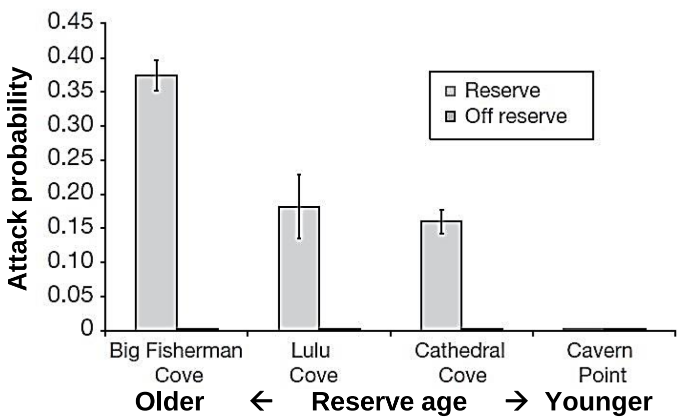
Fishing effort redistributed in response to MPAs

Lobster fishery prefers contiguous habitat areas for setting traps

- Displacement of fishing due to MPAs was more extensive and complex than expected

Kay et al. 2012, Guenther et al. 2015

MPAs can affect predator behavior and ecosystem processes



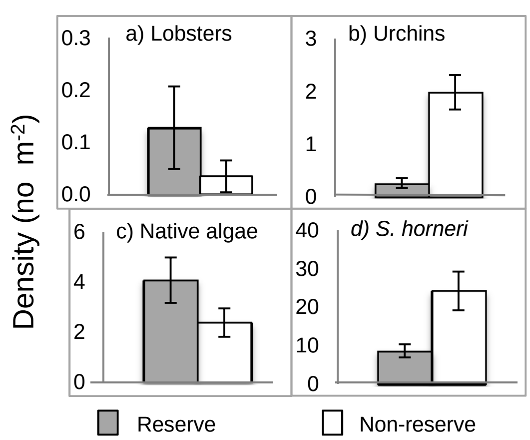
Berriman et al. 2015

- MPAs change abundances but also can change ecological processes
- Lobsters attack chemically defended sea hares inside but not outside reserves
- Example of broader reorganization of the food web when fishing is removed

MPAs and biotic resistance to invasive species

Marks et al. in press

Diver measuring the abundance of *Sargassum horneri*



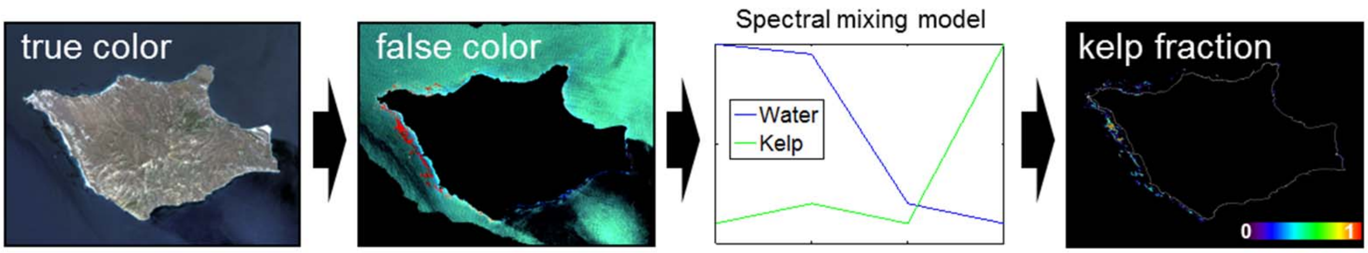
Higher abundance of the invasive seaweed *Sargassum horneri* outside reserves on Channel Islands

Densities of organisms outside of reserves are consistent with a trophic cascade: a) lobsters are reduced, b) urchins are increased, c) native algae are reduced and d) *S. horneri* is more abundant

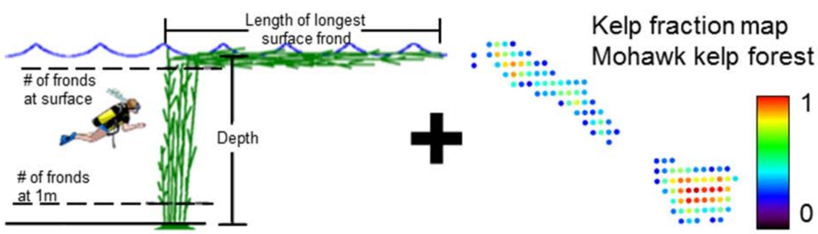
Regional dynamics of giant kelp using remote sensing

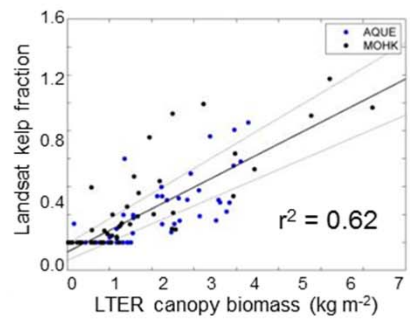
Tom Bell, Kyle Cavanaugh, Dan Reed, David Siegel

Transform Landsat imagery to kelp canopy pixel fraction

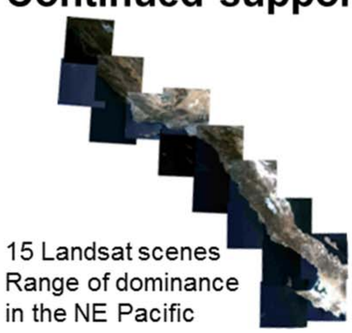


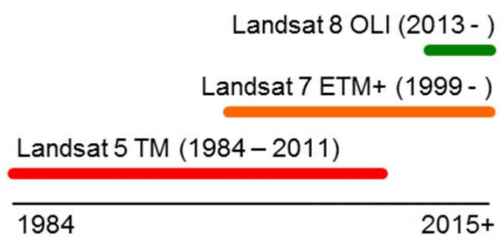
LTER biomass surveys make kelp fraction values meaningful

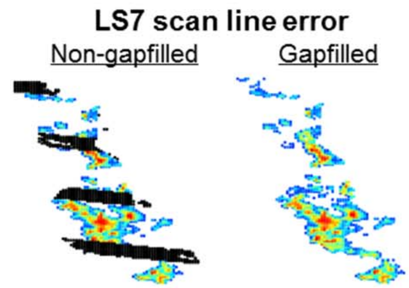




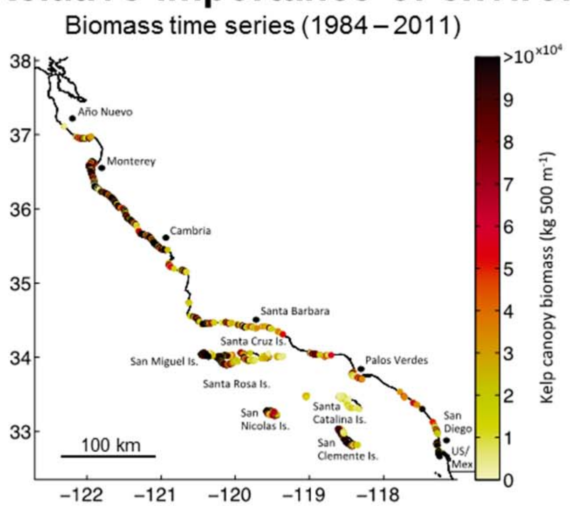
Continued support expands time series spatially and temporally

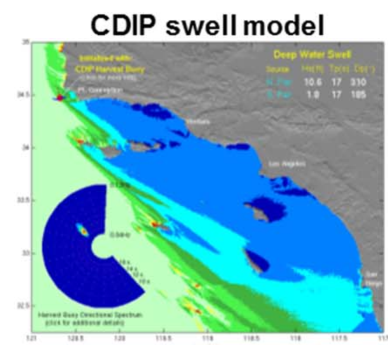


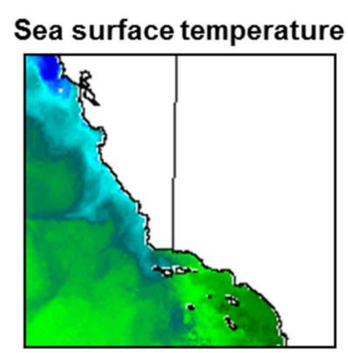




Relative importance of environmental drivers varies spatially

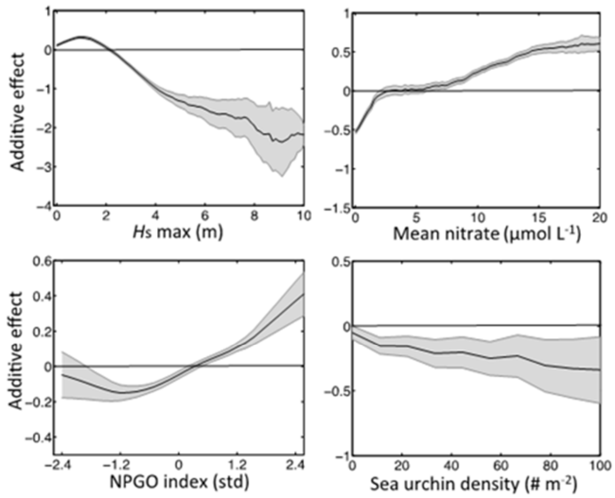


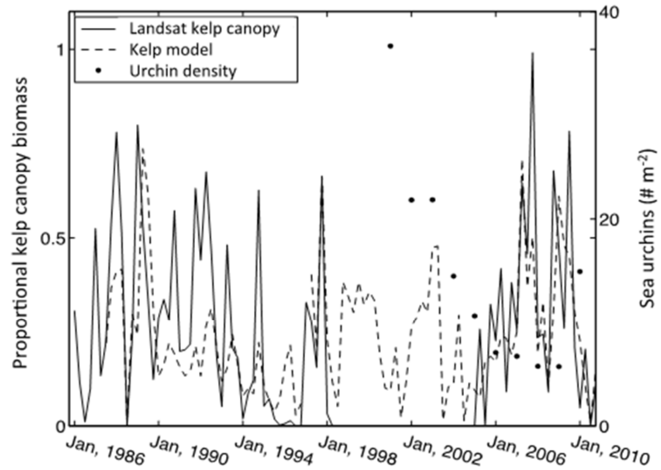




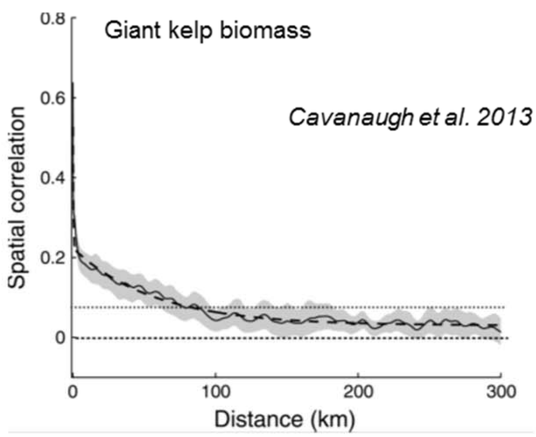
Analysis reveals nonlinear relationships and improves predictive modeling

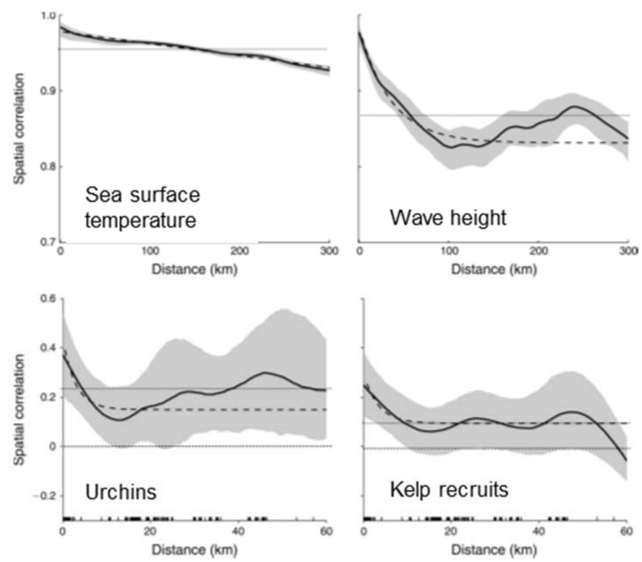
Bell et al. 2015



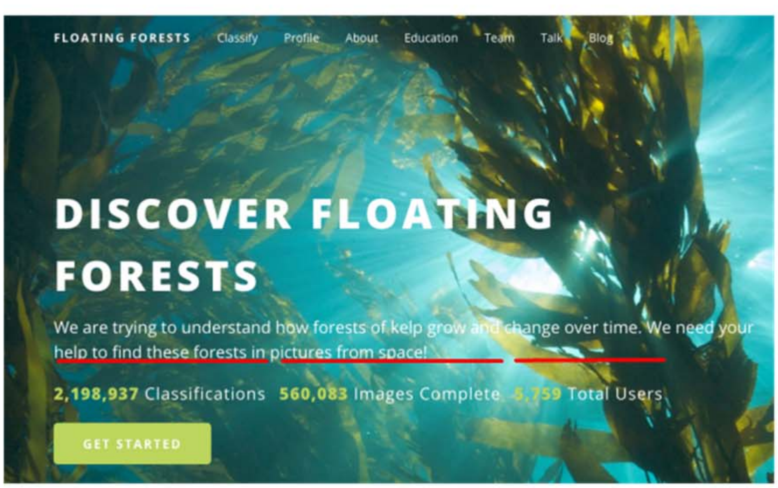


Synchrony analysis reveals local and regional scale drivers





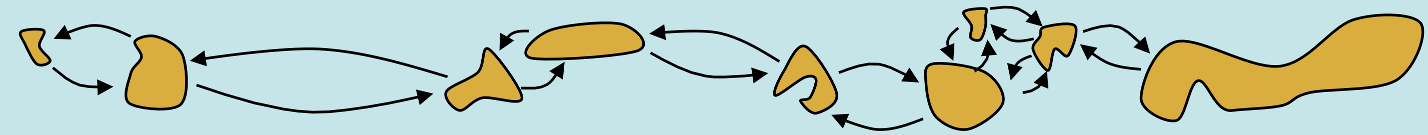
FloatingForests.org: Citizen science for global kelp area mapping



Metapopulation ecology of giant kelp forests

Max Castorani, Dan Reed, Peter Raimondi, Filipe Alberto, Tom Bell, Kyle Cavanaugh, David Siegel, and Rachel Simons

Metapopulation: network of populations that are demographically linked by dispersal



Predictions from metapopulation theory

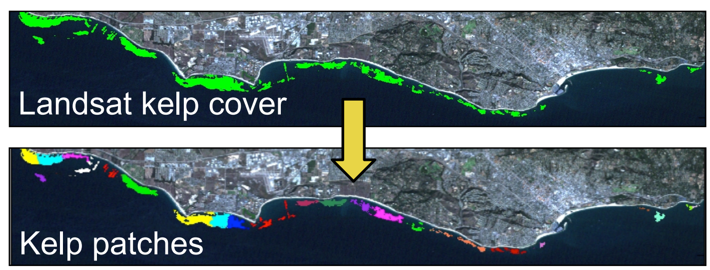
(1) Local scale: Increasing patch size and connectivity improve the probability of colonization and diminish the risk of extinction

(2) Regional scale: Increasing patch-network size, connectivity, and asynchrony enhance metapopulation persistence and resilience

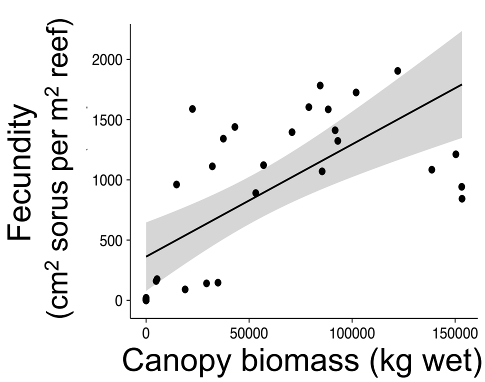
Empirical challenges		SBC LTER solutions
1. Constrained population estimates	➡	Landsat giant kelp biomass time series
2. Poorly defined patch boundaries	➡	Superior patch delineation method
3. Simple connectivity measures	➡	Fecundity estimates + ROMS dispersal

Superior patch delineations using novel synchrony-based method

- Combines spatial synchrony of giant kelp biomass & tools from graph theory
- Avoids consolidating subpopulations & overcomes the *"mega-patch problem"*



Sophisticated, dynamic estimates of demographic connectivity



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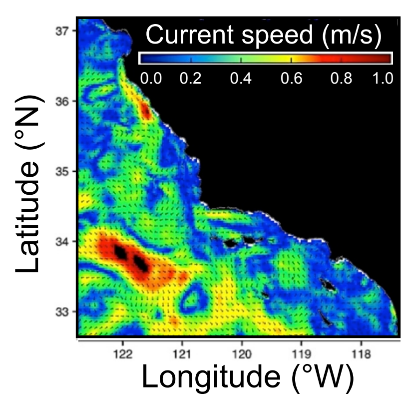
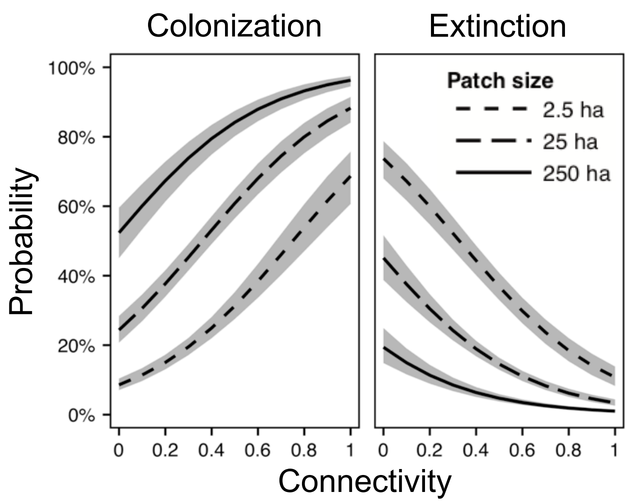
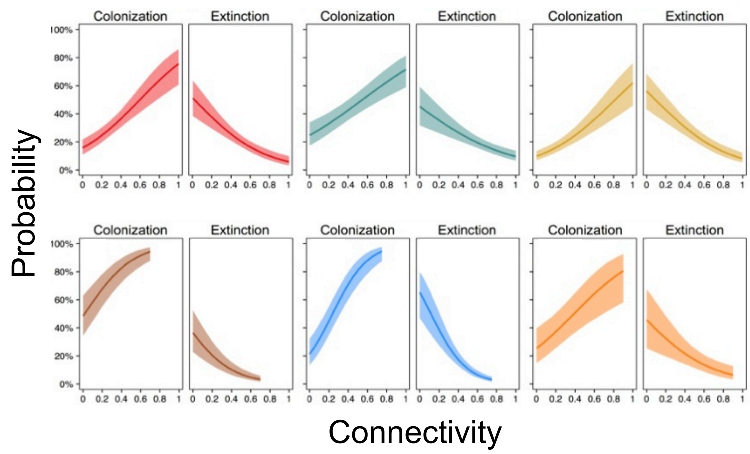


- Diver-calibrated relationship between giant kelp biomass and fecundity
- Spatially & temporally dynamic oceanic dispersal estimates using ROMS

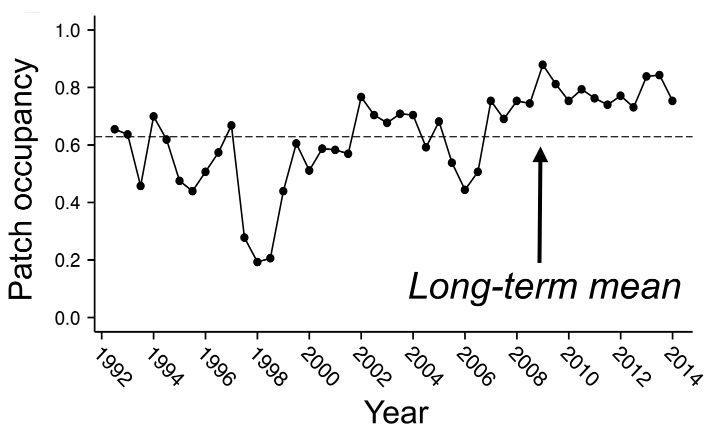
(1) Local scale: Patch connectivity and size mediate local dynamics

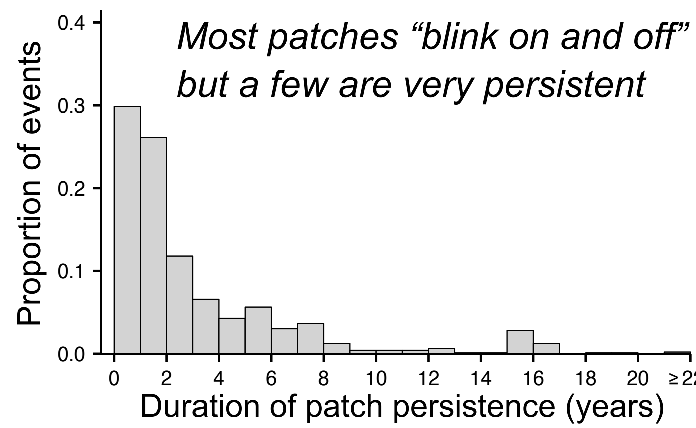


Pattern is repeatable at many subregions



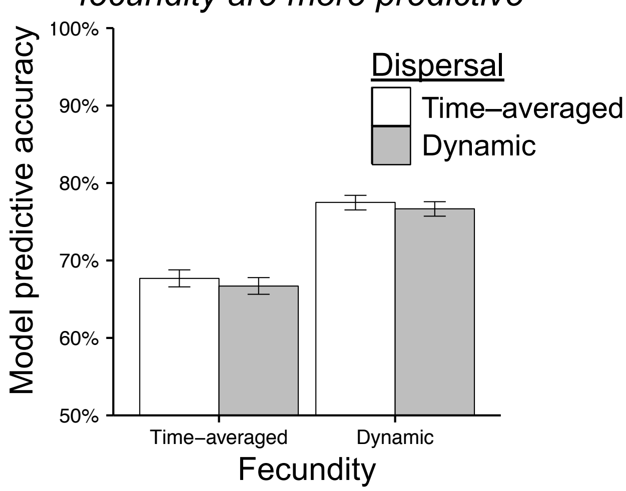
(2) Regional scale: Asynchrony allows metapopulation persistence



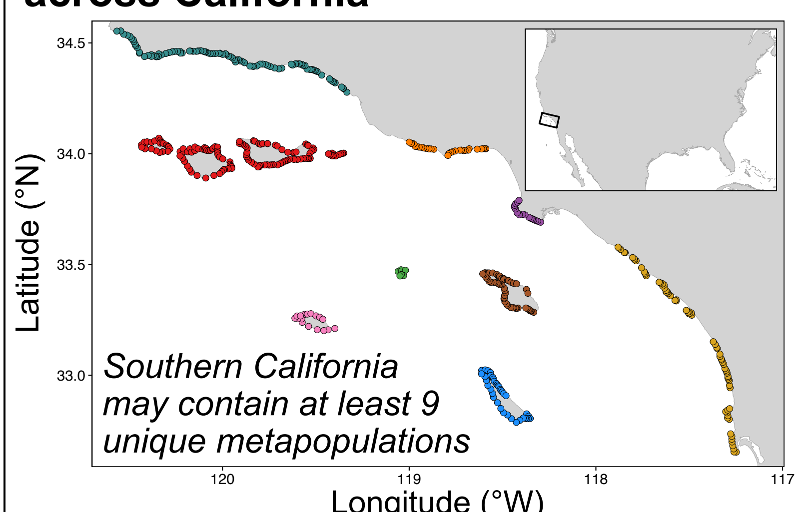


The dynamics of fecundity, rather than dispersal, drive demographic connectivity

Models with temporally-dynamic fecundity are more predictive



Metapopulation modeling and genetic sampling suggest the presence of many metapopulations across California



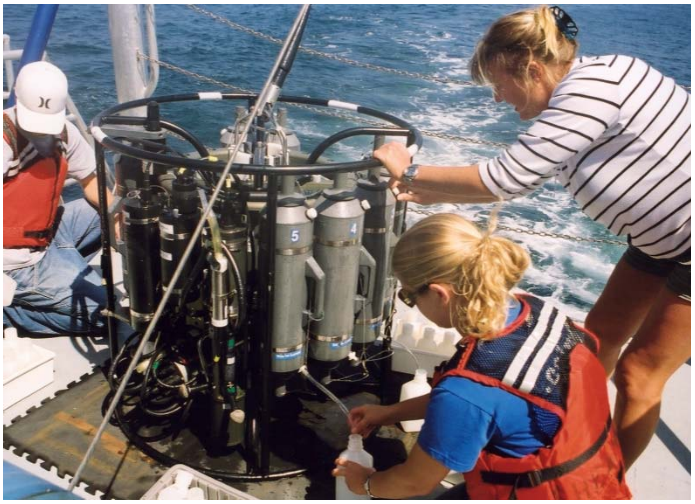
Collaborative research partners in the Santa Barbara Channel

I. Plumes & Blooms - Ocean Color Variability in Case II Ocean

David Siegel & Stéphane Maritorena

Plumes & Blooms (PnB) focuses on understanding ocean color variability in highly variable coastal environments with the goal of improving coastal satellite ocean color observations. PnB makes monthly cross-channel surveys and collaborates with the SBC LTER on studies of oceanographic variability, phytoplankton community structure, HABs, inorganic/organic carbon cycle dynamics, etc. PnB is funded by NASA.

Monthly Sampling of Optical, Physical & Biogeochemical Parameters



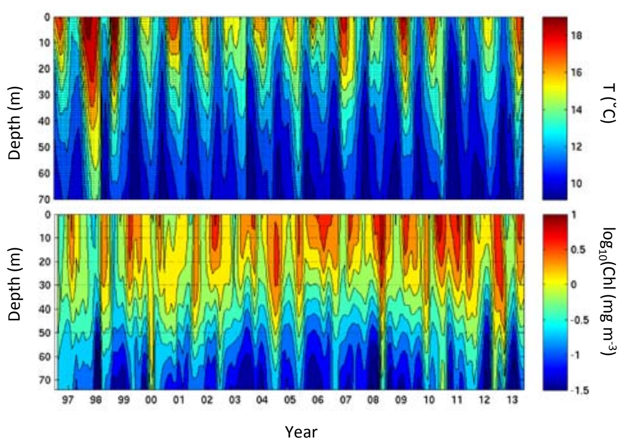
Monthly 7 station transect on NOAA's R/V Shearwater

In situ Profile Parameters Sampled

- Ocean color spectra (profiling radiometer)
- Total absorption & scattering spectra (AC-9)
- Backscatter spectra (Hydroscat-6)
- Particle size spectra (LISST-900)
- Salinity, temperature, depth

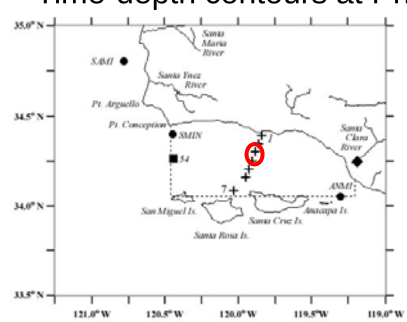
Bottle sample Parameters Sampled

- Phytoplankton, dissolved organic & detrital absorption spectra (spectrophotometry)
- Nutrients (NO_3, PO_4, SiO_4)
- Phytoplankton pigments by HPLC (run by NASA)
- Dissolved inorganic & organic carbon
- Particulate silica (biogenic & lithogenic)
- Water for other investigators especially student projects



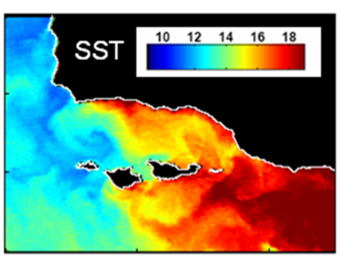
PnB Time Series Observations

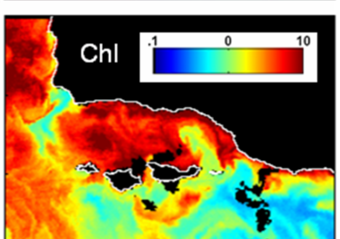
Time-depth contours at PnB Station 4

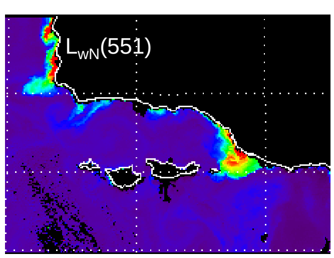


- Dynamic system
- Large El Niño in 97/99
- Overall cooling & increasing chlorophyll

Satellite Data Analyses





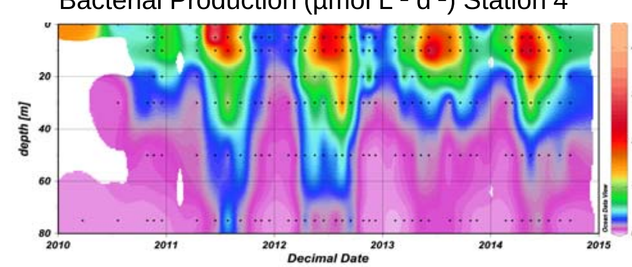


Coastal Plumes
April 6, 2006

Upwelling Bloom
June 12, 2004

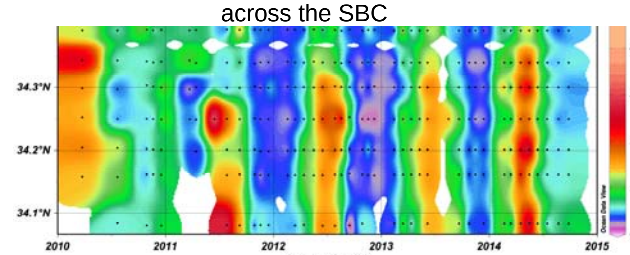
Microbial Dynamics in the SBC

Bacterial Production (µmol L^{-1} d^{-1}) Station 4



Surface Map of Bacterial Production (µmol L^{-1} d^{-1}) across the SBC

In shore



Off shore

Collaborative research partners in the Santa Barbara Channel

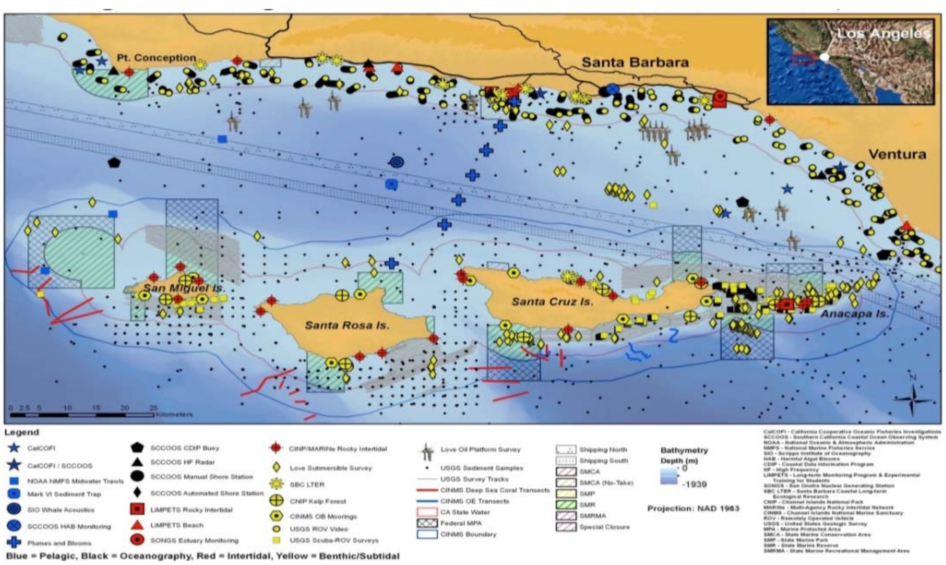
II. SBC Marine Biodiversity Observation Network

Bob Miller, Craig Carlson, Dave Siegel, Dan Reed, Andy Rassweiler, Deborah Iglesias-Rodriguez, Milton Love, Andrew Thompson, John Hildebrand, Doug McCauley

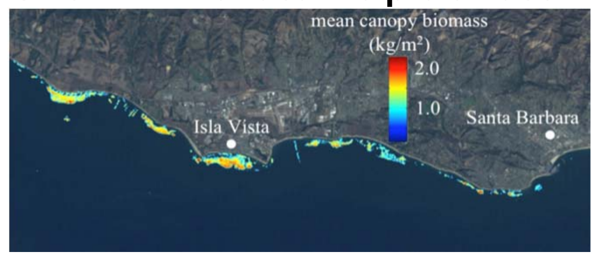
SBC MBON focuses on gaining a more complete picture of marine biodiversity for the purpose of detecting change in marine ecosystems going forward. SBC BON uses biodiversity data from multiple partners including SBC LTER, and is also working to improve methods for measuring biodiversity. SBC BON is funded by NASA, BOEM, and NOAA.

Integrating biodiversity data across the Channel

- **Using geostatistical methods to integrate point data across space**
- **Developing models to link physical and other continuous data with biodiversity**



SBC LTER Landsat kelp biomass



Ecosystems include:

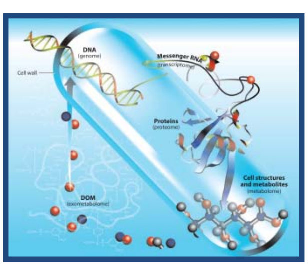
Shallow and deep benthos

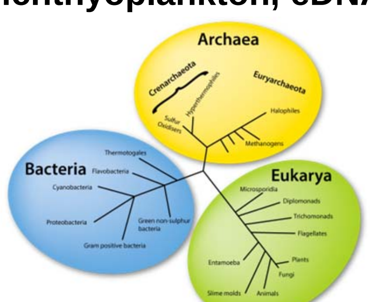
Pelagic

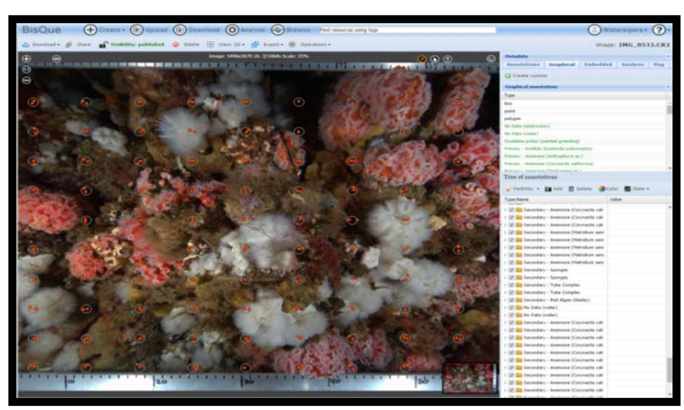
BisQue – an environment for image analysis

Developing methods to improve biodiversity measurement

- **Genomics - microbes, ichthyoplankton, eDNA**

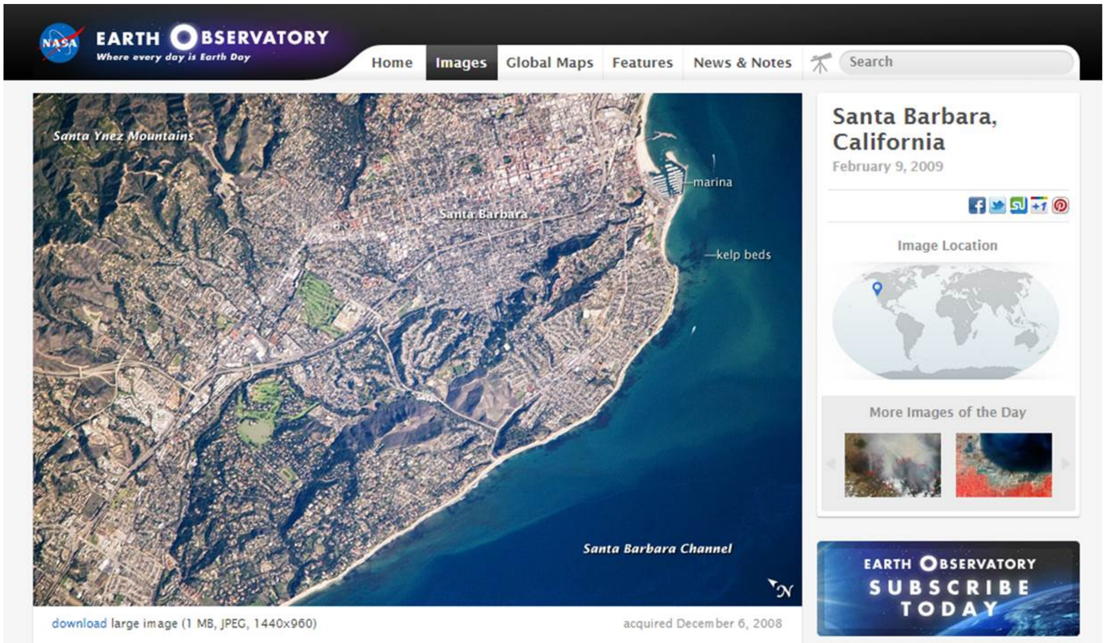






- **Image analysis – benthos, fish**
- **Acoustics – marine mammals**
- **Optimization modeling - tools to design sampling**

SBC LTER featured as NASA image of the day



This detailed astronaut photograph highlights the Santa Barbara, California, metropolitan area, sometimes called the "American Riviera." The geographic setting of the city—between the Santa Barbara Channel to the south and the steep Santa Ynez Mountains to the north—and its year-round mild climate evoke the Mediterranean Riviera. The city was officially founded as a Spanish mission in 1786, and it was incorporated into the United States from Mexico in 1848 following the Mexican-American War.

The dramatic landscape of the city is the result of tectonic forces; the Santa Barbara Channel is part of the boundary between the oceanic Pacific Plate and the continental North American Plate. Movement along the San Andreas Fault—the actual zone of contact between the two plates—over geologic time both raised the Santa Ynez range and lowered the seafloor, forming the deep Santa Barbara Channel. The city has experienced two earthquakes, one in 1812 and another in 1925, that caused significant damage.

The urban street grid is defined by white and red rooftops at image top center; to the southeast lie beaches and the boat slips of a large marina (image top right). Two large golf courses, characterized by expanses of green grass, are visible at image center. Low, east-west-trending hills that parallel the coastline are almost completely covered by residential and commercial development, lending a speckled appearance to the hillsides. Immediately offshore, giant kelp beds are the focus of the **Santa Barbara Coastal Long Term Ecological Research site**, part of the **National Science Foundation's Long Term Ecological Research Network**.

Astronaut photograph ISS018-E-11096 was acquired on December 6, 2008, with a Nikon D2Xs digital camera fitted with an 800 mm lens. It is provided by the ISS Crew Earth Observations experiment and the Image Science & Analysis Laboratory, Johnson Space Center. The image was taken by the Expedition 18 crew. The image in this article has been cropped and enhanced to improve contrast. Lens artifacts have been removed. The International Space Station Program supports the laboratory to help astronauts take pictures of Earth that will be of the greatest value to scientists and the public, and to make those images freely available on the Internet. Additional images taken by astronauts and cosmonauts can be viewed at the NASA/JSC Gateway to Astronaut Photography of Earth. Caption by William L. Stefanov, NASA-JSC.