SBC LTER Annual Report:
September 1, 2011- August 31, 2012

ACTIVITIES

Below we report our activities in the areas of Research, Information Management Education/Outreach, and Supplemental Support for the period September 1, 2011 through August 31, 2012

Research

The primary research objective of the Santa Barbara Coastal Long Term Ecological Research (SBC LTER) program is to understand the linkages among ecosystems at the land-ocean margin with the goal of developing a predictive understanding of the structural and functional responses of giant kelp (*Macrocystis pyrifera)* forests to environmental forcing from the land and the sea. To achieve these goals and objectives we conduct research in kelp forests, coastal watersheds, beaches and the nearshore ocean. Coordinated long-term measurements and experiments pertaining to key environmental drivers and ecological response variables form the core of our research activities. These are supplemented with shorter term "research campaigns" strategically designed to obtain a mechanistic understanding of patterns and processes revealed by our longer term measurements and experiments. A list of ongoing measurements routinely collected by SBC LTER is provided in Table 1. Following is a summary of our major research activities for the period September 1, 2011 to August 31, 2012. Publications resulting from this work are listed under "Products" of this report and are searchable online by author and year on SBC LTER's website (http://sbc.lternet.edu/cgi-bin/publications.cgi). Research presentations by SBC personnel pertaining to these activities can be viewed at: http://sbc.lternet.edu/catalog/presentations.jsp.

KELP FORESTS:

Annual monitoring of community structure was completed at our 11 long-term kelp forest sites in the Santa Barbara Channel to maintain our ongoing time series of population and community dynamics. Data on population abundance (and individual size for selected taxa) were collected for > 200 species of algae, invertebrates and fish that characterize the kelp forest food web. Data were also collected twice per season at five sites using a similar but expanded sampling design that incorporates measurements of ecosystem attributes (e.g., primary production, detrital accumulation, producer and consumer biomass). This was done as part of an ongoing kelp removal experiment initiated in 2008 to examine the consequences of increased disturbance on the structure and function of kelp forest ecosystems. We added a 5th site to this experiment in September 2011 to incorporate a newly designated marine reserve into our experimental design, which allows us to examine the interactive effects of fishing and natural disturbance on kelp forest communities. Additional sampling was done to maintain: (1) a monthly 10-year time series of giant kelp biomass, net primary production, and stoichiometry at three sites along the mainland coast of the Santa Barbara Channel, and (2) an annual 30-year time series of reef fish population density, age structure, reproduction, foraging habitat and food supply at 11 sites off Santa Cruz Island.

We developed a novel method for estimating kelp canopy biomass from Landsat 5 Thematic Mapper satellite imagery to examine regional patterns and drivers of kelp biomass (Cavanaugh et al. 2011). During the past year we expanded our efforts in processing this imagery to produce a comprehensive time series of surface canopy biomass for the entire coast between Monterey Bay, California and Bahia Magdalena, Mexico, including offshore islands. The time series has a

sample frequency of ~ once per every ~6 weeks and extends from 1984-2011. Image acquisition from Landsat 5 was suspended indefinitely in November 2011. We recently developed and validated a method to extract kelp canopy biomass data from Landsat 7 Enhanced Thematic Mapper imagery to preserve the continuity of our satellite kelp biomass.

In 2011 we partnered with Dr. Stephen Schroeter on his unique ongoing 22-year time series of biweekly measurements of invertebrate larval settlement at six sites in southern California, and one site in northern California. We oversee the data collection at four sites in the Santa Barbara region and we manage the data for all sites in the time series. We incorporated the dataset into SBC's data catalog, which required extensive documentation and data organization.

COASTAL WATERSHEDS:

Measurements of rainfall and stream discharge and hydrochemistry were continued to maintain our time-series of nutrient and sediment fluxes from the land to the coastal waters. A new set of pressure transducers were installed in nine streams and rating curves were updated based on surveys of stream cross-sections and manual measurements of discharge. From October to May samples for chemical analyses were collected weekly during baseflow and every 1 to 4 hours during storms with ISCO autosamplers. Biweekly stream samples were collected from June to September, and rain samples were collected on an event basis during each rainfall. Assays for nitrate, ammonium, phosphate, total dissolved nitrogen, particulate nitrogen, total dissolved phosphorus, particulate phosphorus, particulate organic carbon, total suspended sediments and conductivity were performed on the stream samples and for dissolved inorganic constituents on rain samples. Cations (calcium, magnesium, sodium and potassium) and silicon were determined on a subset of stream samples. Following conversion of stage to discharge and assays for nutrients and particulates, calculations were made of fluxes of solutes and particulates per storm and per year and separated into baseflow and stormflow. Rainfall amounts amount per storm and annually for each catchment with discharge measurements and atmospheric loading per storm and per year were also calculated. Modeling of Mission Creek hydrology with the Regional Hydro-Ecological Simulation System (RHESSys) included an assessment of parameter and input uncertainty.

As a continuation of our examination of responses to recent fires, in part supported by other NSF funds, further analysis of a time series of Airborne Visible and Infrared Imaging Spectrometer (AVIRIS) data focused on fire impacts and recovery to vegetation. AVIRIS images obtained before and after the fires were georectificied, reflectances were retrieved, plant-species/cover mapped, and mixture models and fire-related indices applied. Other aspects of these studies considered nitrogen biogeochemistry in soils, invertebrate abundances and nutritional conditions in streams, composition and biomass of terrestrial vegetation and Lidar-derived topography.

BEACHES:

Our ongoing research seeks to understand how beach ecosystems function as: (1) recipients and processors of organic matter exported from kelp forests (wrack), (2) filters of groundwater and seawater and (3) sources of regenerated nutrients to the coastal ocean. During this reporting period we continued to collect long-term data on kelp wrack inputs, shorebird use, consumer populations and beach morphology at beaches in the Santa Barbara region. We added several new beach sites (Arroyo Quemado, Isla Vista and East Campus) to our time series this past year to evaluate the ecological consequences of newly established marine protected areas in our study domain. As part of this effort we conducted extensive intertidal community biodiversity surveys in September and October 2011 and key indicator species (talitrid amphipods, sand crabs) were

surveyed in June 2012. Sample processing is in progress. We are investigating the functional role of upper intertidal zones (above the driftline) in macrophyte wrack accumulation, consumer abundance and nutrient concentrations using a gradient design along ~ 1 km of bluff-backed beach on the mainland coast of the Santa Barbara Channel. Research on the effects of seawalls on these beach features and processes is planned for Fall 2012. As part of our examination of the role of beaches in water filtration and nutrient regeneration we collected pore water samples with mini-piezometers from several depths and locations and assayed for particulate and dissolved organic carbon and nitrogen, dissolved inorganic nitrogen (NH_4 and NO_3) and ^{222}Rn, to permit pore water residence time modeling.

NEARSHORE OCEAN:

We continued to collect core oceanographic data for our ongoing long-term time series of the physical, chemical and biological properties of the inner coastal ocean. These data provide valuable contextual information for our ecological studies and detecting patterns and drivers of oceanographic change over a variety of spatial and temporal scales.

We continue to analyze data collected from 16 shipboard cruises in the Santa Barbara Channel conducted on board the RV Pt. Su during 2001-2006. Analysis during this reporting period focused on observations of water properties (physical, chemical and biological) obtained using towed undulating vehicles. These vehicles were equipped with multiple sensors that measured vertical sections of water properties with a horizontal resolution of about 500 m and vertical resolution of about 2 m along eight cruise tracks spread across the Santa Barbara Channel.

An important research objective of SBC LTER is to develop a framework describing the fate of stream inflows into the Santa Barbara Channel with a focus on quantifying the loading of nutrients and sediments from small streams into kelp forests and their surrounding waters. Our research approach involves: (1) numerical simulations of storm water runoff using a Regional Ocean Modeling System (ROMS) framework that is able to simulate the coastal circulation with very high horizontal resolution (250m), and (2) empirical measurements of stream discharge, ocean currents, water column properties and resulting plume dynamics obtained from instrument arrays that are being deployed over the next several years. The deployment of instrument arrays is being done in collaboration with Steve Monismith and Ali Boehm of Stanford University, which increases our collective knowledge of coastal oceanography, engages a graduate student (Simon Wong) skilled in coastal oceanography and data analysis, and doubled the instrument pool available for the study. During the past winter (December 2011 through April 2012) we deployed an extensive array of sensors to measure temperature, conductivity, currents, and waves upstream and downstream of Arroyo Burro Creek and Mohawk kelp forest as well as with the kelp forest. Rainfall was unusually sparse this past winter and data collection during storm events was limited to three small events characterized by low stream discharge. Conductivity data from these events have been processed and are being analyzed

With supplemental funding from NSF we acquired a Teledyne Webb autonomous glider In late 2010. The glider is a buoyancy-controlled self-propelled underwater vehicle that is equipped with sensors that measure conductivity, temperature and pressure, dissolved oxygen, chlorophyll and CDOM fluorescence and backscatter. We are using this instrument to conduct repeated high resolution sampling of physical, bio-optical and biogeochemical properties of the coastal ocean. To obtain an improved understanding of the temporal and spatial variability of coastal water processes at small regional and short time scales. Our glider mission design consists of repeated 4km long cross-shelf sections off of the Mohawk Kelp Forest, between depths of 20 and 80

meters. This mission design is unique in that it aims for both temporal resolution and spatial coverage, and allows the same transect to be sampled at least four times a day, which is needed to observe the scales of diurnal changes in bio-optical properties and development of episodic processes such as buoyant plumes and phytoplankton blooms.

Information Management

We maintain an open, cross-platform Information Management System (IMS), which is based on Internet standards that leverage existing systems where possible. Our activities focus primarily on the use (and in some cased development) of tools that integrate data publication with collection and processing. SBC's IMS is closely aligned with that of MCR LTER and we work closely with several other LTER sites on specific data management issues. SBC is also well represented in the activities of the LTER Information Managers Committee (IMC), and information manager (O'Brien) is currently the IMC co-chair. Most recently, SBC has been involved in two major network-wide IM activities: a) continued development of the LTER Vocabulary (http://vocab.lternet.edu), and use of EML specification through the EML Metrics and Congruence Checker. Supplemental funds received from NSF during this reporting period were used to higher an assistant (shared with MCR) to perform routine data management tasks that enabled O'Brien to focus on the adoption of Metabase, including code adaptation, population of database tables and export as EML for projectDB, and on code required for presentation of research themes on the SBC website.

Education and Outreach

Supplemental funding for our Schoolyard LTER (SLTER) program targets K-12 students and teachers and is organized around a theme of watershed and marine ecology that incorporates SBC research. By partnering with the REEF (UCSB's educational marine aquarium facility) we reach ~ 7,000 students and the general public per year. Our summer activities involve working with Junior High School girls in collaboration with Tech Trek, a math/science summer program designed to develop interest and self-confidence in young women. We also participated in Santa Barbara's annual Earth Day festival by offering educational material and information on the natural history and stewardship of the region's coastal ecosystems to the 35,765 visitors who attended the event. Supplemental funds from NSF's REU program were used to support seven undergraduate students to work on project related research in the areas of kelp forest ecology and oceanography.

Supplemental Support

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Supplement funds were also used to purchase five deployable loggers equipped with a Honeywell Durafet® pH sensor and temperature probe. These loggers are being used to continuously measure pH at our long-term kelp forest sites and document the natural variation in pH across the strong gradient of oceanographic conditions that exist in the Santa Barbara Channel. These measurements are part of a coordinated cross-site comparison with MCR, CCE and PAL aimed at developing a predictive understanding of the susceptibility of marine species to future anthropogenic ocean acidification in vastly different ecosystems.

Supplement funding from NSF was also used to fund our Schoolyard outreach program, provide research stipends for REU students to work with SBC investigators and support new activities in information management. The activities supported by these supplemental funds are reported in "Information Management" and "Education and Outreach".

NSF funding for an ROA supplement is being used to support Dr. William Wright and his students (Chapman University) research on "trait mediated effects" of lobster predation in the well-established marine protected area at Catalina Is. Their research suggests that critical changes in the foraging behavior of lobsters within the reserve may have key consequences for the kelp forest community. They found convincing evidence that lobsters inside the reserve broaden their diet to include normally unpalatable sea hares (*Aplysia californica*). By presenting sea hares to lobsters *in situ* at various locations inside and outside the reserve, Wright and his students found that lobsters only attack sea hares inside the reserve due to increased hunger caused by higher biomass of lobsters inside the reserve compared to outside. The ROA supplement is funding Chapman's participation in a collaborative study with SBC scientists to obtain data on lobster prey abundance and to test and extend the conclusions derived from Catalina Island to a marine protected area at Anacapa Island located within the SBC LTER domain.

Table 1. Long-term core monitoring performed by Santa Barbara Coastal LTER (data available via the SBC LTER website http://sbc.lternet.edu/data/.)

Title	Summary of measurements	Year initiated
Watershed Hydrology and Stream Chemistry:		
Precipitation	Rainfall at 12 stations	2003
Stream Discharge	Stream stage and discharge at 16 stations	2002
Stream Chemistry	Storm-flow and base-flow sampling of nutrients, major anions and cations at 8 stations	2001
Ocean Physics & Biogeochemistry:		
Nearshore Ocean Water Chemistry Profiles	Profiled CTD and seawater nutrients, organic matter, & chlorophyll collected monthly at 5 reefs	2001
Moored Hydrography and Currents	Near continuous measurements of conductivity, temperature, & currents (ADCP) at 4 reefs	2001
Temperatures	Bottom temperature every 15 min at 11 reefs	2001
Irradiance	Bottom and surface irradiance every minute at 4 reefs	
Kelp Forest Ecology		
Kelp forest Community Structure	Annual data on the abundance (density or % cover), species composition and size structure of fishes, macroinvertebrates, giant kelp and understory algae at 11 reef sites	2000
Long-term Kelp Removal Experiment	Twice per season sampling (every 6 weeks) in kelp-removal and kelp-control plots at 4 reef sites. Sampled variables include: the abundance, species composition and size structure of fish, macroinvertebrates, and macroalgae, standing and detrital biomass of macroalgae.	2008
Kelp Net Primary Production	Monthly data on standing biomass, stoichiometry and biomass loss rates of giant kelp. Seasonal data on giant kelp NPP.	2002
Kelp Canopy Area and Biomass	SBC developed methods for processing satellite images from Landsat 5 Thematic Mapper to create a long-term, high frequency (~ every 6 weeks), spatially extensive (Southern California Bight) dataset on surface canopy area and biomass for giant kelp	1984
Sandy Beach Ecology		
Macroalgal Wrack	Composition, cover and biomass of macroalgal wrack at 5 beaches	2008
Shorebirds	Shorebird density and species composition at 5 beaches	2008

*Other long-term data available from third parties include meteorology, ocean swell height and period, surface currents, satellite imagery (color, SST), and hydrology.

FINDINGS

Below we report our major findings for research and information management for the period September 1, 2011 through August 31, 2012. A complete list of publications for this reporting period can be found in the Journal Publications section of this report and on SBC LTER's website at http://sbc.lternet.edu/cgi-bin/publications.cgi.

Research

KELP FORESTS:

Results of analysis using our long-term time series of standing biomass and net primary production by giant kelp revealed that the strong intra-annual variation observed in biomass was better explained by the demographic rates of fronds than by those of whole plants. To better understand the processes controlling the dynamics of giant kelp we developed an age-dependent model of frond mortality using lifespan data for individual fronds (Figure 1). By combining the output of this model with data on other intrinsic biological properties (i.e., plant size and nutritional status) and external environmental factors (i.e., i.e., wave height, day length, temperature, nutrient concentration, and neighborhood frond density) we found that variation in both frond death rates and birth rates were best explained by frond age structure (Rodriquez et al. in review). This finding runs counter to the long held belief that external environmental factors primarily control fluctuations in the biomass of giant kelp. Vegetation dynamics of many species including giant kelp are often considered largely in the context of external controls on resource availability and physical disturbance Our results indicate that investigations of the processes controlling vegetation dynamics may benefit greatly from the inclusion of intrinsic biological factors such as age-dependent mortality and growth, which can outweigh the effects of external forcing in accounting for fluctuations in vegetation biomass.

Our ongoing long-term time series of NPP by giant kelp does not consider carbon losses resulting from the exudation of dissolved substances. Field and laboratory studies were done to estimate the fraction of NPP lost as dissolved exudates and to characterize their chemical nature. Results obtained to date suggest that the inclusion of carbon lost as dissolve exudates increases our estimates of kelp NPP by as much as 50 %. Analyses are ongoing and a manuscript on this work is in preparation.

With additional support from NSF, we explored the extent to which temporal variation in the stable isotope composition of suspended particulate organic matter (POM) on shallow reefs is explained by phytoplankton biomass and production. We found reef $\delta^{13}C_{POM}$ values were typically ^{13}C-enriched relative to values offshore, which is what we predicted based on patterns of generally higher phytoplankton biomass and productivity along the shallow shelf. Coastal food web studies, particularly those examining kelp contributions, have typically used offshore POM isotope values to represent inshore phytoplankton. Our results show this assumption may bias results of food web mixing models. A manuscript describing these findings is currently under review.

We developed a simple model of primary production for understory algal assemblages that involved relating species-specific light use relationships measured in the laboratory to biomass and light levels measured in field (Miller et al. 2012). We validated the model by comparing primary production measured in situ in enclosed chambers with model estimates for the same incubations. Our results show that primary production was accurately estimated by simple addition of the photosynthetic capacity of each species in the community based on their biomass and the available light (Figure 2). We applied this model to data collected in our long-term kelp

removal experiment to develop a 4 year time series of primary production by intact assemblages of understory macroalgae. Using this time series we investigated the respective roles of bottom irradiance and standing biomass in contribution to intra-annual variation in net primary production (NPP). Our results revealed that biomass alone explained the vast majority of variation observed in daily NPP at all times of the year and that measurements of peak biomass in spring and summer proved to be good predictors of NPP for the entire year (Harrer et al. in review). We plan to apply the relationships between macroalgal biomass and NPP generated from this study to our annual long-term time series data to address topical issues pertaining to drivers and responses of NPP in kelp forest ecosystems.

Regional and local controls of synchrony in the population dynamics of giant kelp in the Southern California Bight were examined by combining remote sensing data of kelp biomass, ocean temperature and waves with diver collected data of kelp recruitment and sea urchin abundance (Cavanaugh et al. in press). We found that population synchrony in giant kelp decreased with distance between populations: an initial rapid exponential decrease between 50 m and 1.3 km was followed by a second, large-scale decrease between distances of 1.3 km and 172 km (Figure 3). The 50 m to 1.3 km spatial scale corresponded to the scales of synchrony in the abundance of sea urchins and young kelp recruits, indicating that local drivers of predation and recruitment influence small-scale synchrony in kelp populations. The spatial correlation patterns of environmental variables, particularly wave height, were similar to the synchrony-distance relationship of kelp populations from 1.3 km to 172 km, suggesting that regional environmental variability, i.e. the Moran effect, was the dominant process affecting synchrony at larger spatial scales.

We also coupled Landsat data with diver data from fixed plots to do a regional comparison that showed disturbance from waves overwhelmed top-down and bottom-up control of primary production by giant kelp in central and southern California. Our paper detailing this work (Reed et al. 2011) was featured in a press release by NSF and was recommended by Faculty of 1000 as a must read (Connell S: 2012. F1000.com/714647801#eval790152801).

We took advantage of the wide gradient of species richness in the benthic community of understory algae and sessile invertebrates produced by our long-term kelp removal experiment to test the extent to which the diversity of the understory benthic community of a kelp forest affects the extent to which grazing by sea urchins alters the benthic community. We found that the percent cover of macroalgae and invertebrates consumed by urchins was greater at higher levels of sessile prey species richness (Byrnes et al. in review). However, this positive relationship was only apparent at low densities of sea urchins. At high densities of sea urchins nearly all algal and invertebrate biomass was consumed irrespective of sessile species richness. This positive relationship between prey richness and urchin consumption was also stronger when the abundance of prey species was more even (i.e., higher Simpson's evenness). Collectively, our results showed that the consumptive impacts of urchins on kelp forest understory communities increases as a function of species diversity (both prey richness and evenness), but that prey diversity becomes irrelevant when urchins reach high densities.

Reproductive rates and survival of young in animal populations figure centrally in generating management and conservation strategies. Model systems suggest food supply can drive these often highly variable properties, yet for many wild species, quantifying such effects and assessing their implications have been challenging. We used our spatially explicit time series of black surfperch at Santa Cruz Island and its known prey resources to evaluate the extent to which fluctuations in food supply influenced production of young by adults and survival of

young to sub adulthood (Okamoto et al. in press). Our analyses showed: 1) variable food available to both adults and to their offspring directly produced an order of magnitude variation in the number of young-of-year (YOY) produced per adult, and 2) food available to YOY produced a similar magnitude of variation in their subsequent survival. We then show that such large natural variation in vital rates can significantly alter decision thresholds (biological reference points) important for precautionary management. These findings reveal how knowledge of food resources can improve understanding of population dynamics and reduce risk of overharvest by more accurately identifying periods of low recruitment.

COASTAL WATERSHEDS:

Concentration versus runoff relationships can reveal how land use and watershed hydrology regulate chemical inputs to streams and downstream aquatic ecosystems. We observed consistent nitrate-runoff patterns within three broad land use classes: dilution in agricultural watersheds, invariance in urban watersheds, and enrichment in an undeveloped watershed (Figure 4). Despite differing land uses and sources of nitrate, we found that stream nitrate concentrations during periods of stormflow were less variable than during baseflow, which indicates a common source of water and nitrate to the watersheds (Goodridge and Melack 2011). We suggest the undeveloped, upland regions of the watersheds as this source, and that this region plays an important role in determining watershed stream nitrate concentrations and nitrate flux to the Santa Barbara Channel (Pacific Ocean).

Based on consideration of uncertainty in soil parameters, irrigation inputs, and spatial extrapolation of both point precipitation and air temperature for an urbanizing, semi-arid coastal catchment (Mission Creek), Shields and Tague (2012) found the seasonal transition from soil parameters to irrigation inputs as a key control on evapotranspiration (Figure 5). Sensitivity to uncertainty in precipitation was primarily in winter runoff predictions. Neither evapotranspiration nor runoff was highly sensitive to uncertainty in spatial interpolation of temperature.

AVIRIS analysis of fire scars, overlain on the prefire vegetation map demonstrated that shrub type appeared to have little impact on fire spread, although moist vegetation, such as riparian areas and orchards did restrict fire spread. The Gap fire scar had extensive areas of incomplete burn with patches of unburned shrubs, whereas the Jesusita fire had near complete consumption of all shrub areas. Fire-unaffected regions had low erosion rates, but fire-affected regions have annual erosion rates >1 mm/yr. Fire-affected regions have >0.5 m channel incision in some places due to unobstructed overland flow that results in higher flow velocities and lower infiltration. Volume-weighted mean nitrate and ammonium concentrations per rainfall event from 2002 through 2011 increased after the fires. Nitrification was significantly enhanced in burned chaparral, perhaps because fires elevated soil pH, which can both raise the solubility of soil organic matter, and stimulate nitrification, or perhaps because fires released nitrifying bacteria from competition with vegetation for ammonium. Stream invertebrate communities changed radically at the sites in burned basins, but changes were more muted in the unburned sites, with opportunistic, vagile taxa, such as *Baetis* mayflies and *Simulium* larvae, dominating at burned sites. Trout populations in burned basins nearly disappeared, but remained at relatively constant levels in unburned basins. Stable isotope and gut analyses showed that algal-based food webs dominated streams in basins where both upland and riparian vegetation burned whereas detrital-based food webs dominated streams draining unburned basins or burned basins where the riparian vegetation remained intact.

BEACHES:

Our finding of a significant relationship between wrack abundance and dry beach width over time (Revell et al 2011), suggests that when dry upper beach zones are narrow or absent, wrack accumulation and its availability to beach consumers, decomposition and remineralization is decreased. Of particular concern in this regard is climate-induced sea level rise which is expected to increase coastal erosion and reduce beach widths. Coastal armoring, which can strongly affect upper beach width and wrack accumulation (Dugan et al 2008) is also expected to expand with sea level rise. Our collaborative research on coastal armoring, beach ecosystems, and the major 2010 earthquake and tsunami in Chile (Jaramillo et al 2012) found post-event ecological recovery was strongly affected by interactions between co-seismic coastal change (subsidence or uplift) and armoring. This study was highlighted in an NSF press release and received international press coverage (BBC, Der Spiegel, Scientific American, etc). Results from our investigations of the functional role of upper intertidal zones in macrophyte wrack accumulation, consumer abundance and nutrient cycling using a gradient design along ~ 1 km of bluff-backed beach suggest that the width of the upper sandy intertidal zone is a key ecological feature. Although width of this zone varied only from 0 to 18 m across the 1 km sampling, wrack biomass and consumer (talitrid amphipod) abundance varied >1000 fold and were significantly correlated with upper intertidal width as were the concentrations of dissolved inorganic nitrogen in intertidal pore water. Carbon stable isotope signatures of intertidal POM and of a deposit-feeding polychaete (*Euzonus mucronata*) were also correlated with upper intertidal width suggesting nutrient sources to the beach ecosystem shifted from a mixture of wrack and phytoplankton to phytoplankton as the upper intertidal beach narrowed and wrack deposition, retention and processing was reduced. These results suggest even relatively narrow upper sandy intertidal zones are critical in maintaining biodiversity and ecological function of sandy beach ecosystems.

Initial results from our analyses of beach pore water using mini-piezometers show that beach pore water is suboxic, presumably due to microbial respiration and mineralization, with mean dissolved oxygen concentrations of 3.48 mg L^{-1} (range of 1.40 – 5.29 mg L^{-1}) and mean ammonium (NH_4^+) concentrations of 186 μM (range of 48.3 – 440.0 μM). Nitrate (NO_3^-) concentrations were a minor fraction of the dissolved nitrogen pool, with mean concentrations of 0.9 μM (range of 0.1 – 3.8 μM).

NEARSHORE OCEAN:

Analyses of data obtained from towed undulating vehicles during 16 channel wide cruises show that phytoplankton layers frequently occur well below euphotic zone depths in the Santa Barbara Channel. These layers were not detected in more traditional CTD casts done at 25 stations uniformly positioned along the eight cruise tracks spread across the Channel. The failure of the CTD data to detect these layers was most likely due to their limited spatial sampling (e.g. 25 CTD profiles per cruise vs. hundreds of profiles per cruise by the undulating vehicles) Three physical transport mechanisms that move the phytoplankton below the euphotic zone have been tentatively identified: (1) wind driven downwelling along the north coasts of the northern Channel Islands, (2) convergence, subduction and downward isopycnal mixing, and (3) downwelling within the cores of cyclonic eddies that frequently form in the Santa Barbara Channel. These processes may be an important, but previously overlooked mechanisms for controlling the duration of phytoplankton blooms, including harmful algal blooms. These results formed the basis of a MA thesis (Dellaripa 2012) and a manuscript on this work is in preparation.

The transport and dispersal of material in the nearshore ocean is important to many ecosystem processes. An analysis of the dispersal of particles near shore was carried out in the

Southern California Bight for two seasons: 1) Fall 2006, and 2) winter 2007-2008 using the Regional Ocean Modeling System (ROMS). Particle dispersal was investigated with respect to the distance from the shore, coastal geometry (bays versus headlands), and direction relative to the coastline. Figure 6 shows a Cartesian map of the eddy kinetic energy or current variance near the surface and shallow bathymetric contours. Guided by the current variance and bathymetry, the nearshore region was divided into 7 regions within 15 km from the shore.

Simulations were done involving the dispersal of ~1000 synthetic particles released every 12 hours near the ocean surface over several release sites in the Southern California Bight. Particles were tracked for five days and releases of new particles were repeated continuously for about three months, yielding robust statistics of the dispersal between pairs of particles with a small initial separation. The results give mean dispersal rates in the along- and cross-shelf direction. Dispersal generally increased with increasing distance from the shore. Headlands consistently exhibited larger dispersal rates than bays regardless of direction. Close to the shore, all regions show dispersal rates along-shelf on average 10 times larger than those in cross-shelf direction. The reduced dispersal rates in bays versus headlands and the preferred dispersal along the shelf have important implications for the transport of nutrients from deeper ocean to nearshore waters as well as the retention of storm water runoff close to the shore. Numerical simulations of storm water runoff within the Santa Barbara Channel show that the fresh water plumes are generally retained nearshore and spread on average 10 times faster along the shelf than in the cross-shelf direction, which is qualitatively consistent with the two-particle statistics described above. .Future investigation will include the effects of surface waves on the dispersal of particles and fresh water runoff within the nearshore environment.

Data obtained from sensor arrays deployed near our long-term studies sites at Mohawk Reef and Arroyo Burro during the winter of 2011-12 revealed that despite the low rainfall (< 30 mm d^{-1}) and brief maximal discharge up to 14 m^3 s^{-1}, the signature of the freshwater runoff plume emanating from Arroyo Burro Creek was evident as lower salinity after the rain events. Background salinity was of order 33.5 ppt, and the plume signature was 32.5 to 33 ppt. In the first storm, 16-20 March, the stream water was detected in the western boundary of Mohawk Reef and was well mixed to three meters. Very little of this water extended to the reef's eastern boundary. Discharge from the 2nd event, 24-28 March, moved offshore quickly and then appeared to move to the west. Salinity depressed simultaneously east of the reef and in its western extent with a greater depression to the east. This depression occurred prior to the dilution offshore of Arroyo Burro Creek and suggests that flow from Mission Creek to the east may have influenced the reef in this 2nd storm. From 11 to 16 April, decreases in salinity occurred at the reef just after they occurred offshore of Arroyo Burro Creek with this timing and the greater dilution to the west suggesting the freshwater came from Arroyo Burro Creek. Decreases in salinity occurred two days later without an increase in discharge suggesting that the plume had remained coherent and that a meander had flowed over the reef. These results are consistent with the plume modeling described above. These empirical measurements serve to ground truth the modeling, and their modeling in return provides a larger scale perspective enabling greater understanding of controls of plume dynamics. The sensor array will be redeployed in winter 2012-13, which is predicted to have much greater rainfall.

The first four deployments of our autonomous glider (August 2011, November 2011, February 2012 and March 2012) lasted about 4 days each and enabled the characterization of the general profile of the coastal ocean showing: (1) strong vertical and horizontal gradients of physical and optical properties, including large differences in spatial patterns within short time

scales; (2) patchy and dynamic sub-surface chlorophyll maxima around 15 m depth; (3) persistent backscatter signals near the bottom, which seems to be related to re-suspension of particles due to the passage of solitary waves and tidal forces; and (4) sharp temperature and density profiles related to internal wave structures (Figure 7). Importantly, these initial deployments served as tests to understand the best way to fly the instrument in the inner shelf and to observe the quality of the data recorded by the sensors. Numerous problems with software and the operation of some of the sensors were encountered during these missions and the glider was sent back to the manufacturer for repair in March 2012 where it stayed for 3 months. Replacement optical pucks have been ordered and are scheduled to be ready by September 2012, when the glider will be sent to the manufacturer once again. Future missions are scheduled bimonthly beginning autumn 2012 and will last up to 20 days each in order to resolve diurnal changes in optical properties in various ocean regimes. The possibility of comparing individual transects to satellite imagery for the period will provide a holistic understanding of the evolving coastal ocean. Calibration and validation protocols are being developed to ensure data quality, and an ADCP will be mounted to the glider shortly using existing NSF funds (L. Washburn PI).

Information Management

EML DATASET MANAGEMENT

We have continued our collaboration with three other LTER sites (MCR, CWT, GCE), to adapt the GCE relational database schema "Metabase" for use at SBC to replace some of the more manual steps in dataset management. Metabase work was advanced on two fronts. First we developed our XSL tools to populate the database from our existing EML datasets. Secondly, we added a schema to describe data packages for inventory management. These code projects are both deliberately generalized to enable their further development as a network resource. The inventory schema will be reviewed by our Metabase collaborators first, and presented to the IMC at the upcoming annual meeting.

During this reporting period SBC expanded its data holdings from 127 data packages to 152. Eight new data packages are ongoing time-series, bringing the current number of SBC's ongoing multi-site time-series to 32. We expanded the beach habitat and Santa Cruz Island holdings, and incorporated two new data types: 'genomics', for kelp microsatellites and for bacterial populations, and 'remote sensing' for Landsat-derived estimates of kelp biomass. Several data packages were added specifically to accompany paper submissions or for graduate student theses. All datasets now routinely receive Network controlled vocabulary keywords and units, and all core datasets are geo-located to the level of sampling-site. All ongoing time-series were updated to the most recently available calendar year.

At the request of the LTER Network Office, several SBC datasets were uploaded to the prototype PASTA system for demonstration in May 2012. All SBC data packages are now held to this high standard, and all datasets tested have passed evaluation by that system, signifying that they can be uploaded to PASTA when it reaches production level. As the chair of this IMC working group, SBC's information manager (O'Brien) has been instrumental in organizing activities related to EML data package quality and availability, including outlining data features required by PASTA, co-hosting a Network-level workshop, preparing documentation for review by stakeholders, and engaging other LTER site information managers in its adoption. Development of the EML dataset checking tools are near completion, and will be invaluable for dataset evaluation by sites and PASTA workflow developers, and to the Network for routine assessment.

WEBSITE

SBC's website is modular, which allows improvements to be made on individual components. In the past year, SBC redesigned its research project area using Metabase, the relational database adopted from GCE, and ProjectDB, a suite of software tools to manage research projects developed collaboratively by LTER information managers. SBC's project descriptions were our first exports from Metabase. Because the LTER-project schema is a subset of EML schema, limiting the scope of exports would quickly demonstrate the usability of both Metabase and ProjectDB. Our project descriptions are of broad research themes that can serve as a framework for further description of specific research activities. Themes can be browsed using SBC keywords in a manner similar to that used by our data catalog so the two catalogs look the same from a user's point of view, and data queries can be easily linked between the two.

Sampling sites outlined in our recently funded renewal (SBC-III) have been described in a standardized format compatible with KML, and a map application depicting them is nearly ready for launch. Our XSL style sheets for EML datasets continue to be upgraded incrementally. The style sheets and their accompanying Perl code are now used by two other LTER data catalogs, a) hosted by the Virginia Coast Reserve LTER (VCR), and b) the catalog linked to the LTER IMC Controlled Vocabulary term browser (developed by VCR and SBC).

MEASUREMENTS DICTIONARY AND ONTOLOGY

Work continues on SBC's dictionary of measurements (an extension of the ontology developed by a related NSF project Semantic Tools for Data Management), which is providing software for increased data access, discovery, and integration using semantically annotated metadata. Through this project, SBC has access to knowledge modeling experts in building a detailed dictionary of its own ecological and environmental measurements. Current work focuses on aligning the SBC dictionary with recently added modules. This work has been presented to the LTER IMC, and also will contribute to the broader measurement standardization efforts in the LTER network. O'Brien was also invited to present this work at the annual meetings of the International Long Term Ecological Research (ILTER) Network hosted by the Chinese Ecosystem Research Network (CERN)/National Ecosystem Research Network of China (CNERN) to present She also discussed mechanisms for applying ontological concepts to problems encountered in international data discovery.

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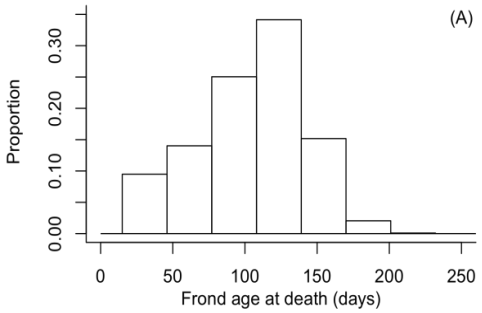

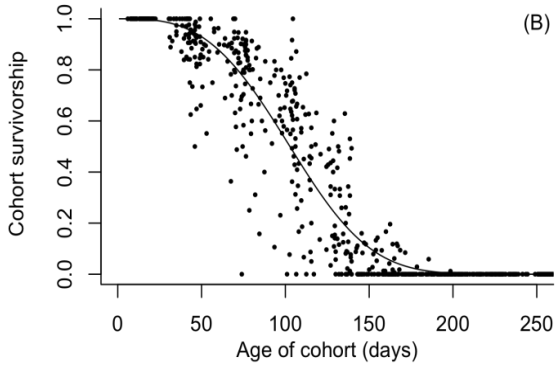

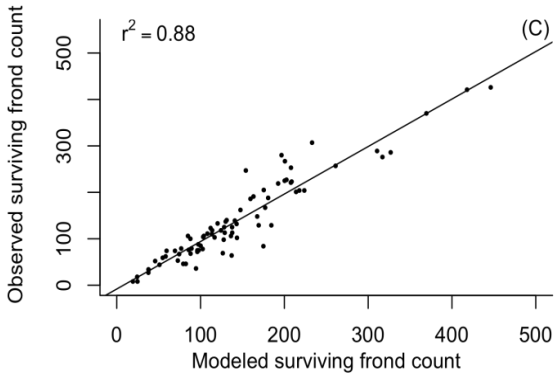

Figure 1. Demographic data for *Macrocystis pyrifera* fronds near Santa Barbara, CA, USA. (A) Histogram of frond lifespans (N = 4628 fronds) binned by 31 day intervals (approximately monthly). (B) Survivorship of *Macrocystis pyrifera* frond cohorts by age with fitted Weibull CDF. Note that each cohort appears in the graph several times as it ages (N = 93 cohorts). (C) Observed surviving fronds vs. predicted surviving fronds for each sample period. Modeled frond counts are based on age-dependent mortality derived from 2B and frond age structure.

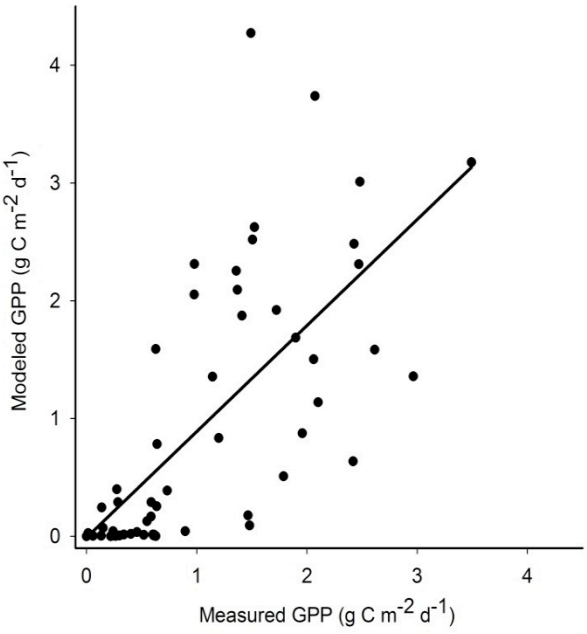

Figure 2. The relationship between measured field estimates of areal Gross Primary Production (GPP) in chambers placed over intact assemblages of understory macro algae and modeled estimates of GPP based on light, taxa specific photosynthetic parameters and taxa specific biomass in each chamber ($y = 0.90x$, $r^2 = 0.70$)

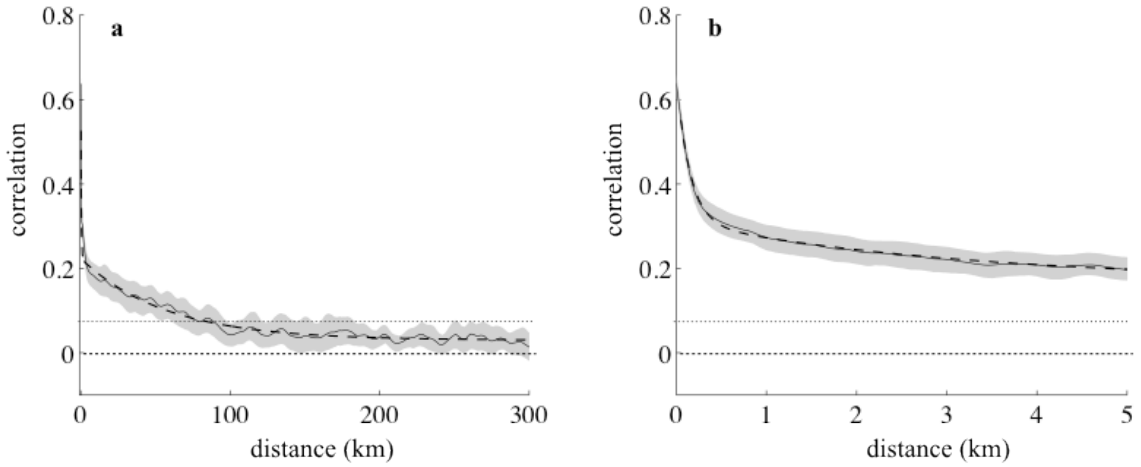

Figure 3. Relationship between distance and synchrony in giant kelp biomass dynamics from 2000 to 2011. In each plot, the solid black line represents the mean pairwise correlation between kelp biomass dynamics of populations separated by the given distance. (b) shows the same data as in (a) but with a different x-axis scale. The grey shaded areas give the 95% bootstrap confidence intervals. The dashed curve represents a modeled double exponential fit for the kelp correlation function ($r^2 = 0.99$). The dotted horizontal line gives the regional mean correlation and the dashed horizontal line represents 0 synchrony.

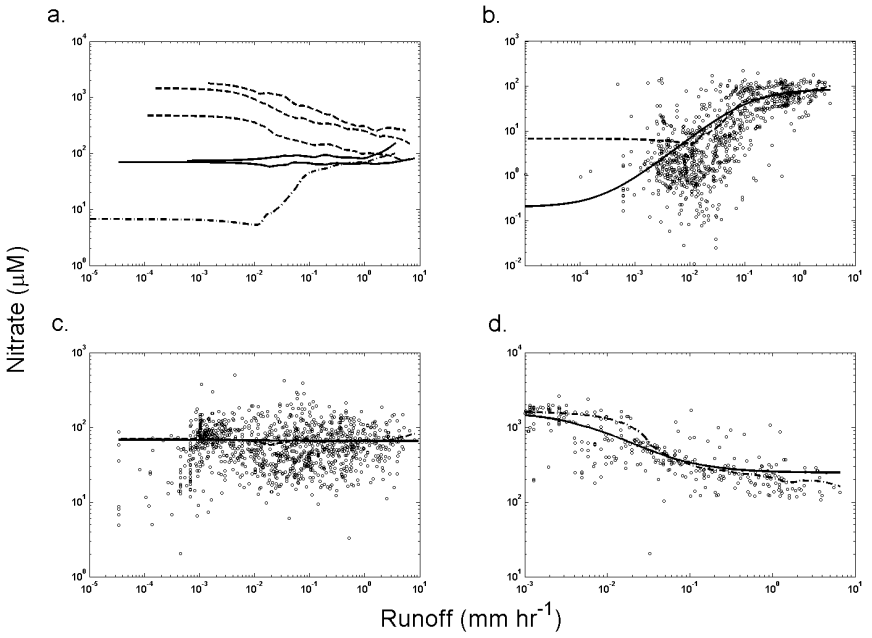

Figure 4. (a) Locally weighted scatter plot smooths (LOWESS) of nitrate concentration (μM) versus runoff (mm hr^{-1}) for watersheds delineated by land use class; undeveloped (dashed-dotted), urban (solid), and agricultural (dashed) watersheds. From top to bottom, the agricultural smooths correspond to Franklin, Bell Canyon, and Carpinteria. (b-d) Scatter plots of nitrate versus runoff, LOWESS smooths (dashed), and hyperbolic equation fits (solid) for (b) Rattlesnake, (c) Mission, and (d) Bell Canyon watersheds. Note: the apparent large deviation between the LOWESS smooth and hyperbolic equation fit for lower nitrate-runoff data points for Rattlesnake watershed is a function of the log-log scale, as the magnitude deviation in y-intercept nitrate concentrations is only ~7 μM.

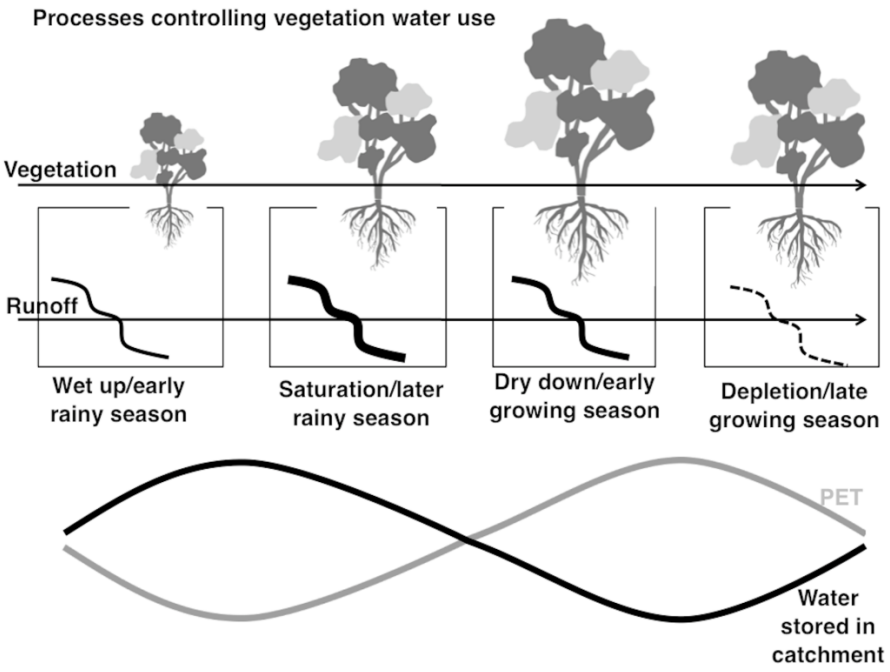

Figure 5. Controls on vegetation water use shift through the water year. In the fall, the system is initially water-limited. As soils become saturated through the winter rainy season and plants are less active, vegetation water use is limited by demand. Vegetative demand for water (PET) rises through the growing season and water stores deplete, returning the system to a water limited state at the end of the water year.

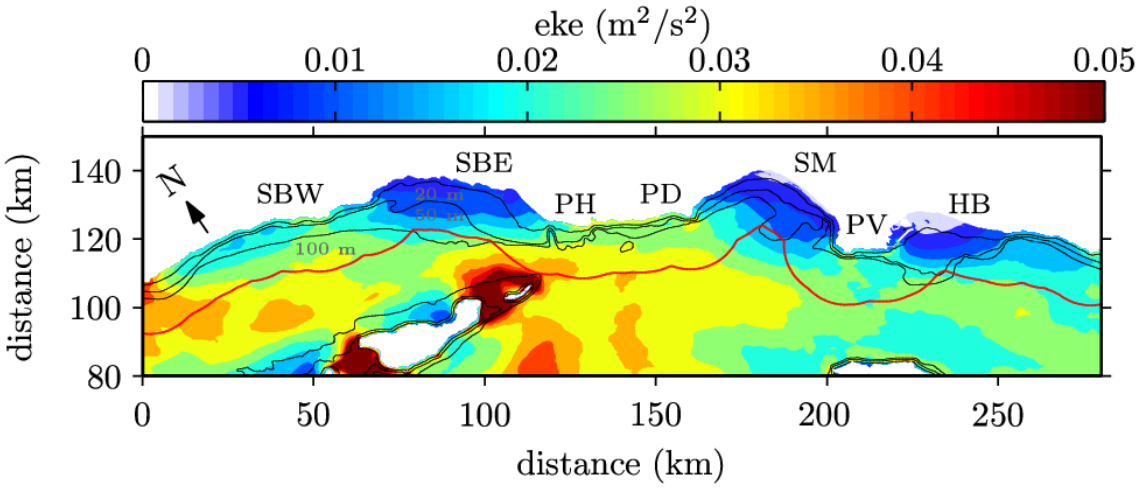

Figure 6. Surface eddy kinetic energy *eke* or surface current variance map for the winter 2007-2008 in the Southern California Bight from a 250m resolution ROMS simulation. The black lines are bathymetric contours at 20, 50 and 100m. The red line delineates a coastal band 15km wide. In this study the coastal band was divided into 7 parts: Santa Barbara West (SBW), Santa Barbara East (SBE), Port Hueneme (PH), Point Dume (PD), Santa Monica (SM), Palos Verdes (PV), and Huntington Beach (HB). Notice that "bays" are generally shallow and less energetic that "headlands".

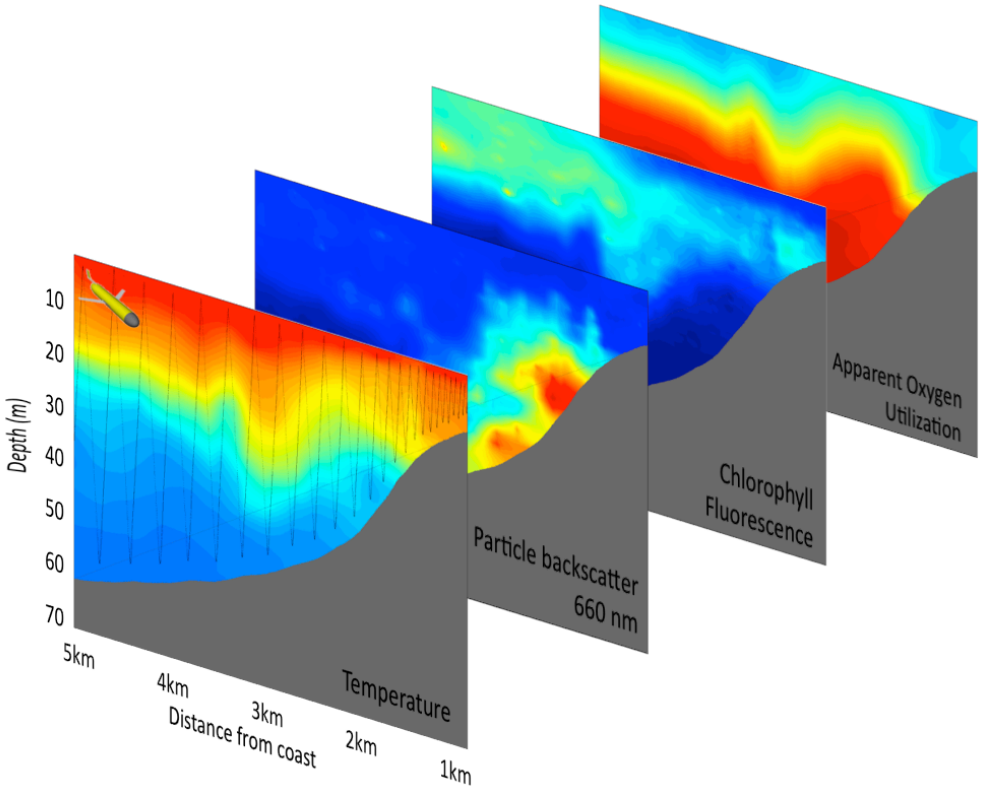

Figure 7. Examples of temperature, particulate backscatter, chlorophyll fluorescence, and apparent oxygen utilization data from one 4km long cross-shelf section (March 2012 deployment). Color scale blue to red = low to high values. Glider saw-tooth path is superimposed on temperature data, which is interpolated using kriging techniques. Internal wave structures are observed in temperature data; High backscatter patches associated with particle re-suspension are observed near the bottom; chlorophyll fluorescence patterns and oxygen data correlate with temperature distribution.

Training and Development

Education and training are tightly integrated into all aspects of SBC LTER research. As of August 2012, 15 post docs, 58 graduate students, 18 REU students and more than 270 undergraduate students have participated in SBC research during the last 6 years representing our current award. UCSB undergraduates have a high propensity to get involved in sponsored research and the SBC LTER contributes substantially in this regard. In addition to gaining valuable research experience, many undergraduates earn academic credit or received monetary compensation for participating in SBC research as interns and honors students. SBC investigators, graduate students and staff serve to mentor independent research by undergraduates and local high school students. SBC LTER is an active participant in NSF's Research Experience for Undergraduates program and in several other mentorship programs sponsored by the University of California. REU students work closely with SBC LTER researchers on a wide range of topics and most choose to pursue an advanced degree following the undergraduate education

SBC LTER graduate student and postdoctoral training is coordinated with several graduate programs on the UCSB campus most notably, the Interdepartmental Graduate Program in Marine Science, the Department of Ecology, Evolution and Marine Biology and the Bren School of Environmental Science and Management. SBC LTER work with these programs to promote opportunities for interdisciplinary graduate research that examines how coastal ecosystems change in response to natural and human-induced alterations in the environment. Students and post docs work on topics in terrestrial, aquatic, and marine environments with interests ranging across ecology, physiology, geology, hydrology, oceanography, modeling and coastal policy. This enables valuable cross-training on environmental issues pertaining to coastal ecosystems, provides a common language for communicating scientific information on these issues, and contributes to the creation of a diverse scientific community of students and postdocs that fosters a respect and appreciation for other disciplines. Our students, postdoctoral fellows, and investigators attend SBC LTER's Annual Science Meeting and the triennial LTER Network All Scientists Meeting and present results from their SBC research and collaborative projects in poster sessions and oral presentations.

SBC LTER is actively working to provide opportunities for research training to students from non-traditional research universities. To this end we recently received supplemental funding for a NSF Research Opportunity Award (ROA) to collaborate with students and faculty from Chapman University a small, liberal arts college that does not offer a graduate degree, and is a RUI-eligible institution. The collaborative project seeks to examine some potential ecological consequences of implementing the Marine Life Protection Act, which restricts or prevents exploitation of designated rocky reefs throughout California. The ability to accurately predict these consequences is intimately tied to a comprehensive understanding of the ecological system encompassed by SBC LTER. The collaboration between SBC LTER and Chapman University will broaden the institutional and geographic scope of SBC LTER, and deliver intensive training to young scientists just starting their careers.

Educational opportunities at SBC are not limited to university students and post docs. Teachers and numerous volunteers from the general public regularly participate in our stream sampling program and gain considerable knowledge on the constituents of runoff and of the processes that influence their concentrations.

Outreach Activities:

The SBC-LTER Programs Sept. 2011-Aug. 2012
SBC's Schoolyard LTER (sLTER) program is organized around a theme of kelp forest ecology in the context of the Research Overview of the SBC LTER. Curriculum is developed around and delivered through the Research Experience & Education Facility (REEF), UCSB's teaching aquarium. Our focus on long-term connections with local, regional and state middle and junior high schools through a number of partnerships that include both on, and off, campus programs. Our approach also allows for an integrated program that spans both academic year activities, as well as summer programs, and includes K-12 students, K-12 teachers, the General Public, undergraduate and graduate students, and staff.

The Research Experience & Education Facility (REEF)
The SBC SLTER outreach, education and training programs benefit from a close association with the University of California at Santa Barbara's Research Experience & Education Facility, better known as The REEF, an interactive, teaching aquarium facility. The REEF is equipped with state-of-the-art, aquaria and touch tanks. The REEF also utilizes a high-tech life support system for the Research Tank, which highlights current, on-going research at UCSB and the Marine Science Institute, including SBC and MCR LTER research. One of the joint goals of the SBC LTER and the REEF programs is to provide UCSB undergraduates majoring in Aquatic Biology, with a solid foundation in temperate and tropical marine ecology and research. The REEF training provides them with the basis for communicating this knowledge in an educational format. To that end, The REEF develops its curriculum around a number of research programs at UCSB. The SBC LTER is the most significant contributor to this endeavor. Support from the SBC sLTER program has allowed the REEF to obtain teaching supplies and equipment for curriculum as well as provide salaries for professional staff and undergraduate internships. The REEF also utilizes graduate students, staff researchers, and post-docs from the SBC LTER to train REEF undergraduate staff, which, in turn, enhances their training as laboratory and field assistants and research divers for SBC LTER research.

Program Format: First, we work with 35 undergraduate interns in a rigorous and pedagogically sound program of training in marine science and science pedagogy. These interns engage directly with middle school students as teachers and role models. Second, we continue to develop and adapt marine science lesson plans that engage students with learning about the local environment in the context of the LTER. These lesson plans incorporate ongoing SBC LTER research and include working with data generated by monitoring and experiments. The program is developed to build student's skills in scientific inquiry through activities that move from structured or guided investigation to open-ended inquiry and experimentation. Third, our program includes a combination of school-based activities, field trips, and on-campus experiences that immerse students in the environment of a college campus.

Focused sLTER Programming:
This year, sLTER focused on three partnership programs, 1) the American Association of University Women's (AAUW): Tech Trek Program, 2) Math-Science-Partnership (MSP) Project: Pathways to Environmental Literacy, and 3) The American Indians Scholarship Program

(AISP) and the "Advancing Native Culture and Heritage through Outreach and Retention" (ANCHOR) initiative program.

AAUW: *Tech Trek*
Tech Trek is a math/science summer program designed to develop interest, excitement and self-confidence in young women entering the eighth grade. It features hands-on activities in math, science and related fields. Tech Trek is a campus residential program that includes educational and recreational activities, all of which are located on a university campus where camps are held. Tech Trek is part of an interdisciplinary partnership involving science, technology, engineering, and math departments at UCSB through the Office of Education Partnerships (OEP-neeAPEO). The goal of OEP is to build college-going communities that improve student learning, increase college-going rates in underrepresented populations, and provide equal access to higher education for California's diverse students. In working with Tech Trek, the SBC SLTER program engaged two a groups of approximately 72 girls each from junior high and middle schools from counties surrounding Santa Barbara (SLO, Ventura, Kern, LA, etc). The participants are diverse, representing a broad range of socioeconomic and demographic groups. During each group's weeklong residential immersion at UCSB, students participate in "core" science courses focus on science basics, which include; physics, math, chemistry, and ecology. These courses are then complimented through practical application activities that engaged students in SBC LTER research-based learning activities, conduct field activities, and explore the possibility of attending a 4-year college. Activities include explorations of ecology and adaptation at the UCSB aquarium, SBC LTER research site monitoring protocols, and a Floating Lab trip, on a 75' catamaran, to multiple SBC kelp monitoring sites. An additional benefit expected in future years is the long-term connection we maintain with participating students both through OEP support (they work with some of these same students throughout their high school years) and through continued engagement with students as they move into high school and college. This program supports interested students with science fair projects, summer research opportunities, and mentoring opportunities. Through this long-term commitment, we are now seeing former program participants enrolling in UCSB. Three former participants now attend UCSB and work at the REEF.

(MSP) Project: *Pathways to Environmental Literacy*
The MSP project connects the research and education strengths in the environmental sciences of universities and sites within LTER with teacher professional development in science and mathematics of partner middle schools and high schools. It involves four LTER research sites; the Short grass Steppe (SGS), Baltimore Ecosystems Study (BES), Kellogg Biological Station (KBS), and Santa Barbara Coastal (SBC) and their partnering institutions, the LTER Network Office, and a group of 142 K-12 schools and districts that will directly impact over 355 science and mathematics teachers and up to 70,000 students from diverse backgrounds. This year, SBC LTER site worked with over 35 junior high, and high school teachers providing professional development to deliver in-class science curriculum based on SBC LTER field study sites, data and ecological principles to 2,500 Santa Barbara, Ventura, and West Los Angeles County students. The MSP project provided funds to support a program coordinator, a post-doctoral fellow, and 1 SBC LTER graduate student fellow, a Teacher in Resident (TIR) and 4 undergraduate teaching and administrative assistants. These project participants worked with science teachers at two local schools, La Cumbre Junior High School and Santa Barbara Junior

High School, implementing programming that impacted approximately 650 junior high school students. All participants were actively engaged in developing and leading two field trips that brought all students one of two nearby LTER monitoring site and on-campus visit that included an SBC research seminar and SBC ecology based activities at the beach, in a lab and the UCSB Aquarium, the REEF. A number of SBC graduate students, post-docs and investigators gave talks on their research and led activities for the MSP field trips and programs. This year, the summer PD included a week-long workshop that included training on curricula associated with the projects environmental literacy strands of Biodiversity, Carbon and Water, as well as a theme-based, Citizenship activity. Participants were also led on a tour of one of the SBC LTER watersheds. Each day was highlighted with a strand focused research seminar lead by SBC graduate researchers, post-docs and senior scientists and included a keynote, strand synthesis seminar.

AISP and the *ANCHOR Program (pilot)*
The American Indian Scholars Program (AISP) is an academic preparation program that promotes academic success and college going among primarily American Indian students and families residing in Santa Barbara County. University staff and college mentors work one-on-one with AISP students to develop individualized academic success strategies, meet with parents and share information to empower families to plan for and support their student's educational goals. It also partners with culturally relevant, place-based, on-campus education and outreach programs. Santa Barbara Coastal sLTER developed content that focused not only on kelp forest ecology but the socio-ecological and cultural relationships associated with our current maritime community and those of the indigenous peoples of the area, the Chumash.

The REEF program delivered SBC LTER-based curriculum, rich in STEM content that supported California State Science Standards to 14,300 visitors from September 2011 to August 2012, through continued outreach visits to schools, community events and on-campus programs. This included visits from primary and secondary schools from the San Joaquin Valley and Los Angeles, Ventura, Kern, San Bernardino, and San Luis Obispo Counties! The REEF continued to serve as a marine ecology learning facility for many colleges including Cal Lutheran Thousand Oaks, CSU Channel Islands, Oxnard, Ventura and Santa Barbara Community Colleges, Westmont College and UCSB. At UCSB, The REEF serves as an interdisciplinary laboratory for undergraduate courses including: Geology 4 (Intro to Oceanography), EEMB 3 (Intro Biology), EEMB 106 (Biology of Fishes), Writing 2 and Writing 109 ST. This year sLTER specific program content reached nearly 5,000 students in grades 6-12.

Additional SBC Outreach Activities

Investigators and students regularly mentor local K-12 students in science fair projects. SBC LTER research and expertise are frequently shared with the public through a variety of media outlets including local and national newspapers, magazines, internet news feeds, podcasts, blogs, radio and television. SBC investigators also serve as participants and advisors that provide educational and scientific perspectives to a number of community groups, including the Santa Barbara Community Environmental Council, Friends of the Santa Clara River, Santa Barbara Creeks Council and the UCSB Coastal Fund. Direct outreach to the public is an active area for many SBC investigators and students. To raise public awareness of marine ecosystems, SBC LTER investigators, staff and students jointly hosted a public outreach booth with the MCR

LTER at the Santa Barbara Earth Day Festival in April 2012. This event attracted more than 35,000 people. SBC offered children's activities including making prints of marine algae using tempura paint on paper, coloring pages and ink stamp crafts. Site research posters and brochures were set up for viewing and SBC researchers and students were on hand to field questions and lead the activities.

Contributions within Discipline

The understanding of ecosystem level processes in giant kelp forests has lagged behind the increasing body of knowledge at the species, population, or community level of kelp forests over the last four decades. Results from our reef studies are helping to address the growing need for research at the ecosystem level in kelp forests. Of particular significance are our studies of 1) primary production, 2) integrating kelp forest population dynamics and genetics on local to basin-wide spatial scales and across temporal scales 3) kelp forest food webs using stable isotope analyses, 4) the role of nutrients from multiple sources, including N-recycling, in altering these food webs and meeting nutrient demands of kelp forest ecosystems 5) the effects of wave disturbance on the complexity and diversity of kelp forest food webs and 6) links between kelp forests and sandy beach food webs.

Our coastal ocean research has identified several physical transport mechanisms important for delivering nutrients to kelp forest ecosystems. Examples include upwelling, runoff, and internal tides, and we are quantitatively assessing the flux of nutrients associated with each mechanism. This research is providing valuable information about transport processes on the inner shelf, which are poorly understood. Quantifying fluxes into and out of the inner shelf is extremely important for understanding the cross-margin transport of carbon, nutrients, and sediments. Most inner-shelf process studies to date have been conducted on the Atlantic coast of North America. Our work in the Santa Barbara Channel thus fills an important gap and is one of the first studies to focus on a coastal upwelling system.

Our oceanographic research is also helping to further our understanding of physical mixing of freshwater plumes as they enter the coastal ocean. Satellite ocean color estimates of sediment content show that less than 0.01% of sediment discharged in runoff events remains suspended in offshore plumes. Presumably the remainder settles quickly onto the inner-shelf substrate, and some of it may then be redistributed through resuspension or via buoyancy-driven flows. Our measurements will be important for determining the fate of this sediment, and this may have important consequences for the distribution of nutrients after the runoff season is over. Our moored instruments, with their combination of hydrographic and biological sensors allow us to measure outflow events even from very small streams. This allows us to better characterize the transport of materials from land to ocean ecosystems.

Our extensive and intensive measurements and models of solute and particulate concentrations and export from the steep, flashy catchments along the central/southern coast of California provide important comparative information to the field of watershed science that is otherwise lacking. The hydrologic model that we are developing will aid in predicting how climate, land-use, and the physical and biological structure of coastal streams influence the runoff of material constituents. The model simulates rainfall-runoff and routing processes from three sources

(surface, shallow soils and groundwater) for both undisturbed and urban lands and will ultimately be integrated with water quality modules to simulate the discharge of water, associated solutes, and sediments from the land to the ocean.

Contributions to Other Disciplines

The research mission of SBC LTER is very interdisciplinary in scope. As such, our research contributes to a wide range of disciplines including: terrestrial, aquatic and marine ecology, physical, biological and chemical oceanography, hydrology, geology, geography, toxicology, environmental history, science education and informatics. Coordinated studies among the many disciplines represented by SBC LTER are leading to an improved understanding of the patterns and processes that link land and ocean environments and their consequences for coastal ecosystems. This improved understanding is not only contributing to furthering the many disciplines listed above, but is of considerable value to those interested in studying the extent to which society contributes to and is influenced by impacts to coastal systems. For example, Investigator Lenihan leads a collaborative fishery research program, CALobster (http://www.calobster.org/), focused on the spiny lobster fishery with a goal of promoting and conducting community-based research that lead to the best management practices and help maintain working harbors. Similarly, Investigators Page and Dugan are investigating aquatic invasive species in southern California harbors in cooperation with state marine advisors. Investigators Guerrini and Dugan are writing and editing an interdisciplinary multi-authored book on the deep human and environmental history of a Santa Barbara coastal wetland and watershed.

Contributions to Human Resource Development

Our project provides significant opportunities for research and teaching in science at multiple levels including: K-12, university undergraduate, graduate and post doctoral levels, and the professional development of project research staff.

In addition to the training of our project's participants, our faculty-level investigators actively incorporate the activities and findings of SBC LTER research into their teaching and curriculum development, thereby extending the project's contributions to the broader student body. Many investigators give guest lectures and class demonstrations on SBC LTER research to university courses. They along with the project's post docs, graduate students and support staff routinely integrate undergraduate students into their research activities and also mentor them and high school students on their own research projects. In 2012, Investigator Carlson taught an immersion course on Microbial Oceanography at the Bermuda Institute of Ocean Sciences. This lecture and laboratory course provided training in various techniques in microbial ecology and oceanography used in both the LTER programs and the Microbial Observatory program and was attended by students from SBC LTER. Pre-college teachers and non-scientists from the local community routinely participate in our ongoing stream sampling program and gain considerable knowledge on the constituents of runoff and of the processes that influence their abundance. In 2012, SBC co-hosted an Earth Day Festival Booth in collaboration with MCR LTER.

Increased exposure to the SBC LTER research is achieved through its extensive outreach programs (see the Outreach Activities section of this report), which primarily target K-12 students and teachers. We hosted several workshops from 2009 -2012 as part of an innovative

Pathways to Environmental Literacy project, which is a cross-site targeted partnership in math and science funded by NSF involving four LTER sites and the LTER Network Office. The project focuses on the critical education junction of middle school through high school to develop a program of teacher professional development in science and mathematics driven by framework of environmental science literacy surrounding the learning progressions of core science and math concepts. The goal is to connect the research capabilities of partner universities and LTER sites with K-12 teacher professional development in science and math at partner schools. In 2012, SBC hosted a one week summer PD workshop "From the Ground Up," that involved 20 junior high and high school teachers from Santa Barbara and Ventura Counties from five different school districts. The workshop included training on curricula associated with the projects environmental literacy strands of Biodiversity, Carbon and Water, as well as a theme-based, Citizenship activity.

Contributions to resources for research and education

Physical resources

NSF funds from our project are used to maintain a custom 22' research vessel that is specially designed for scuba and oceanographic research. Other research groups on the UCSB campus have access to this vessel for their research needs as well.

Information Resources

SBC's website contributes to information resources by providing the scientific community and the general public access to unique datasets that are of interest to a diverse array of people. Some examples of such datasets include: historical data on giant kelp abundance in the northeast Pacific, SST imagery from NOAA-AVHRR polar orbiters of the Santa Barbara Channel, high frequency radar data of surface currents in the Santa Barbara Channel, precipitation data and soil mapping and land-use coverage of the Santa Ynez Mountains.

Contributions Beyond Science and Engineering

SBC LTER investigators are very active in applying their knowledge of Santa Barbara's coastal ecosystems to inform and implement changes in local and regional policies. Investigators serve as advisors and committee and board members for a number of local and national groups concerned with conservation and management of natural resources.

Investigators Reed and Page work with the staff of the California Coastal Commission (CCC) on a large multi-dimensional program designed to mitigate for the loss of coastal marine resources caused by the operation of the San Onofre Nuclear Generating Station (SONGS), a coastal power plant located in north San Diego County. The major emphasis in this program is compensation for lost marine resources via wetland and kelp forest restoration. Reed and Page's primary responsibilities are to consult with the employees of the power plant (Southern California Edison), the CCC and their staff, and other resource agencies on ecological issues relating to the design of the mitigation projects and to develop and implement monitoring programs capable of determining whether the biological and physical performance of these projects meet pre-determined standards. Much of the science done on these mitigation projects is quite complementary to that done by SBC LTER and there is considerable exchange of information and ideas between the two projects.

Our researchers are also engaged in shaping policy towards local watershed issues as well. We have developed mutually beneficial, cooperative associations with local and national government agencies and departments, and NGOs. Santa Barbara County's Project Clean Water is engaged in sampling local creeks during the initial rise of the hydrograph and measuring a suite of pollutants including metals, pesticides and herbicides. Our intensive sampling of nutrients and particulates during the entire hydrograph for most storms complements the County's effort, and we cooperatively share data and interpretations. We assist with field measurements and monitoring, and perform high quality nutrient chemistry analyses on water samples from local streams and rivers for regional NGO groups, including Santa Barbara Channelkeeper, the City of Santa Barbara, Ventura Surfrider and Friends of the Santa Clara River. Co-Investigator Melack serves on the Technical Advisory Committee for Friends of Santa Clara River water quality monitoring program and the Board of Directors for the Santa Barbara Community Environmental Council. Post-doc Al Leydecker provided regular reports on the status of algal blooms and eutrophication to interested parties involved in the TMDL regulatory process managed by the Regional Water Board. Investigator Cooper advised and contributed input to city and county agencies and departmental programs on a variety of topics including impacts and design of studies related to UV treatment of stream waters (City of Santa Barbara), the Southern Coastal Santa Barbara Creeks Bioassessment Program (Creek Division of the City and Project Clean Water of the County of Santa Barbara), and Storm Water Management Plan (City of Goleta). Investigator Gaines serves on several committees and advisory groups concerned with fisheries and marine conservation including the Science Advisory Panel for the California Marine Life Protection Act, the Science Advisory Group for the Interagency Ecological Program of the California Department of Water Resources, the Joint Ocean Commission and the Marine Life Protection Act Baseline Science Management Panel.

In the wake of three major fires, the Gap Fire in July 2008, Tea Fire in November 2008 and the Jesusita Fire in May 2009, in the Santa Barbara area our long-term measurements of stream hydrology and chemistry in local catchments are providing new information on the short and long term effects of these three major fires. SBC investigators worked with NGOs and county and federal agencies to document effects of the fires and contributed to planning and preparation for post fire impacts by providing input and advice to County of Santa Barbara Flood Control and environmental organizations on post-fire mitigation activities. SBC investigators, Melack, Cooper, Schimel, D'Antonio, Roberts, and Bookhagen built new collaborations and obtained support for more intensive studies of the burned catchments that were initiated in 2009 and are nearing completion this year.

The conservation and management of sandy beach ecosystems lags behind that of coastal wetlands and riparian habitats. Our research findings from sandy beaches has led to the recognition of kelp and other macroalgal wrack as an ecological resource by local and state agencies and contributed to the development of new policies for coastal management. Dugan plays an active advisory role with coastal consortiums and groups concerned with improving the conservation and management of beach ecosystems including the NSF-funded Coastal Barrier Island Network (CBIN), which focuses on the management of barrier island ecosystems under the pressure of global climate change and urbanization, the California Coastal Commission, and the Beach Ecology Coalition, a professional organization for beach managers that provides a

forum for education, outreach, training and development of best practices and cooperative research on sandy beach ecosystems in California.