

SBC LTER III Year 2 Annual Report

ACCOMPLISHMENTS

What are the major goals of the project?

The Santa Barbara Coastal LTER (SBC) seeks to develop a predictive understanding of how land and ocean processes alter the biological structure and ecological functions of giant kelp forests under varying conditions of disturbance and climate. The amount of inorganic nutrients, organic matter, and sediments exchanged between kelp forests and the land and sea that adjoin them varies in response to changes in climate, ocean conditions and land use. Variation in the supply of these materials interacts with natural and human-caused disturbances to influence the abundance and species composition of the forest inhabitants, their ecological functions and the ecosystem services that they provide. Thus a general goal of SBC is to understand how coastal ecosystems at the land-sea margin are linked through the exchange of materials. Giant kelp forests are highlighted in our research because they are prominent coastal ecosystems in California and other temperate regions of the world. Site-based research focuses around the following three inter-related themes: (1) Biotic and abiotic drivers of kelp forest structure and function, (2) Material exchange at the land-ocean margin, and (3) Movement and fluxes of inorganic and organic matter in the coastal ocean.

The major goal of each research theme is as follows:

THEME 1: To determine how variations in climate, wave disturbance and fishing influence the structure and dynamics of kelp forest communities and the fate of net primary production by giant kelp.

THEME 2: To determine how the input of dissolved and particulate nutrients from watersheds and coastal margins to nearshore waters vary as a function of land use, disturbance by fire and storms. The very large temporal and spatial variability in these fluxes requires a multi-tiered research approach to capture their full range.

THEME 3: To determine how oceanographic processes act to influence: (a) the dilution and dispersal of freshwater runoff plumes, (b) nitrogen recycling and efflux from benthic sediments within and adjacent to kelp forests, and (c) the fate of net primary production by phytoplankton.

What was accomplished under these goals (you must provide information for at least one of the 4 categories below)?

Major Activities:

We collected data for a core group of long-term integrated measurements on land and in the ocean aimed at quantifying climate, disturbance and inorganic and organic subsidies to and from giant kelp forests in the Santa Barbara Channel and their effects on kelp forest community structure, productivity and dynamics. Other major activities for each research theme follow below.

THEME 1A. Effects of wave disturbance on kelp forest structure and function:

We continued to monitor and maintain our long-term kelp removal experiment designed to investigate the consequences of increased wave disturbance and fishing on kelp forest communities. We have nearly completed the conversion of time-series data on the abundance (% cover and density) of algae, invertebrates and fishes into various metrics of biomass using field derived relationships and a manuscript on taxonomic relationships between abundance and biomass and the factors that affect them is in preparation. A 20+ year dataset of weekly to biweekly settlement of sea urchins (the principal grazer in kelp forests) was formalized and is being analyzed to examine the role of climate and resource availability in structuring populations of sea urchins, a key kelp forest grazer. We extended the 28 + year Landsat time series of kelp biomass from near Pt. Reyes, California, to Punta Abreojos, Baja California, Mexico and are using it to examine geographic differences in the environmental controls of kelp dynamics.

THEME 1B. Determining the fate of kelp NPP:

Field experiments were conducted to determine whether the lifespan and various physical/chemical properties of kelp blades varied with resource availability as predicted by leaf lifespan theory. We continued to analyze results from field incubations aimed at determining the production of DOC by kelp and the factors that influence it. Feeding and growth experiments were done in the lab to determine the potential for kelp detritus to serve as a food resource for coastal suspension feeders. We examined the contribution of kelp to forest canopy food webs using field experiments aimed at determining the contribution of kelp grazers vs. suspension feeders to the diets

of predatory fishes living in the forest canopy.

THEME 1C. Effects of fishing on kelp forest structure and function:

Quarterly sampling of community structure and NPP in experimental plots was completed at two reefs protected from fishing and three reefs unprotected from fishing. Densities of the extensively fished spiny lobster (a key kelp forest predator) were also assessed at these reefs and lobster fishing effort was measured twice per month during the fishing season. Studies were continued inside and outside of MPAs to determine whether fishing increased susceptibility to invasion by the introduced seaweed *Sargassum horneri* and the introduced bryozoan *Watersipora*.

THEME 2A EXPORT of nutrients from watersheds

We continue to determine stream discharge and to measure concentrations and calculate fluxes of dissolved and particulate nutrients, organic matter and sediments in streams representing various land uses and in watersheds recovering from fires. Time series analyses of hydrological data using the ecohydrological model RHESys were begun to assess how climate variability influences hydrologic responses and associated nutrient fluxes over a range of time scales and fire frequency/severity scenarios. We conducted field-based sampling and simulation modeling of soil nitrogen dynamics in burned and unburned watersheds. Studies of stream metabolism, temperature, and trophic relationships were initiated to examine in-stream processing of nutrients and organic matter in streams experiencing differing degrees of urban influence.

THEME 2B. Trajectories of landscape changes in coastal watershed:

A significant aspect of material input to nearshore waters concerns how fire, urbanization and agriculture alter the landscape to modify these inputs. To examine this we used AVIRIS airborne hyperspectral imagery from 2004-2013 to develop a time series of land cover that was used to quantify landscape changes in the upper reaches of the Santa Barbara coastal watershed, which included 3 large fire scars resulting from fires that burned in 2008 and 2009. To examine longer term aspects of landscape change we are performing cosmogenic radionuclide analysis of riverine sands and collected and analyzed long (15 m) Geoprobed cores and shorter (2-4 m) vibracores from accumulated deposits at Carpinteria Marsh and Devereux Slough.

THEME 2C. Exchanges of nutrients on beaches

We continued monthly measurements of biomass of macroalgal wrack and densities of beach wrack consumers and shorebirds on select beaches. We surveyed consumers, wrack and concentrations of nutrients in intertidal porewater at additional beaches with and without sea walls to further assess the effects of coastal armoring on beach food web structure and biogeochemical cycling. We sampled the dissolved and particulate C and N, dissolved O₂, radon residence time, and specific conductance in beach porewater to estimate rates of biogeochemical processing. Laboratory experiments were conducted to determine rates of metabolism of organic material in porewater by near shore plankton

THEME 3A. Dilution and dispersal of freshwater runoff plumes

We performed improved numerical simulations of storm runoff plumes to parameterize the dilution field surrounding kelp forests as a function of water properties, ocean currents, surface waves, and wind conditions. Numerical simulations with the Regional Ocean Modeling System (ROMS) of storm water plumes from two creeks near Mohawk Reef encompassed the wet seasons of two years. The ROMS code was modified for improved performance of the salinity field near the mouth of the creeks by eliminating unphysical fluctuations during periods of relatively strong discharge and enhanced diffusion. Model simulations focused on the strongest runoff events. The dispersal and dilution of storm water plumes was analyzed and characterized with respect to several environmental parameters, including total discharge, distance from the source, cross-shelf distance, currents, winds, stratification, and vertical mixing.

THEME 3B. Nitrogen recycling and efflux from sediments

Nothing to report.

THEME 3C. Transport and fate of phytoplankton NPP

Our autonomous underwater glider was used to extract simultaneous physical and bio-optical information across the inner shelf of the SB Channel to allow characterization of the mechanisms controlling the distribution of particles, oxygen and net community production over biologically relevant time scales. The field work involving cross-shelf glider surveys was finalized, and results from over 400 cross-shelf sections obtained every 3 hours over a wide range of oceanographic conditions are currently being analyzed. Modeling efforts with ROMS focused on the dynamical characterization of shelf currents, including coastal-trapped waves and submesoscale variability, important for cross-shelf transport. Analysis includes Empirical Orthogonal Functions (EOFs), as well as Lagrangian experiments to identify areas of particle convergence. Analysis of high-resolution towed profiler data from 16 cruises continued over the past year. This has yielded new insights into the fate and transport of

phytoplankton produced offshore of kelp forests in the SBC LTER study domain. We began collaborating with Drs. Claudia Benitez-Nelson and Robert C. Thunell, University of South Carolina and the CCE LTER to maintain a 20+ year sediment trap time series in the Santa Barbara Basin located at 250 and 540 m depth. The mooring was successfully recovered and redeployed in October 2013 and June 2014..

Specific objectives:

THEME 1A. Effects of wave disturbance on kelp forest structure and function:

Determine the importance of wave disturbance on kelp forest community structure primary production and metapopulation dynamics under different climatic conditions from analyses using data from long-term experiments and core time-series measurements.

THEME 1B. Determining the fate of kelp NPP:

Determine the amount, rates and forms of biomass lost by giant kelp, the factors affecting these losses and the proportion of giant kelp NPP that is retained and utilized in the kelp forest versus exported to other ecosystems.

THEME 1C. Effects of fishing on kelp forest structure and function:

Experimentally investigate the short and long-term effects of fishing on kelp forest structure and function, and place these effects within the context of past variability resulting from different climatic conditions.

THEME 2A. Export of nutrients from watersheds:

Determine climatic variation in the fluxes of dissolved and particulate nutrients, organic matter and sediments to the Santa Barbara Channel from watersheds with different fire histories and land uses. Estimate post-fire nitrogen cycling and vegetation growth in chaparral ecosystems and determine the factors controlling the amount of nitrogen exported from them.

THEME 2B. Trajectories of landscape changes in coastal watersheds:

Use time series of airborne hyperspectral data to develop land cover maps before and after fires for use in ecohydrological modeling, nutrient flux calculations and examination of riparian conditions along streams. Calculate gully depths and erosion rates from Lidar data for unburned and burned catchments. Extend the time scale of our examination of landscape changes with cosmogenic radionuclide analysis of riverine sands and analyses of sediment cores taken from estuaries that border the Santa Barbara Channel.

THEME 2C. Exchanges of nutrients on beaches

Determine the degree to which beach ecosystems supply recycled marine nutrients to nearshore waters. Determine the effect of varying organic matter source and processing history on the dissolved organic and inorganic carbon and nitrogen dynamics in beach sands.

THEME 3A. Dilution and dispersal of freshwater runoff plumes

Simulate several realizations of stormwater plumes to enable a robust statistical characterization of the dispersal and dilution of runoff in the coastal environment. Analyze the flow fields generated with ROMS and data collected from moored instrument arrays during the 2012 runoff season to better understand cross-shelf exchanges in the nearshore due to runoff.

THEME 3B. Nitrogen recycling and efflux from sediments

Determine the importance of regenerated N to the nitrogen demand of giant kelp by measuring rates of nitrogen efflux from sediments and rates of N recycling by kelp forest consumers

THEME 3C. Transport and fate of phytoplankton NPP

Characterize coastal dispersal with respect to several environmental parameters such as season, coastal geometry, distance from the shore, surface wave forcing, and flow characteristics. Deploy an autonomous glider to obtain highly resolved cross-shelf sections of physical and bio-optical properties for various oceanographic conditions. Calculate and validate derived bio-optical information, including net community production, particle size distribution, particulate organic carbon, and transport velocities. Use statistical methods and time-series data from moored instruments and cruises to determine patterns and sources of variation in ocean physics, particle distributions, net community production and chlorophyll at biologically relevant time and space scales.

Significant results:

THEME 1A. Effects of wave disturbance on kelp forest structure and function

Results from the first 6 years of our long-term kelp removal experiment were not as expected, and underscore

the value and need for multi-site, multi-year experiments. A combination of natural processes acted indiscriminately to reduce kelp in both kelp removal and kelp control plots leading to predicted patterns of community structure at only 1 of 4 sites. Monthly and interannual patterns of larval settlement in sea urchins over the past 20 years exhibited a strong, negative relationship with sea surface temperature; larval and adult food supply were unrelated to settlement and offshore transport only weakly related. Regional analyses of the 28-y Landsat kelp time series showed wave disturbance, nitrate availability, and the state of the NPGO were the most important environmental factors controlling the biomass dynamics of giant kelp. Wave disturbance explained more variability in central California than southern California, where primary drivers also included nitrate availability, and sea urchin density.

THEME 1B. Determining the fate of kelp NPP

Shorter blade lifespans and larger blade areas were associated with higher light environments in the kelp forest. N content and photosynthetic performance decreased with blade age, with the decrease in N content greater in shorter-lived blades. These findings are largely consistent those predicted for land plants by leaf lifespan theory. Temporal variation in exudation rates of DOC by kelp was explained in part by mean surface irradiance during the incubations. Results from lab experiments indicated that kelp detritus is not a viable food source for kelp forest suspension feeders whose growth was unaffected by kelp detritus in the presence or absence of phytoplankton. Fish predators in the canopy preferred small invertebrate grazers to suspension feeders suggesting that these small grazers represent an important trophic link between kelp and coastal food webs.

THEME 1C. Effects of fishing on kelp forest structure and function

Data on lobster fishing effort were used in a model to integrate MPAs into fishery management that is being developed by fishery scientists working jointly with commercial trap fishermen. We submitted a manuscript demonstrating prey reductions in MPAs caused lobsters to broaden their diet, which amplified top-down effects on community structure.

THEME 2A. Export of nutrients from watersheds

Stream discharges and nutrient fluxes were very low in 2014 due to extended drought. Soil nitrate production was highest in the most recently burned sites. Nitrification appears most constrained by ammonium supply, though increases in pH that occur after fire can enhance nitrification when substrate is available. Charcoal may enhance N cycling immediately after fire, but impacts are short-lived. Studies of stream metabolism revealed greater daily variation in DO concentrations, more exaggerated daily cycles, and higher maximum and lower minimum daily concentrations in urban sites vs. undeveloped sites. Stable isotope analyses involving deuterium provided wide end-member separation between land and stream sources of production and among stream grazers and detritivores, which will permit the use of mixing models to estimate the importance of terrestrial subsidies to food webs of streams that varied in exposure to fire, catchment area, riparian cover, flow velocity, and algal biomass.

THEME 2B. Trajectories of landscape changes in coastal watersheds

Analyses of AVIRIS imagery revealed a dependency of landscape recovery on interannual climatic variation, rather than fire severity, which has important implications for coastal water quality given the higher erosion potential for exposed soils and the potential for future climatic variability. The uppermost bedsets of the Geoprobe cores at Carpinteria Marsh contained the same stratigraphy as the shorter vibracores. In both cases a distinct marine sand unit was found at a depth of ~50 cm. Age analysis link this layer to the 1812 tsunami, which was also evident in cores from Devereux Slough.

THEME 2C. Exchanges of nutrients on beaches

Beach wrack exhibited a strong seasonal pattern with peak biomass in late summer and fall, well before major losses are detected in kelp forests in winter. Shorebird abundance and diversity were strongly correlated with stranded kelp plant abundance, which in turn was correlated with wrack biomass. The ratio of DOC:to total dissolved N in porewater was correlated with residence time and DIN concentration. Low porewater respiratory quotients in lab experiments suggest oxidation of reduced compounds. Protein-like fluorescence intensities in the porewater treatment remained fairly constant for several days, indicative of reliance on oxidation of amino acids.

THEME 3A. Dilution and dispersal of freshwater runoff plumes

The numerical simulations of storm water runoff predict plumes that are generally trapped against the coast and cross-shelf exchange that is largely influenced by surface winds and flow structures. Lateral spreading of plume from storm water runoff is largely anisotropic, spreading 10 times faster along-shelf than cross-shelf. Analysis of simulated runoff events over 2 seasons revealed a consistent general pattern linked to the wind forcing, which leads to an initially narrow freshwater front at ~ 0.5 km from shore that widens to a cross-shelf extent of ~ 2 km.

Both dye and density fronts generally track each other only during strong discharge events. These results were used to develop a model describing the dilution field as a function of discharge, input tracer concentration, wind and current variability, and background density gradients. The results also allowed the quantification of relevant measures of the dilution field such as the fraction of time exceeding threshold concentrations, maximum dilution and probability density functions of the dilution field.

THEME 3B. Nitrogen recycling and efflux from sediments

Nothing to report

THEME 3C. Transport and fate of phytoplankton NPP

Field data were used to characterize the sub-surface cross-shelf propagation of phytoplankton in terms of: 1) the existence of bottom nepheloid layers that develop with different mixing conditions, 2) the effect of large waves and local wind changes in determining the bulk optical properties of the water, and 3) the persistence and maintenance of intermediate nepheloid layers that may serve as important mechanisms for particle transport. Data from moored sensors and autonomous glider surveys revealed optical and bio-physical links between innershelf and offshore waters, clarifying the mechanisms by which these regions support and control production and export of particles over various time scales.

Subtidal velocity EOF analyses from ROMS exhibited two modes of variability in currents confined to the shelf, each with a specific velocity signal and frequency: a near shore higher frequency mode and an offshore lower frequency mode. The individual modes are linked to various forcings with prevalent structures associated with temperature and salinity. Analyses of cruise data revealed strong subduction of phytoplankton out of the euphotic zone via sinking occurs in a persistent convergence region in the SB Channel where productive upwelled waters from central California collide with warm waters from southern California. The towed profiler data also revealed large plumes of phytoplankton descending in an area of strong cyclonic circulation in the western SB Channel. Sediment trap samples from the SB Basin were incorporated into a modern calibration study relating foraminiferal morphometrics to surface ocean carbonate ion concentration with a goal of reconstructing paleo surface ocean carbonate ion concentration through the last several centuries to evaluate the onset and progression of ocean acidification in the California Current System.

Key outcomes or Other achievements:

See significant results.

What opportunities for training and professional development has the project provided?

Education and training are tightly integrated into all aspects of SBC LTER research. During the past year (year 2 of SBC III), 2 postdoctoral fellows, 39 graduate students, 4 REU students and 104 additional undergraduate students participated in SBC research. 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. REU students work closely with SBC LTER researchers on a wide range of topics and most choose to pursue an advanced degree following their undergraduate education. Five of the 13 undergraduate students who graduated with distinction in the major did their senior honors project with SBC and two of those SBC-mentored students won two of the four awards for outstanding undergraduate student in their department.

The focus of SBC's mentoring and training of postdoctoral scientists is on providing them with strong interdisciplinary skills, professional development opportunities, and the experience, and support required for them to transition to career faculty positions. In addition to the specific training associated with the SBC project, postdoctoral scientists are mentored through grant proposal development and writing and the job application and interview process by SBC investigators and via access to UCSB's resources for postdoctoral scientists. Co-PI Siegel served as the primary mentor for post doc, Leonel Romero, on a proposal submitted to NSF's Physical Oceanography program and on a research paper with a planned submission date of November 2014. During this past year former SBC post doc, Kyle Cavanaugh, accepted a position as a tenure-track assistant professor at the University of California, Los Angeles.

SBC graduate student and postdoctoral training is coordinated with several graduate programs on the UCSB campus to promote opportunities for interdisciplinary graduate training in ecology, physiology, geology, geography, hydrology, oceanography, 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.

UCSB's teaching aquarium (Research Experience & Education Facility known as the "REEF") features SBC LTER research and provides a wide range of training and professional development opportunities. The REEF also serves as a marine ecology teaching facility for UCSB courses in Earth Sciences, Ecology Evolution & Marine Biology, English and Teacher Ed programs through the Gevirtz Graduate School of Education, and for many area colleges including Cal Lutheran Thousand Oaks, California State University Channel Islands, and Santa Barbara and Ventura county community colleges. 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 features current SBC 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 *Oceans-to-Classrooms* curriculum around a number of research programs at UCSB and SBC LTER is the most significant contributor to this endeavor. Support from the SBC Schoolyard LTER 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 SBC graduate students, research staff, and post-docs from the SBC LTER to train REEF interns, which, in turn, enhances their training as laboratory and field assistants and research divers for SBC research. A total of 69 undergraduate interns were trained this year in this rigorous and pedagogically sound program.

Describe how the results have been disseminated to communities of interest

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 and the Marine Science Institute's *Oceans-to-Classrooms* curricula. Our focus is on long-term connections with local, regional and state 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 undergraduate and graduate students, K-12 teachers, K-12 students, the UC Community and the general public. Through *Oceans-to-Classrooms* and the REEF, SBC LTER-based curriculum, rich in STEM content that supports California State Science Standards, Common Core Standards and the Next Generation Science Standards, was presented to over 20,000 visitors last year, 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 Counties and Sedona, Arizona! This year's SBC sLTER specific program content reached nearly 7,000 students in grades 6-12. We continue to develop and adapt marine science lesson plans that engage students with learning about the local environment in the context of SBC LTER. These lessons incorporate ongoing SBC research that includes working with project data. The program is developed to build student skills in scientific inquiry through activities that move from structured or guided investigation to open-ended inquiry and experimentation. 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.

1. 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, 3) and Kids In Nature (KIN).

- Tech Trek is an on-campus residential science and math summer program designed to develop interest, excitement and self-confidence in young women entering the eighth grade. Tech Trek is part of a partnership involving science, technology, engineering, and math departments at UCSB through the Office of Education Partnerships (OEP). 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 groups of 78 girls each from junior high and middle schools from Santa Barbara and surrounding areas, representing a diverse range of socioeconomic and demographic groups. During a weeklong residential camp at UCSB, students participated in "core" science courses that included socio-ecological and science and math activities. The girls engaged in a number of place-based, hands-on, activities that promoted concept application and citizenship, including a trip to Platform Holly, visits to SBC kelp forest study sites and the SBC-based Floating Lab. Verizon has shown interest in supporting the program and worked with us this year to develop an apps course. This year's program was visited by US Congresswoman Lois Capps and key AAUW National Office personnel interested in

expanding our learning model to other Tech Trek sites.

- The MSP Pathways to Environmental Literacy 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, as well as K-12 schools. In 2013-14, work has focused on learning progression research analysis and dissemination. SBC worked with 14 teachers from the 2013 summer professional development workshop to implement science units in the classroom with over 1,500 Santa Barbara County and Ventura County students. In Fall 2013 a 2-day workshop with these teachers fostered the development of a place-based, locally relevant adaptation of the Biodiversity Unit that explores current ideas in the context of the local coastal ecosystems. In June 2014, a 5-day Professional Development workshop provided 23 teachers with resources to add place-based extensions and related data sets to the existing Biodiversity and Carbon curricula. Teachers also explored integration of Common Core State Standards and Next Generation Science Standards in their classrooms through the implementation of Water, Carbon and Biodiversity curriculum units. The MSP engaged and supported a program coordinator, a graduate student, a Teacher in Resident (TIR) and 2 undergraduate assistants.
- The *Kids In Nature* program based at UCSB's Cheadle Center for Biodiversity and Ecological Restoration provides selected classrooms with a total of twelve educational activities offered by their partners, including the REEF. KIN curriculum emphasizes hands-on, place based activities in outdoor environments and includes classroom visits where UCSB students mentor and assist with fifth grade activities in native plant gardens at schools. KIN students spend time on the UCSB campus, giving them opportunities to learn about college and the campus environment.

2. "California kelp forests" and "California tide pools" are 2 new free applications for smart phones, supported by UCSB Marine Science Institute's Outreach Center for Teaching Ocean Science (OCTOS) and Channel Islands National Marine Sanctuary. Together, these new applications provide a rich experience for students and nature lovers to learn about the local marine life.

3. Former SBC postdocs Jarrett Byrnes and Kyle Cavanaugh launched a new citizen scientist project called Floating Forests in August 2014. Floating Forests (<http://www.floatingforests.org/#/>) is a Zooniverse Project to study change in the global abundance of giant kelp using Landsat imagery from space. The project builds on SBC's unique 30-y time series of giant kelp abundance along the California coast developed by Cavanaugh using Landsat imagery. Floating Forests seeks to expand the time series globally by directly engaging citizen scientists in quantifying the changes in giant kelp forests over time.

4. SBC hosted a booth at the 2014 Santa Barbara Earth Day Festival to raise public awareness about LTER research. This year's festival attracted 37,364 people. A virtual kelp forest in which SBC students and staff acted as 'dive buddies' for children who toured the forest and collected data was a highlight.

5. SBC investigators and students contributed to the following stories that appeared in newspapers and other media outlets.

- Citizen scientists quantify kelp forests: <http://www.independent.com/news/2014/aug/22/counting-kelp/>
- Archiving digital information: <http://www.news.ucsb.edu/2014/014053/here-today-gone-meta>
- Coverage of the 2014 teacher professional development workshop: Teaching Environmental Science in a Changing Climate:
 - <http://www.news.ucsb.edu/2014/014288/nature-clasroom>
 - <http://www.keyt.com/news/teachers-become-students-at-climate-change-workshop/26590796>
- Harding University Partnership School 6th Graders learn about kelp forests and SBC LTER:
 - <http://www.news.ucsb.edu/2014/014169/i'm-going-ucsb/>
 - <http://www.independent.com/news/2014/may/02/harding-university-partnership-school-brings-its-e/>
 - http://www.noozhawk.com/article/011713_santa_barbara_students_nature_ucsb_program/

What do you plan to do during the next reporting period to accomplish the goals?

Continue as planned

PRODUCTS

Books

Book Chapters

- Carr, MH and Reed, DC (). Shallow rocky reefs and kelp forests. *Ecosystems of California – A source book* Mooney, H and Zavaleta, E. University of California Press. . Status = ACCEPTED; Acknowledgement of Federal Support = No ; Peer Reviewed = Yes
- Dugan, JE and Hubbard, DM (). Sandy Beach Ecosystems. *Ecosystems of California – A source book* Mooney, H and Zavaleta, E. University of California Press. . Status = ACCEPTED; Acknowledgement of Federal Support = No ; Peer Reviewed = Yes
- Foster, M. S., D. C. Reed, M. H. Carr, P. K. Dayton, D. P. Malone, J. S. Pearse and L. Rogers-Bennett (2013). Kelp forests in California. *Research and Discoveries: The Revolution of Science Through SCUBA, Smithsonian Contributions to the Marine Sciences* 39. Lang, M A. Lang, R. L. Marinelli, S. J. Roberts, and P. R. Taylor. Smithsonian Institution Press. 115. Status = PUBLISHED; Acknowledgement of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.5479/si.1943667X.39.
- Guerrini, A (2009). The trouble with plovers. *New Visions of Nature: Complexity and Authenticity* Keulartz, J and Drenthen, M and Proctor, JD. Springer. . Status = PUBLISHED; Acknowledgement of Federal Support = No ; Peer Reviewed = Yes ; ISBN: 978-90-481-2611-8.
- Moore, SD, Haviland, D., Whitmer, A. and Brady, J. (2014). CoastLines: Commitment, Comfort, Competence, Empowerment, and Relevance in Professional Development,. *Teaching Science and Investigating Environmental Issues with Geospatial Technology: Designing Effective Professional Development for Teachers*. MaKinster, J., Trautman, N. and Barnett, M.,. Springer Science+Business Media B.V. 201. 133. Status = PUBLISHED; Acknowledgement of Federal Support = No ; Peer Reviewed = Yes ; DOI: 10.1007/978-90-481-3931-6.
- Power, ME, Kupferberg, SJ, Cooper, SD and Deas, ML (). California's river ecosystems. *Ecosystems of California – A source book* Mooney, H and Zavaleta, E. University of California Press. . Status = ACCEPTED; Acknowledgement of Federal Support = No ; Peer Reviewed = Yes
- Schlacher, T. S., A. R. Jones, J. E. Dugan, M. Weston, L. Harris, D. S. Schoeman, D. Hubbard, F. Scapini, R. Nel, M. Lastra, A. McLachlan and C. H. Peterson (2014). Open-coast sandy beaches and coastal dunes, Chapter 5. *Coastal Conservation* Maslo, B. and J. L. Lockwood. Cambridge University Press. 37. Status = PUBLISHED; Acknowledgement of Federal Support = No ; Peer Reviewed = No

Conference Papers and Presentations

- Dugan, JE, Hubbard, DM and Quigley, B (2013). *Beyond beach width: steps toward identifying and integrating dynamic ecological envelopes with geomorphic features and datums for sandy beach ecosystems (invited)*. 44th Annual Binghamton Geomorphology Symposium. Newark, NJ. Status = OTHER; Acknowledgement of Federal Support = Yes
- Goodridge, B and Melack, JM (2013). *Carbon and nitrogen stoichiometry regulates the magnitude and temporal dynamics of nitrogenous nutrient regeneration in sandy beach pore water*. American Geophysical Union, Annual Meeting. San Francisco, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
- Jones, J (2014). *Carbonate system monitoring and manipulation: current and future research*. UCSB Interdepartmental Graduate Program in Marine Science Seminar. Santa Barbara, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
- Schooler, NK, Dugan, JE, Hubbard, DM and Straughan, D (2013). *Changing sandy beach ecosystems in California: comparisons of intertidal biodiversity three decades apart*. 44th Annual Binghamton Geomorphology Symposium. Newark, NJ. Status = OTHER; Acknowledgement of Federal Support = Yes
- Schooler, NK, Dugan, JE, Hubbard, DM and Straughan, D (2013). *Changing sandy beach ecosystems in California: comparisons of intertidal biodiversity three decades apart (poster)*. 44th Annual Binghamton Geomorphology Symposium. Newark, NJ. Status = OTHER; Acknowledgement of Federal Support = Yes

- Hendriks-Freitas, F, Stassinis, F, Halewood, S, Washburn, L and Siegel, DA (2014). *Coupling between physical and bio-optical variability across the innershelf Santa Barbara Channel, CA (poster)*. 2014 Ocean Sciences Meeting (ASLO, TOS, AGU). Honolulu, HI. Status = OTHER; Acknowledgement of Federal Support = Yes
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- O'Brien, MC (2014). *Lessons learned using Ecological Metadata Language with LTER data*. Earth Science Information Partners (ESIP), Summer Meeting. Copper Mountain, CO. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Hubbard, DM, Dugan, JE, Schooler, NK, and Viola, S. (2013). *Local extirpations and regional declines: the case of endemic upper beach fauna in southern California*. Coastal and Estuarine Research Federation. San Diego, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
- Jones, J, Sweet, J, Gotschalk, C, Washburn, L, Hofmann, GE and Passow, U (2014). *Monitoring the carbonate system at Stearns Wharf*. UCSB Interdepartmental Graduate Program in Marine Science Seminar. Santa Barbara, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
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- Bell, TW, Cavanaugh, KC, Reed, DC and Siegel, DA (2013). *Primary controls on giant kelp biomass throughout California*. Annual Meeting of the Western Society of Naturalists. Oxnard, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
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- Jin, H.; Shin, H.J.; Johnson, M.; Kim, J.; Anderson, C.W. (2014). *Promise and Problems of Learning Progression-guided Interventions*. Oral presentation. National Association for Research in Science Teaching Annual International Conference. Pittsburgh, PA. USA. Status = OTHER; Acknowledgement of Federal Support = Yes
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- Reynolds, L, Simms, AR, King, B, Rockwell, T and Peters, R (2013). *Sedimentological Evidence of the 1812 Santa Barbara Tsunami in Carpinteria Marsh, CA*. American Geophysical Union, Annual Meeting. San Francisco, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
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- Rahimi, A.M., Miller, R.J., Fedorov, D.V., Sunderrajan, S., Doheny, B.M., Page, H.M. and Manjunath, B.S. (2014). *Subtidal marine biodiversity classification using dropout regularization*. Proceedings of the 22th International Conference on Pattern Recognition (ICPR); workshop on Computer Vision for Analysis of Underwater Imagery. . Status = SUBMITTED; Acknowledgement of Federal Support = Yes
- Reed, DC (2014). *Targets and evaluation of ecological restoration (invited)*. Marine Ecological Restoration (MER) Workshop. Eilat/Israel. Status = OTHER; Acknowledgement of Federal Support = Yes
- Aristizabal, MF, Fewings, MR, Washburn, L and Dorman, C (2014). *The influence of internal waves on the temperature variability in the Santa Barbara Channel*. 2014 Ocean Sciences Meeting (ASLO, TOS, AGU). Honolulu, HI. Status = OTHER; Acknowledgement of Federal Support = Yes
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Inventions

Journals

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- Barron, R. K., D. A. Siegel, N. Guillocheau (2014). Evaluating the importance of phytoplankton community structure to the optical properties of the Santa Barbara Channel, California. *Limnology and*

Oceanography. 59 927. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

- Carney, L. T., A. J. Bohonak, M. S. Edwards and F. Alberto (2013). Genetic and experimental evidence for a mixed age, mixed origin bank of kelp microscopic stages in southern California. *Ecology*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
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- Collins, DG and Melack, JM (2014). Biological and chemical responses in a temporarily open/closed estuary to variable freshwater inputs. *Hydrobiologia*. 743 97. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1007/s10750-014-1872-y
- Coombs, J. S. and J. M. Melack (2013). The initial impacts of a wildfire on hydrology and suspended sediment and nutrient export in California chaparral watersheds. *Hydrological Processes*. 27 (26), 3842. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- Cooper, S. D., P. S. Lake, S. Sabater, J. M. Melack and J. L. Sabo (2013). The effects of land use changes on streams and rivers in Mediterranean climates. *Hydrobiologia*. 719 383. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- Deutsch, C, Berelson, W, Thunell, RC, Weber, T, Tems, C, McManus, J, Crusius, J, Ito, T, Baumgartner, T, Ferreira, V, Mey, J and Van Geen, A (2014). Centennial changes in North Pacific anoxia linked to tropical trade winds. *Science*. 345 665-668. Status = PUBLISHED; Acknowledgment of Federal Support = No ; Peer Reviewed = Yes ; DOI: 10.1126/science.1252332
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- Hofmann, GE, Evans, TG, Kelly, MW, Padilla-Gamiño, JL, Blanchette, CA, Washburn, L, Chan, F, McManus, MA, Menge, BA, Gaylord, B, Hill, TM, Sanford, E, LaVigne, M, Rose, J, Kapsenberg, L and Dutton, JM (2014). Exploring local adaptation and the ocean acidification seascape – studies in the California Current Large Marine Ecosystem. *Bio-geoscience*. 11 1053-1064. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.5194/bg-11-1053-2014
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- Kim, SY, Terrill, EJ, Cornuelle, BD, Jones, B, Washburn, L, Moline, MA, Paduan, JD, Garfield, N, Largier, JL, Crawford, G and Kosro, PM (2013). Poleward propagating subinertial alongshore surface currents off the U.S. West Coast. *Journal of Geophysical Research - Oceans*. 118 1. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/jgrc.20400
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- Reed, DC, Rassweiler, AR, Miller, RJ, Page, HM and Holbrook, SJ (). The value of a broad temporal and spatial perspective in understanding dynamics of kelp forest ecosystems. *Marine and Freshwater Research*. . Status = ACCEPTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- Romero, L., Y. Uchiyama, J. C. Ohlmann, J. C. McWilliams and D. A. Siegel (2013). Simulations of nearshore particle-pair dispersion in Southern California. *Journal of Physical Oceanography*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1175/JPO-D-13-011.1
- Schlacher, TS, Schoeman, DS, Jones, AR, Dugan, JE, Hubbard, DM, Defeo, O, Peterson, CH, Weston, M, Maslo, B, Olds, AD, Scapini, F, Nel, R, Harris, LR, Lucrezi, S, Lastra, M, Huijbers, CM and Connolly, RM (2014). Metrics to assess ecological condition, change, and impacts in sandy beach ecosystems. *Journal of Environmental Management*. 144 322. Status = PUBLISHED; Acknowledgment of Federal Support = No ; Peer Reviewed = Yes ; DOI: 10.1016/j.jenvman.2014.05.036
- Schooler, NK, Dugan, JE and Hubbard, DM (). Detecting change in intertidal species richness over time on sandy beaches: calibrating across sampling designs. *Estuarine, Coastal and Shelf Science*. . Status = AWAITING_PUBLICATION; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.ecss.2013.10.016
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- Wilson, JR, Valencia, SR, Kay, MC and Lenihan, HS (). Integration of no-take marine reserves in the assessment of data-limited fisheries. *Conservation Letters*. . Status = AWAITING_PUBLICATION; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1111/conl.12073
- Yorke, CE, Miller, RJ, Page, HM and Reed, DC (2013). The relative importance of kelp detritus as a component of suspended particulate organic matter in giant kelp (*Macrocystis pyrifera*) forests. *Marine Ecology Progress Series*. 493 113-125. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.3354/meps10502

Licenses

Other Products

- *Educational aids or Curricula*.
Doherty, J.; Harris, C.; Hartley, L.; Anderson, C.W.; Angle, M.; Burke, M.; Grant, T.; **Johnson, M.**; Kilmartin, D.; McMahon, S.; Moore, J.; Ratashak, L.; Schiebout, M.; Schramm, J.; Simon, S.E; Spindler, L.; Wilke B. **2012**. Biodiversity: Diversity in a Leaf Pack, High School Teacher Guide. **Curriculum** created for the Math Science Partnership: Culturally relevant ecology, learning progressions and environmental literacy.
- *Educational aids or Curricula*.
Floating Forests (formerly Kelp Hunters). This is a site that engages citizen scientists to help track change in kelp forests, <http://www.floatingforests.org/>
- *Educational aids or Curricula*.
SBC LTER kelp forest field guide iPhone application. This application is a free field guide to 150 algae, plants, fish and invertebrates that inhabit the unique ecosystem of California's kelp forests. The app is available from the iTunes store under "California Kelp Forest", and plans are underway for a version for the iPad and Android operating systems.
- *Educational aids or Curricula*.

Schramm, J.; Keeling, E.; Figueroa, D.; Mohan, L.; **Johnson, M.**; Anderson, C.W.; Hach, C.; Drayton, B.; Cisterna, D.; Pitot, L.; and Switzer, M.; Yestness, N. **2012**. Plant Growth and Gas Exchange, Middle/High School Teacher's Guide. **Curriculum** created for the Math Science Partnership: Culturally relevant ecology, learning progressions and environmental literacy.

- *Data and Research Materials (e.g. Cell lines, DNA probes, Animal models)*. SBC datasets on climate, hydrology, stream chemistry, watershed characteristics, coastal ocean currents and biogeochemistry, net primary production of kelp, historical kelp biomass, cover of sessile organisms on reefs, reef fish abundance, abundance and size of giant kelp, reef invertebrate and algal density and stable isotope data from kelp forest food webs are being collected and updated annually. Available final datasets are listed in the metadata catalog on the site's website <http://sbcdata.lternet.edu/catalog/> SBC's data catalog currently contains 180 datasets including both data from core measurements, time series and process studies conducted by SBC.

Other Publications

- Nielsen, K J., S.G. Morgan, J. E. Dugan (2013). *Baseline Characterization of Sandy Beach Ecosystems in California's North-Central Coast Region..* Final Report to the Ocean Science Trust, California Ocean Protection Council and California Sea Grant.. Status = PUBLISHED; Acknowledgement of Federal Support = No

Patents

Technologies or Techniques

Thesis/Dissertations

- Emery, K.. *Does evidence matter? How middle school students make decisions about socioscientific issues.* (2013). University of California, Santa Barbara. Acknowledgement of Federal Support = Yes

Websites

- *Pathways Project website:*
<http://www.pathwaysproject.kbs.msu.edu/>
Website for the Math-Science Partnership “Culturally relevant ecology, learning progressions and environmental literacy” project to disseminate teaching materials, professional development materials, and information about learning progressions research.
- *SBC LTER Project Website*
<http://sbc.lternet.edu/>
This is the project website which describes the research questions, progress, people, outreach and education programs and resources. publications, presentations and data products of the Santa Barbara Coastal LTER.

Participants & Other Collaborating Organizations - Who has been involved?

- * What individuals have worked on the project?

Name	Most Senior Project Role	Nearest Person	Month Worked	Action
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- **What other organizations have been involved as partners?**
 - *** Have other collaborators or contacts been involved?**
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Impact - What is the impact of the project? How has it contributed?

What is the impact on the development of the principal discipline(s) of the project?

Results from SBC research are helping to address the growing need for understanding ecosystem level processes in kelp forests. Of particular significance are our unique time series data and findings pertaining to: (1) controls and fate of primary production, (2) the movement and utilization of different sources and forms of nutrients, (3) environmental drivers of nearshore food webs, and (4) exchange of organic and inorganic materials among ecosystems.

SBC's development of an ongoing time series of canopy biomass for giant kelp in California and Mexico from Landsat satellite imagery has provided an unprecedented opportunity to study the patterns and drivers of population dynamics of this foundation species at unprecedented temporal resolution and spatial and temporal scales. The time series has generated considerable interest from the science community and led to several new collaborations this past year. This past year former SBC post docs and current Affiliated Investigators Byrnes and Cavanaugh partnered with ZooInverse to develop a web-based citizen science project that uses the efforts of volunteers to analyze Landsat imagery of giant kelp from across the world. The project "Floating Forests" makes use of the methodology developed by Cavanaugh and collaborations with kelp forest scientists in the recently formed Kelp Ecosystem Ecology Network (KEEN) organized by Byrnes and SBC LTER to develop a standardized long-term dataset for assessing changes in giant kelp abundance for most of the globe,

Lead PI Reed was invited to deliver the opening key note address at the 10th International Reef Symposium in Perth Australia. The theme of his talk and the subsequent synthesis paper (Reed et al. in press) was that comprehensive research programs, such as LTER, that integrate coupled time series observations of physical variables and ecological responses, manipulative experiments and synthetic analyses over the long term are essential for advancing our understanding of ecological responses associated with climate change, and the physical and biological processes that control them. Four case studies from SBC LTER were featured to highlight this theme and to demonstrate the value of a broad temporal and spatial perspective in understanding the causes and ecological consequences of short-term local dynamics of giant kelp forests.

SBC investigators, Miller, Carlson, Rassweiler, Reed and Siegel, were recently awarded funding from NASA and BOEM to establish a prototype marine Biodiversity Observation Network (BON) in the Santa Barbara Channel. Funding for this new program was very competitive and ongoing research by SBC LTER was well integrated into the successful proposal. The impetus for this program is to track biodiversity in marine habitats to improve our capacity for science-based decision-making aimed at protecting natural ecosystems and sustaining the services that they provide. The Santa Barbara Channel was considered to be an ideal testing ground for such an effort due to the concentration of biodiversity measurements already taking place there, particularly by SBC LTER and Channel Islands National Park. Additionally, this new project will build strongly on LTER's Information management framework to manage the large amount of biodiversity data generated by the BON.

Ongoing analysis of the large volume of data collected during the SBC LTER UNOLS cruises is providing new insights into the fate and transport of phytoplankton. This will positively impact the principal discipline of biological oceanography. In particular, modeling efforts to understand the evolution of phytoplankton blooms, including harmful algal blooms, in the coastal ocean will improve as they incorporate effects of frontal process that lead to subduction of phytoplankton biomass.

SBC partnership with other research programs to maintain spatially extensive array of moored sensors is providing spatially comprehensive high frequency data on ocean properties including currents, temperature and pH. This year with help of supplemental funding we are adding measurements of oxygen, total alkalinity and total pCO₂.

SBC investigators have broadened the reach of SBC research and fostered synthesis through a number of cross site collaborations within a variety of disciplines.

- Investigator Cooper is a member of an ongoing LTER working group that is conducting a meta-analysis of the effects of nutrient inputs on stream ecosystems. To foster strong relationships between NEON/STREON and LTER stream researchers, he serves on the STREON technical advisory committee, advises NEON personnel on stream ecology issues, and organizes workshops for the NSF Stream Resiliency Research Coordination Network, collectively dealing with the effects of nutrient loading, biodiversity loss, and extreme events on stream ecosystems.
- Investigator Cooper is also the co-organizer and co-editor for an upcoming special issue of *Freshwater Science* on “The Effects of Fire on Freshwater Ecosystems” (anticipated date of publication: Sept., 2015).
- Investigator Dugan is a member of an ongoing LTER working group that is developing a new synthesis of the responses of soft sediment ecosystems to armoring and coastal squeeze.
- SBC is collaborating with CCE to help maintain a 20+ year sediment trap time series in the Santa Barbara Basin that is managed by researchers from the University of South Carolina. Data from this novel time series are being used to address a variety of research topics including the transport and fate of harmful algal blooms, and the development of proxies that can be used to reconstruct changes in climate over the geologic past.

What is the impact on 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, environmental history, science education and informatics. Investigator Guerrini is working with other LTER sites to analyze and explore the history of LTER programs. The theme of history record-keeping and analysis is likely to become a more important feature of LTER programs as the first generation of LTER researchers move on. Plans for a working session and symposium on history and archives to be presented during the 2015 ESA centennial meeting in Baltimore, Maryland, are underway. The MSP Pathways to Environmental Literacy project is connecting the research and education strengths of LTER sites with teacher professional development in science and mathematics. This program, which involves four LTER sites and their associated institutions and the LTER Network office, engaged teachers in learning progression research analysis and dissemination through workshops and curriculum development in 2013-14.

What is the impact on the development of human resources?

Our project provides significant opportunities for scientific training in research at multiple levels. During the past year 106 undergraduate students, 39 graduate students, 3 post doctoral fellows and 10 middle and high school students were trained through substantial involvement in SBC research. Additionally, SBC faculty 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. The active involvement of large numbers of undergraduate students in SBC research (typically >100 each year) not only provides valuable undergraduate training, but also affords SBC's graduate students and post docs with significant opportunities for mentorship training. The experience gained from such training has proven to be very important to SBC graduate students and postdoctoral fellows who routinely go on to academic positions where the training legacy from SBC LTER continues. During this award period this has included Kyle Cavanaugh, now an assistant professor at the University of California, Los Angeles, Matt Kay, now an assistant professor at Santa Barbara City College, and Jarrett Byrnes, now an assistant professor at the University of Massachusetts, Boston.

Additional impacts on the development of human resources are achieved through SBC's extensive outreach programs (see Accomplishments), which primarily target K-12 students and teachers. These outreach programs, particularly the REEF, provide large numbers of undergraduate student interns with a solid foundation in marine ecology and training in communicating their knowledge in an educational format. The REEF utilizes SBC graduate students, research staff, and post-docs to train REEF interns, which, in turn, enhances their training as laboratory and field assistants for SBC research. The success of SBC's outreach programs has led us to explore new methods for reaching larger audiences. To this end Investigator Blanchette is leading SBC's efforts on an LTER children's book that highlights the links between giant kelp forests and sandy beaches. The proposal for the book was approved this past year by the editorial committee of the LTER Schoolyard Book Series. In addition, the SBC LTER Kelp Forest Field Guide has been developed into a free iPhone application available on iTunes. This interactive field guide provides information on 150 algae, plants, fish and invertebrates that inhabit the unique ecosystem of California nearshore kelp forests.

What is the impact on physical resources that form infrastructure?

NSF funds awarded to SBC were used to purchase and maintain a custom 22' research vessel that is specially designed for diving and oceanographic research and an autonomous ocean glider that is customized for coastal research. Research groups collaborating with SBC have access to this vessel and glider for their research needs. SBC partners with other research programs to maintain an extensive array of moored sensors that is providing spatially comprehensive high frequency data on ocean properties including currents, temperature salinity, chlorophyll, oxygen and pH. This includes working with SCOOS to maintain instruments on Stearns Wharf that produce real time data that is publicly accessible and widely used..

What is the impact on Information Resources that form infrastructure?

SBC's publicly available data holdings increased by about 10% during 2013-2014. About half of our holdings represent ongoing time series that are updated annually. All datasets include methods and/or protocol documents to provide context. All metadata are available in the XML specification Ecological Metadata Language (EML), and were contributed to the recently developed LTER Network Information System catalog in 2013. SBC's own data catalog (based on the same corpus of datasets) is organized into sampling collections, and is accessible from the website's research descriptions and sampling sites map. Web servers were upgraded in 2014. Our local infrastructure provides nightly back-up for archival and work-in-progress.

A major focus this year has been the development of several new data products related to ocean carbon cycle measurements. These include discrete, manually collected pH samples, sensor data from instrument deployments, and ongoing time-series of post-processed data for integration with other SBC data products. Data processing methods are complex, interdependent, and some are still in development. SBC has led community efforts to formalize these processes, and to integrate information management with data processing. We continue to upgrade all SBC data handling protocols for integration with our code for metadata export, which was completed in 2013, collaboratively with Moorea Coral Reef, MCR. SBC's data handling protocols are now more strictly defined and formalized, and will be used by the recently-funded Santa Barbara Channel Marine Biodiversity Observation Network) led by SBC Investigators Miller, Carlson, Rassweiler, Reed and Siegel.

SBC's information manager (O'Brien) leads 2 LTER working groups, 1) to define a system of structural quality standards for data packages contributed to Network catalog, and 2) to formalize data package design patterns for approximately 20 dataset categories. Her expertise in the use of the EML schema continues to be a resource for many other LTER sites. O'Brien continues to work with the DataONE project, specifically in the areas of semantics and data discovery, a position which highlights the usability of SBC data, and increases the visibility of all LTER data in that federated system. At UCSB, O'Brien participated in an advisory panel for the establishment of a data curation services program at the UCSB library.

What is the impact on society beyond Science and Technology?

SBC 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.

The new insights into the fate and transport of phytoplankton and the evolution of phytoplankton blooms, including harmful algal blooms, generated by the ongoing analyses of SBC and related datasets (including the sediment trap time series in the Santa Barbara Basin) and modeling contribute to improving public health by increasing the ability of managers to predict how harmful algal blooms evolve in the coastal ocean.

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 CCC and their staff, the employees of the power plant (Southern California Edison), 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 very complementary to that done by SBC and there is considerable exchange of information and ideas between the two projects.

SBC researchers are also engaged in informing policy for local watershed issues. We have developed mutually beneficial, cooperative associations with local and national government agencies and departments, and NGOs. Our intensive sampling of nutrients and particulates during the entire hydrograph for most storms complements the agency data collection, and we cooperatively share data and interpretations. In 2014 we performed high quality nutrient chemistry analyses on water samples from local streams and rivers for Santa Barbara Channelkeeper. Investigator Melack chairs UCSB's committee on wetlands that is overseeing restoration of campus wetlands that is being used as mitigation for staff and student housing projects. Investigator Cooper regularly provides advice about stream environmental issues and the monitoring and management of southern California steelhead populations to personnel from the California Department of Fish and Wildlife (DFW), National Marine Fisheries Service (NMFS), U.S. Forest Service (USFS), the cities of Santa Barbara and Goleta, and the Environmental Defense Center and the Audubon Society's Conservation Committee.

SBC investigators Reed, Melack, Page and Dugan are co-investigators on an ongoing climatic change vulnerability study entitled "Santa Barbara Area Coastal Ecosystem Vulnerability Assessment" funded by NOAA and Sea Grant. This new study relies largely on SBC core datasets and is fostering collaboration with climate scientists from Scripps Institution of Oceanography and coastal processes scientists from USGS. This study is actively engaging the cities of Santa Barbara, Goleta and Carpinteria in assessment and evaluation of the responses of SBC coastal ecosystems, including, wetlands, beaches and coastal watersheds to climatic forcing.

SBC research has led to a growing recognition of the unique biodiversity, functions and wildlife supported by beaches and the role of kelp and other macroalgal wrack as an ecological resource on beaches by local and state agencies. SBC results are contributing to the development of new policies for beach conservation and management. Investigator Dugan plays an active advisory role with coastal consortiums, state agencies and groups concerned with improving the conservation and management of beach ecosystems, including the California Coastal Commission, California Dept. of Fish and Wildlife, and the Ocean Science Trust. This past year Dugan co-authored a paper that evaluates potential indicator metrics for beach ecosystems, which fills a critical need for coastal managers.

Changes/ Problems

Changes in approach and reasons for change

Nothing to Report

Actual or Anticipated problems or delays and actions or plans to resolve them

Nothing to Report

Changes that have significant impact on expenditures

Nothing to Report

Significant changes in use or care of human subjects

Nothing to Report

Significant changes in use or care of vertebrate animals

Nothing to Report

Significant changes in use or care of biohazards

Nothing to Report