

SBC LTER 2016-2017 Annual Report

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PD/PI Name:

- Daniel C Reed, Principal Investigator
- Sally J Holbrook, Co-Principal Investigator
- John M Melack, Co-Principal Investigator
- Robert J Miller, Co-Principal Investigator
- David A Siegel, Co-Principal Investigator

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University of California-Santa Barbara

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Submitting Official (if other than PD/PI):

- Daniel C Reed
- Principal Investigator

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Signature of Submitting Official (signature shall be submitted in accordance with agency specific instructions)

Daniel C Reed

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 amounts of inorganic nutrients, organic matter, and sediments exchanged between kelp forests and the land and sea that adjoin them vary 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 kelp 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 objectives of each of our three research themes are:

Theme 1: To determine how variations in climate, wave disturbance and fishing influence the structure and dynamics of kelp forest communities and the patterns and 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, coastal erosion and storms.

Theme 3: To determine how oceanographic processes influence: (a) the dilution and dispersal of freshwater runoff plumes, (b) nitrogen recycling, consumer excretion, efflux from benthic sediments within and adjacent to kelp forests, and the utilization of recycled N by giant kelp, and (c) the fate of net primary production by phytoplankton which are an important food source to a diverse array of kelp forest consumers.

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

Major Activities:

We continued collecting data for a core group of long-term integrated measurements in the ocean and on land with the goal of quantifying climate, disturbance, and inorganic and organic subsidies to and from giant kelp forests 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 and climate variation on kelp forest structure and function:

We continued to maintain and evaluate our long-term kelp removal experiment designed to investigate the consequences of increased wave disturbance on kelp forest communities. We analyzed our ongoing kelp forest community time series at 11 reefs (16 years and counting) to examine how giant kelp, a foundation species that is disproportionately removed by wave disturbance, affects the biomass, diversity and stability of the reef community. We continued processing Landsat satellite imagery to update our 34-y (and counting) dataset of giant kelp biomass throughout California and Baja California, Mexico to facilitate our ongoing research on the regional determinants of kelp biomass, metapopulation dynamics, and genetic structure. This involved calibrating and integrating reflectance data from Landsat 5, 7 and 8 imagery.

Theme 1b. Determining the fate of kelp NPP:

We improved the accuracy of our time series of giant kelp NPP by incorporating losses of particulate and dissolved organic matter from tissue erosion and exudation into our model of kelp NPP. These loss terms, which were previously unaccounted for in our earlier estimates of NPP were modeled from our recently published in situ measurements of blade erosion and exudation. We used of airborne hyperspectral imagery of giant kelp coupled with in situ tissue sampling to investigate the importance of extrinsic environmental drivers vs. intrinsic demographic processes in accounting for variation in kelp physiological condition (as determined by Chl/C of blades) and NPP.

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 were assessed at these reefs and lobster fishing effort was measured twice per month during the fishing season. Before-After Control-Impact Paired Analyses (BACIP) of kelp biomass data derived from 33-years of Landsat imagery were initiated to examine the indirect effects of fishing on giant kelp biomass by comparing kelp biomass inside and outside of Marine Protected Areas (MPAs) before and after the MPAs were established. These results are being combined with spillover effects of protection to determine the impact of MPA establishment on the presence of kelp outside the boundary and how it dissipates with distance.

Theme 2A Export of nutrients from watersheds

Rainfall and discharge data were used to examine correlations with indices of climate variability including the occurrence of atmospheric rivers, Madden-Julian Oscillations and ENSO events of differing intensity.

Measurements of nutrients, sediments and discharge during baseflow and stormflow in eight watersheds were continued. Calculation of material fluxes based our multi-year records of stream discharge and solute concentrations were completed and used in statistical models examining the relationships between material fluxes and watershed characteristics. The balance between ash N loss, plant N uptake and stream N export were investigated for an upland chaparral watershed that extensively burned by using a combination of stream and vegetation data. Patterns in the hysteresis of concentration-discharge (C-Q) during storms across ten sites and water years 2002 to 2015 for nutrients and total suspended solids were examined by quantifying the slope of the C-Q relationship and the rotational pattern of the hysteresis loop.

Theme 2b. Trajectories of landscape changes in coastal watersheds:

Analyses of land cover derived from airborne hyperspectral data were aggregated into categories appropriate for statistical analyses of solute export; and area and connectedness of impervious surfaces was significantly improved. We extended our historical analyses by collecting seven additional cores from marsh sediments and obtaining 30 new radiocarbon ages.

Theme 2c. Exchanges of nutrients on beaches

We continued measuring variation in macrophyte wrack subsidies and wrack consumers on six beaches located near kelp forests. To investigate the potential importance of shredding by invertebrate consumers to

wrack nitrogen remineralization in intertidal porewater we measured porewater DIN concentrations over time in experimental beach sand columns with treatments of kelp wrack and wrack consumers. Using our data on kelp wrack inputs, biogeochemical processing and pore water nitrogen concentrations and residence times we estimated the potential contribution of kelp wrack-derived N from beaches to nearshore waters.

Theme 3a. Dilution and dispersal of freshwater runoff plumes

We completed and published an analysis evaluating the controls on suspended sediments in the Santa Barbara Channel and beyond using 18 years of satellite ocean color imagery and the roles that transport of sediments into the ocean from coastal streams may play. Work is also underway using results from our Regional Ocean Modeling System (ROMS) simulations of storm water plumes from two creeks near Mohawk Reef to estimate the impacts of coastal streams on offshore nutrient concentrations throughout the entire SBC LTER study domain.

Theme 3b. Nitrogen recycling and efflux from sediments

We continued to characterize spatial and temporal variability in urea availability at SBC study sites, via an ongoing monthly time series started in May 2016. Four in situ experiments to quantify rates of urea uptake by kelp and phytoplankton under different ocean conditions were completed. Numerous laboratory experiments focused on resolving the physiology of urea, nitrate and ammonium use by kelp, including how factors such as ambient concentrations, competition with phytoplankton, irradiance intensity and tissue type influence rates of uptake were completed. We began experiments to test the degree to which kelp are able to benefit from high concentration pulses of nitrogen that result from short-lived, spurious events like internal waves or animal excretion. Combined, these results will allow us to identify the forms of nitrogen most important to sustaining kelp growth on monthly to inter-annual timescales, and develop a robust physiological model of nitrogen use by kelp.

Theme 3c. Transport and fate of phytoplankton NPP

We published analysis of physical and bio-optical data collected from >400 cross-shelf sections obtained from an ocean glider over a wide range of oceanographic conditions. During this reporting period we redeployed the ocean glider on a month-long mission along the 35 m isobath off the Mohawk kelp forest to assess cross-shelf fluxes of phytoplankton, dissolved oxygen and particles. A bottom-mounted ADCP mooring and an ADCP on the glider were deployed to enable the estimation of cross- and along-shelf fluxes. We continue to collaborate with researchers from the 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 depths.

Specific Objectives:

Theme 1a. Effects of wave disturbance and climate variation 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 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 to the coastal ocean.

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 sources and processing history on the dissolved organic and inorganic carbon and nitrogen dynamics in intertidal beach sands.

Theme 3a. Dilution and dispersal of freshwater runoff plumes

Simulate many realizations of ROMS-modeled stormwater plumes to enable a robust statistical characterization of the dispersal and dilution of runoff in the coastal environment. Use ROMS output to quantify freshwater plume dilution fields as a function of along-and cross-shore distance from creek mouths and creek discharge rate. Assess the impacts of freshwater runoff events on ocean suspended particle and phytoplankton distributions from available satellite ocean color imagery.

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: 1) N efflux from sediments, 2) N recycling by kelp forest consumers and 3) uptake of different forms of recycled N by giant kelp.

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, and flow characteristics from high-resolution ROMS output. Analyze data from an autonomous glider to resolve cross-shelf sections of water properties and particle fields during various oceanographic conditions. Assess time/space distributions of suspended particles and phytoplankton from both glider and satellite ocean color observations and the roles of environmental variability.

Significant Results:

Theme 1a. Effects of wave disturbance and climate variation on kelp forest structure and function

Results from our long-term kelp removal experiment show that the frequency of disturbance to giant kelp changed the biomass and composition of community guilds in a manner commensurate with their dependence on physical, trophic, and habitat resources mediated by kelp. By contrast, the effects of variation in disturbance severity were much less pronounced. These results broaden the foundation species concept by demonstrating that repeated disturbance to a foundation species can outweigh the influence of less-frequent severe disturbances for the surrounding community by predictably altering resources and species interactions. Results from analyses of 15 years of kelp forest community data generally support Darwin's observations that kelp forests contain higher species richness and biomass. Structural equation modeling revealed the foundational qualities of giant kelp in structuring reef communities result from its dominant physical structure rather than its role as a food source. Additional analyses of these data showed that the stability of the benthic community of algae and sessile invertebrates is greatly influenced by the stability of giant kelp, which in turn is affected by the wave disturbance regime.

Theme 1b. Determining the fate of kelp NPP

Accounting for biomass lost to blade erosion and exudation increased estimates of giant kelp NPP by 30-40% and estimates of the turnover of standing biomass from 6-7 times per year to 10-12 times per year. Data from hyperspectral imagery revealed that regional patterns of Chl:C were associated with large-scale fluctuations in SST. However, local scale variability in Chl:C across a single kelp forests was comparable to regional variability, implying that intrinsic processes occurring at local scales (e.g. age-dependent senescence) also play a role in the physiological condition and subsequent productivity of this species.

Theme 1c. Effects of fishing on kelp forest structure and function

Lobster densities generally declined and sizes were consistently lower in 2016 causing there to be little difference between sites, regardless of whether they were protected from fishing or not. BACIP analyses of kelp biomass inside and outside of MPAs before and after their establishment are ongoing and results were not available at the time of this report.

Theme 2a. Export of nutrients from watersheds

Environmental variables most strongly related to nutrient and suspended sediment fluxes were associated with hydrological variability and land cover. Annual nitrogen fluxes were positively related to agriculture (DON, nitrate), impervious area (ammonium, nitrate), and negatively related to irrigated grass (nitrate); Phosphate fluxes were negatively related to catchment slope and positively related to non-marine

sedimentary rock, and TSS fluxes were negatively related to impervious area. The relationship between nutrient fluxes during storms and runoff was strongest at sites with higher portions of impervious surfaces. Elevated stream export of nitrate and ammonium during the first post-fire rainfall was short-lived and returned to pre-fire levels within 2 to 5 months. A watershed-scale N mass balance revealed that most of N associated with ash could be accounted for in plant growth with the remainder exported via streams. We found a wide range of C-Q responses among sites and seasons as a function of different hydrological and biogeochemical characteristics of catchments and storms. After four years of drought, the 2017 water year experienced above average rainfall and runoff with elevated fluxes of suspended sediments from the Refugio watershed that had partially burned in June 2016. Atmospheric rivers were an important component of the enhanced rainfall, as indicated by statistical analyses of climate factors that influence rainfall.

Theme 2b. Trajectories of landscape changes in coastal watersheds

Analyses using a time-series of airborne hyperspectral data showed vegetation recovery following fires in local watersheds was linked to changes in nutrient export. Results of sediment core analyses and radiocarbon dating showed that a succession of storms in 1861-1862 produced an overwash fan of the same scale as that produced by hurricanes and that Carpinteria Marsh subsided > 3 m during an earthquake ~1,000 years ago.

Theme 2c. Exchanges of nutrients on beaches

Beach ecosystems, including wrack and consumer populations, continued to slowly recover from elevated sea levels and erosion associated with multi-year drought and the 2015-16 ENSO. Intertidal consumers significantly influenced porewater DIN concentrations in experimental sand columns. Kelp wrack accumulation on beaches and its consumption by intertidal consumers resulted in high concentrations of DIN in beach porewater and elevated DIN concentrations in adjacent surf zone water. Estimates of the annual flux of organic N delivered by kelp to beaches that returns to near-shore water ranged from 1.8 to 9 moles N per m of shoreline for DIN and 2 moles per m of shoreline for DON. Calculations based on porewater turnover time and volume indicate beach contributions to coastal DIN supply is quickly diluted and elevated concentrations are limited to ~50 meters from shore.

Theme 3a. Dilution and dispersal of freshwater runoff plumes

Analysis of satellite ocean color imagery showed strikingly higher particle optical backscattering (a proxy for suspended sediment concentrations) for water depths less than ~100 m. This signal had a large seasonal component and was highly correlated with regional surface wave height observations. The effects of discharge from coastal creeks can be observed during the rare times when the creeks are running, but the influence of coastal creeks on suspended sediment concentrations is much smaller than the effects of surface waves. The finding of the dominant control of suspended sediments by resuspension due to surface waves contradicts previous findings from the study region.

Theme 3b. Nitrogen recycling and efflux from sediments

Physiological experiments provided the first direct evidence of urea being transported from the ocean into kelp tissues as a whole molecule, rather than first being broken down and the resulting nitrogen assimilated. Field incubation experiments confirm urea use by kelp and indicate similar rates of urea uptake throughout the year, irrespective of ocean conditions. Unlike phytoplankton, uptake rates by kelp were largely independent of light and the form of nitrogen, potentially allowing kelp to capture a larger fraction of the nitrogen pool in darkness, when phytoplankton uptake is substantially reduced. Monthly sampling since May 2016 has shown urea to be consistently present in inner shelf waters at concentrations typically = or > those of NH_4 and NO_3 . Combined these results suggest urea is important form of N that enables kelp to sustain its growth throughout the year, particularly during summer, when nitrate is scarce and urea comprises ~30% of the dissolved N pool.

Theme 3c. Transport and fate of phytoplankton NPP

The bio-optical and water property data from the glider sections, and complementary data from instrumented moorings, reveal cross-shore flow pathways between the inner-shelf and offshore. The role of surface gravity waves in the resuspension of sediments was clearly visible in these data. Analysis of satellite ocean color imagery showed phytoplankton blooms in the warmer portions of the of the Southern California Bight occurred in phase with SST minima, usually in early spring, while blooms in the cooler regions lagged SST minima and occurred simultaneously with the strongest equatorward winds, often in the summer. Connections with El Niño conditions were also found, illustrating the wide range of processes that affect chlorophyll variability.

Key outcomes or Other achievements:

During the past year, SBC scientists published 23 journal articles, and currently have 4 additional journal articles in review and an LTER children's book, *The Golden Forest*, is in press. SBC graduate students produced 3 doctoral dissertations and two Masters theses. A complete list of SBC publications and presentations can be found at: <http://sbc.lternet.edu/cgi-bin/publications.cgi>. A total of 189 SBC datasets including time series and short-term studies are now in the SBC data catalog. Since Sept 2016, half of ongoing time series were updated with the latest available data (collected within previous year), and 7 new datasets were added.

We are using our long-term data to follow recovery of kelp forest and beach communities from an unprecedented warming event that occurred in 2014-2015 combined with a drought of unprecedented magnitude and a strong El Nino event in 2015-2016. The warming event was characterized by high mortality of key consumers affected by disease (stars and urchins) and the El Nino with a historically significant loss of beach habitat and biota. Long term data collected by SBC are being used to document the ecological consequences of these changes and to track recovery.

SBC continues to be a leading contributor to the Kelp Ecosystem Ecology Network (KEEN) <http://www.kelpecosystems.org/e>, which was founded by former SBC post doc Jarrett Byrnes. KEEN is an association of ~ 70 marine scientists from around the globe interested in assessing the impacts of global change on kelp forests. Its primary objectives are to: (1) unify past kelp forest data sets from a wide variety of sources to examine the effects of different drivers of global change, (2) coordinate parallel experiments aimed at determining how kelp systems will change in the future, and (3) develop standardized sampling protocols to create a unified global kelp forest community dataset for public use. The latter objective relies extensively on sampling protocols developed by SBC. A significant outcome from the first objective was a paper published in December 2016 in the *Proceedings of the National Academy of Sciences* that included 37 authors (5 from SBC) from 11 countries. The study's finding that local stressors and regional variation in environmental drivers dominate kelp dynamics is novel in that differed from many other marine and terrestrial systems which are being severely threatened by global climate change..

Coastal armoring is widely used to protect infrastructure and development from inundation and erosion, however, its impacts on coastal ecosystems are poorly synthesized across settings and contexts. To address this key gap in knowledge, SBC investigator Dugan led an LTER cross site working group effort to generalize the ecological effects of coastal armoring across soft sediment ecosystems. The team developed and evaluated a new conceptual model that relied on two relatively simple parameters to predict ecological responses to armoring. This work represents an important step in advancing the general understanding of ecological impacts of coastal armoring in soft sediment ecosystems and is being published as a paper in a special issue of *Estuaries and Coasts* on coastal armoring and land use in fall 2017.

SBC Investigators Melack, Page and Dugan collaborated with climate scientists from Scripps Institution of Oceanography and coastal process scientists from the USGS Pacific Coastal and Marine Science Center on a recently completed study of climate change vulnerability entitled "Santa Barbara Area Coastal Ecosystem Vulnerability Assessment" which used the best-available science to inform ecosystem-based climate adaptation planning at a local scale. The NOAA-funded study engaged officials from Santa Barbara County and the cities of Santa Barbara, Goleta and Carpinteria in assessing and evaluating the responses of their wetlands, beaches and coastal watersheds to climatic forcing. Relying largely on SBC LTER core datasets and modeling, the study results suggest significant alteration of coastal ecosystems, particularly wetlands and beaches will occur with as little as 0.5 m of sea level rise. Under the mid-range SLR scenario and RCP 8.5 emission scenario, sea level heights were projected to increase about 20 cm by 2030, which amounts to the total SLR estimated to have occurred along the Southern California coast during the last 100 years. The mid-range scenario has continuing SLR throughout the 21st century, with 30 cm by 2050, and 100 cm by the end of the century. The frequency and duration of extreme sea level events are projected to also increase significantly. These high sea level events are often associated with strong low-pressure storm systems with high wind speeds. When these events coincide with high tides and are accompanied by large waves and high runoff, they result in damaging conditions along the shoreline. Using these outputs, the report identified the potential vulnerabilities of coastal ecosystems to projected climate change impacts, and estimated tipping points for coastal ecosystems. Results for beaches and wetlands suggest that sea level rise of 0.5-1.0 m (~20-40") could be a major tipping point, above which ecosystem change increases dramatically. At the same time more intense storms are projected to occur as the climate changes, with the frequency and magnitude of large sediment fluxes from watersheds projected to increase. As a

consequence, sediment deposition in coastal wetlands and inputs to local beaches are likely to increase. These results will be used to inform updates to coastal land use plans and sea level rise adaptation plans.

Other key research outcomes and achievements by SBC from the past year are listed in “Accomplishments”

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 5 of SBC III), 9 postdoctoral fellows, 32 graduate students, 9 REU students and 117 undergraduate students participated in SBC research. REU students work closely with SBC researchers on a wide range of topics and many choose to pursue an advanced degree following their undergraduate education. UCSB undergraduates have a high propensity to get involved in sponsored research and the SBC LTER contributes substantially to this. In addition to gaining research experience, many undergraduates earn academic credit or receive monetary compensation for participating in SBC research as interns and honors students. This year 31 UCSB students participated in SBC’s undergraduate research training program. Students in the program actively assist in the collection, processing and analysis of core data and 4 developed their own independent research projects. In the first term, students read primary literature to gain a foundation in core research areas, key findings, current research objectives and methods of the SBC LTER. This year SBC also provided a seminar course for undergraduates involved with SBC research that focused on reading and discussing primary literature based on SBC research results. Next, students gain laboratory and field research experience. Two SBC students presented posters of their SBC research projects at UCSB’s Undergraduate Research Colloquium on May 16, 2017. Taylor Traxler presented “Disturbance frequency structures Santa Barbara kelp forest communities” mentored by SBC post doc Castorani and lead investigator Reed and Chance English presented “Using carbon mass balance to estimate microbial remineralization” mentored by investigator Carlson and technician Opalk. This campus wide annual colloquium and poster exhibition recognizes the scholarly achievements of UCSB’s undergraduates and offers them an opportunity to share their hard work and develop their research and presentation skills. Post-graduation, many SBC student participants are accepted into graduate studies, begin careers in their field or obtain highly competitive internships.

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. During this past summer post doc Max Castorani left SBC to begin a tenure-track assistant professor position at the University of Virginia where he will work with the VCR LTER.

SBC graduate student and postdoctoral training are coordinated with several 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 respect and appreciation across disciplines. SBC graduate students and postdocs were first authors on 11 journal articles and gave 15 papers at national conferences this year. This year 3 SBC graduate students completed their PhD degrees and two students completed their masters degrees. SBC master’s student Sloane Viola became a California State Sea Grant fellow in the Lieutenant Governor’s office this year. Seminars hosted by SBC faculty, SBC Annual All Scientist Meeting and SBC workshops on key themes served to engage SBC graduate students in the culture and diverse research offered by SBC. This year SBC sponsored one graduate seminar course for PhD students involved in SBC research which focused on developing research activities and learning about relevant approaches with an emphasis on nitrogen biogeochemistry.

The LTER student blog, “Short Stories About Long-Term Ecological Research” (SSALTER), is entering its 2nd year: <https://ssalterblog.wordpress.com>. The blog was created by LTER graduate students following a joint SBC-MCR-CCE LTER graduate student symposium and the 2015 LTER All Scientists Meeting. The blog is providing a creative outlet for students engaged in long-term ecological research to informally share their research experiences with each other and the wider world. Current moderators are Christie Yorke (SBC) and Ali Freibott (CCE). SSALTER also has a facebook page ("ssalterblog") and a twitter feed ("ssalterblog1").

With the support of a Research Opportunity Award (ROA) SBC linked with a local community college, Santa Barbara City College (SBCC), which awards associate and certificate degrees. SBCC is a Hispanic-Serving Institution and in 2013 received the Aspen Prize for Community College Excellence. This funding allows SBC to provide research opportunities for SBCC science faculty and students. Undergraduate teaching is an important focus at SBCC, but research opportunities are rare. SBCC students receive seven weeks of training and experience in scientific research, interact with UCSB scientists and graduate students, and participate in SBC's undergraduate training program which provides research context and key scientific questions. Dr. Michelle Paddack, an assistant professor in Biology at SBCC, introduces SBC LTER in her marine science classes, recruits students to work on the ROA, and mentors them in the project. The ROA also enables Dr. Paddack to conduct research with the help of UCSB and SBC LTER infrastructure and context. In spring 2016, 10 SBCC students participated in the training program, and four of them went on to conduct research internships with SBC LTER or other labs at UCSB. One student working on the ROA project, Gordon Blasco, transferred to UCSB in fall 2017. Dr. Paddack is recruiting new SBCC students for next academic year.

Opportunities for training in public education and student mentoring arise from SBC's partnership with UCSB's teaching aquarium, the REEF, which is also designed to provide UCSB undergraduates majoring in Aquatic Biology with training in communicating their marine ecology knowledge. The REEF features SBC LTER research and provides a wide range of training and professional development opportunities. A total of 61 undergraduate interns were trained in this rigorous and pedagogically sound program this year. The REEF also serves as a 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 University, California State University Channel Islands, and local community colleges. 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 marine ecology and research. 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. SBC graduate students, research staff, and post-docs also train REEF interns, which, in turn, enhances their training as laboratory and field assistants and research divers for SBC research.

How have the results 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 SBC LTER. Curriculum is developed for and delivered through UCSB's Marine Science Institute's Research Experience & Education Facility (REEF) and its Oceans-to-Classrooms (O₂C) curricula. We focus on long-term connections with local, regional and state schools through partnerships that include both on, and off, campus programs. Our approach supports an integrated program that spans academic year activities, as well as summer programs, and includes undergraduate and graduate students, K-12 teachers and students, the UC Community and the general public. SBC LTER-based curriculum is rich in STEM content and meets Next Generation Science Standards (NGSS), Common Core State Standards, as well as NOAA's Climate, and Ocean, Literacy Principles. O₂C and the REEF served over 19,000 visitors this past year, up by 3,000, through our on-campus programs, outreach visits to schools, and community events. This included visits by primary and secondary schools from the San Joaquin Valley and Los Angeles, Ventura, Kern, San Bernardino Counties, Sedona, Arizona and Taiwan. This year sLTER specific program content reached over 13,000 students in grades K-12. On-campus efforts communicated SBC research to UCSB undergraduate and graduate students (See Training and Development section). We continue to develop and adapt marine science lesson plans that engage students with learning about the local marine environment in the context of the SBC LTER. These lessons incorporate ongoing SBC research and include working with SBC data. 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. It also 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 continued to focus on two partnership programs, 1) the American Association of University Women's (AAUW): Tech Trek Program, 2) Santa Barbara Unified School District (SBUSD) Ocean Science Sequence (OSS) Partnership.

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 an interdisciplinary 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 80 girls each (160 TOTAL) from junior high and middle schools from San Luis Obispo, Santa Barbara, Ventura, Kern and Los Angeles counties, representing a diverse range of socioeconomic and demographic groups. During a weeklong residency at UCSB, students participated in "core" science courses. This year the program focused on solutions to three real-world challenges, Ocean Exploration and Climate Change, Sustainable Foods, and What to Do With Decommissioned Oil Rigs. Participants enrolled in a "core" class based on their interests: Physics, Math, Engineering, or Marine Science. Students also engaged in a number of place-based, hands-on, activities that promoted concept application and citizenship, including a boat trip to SBC Kelp Forest study sites and SBC-based Floating Lab that focused on marine ecology and ecosystem services. We are now seeing former program participants enrolling in UCSB.

SBC LTER's partnership with O₂C and the REEF completed an incredibly successful year in teacher professional development, as well as academic support in participant classrooms. We remain committed to equipping educators with the tools they need to teach ocean and environmental science, foster science literacy, and cultivate the next generation of ocean stewards. Since 2014, the Santa Barbara Unified School District (SBUSD) has adopted ocean science as a theme for their sixth grade curriculum and partnered with us and BaySci, a coordinated effort of science education leaders, institutions, school districts, and teachers led by the Lawrence Hall of Science that seeks to systematically enhance the quantity and quality of K-12 science teaching and learning in districts and schools. Partnering with BaySci helps ensure that Next Generation Science Standards and the Common Core State Standards are jointly implemented, which is essential to curricular and intellectual coherence in our education system. SBC scientists and professional education staff received training through the Lawrence Hall of Science on science content, pedagogy, and implementation of the material.

2. SBC co-hosted a booth with MCR LTER at the 2017 Santa Barbara Earth Day Festival to raise public awareness about LTER research. This year's festival attracted over 20,000 people. A highlight was a virtual kelp forest (VKF) in which SBC students and staff acted as 'dive buddies' for children who toured the forest and collected data on kelp forest biota. With help from investigator Hofmann and SBC graduate students, VKF was featured at this year's World Oceans Day, hosted at the SBMNH Sea Center for an estimated 1,500 visitors.

3. We broadened our K-12 outreach by developing "The Golden Forest", a new book in the LTER Schoolyard Book Series that highlights connections between kelp forests and sandy beaches. The new book has been beautifully illustrated and completed with publication expected in Fall 2017. The new book will be a key feature in upcoming our sLTER efforts. Other key outreach efforts include the production of a Sandy Beaches Field Guide as a free iPhone application to complement SBC's Subtidal Field Guide and a local tidepool field guide that are available on iTunes.

4. This year investigator Dugan mentored a science fair project by Sydney Carlson, a local middle school student. Her project entitled "Where does Kelp Go? The role of *Megalorchestia corniculata* in the removal of kelp on southern CA beaches" was awarded 1st place in the Jr. Botany and Zoology division at the Santa Barbara County Science Fair and 3rd place in the Zoology division at the California State Science Fair.

5. SBC investigators and students contributed to stories in the press.

Using long-term ecological data, marine scientists evaluated the sentinel status of giant kelp during a recent marine heat wave

<http://www.news.ucsb.edu/2016/017468/kelp-beats-heat>

<https://www.sciencedaily.com/releases/2016/12/161213130543.htm>

https://www.eurekalert.org/pub_releases/2016-12/uoc--kbt121316.php

An LTER cross site synthesis of ecological impacts of coastal armoring is a first step in generalizing these impacts across soft sediment ecosystems

<https://www.coastalreview.org/2017/08/study-predicting-how-seawalls-affect-ecology/>

http://www.terraily.com/reports/Coastal_armoring_and_its_ecological_effects_in_soft_sediment_environments_99.html

<http://www.scpr.org/news/2017/08/08/74248/seawalls-pose-greater-risks-with-higher-ocean-level/>

A multidecadal analysis of long term change in beach ecosystems revealed the strong role of local scale processes on biodiversity

<http://kclu.org/post/south-coast-scientists-study-changes-biodiversity-california-beaches>

<http://www.news.ucsb.edu/2017/018077/beach-time-capsule>

Climate Experts Release Coastal Ecosystem Vulnerability Assessment for Santa Barbara Area

<https://casegrant.ucsd.edu/news/coastal-ecosystem-vulnerability-assessment-for-santa-barbara>

Invasive algae abatement in southern California:

<http://www.dailybreeze.com/environment-and-nature/20160918/divers-off-palos-verdes-peninsula-begin-fight-against-algae-invading-southern-california-coast>

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

Continue research activities and analyses as planned

Products

Books

- Blanchette, C and J. E. Dugan (). *The Golden Forest* Rhinehart, A. Muddy Boots. Status = AWAITING_PUBLICATION; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Book Chapters

Inventions

Journals or Juried Conference Papers

- Assis, J and Bercibar, E and Claro, B and Alberto, F and Reed, DC and Raimondi, PT and Serrao, EA (2017). Major shifts at the range edge of marine forests: the combined effects of climate changes and limited dispersal. *Scientific Reports*. 7 44348. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1038/srep44348
- Castorani, MC and Reed, DC and Alberto, F and Bell, TW and Simons, RD and Cavanaugh, KC and Siegel, DA and Raimondi, PT (2015). Connectivity structures local populations dynamics: a long-term empirical test in a large metapopulation system. *Ecology*. 96 3141-3152. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1890/15-0283.1
- Castorani, MC and Reed, DC and Raimondi, PT and Alberto, F and Bell, TW and Siegel, DA and Simons, RD (2017). Fluctuations in population fecundity drive demographic connectivity and structure metapopulation dynamics. *Proceedings of the Royal Society B*. 284 20162086. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1098/rspb.2016.2086
- Chan, F and Barth, J and Blanchette, CA and Byrne, R and Chavez, F and Cheriton, O and Feely, R and Friederich, G and Gaylord, BP and gouhier, T and Hacker, S and Hill, T and Hofmann, GE and McManus, M and Menge, B and Nielsen, K and Russell, A and Sanford, E and Sevadjan, J and Washburn, L (2017). Persistent spatial structuring of coastal ocean acidification in the California Current System.. *Nature Scientific Reports*. 7 2526. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1038/s41598-017-02777-y
- Emery, K and Harlow, D and Whitmer, AC and Gaines, SD (2017). Compelling evidence: an influence on middle school students' accounts that may impact decision-making about socioscientific issues. *Environmental Education Research*. 23 115. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1080/13504622.2016.1225673
- Fewings, MR and Washburn, L and Dorman, C and Gotschalk, C and Lombardo, K (2016). Synoptic Forcing of Wind Relaxations at Pt. Conception, California. *J. Geophys. Res. Oceans*. 121 5711–5730. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/2016JC011699
- Hanan, EJ and Tague, CL and Schimel, JP (2017). Nitrogen cycling and export in California chaparral: the role of climate in shaping ecosystem responses to fire. *Ecological Monographs*. 87 76–90. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/ecm.1234

- Hendrikk Freitas, F and Siegel, DA and Maritorena, S and Fields, E (2017). Satellite assessment of particulate matter and phytoplankton variations in the Santa Barbara Channel and its surrounding waters: Role of surface waves. *J. Geophys. Res. Oceans.* 122 355-371. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/2016JC012152
- Hendrikk Freitas, F and Siegel, DA and Washburn, L and Halewood, S and Stassinis, E (2016). Assessing controls on cross-shelf phytoplankton and suspended particle distributions using repeated bio-optical glider surveys. *Journal of Geophysical Research - Oceans.* 121 7776-7794. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/2016JC011781
- Jaramillo, E and Dugan, JE and Hubbard, DM and Contreras, H and Duarte, C and Acuna, E (2017). Macroscale patterns in body size of intertidal crustaceans provide insights on climate change effects. *PLoS ONE.* 12 0177116. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1371/journal.pone.0177116
- Jones, J and Sweet, J and Brzezinski, MA and McNair, H and Passow, U (2016). Evaluating Carbonate System Algorithms in a Nearshore System: Does Total Alkalinity Matter?. *PLoS ONE.* 11 e0165191. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1371/journal.pone.0165191
- Kapsenberg, L and Okamoto, DK and Dutton, J and Hofmann, GE (2017). Sensitivity of sea urchin fertilization to pH varies across a natural pH mosaic. *Ecology and Evolution.* 7 1737-1750. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/ece3.2776
- Koweek, D and Nickols, KJ and pleary, P and Litvin, S and Bell, TW and Luthin, T and Mucciarone, D and Dunbar, R and Lummis, S (2017). A year in the life of a central California kelp forest: physical and biological insights into carbon cycling. *Biogeosciences.* 14 31-44. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.5194/bg-14-31-2017
- Krumhans, K and Okamoto, DK and Rassweiler, A and Novak, M and Bolton, J and Cavanaugh, KC and Connell_, S and Johnson_, C and Conar, B and Ling, S and Micheli, F and Norderhaug, K and Perez-Matus, A and Sousa-Pinto, I and Reed, DC and Salomon, A and Shears, N and Wernberg, T and Anderson, R and Barrett, N and Buschmann, A and Carr, M and Caselle, J and Derrien-Courtel, S and Edgar, G and Edwards, M and Estes, J and Goodwin, C and Kenner, M and Kushner, D and Moy, F and Nunn, J and Steneck, R and Vásquez, J and Watson, J and Witman, J and Byrnes, JE (2016). Global patterns of kelp forest change over the past half-century. *Proc. Nat. Acad. Sci.* 113 13785-13790. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1073/pnas.1606102113
- Lastra, M and Lopez, J and Troncoso, J and Hubbard, DM and Dugan, JE (2016). Scavenger and burrowing features of *Hippa pacifica* (Dana 1852) on a range of tropical sandy beaches. *Marine Biology.* 163 212. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1007/s00227-016-2985-9
- Liebowitz, D and Nielsen, KJ and Dugan, JE and Morgan, SG and Malone, DP and Largier, J and Hubbard, DM and Carr, MH (2016). Ecosystem connectivity and trophic subsidies of beach ecosystems. *Ecosphere.* 7 e01503. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/ecs2.1503
- Marks, LM and Reed, DC and Obaza, (2016). Assessment of control methods for the invasive seaweed *Sargassum horneri* in California, USA. *Management of Biological Invasions.* 8 205–213. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.3391/mbi.2017.8.2.08
- McLaughlin, K and Dickson, A and Weisberg, S and Coale, K and Elrod, V and chunter, C and Johnson, K and Dramb, S and Kudela, R and Martz, T and Negrey, K and Passow, U and Shaughnessy, F and Smith, J and Tadesse, D and Washburn, L and Weis, K (2017). An evaluation of ISFET sensors for coastal pH monitoring applications. *Regional Studies in Marine Science.* 12 11. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.rsma.2017.02.008
- Miller, RJ and Page, HM and Reed, DC (2015). Trophic versus structural effects of a marine foundation species, giant kelp (*Macrocystis pyrifera*). *Oecologia.* 179(1199-209. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1007/s00442-015-3441-0
- O'Brien, MC and Costa, D and Servilla, M (2016). Ensuring the quality of data packages in the LTER network data management system. *Ecological Informatics.* 36 237-246. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.ecoinf.2016.08.001

- Osborne, EB and Thunell, RC and Marshall, BJ and Holm, JA and Tappa, EJ and Benitez-Nelson, CR and Cai, WJ and Chen, B (2016). Calcification of the planktonic foraminifera *Globigerina bulloides* and carbonate ion concentration: Results from the Santa Barbara Basin. *Paleoceanography*. 31 1083–1102. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/2016PA002933
- Reed, DC and Washburn, L and Rassweiler, A and Miller, RJ and Bell, TW and Harrer, S (2016). Extreme warming challenges sentinel status of kelp forests as indicators of climate change. *Nature Communications*. 7 13757. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1038/ncomms13757
- Rivest, EB and O'Brien, MC and Kapsenberg, L and Gotschalk, C and Blanchette, CA and Hoshijima, U and Hofmann, GE (2016). Beyond the benchtop and the benthos: dataset management planning and design for time series of ocean carbonate chemistry associated with Durafet®-based pH sensors. *Ecological Informatics*. 36 209-220. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.ecoinf.2016.08.005
- Rodriguez, GE and Reed, DC and Holbrook, SJ (2016). Blade life span, structural investment, and nutrient allocation in giant kelp. *Oecologia*. 182 397. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1007/s00442-016-3674-6
- Simms, AR and Reynolds, L and Bentz, M and Roman, A and Rockwell, T and Peters, R (2016). Tectonic subsidence of California estuaries increases forecasts of relative sea-level rise. *Estuaries and Coasts*. 39 1571–1581. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1007/s12237-016-0105-1

Licenses

Other Conference Presentations / Papers

- Dugan, J., K. Emery, M. Alber, C. Alexander, J. Byers, A. Gehman, S. Lawson, K. McGlathery, N. McLenaghan (2015). *A conceptual model for predicting the ecological effects of coastal armoring in soft sediment environments*. 2015 LTER All Scientists Meeting. Estes Park, Colorado. Status = OTHER; Acknowledgement of Federal Support = Yes
- Schooler, NK and Dugan, JE and Martin, K and Hubbard, DM (2016). *A new method for monitoring urban beach ecosystems*. National Sea Grant Site Review, University of Southern California. Los Angeles, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
- Osborne, E., Thunell, R., Bizimis, M., Buckley, W., and Cai, W. (2015). *A sediment trap evaluation of B/Ca in planktonic foraminifera as a carbonate system proxy, August 2015*. Goldschmidt Conference. Prague., Status = OTHER; Acknowledgement of Federal Support = Yes
- Jones, J, J Sweet, U Passow, GE Hofmann and L Washburn (2013). *A year of in situ pH monitoring at Stearns Wharf: Establishing variance and reliability with point sampling*. SBC LTER Annual Meeting. Santa Barbara, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
- Dugan, JE and Schooler, NK and Martin, K (2015). *All Ashore - Introducing a New Program for Monitoring Sandy Beaches by Citizen Scientists*. Beach Ecology Coalition, Pepperdine University. Malibu, CA. Status = OTHER; Acknowledgement of Federal Support = No
- Bell, TW and Siegel, DA (2016). *Assessment of giant kelp physiological state using airborne hyperspectral imagery (EC21B-04)*. 2016 Ocean Sciences Meeting (ASLO, AGU, TOS). New Orleans, LA, USA. Status = OTHER; Acknowledgement of Federal Support = Yes
- Dugan, JE and Nielsen, K and Wood, M and Hubbard, DM and Mulligan, T and Craig, S and Laucci, R and Schooler, NK (2017). *Baseline Characterization of Sandy Beach Ecosystems along the North Coast of California*. North Coast MPA Baseline Monitoring Symposium. Humboldt State University, Arcata, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- 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

- Dugan, JE and Hubbard, DM and Blanchette, CA (2016). *Birds as indicator of ecosystem condition on rocky and sandy shores*. Annual Meeting of the Western Society of Naturalists. Sacramento, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
- Wear, EK and Carlson, CA and Siegel, DA and Guillocheau, N and Nelson, CE (2016). *Bottom-up controls on a coastal bacterioplankton time-series: relative utility of in situ vs. remotely-sensed measurements*. Coastal and Estuarine Research Federation. Portland, OR. 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
- Ma, S (2017). *Chaparral succession during drought conditions and linking field measurements with hyperspectral imagery*. Ecological Society of America. Portland, OR. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Romero, L and Siegel, DA and McWilliams, JC and Uchiyama, Y and Jones, C (2016). *Characterizing stormwater dispersion and dilution from small coastal streams (EC12B-04)*. 2016 Ocean Sciences Meeting (ASLO, AGU, TOS). New Orleans, LA, USA. Status = OTHER; Acknowledgement of Federal Support = Yes
- Washburn, L (2014). *Circulation along the central California coast: Response to relaxations of upwelling winds*. King Abdullah University of Science and Technology. Thuwal Kingdom of Saudi Arabia. Status = OTHER; Acknowledgement of Federal Support = Yes
- Dugan, JE (2016). *Coastal Ecosystem Vulnerability Assessment for Santa Barbara County: Sandy Beaches*. Workshop: Santa Barbara Area Coastal Ecosystem Vulnerability Assessment for Coastal Communities (SBA CEVA). Santa Barbara, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
- Melack, JM (2016). *Coastal Ecosystem Vulnerability Assessment for Santa Barbara County: Watershed Impacts*. Workshop: Santa Barbara Area Coastal Ecosystem Vulnerability Assessment for Coastal Communities (SBA CEVA). Santa Barbara, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
- Page, HM (2015). *Coastal Ecosystem Vulnerability Assessment for Santa Barbara County: Wetland vulnerability*. Workshop: Santa Barbara Area Coastal Ecosystem Vulnerability Assessment for Coastal Communities (SBA CEVA). Santa Barbara, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
- Emery, N (2017). *Coastal fog and plant flammability in California shrublands*. Ecological Society of America. Portland, OR. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Emery, N and D'Antonio, C (2014). *Coastal fog effects on live fuel moisture of California shrublands*. International Society of Mediterranean Ecology (MEDECOS XIII). Olmue Chile. Status = OTHER; Acknowledgement of Federal Support = Yes
- Okamoto, DK (2016). *Competition among Eggs Shifts to Cooperation along a Sperm Supply Gradient in an External Fertilizer*. International Temperate Reef Symposium. Pisa Italy. Status = OTHER; Acknowledgement of Federal Support = Yes
- Okamoto, DK (2014). *Competition among eggs shifts to cooperation along a sperm supply gradient in an external fertilizer*. Annual Meeting of the Western Society of Naturalists. Tacoma, WA. Status = OTHER; Acknowledgement of Federal Support = Yes
- Castorani, MC, DC Reed, F Alberto, TW Bell, RD Simons, KC Cavanaugh, DA Siegel and PT Raimondi (2015). *Connectivity structures local population dynamics: a long-term empirical test in a large*

- metapopulation network*. Annual Meeting of the Ecological Society of America (ESA). Baltimore, MD. Status = OTHER; Acknowledgement of Federal Support = Yes
- Hendrikx-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
 - Dugan, JE and Emery, K and Alber, M and Alexander, C and Beyers, J and Gehman, A and McLenaghan, N and Sojka, S (2016). *Cross-site synthesis: a conceptual model for predicting the ecological effects of coastal armoring in soft-sediment environment (Poster)*. Coastal and Estuarine Research Federation. Portland, OR. Status = OTHER; Acknowledgement of Federal Support = Yes
 - Simon, SE, Johnson, M, Cano, A.; Blanchette, C, and Whitmer, A.C. (2013). *Culturally Relevant Ecology, Learning Progressions and Environmental Literacy at the Santa Barbara Coastal LTER, Poster*. Santa Barbara Coastal Long-term Ecological Research Project Annual Meeting. Santa Barbara, CA. USA. Status = OTHER; Acknowledgement of Federal Support = Yes
 - Johnson, M, Simon, SE, Cano, A, Blanchette, C, and Whitmer, AC (2013). *Culturally Relevant Ecology, Learning Progressions and Environmental Literacy at the Santa Barbara Coastal LTER. Poster..* Santa Barbara Coastal Long-term Ecological Research Project Annual Meeting. Santa Barbara, CA. USA. Status = OTHER; Acknowledgement of Federal Support = Yes
 - O' Brien, M., M. Schildhauer, M. Jones, D. McGuinness, B. Leinfelder, C. Jones, S. Hou, L. Walker (2015). *DataONE Semantics and Provenance*. 2015 LTER All Scientists Meeting. Estes Park, Colorado. Status = OTHER; Acknowledgement of Federal Support = Yes
 - Reynolds, LC and Truong, C and Ejarque, M and Simms, AR and Anderson, S (2016). *Dating historical sediments in estuaries: A multiproxy approach (Poster)*. American Geophysical Union, Annual Meeting. San Francisco, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
 - Castorani, MC and Reed, DC and Raimondi, PT and Alberto, F and Bell, TW and Cavanaugh, KC and Siegel, DA and Simons, RD (2016). *Demographic connectivity structures the dynamics of giant kelp metapopulations*. International Temperate Reef Symposium. PisaItaly. Status = OTHER; Acknowledgement of Federal Support = Yes
 - Catlett, D and Siegel, DA and Guillocheau, N (2017). *Derivative analysis demonstrates the potential and limitations for deriving phytoplankton community structure from hyperspectral ocean color observations (Poster)*. ASLO, AGU, TOS - Ocean Sciences. Honolulu, HI. Status = OTHER; Acknowledgement of Federal Support = Yes
 - Marks, LM and Reed, DC and Holbrook, SJ (2016). *Development of management strategies for the invasive seaweed Sargassum horneri (poster)*. International Conference on Marine Bioinvasions. SydneyAustralia. Status = OTHER; Acknowledgement of Federal Support = Yes
 - Marks, LM and Reed, DC and Holbrook, SJ (2016). *Ecological causes and consequences of the invasive seaweed Sargassum horneri in the eastern Pacific*. International Conference on Marine Bioinvasions. SydneyAustralia. Status = OTHER; Acknowledgement of Federal Support = Yes
 - Guerrini, A (2015). *Ecological histories: Contrasting uses of history at two LTER sites*. Annual Meeting of the Ecological Society of America (ESA). Baltimore, MD. Status = OTHER; Acknowledgement of Federal Support = Yes
 - Frazier, HN and Melack, JM (2016). *Ecosystem metabolism response to urban development in coastal California streams*. Society for Freshwater Science Annual Meeting. Sacramento, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
 - Hanan, E and Schimel, JP and Tague, CL (2016). *Effects of climate and fire timing on nitrogen cycling and retention in chaparral watersheds*. American Geophysical Union, Annual Meeting. San Francisco, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
 - Reed, DC and Washburn, L and Rassweiler, A and Miller, RJ and Bell, TW and Harrer, S (2017). *El Niño coupled with anomalous ocean warming challenge sentinel status of giant kelp as an indicator of climate change*. ASLO, AGU, TOS - Ocean Sciences. Honolulu, HI. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
 - James, A., C. Carlson, U. Passow, M. Brzezinski, R. Parsons, J.N. Trapani (2015). *Elevated pCO2 Increases Respiration of DOC by Natural Bacterioplankton*. 2015 LTER All Scientists Meeting. Estes Park, Colorado. Status = OTHER; Acknowledgement of Federal Support = Yes

- James, A (2016). *Elevated pCO₂ Increases Respiration of DOC by Natural Bacterioplankton (poster)*. LTER All Scientists Meeting. Estes Park, CO. Status = OTHER; Acknowledgement of Federal Support = Yes
- Servilla, M, O'Brien, MC, and Costa, D (2013). *Ensuring the quality of data packages in the LTER Network data management system*. American Geophysical Union, Annual Meeting. San Francisco, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
- Huynh, N and Carlson, CA and Kopalk, K and Wear, EK (2017). *Estimating DOC availability in the Santa Barbara Channel with Marine Bioreactors*. ASLO, AGU, TOS - Ocean Sciences. Honolulu, HI. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Voelker, N and Castorani, MC and et al, (2017). *Evaluating the link between metacommunity stability and environmental variability across trophic groups represented at LTER sites*. Ecological Society of America. Portland, OR. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Ellis, DP, Washburn, L, Ohlmann, C, Schofield, O and Moline, M (2014). *Evaluating the performance of underwater gliders as virtual moorings off Pt. Sal, California*. 2014 Ocean Sciences Meeting (ASLO, TOS, AGU). Honolulu, HI. Status = OTHER; Acknowledgement of Federal Support = Yes
- Reed, DC (2016). *Extreme warming challenges kelp forests as sentinels of climate change*. International Temperate Reef Symposium. Pisa, Italy. Status = OTHER; Acknowledgement of Federal Support = Yes
- Hanen, E., N. Tague, J. Schimel (2015). *Factors regulating nitrogen retention during the early stages of recovery from fire in coastal chaparral ecosystems*. 2015 LTER All Scientists Meeting. Estes Park, Colorado. Status = OTHER; Acknowledgement of Federal Support = Yes
- Hanan, E (2015). *Factors regulating nitrogen retention during the early stages of recovery from fire in coastal chaparral ecosystems (poster)*. LTER All Scientists Meeting. Estes Park, CO. Status = OTHER; Acknowledgement of Federal Support = Yes
- Liedle, J and Yorke, C (2016). *Feeding and distribution of the Norris's kelp snail*. UCSB Undergraduate Research Colloquium. Santa Barbara, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
- Harrison, CS, Siegel, DA and Mitarai, S (2014). *Filamentation and eddy-eddy interactions in marine larval accumulation and transport*. 2014 Ocean Sciences Meeting (ASLO, TOS, AGU). Honolulu, HI. Status = OTHER; Acknowledgement of Federal Support = Yes
- Bentz, M and Simms, AR and Buzzas-Stephans, P (2015). *Foraminifera zonations in southern California Salt Marshes. (poster)*. Pacific Section American Association of Petroleum Geologists/Society for Sedimentary Geology (AAPG/SEPM). Oxnard, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
- Osborne, EB, Thunell, RC, Benitez-Nelson, CR and Cai, WJ (2013). *Foraminiferal area density as a proxy for changing ocean acidity in the California Current System (poster)*. American Geophysical Union, Annual Meeting. San Francisco, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
- Reed, DC (2014). *Forest Restoration: A case study of the Wheeler North Artificial Reef in southern California (invited)*. Marine Ecological Restoration (MER) Workshop. Eilat, Israel. Status = OTHER; Acknowledgement of Federal Support = Yes
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Other Products

Other Publications

- Myers, M and Cayan, D and Iacobellis, S and Melack, JM and Beighley, R and Barnard, P and Dugan, JE and Page, HM (2017). *Santa Barbara Area Coastal Ecosystem Vulnerability Assessment. CASG-17-009*. Technical Report. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Patents

Technologies or Techniques

Thesis/Dissertations

- Bell, T. *Environmental Drivers of Giant Kelp Biomass and Physiological Condition Dynamics Across Space and Time*. (2016). University of California Santa Barbara.. Acknowledgement of Federal Support = Yes

- Bentz, M. *Establishing foraminifera based biofacies within shallow marine deposits, Carpinteria Slough, CA. Implications for southern California sea-level studies.* (2016). University of California Santa Barbara. Acknowledgement of Federal Support = Yes
- Reynolds, L. *Late Quaternary Evolution of the Southern California Coast: Sea-Level Change, Storms, and Subsidence.* (2017). University of California Santa Barbara. Acknowledgement of Federal Support = Yes
- Viola, S.M.. *Anthropogenic disturbance facilitates a non-native species on offshore oil platforms.* (2016). University of California Santa Barbara. Acknowledgement of Federal Support = Yes
- Wear, Emma K.. *Bottom-up drivers of bacterial community composition and metabolism of dissolved organic carbon in the Santa Barbara Channel, CA.* (2017). University of California Santa Barbara. Acknowledgement of Federal Support = Yes

Websites

- *SBC LTER*
<http://sbc.lternet.edu/>
SBC LTER project website

Participants/Organizations

What individuals have worked on the project? Not listed here

What other organizations have been involved as partners? Not listed here

Impacts

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

Results from SBC are addressing the growing need for understanding ecosystem level processes in coastal systems. Of particular importance 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 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 outstanding opportunity to test ecological theory regarding patterns and drivers of population dynamics at unprecedented temporal resolution and spatial and temporal scales. In Baja California, physical disturbances, such as the ENSO events of 1982-83, 1997-98, and 2015-16 have diminished *M. pyrifera* abundance and caused range contractions near its southern distribution limit. With co-funding from UC Mexus, the SBC time series of giant kelp canopy area and biomass across its range from 1984-present is being used to examine historical variability in its abundance and distribution in Baja California, Mexico including disturbance events such as the notable ENSO events of 1997-1997 and 2015-2016. Remote estimates of giant kelp canopy cover and biomass are being validated with in situ diver measurements and high resolution unmanned aerial vehicle (UAV) imagery. High resolution maps and datasets of giant kelp distributions will provide a baseline for future monitoring and management of giant kelp ecosystems in Mexico.

Investigators Byrnes and Cavanaugh (both former post docs) are continuing their partnership with Zooniverse to develop Floating Forests (<https://www.floatingforests.org/>), a web-based citizen science project that uses the volunteers to analyze Landsat imagery of giant kelp around the globe. To date, Floating Forests has logged 7052 users who have conducted more than 2.8 million classifications and analyzed more than 687,000 images. Byrnes also participates in the Kelp Ecosystem Ecology Network (KEEN) designed to assess the impacts of environmental change on kelp forests globally. This network includes 79 members from >20 bioregions and six continents who use standardized sampling methods and experimental protocols (based on those developed by SBC LTER) to create an unified open access dataset for assessing past and predicting future changes in kelp forests worldwide.

With funding from NASA, BOEM, and NOAA, SBC investigators Miller, Carlson, Iglesias-Rodriguez, Rassweiler, Reed and Siegel, are developing a prototype marine Biodiversity Observation Network (MBON) in the Santa Barbara Channel that is intimately linked with SBC LTER. Tracking biodiversity in marine habitats will improve

capacity for science-based decision-making intended to protect natural ecosystems and sustain the services that they provide amid increasing threats of coastal development, invasive species and climate change. The wide array of biodiversity measurements already taking place in the Santa Barbara Channel, particularly by SBC LTER and Channel Islands National Park, make this area ideal for testing this pioneering effort. To date we have assembled data from 173 coastal sites monitored by 4 different programs, many of which have 30+ year data series, and documented abundance of more than 350 distinct taxa of fish, invertebrates and algae. To facilitate data synthesis, we developed a scalable taxonomic database to enable comparison of biodiversity data from different sources. The MBON builds strongly on SBC's Information management framework to manage and publish the large amount of biodiversity data generated. In collaboration with SBC LTER, SBC MBON is analyzing these data to explore physical drivers of biodiversity and such relationships may inform ecological forecasting models that predict changes in biodiversity and community composition with climate.

Ongoing analysis of the large volume of data collected during the SBC LTER UNOLS cruises continues to provide new insights into the fate and transport of phytoplankton. These analyses 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 processes that lead to subduction of phytoplankton biomass.

Additional efforts and cross site collaborations that broaden the reach of SBC research during the past year include:

Investigator Cooper is a member of an LTER working group conducting a meta-analysis of nutrient enrichment effects on stream ecosystems and serves on the STREON technical advisory committee, advises NEON personnel on stream ecology issues, and organized an NCEAS 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 this year.

SBC LTER data manager O'Brien and postdoc Castorani participated in a meeting of the NSF-funded Environmental Data Initiative in June 2017 focused on data manipulation and management for population, community, and biodiversity datasets. SBC LTER data were instrumental in (1) identifying the best data formats, code, packaging patterns, metadata content, and vocabularies, and (2) building formal recommendations for data providers.

Two postdoctoral researchers (M. Castorani, T. Lamy) are part of the LTER Metacommunities Working Group at NCEAS (funded by LTER NCO). SBC spatial time series community data figured prominently in the research of this working group. SBC researchers coauthored two resulting talks at ESA's 2017 meeting. The working group has also written two journal manuscripts (one to Trends in Ecology & Evolution and one to Bioscience). Lamy and Castorani are coauthors on both, one is led (first-author) by Lamy.

Postdoctoral researcher (M. Castorani) also participated in the LTER Synchrony Working Group (LTER-NCO funded) at NCEAS. In addition to showcasing SBC LTER data, his participation led to a new collaborative project between researchers at SBC LTER and the University of Kansas aimed at understanding the spatiotemporal scales and drivers of synchrony in giant kelp populations of southern California. This research is underway and planned to be completed early in 2018.

Investigator Dugan led an LTER working group that developed a new synthesis of the ecological responses of soft sediment ecosystems to armoring and coastal squeeze. The team developed and evaluated a new conceptual model that relied on two relatively simple parameters to predict ecological responses to armoring. This work was published in Estuaries and Coasts and represents an important and much needed step in advancing a general understanding of the ecological impacts of coastal armoring across soft sediment ecosystems.

Postdoctoral researcher Lamy and investigators Holbrook, Miller and Reed collaborated with other coastal ILTER sites on a paper for a special issue in Science of the Total Environment. They examined ecological responses to climate variability at 5 ILTERs (NE Pacific (SBC), Arctic Ocean, Baltic Sea, North Sea, and Mediterranean Sea). Ecological changes coincided with the 2000 climate/abrupt biological regime shift highlighting the existence of connectivity among climate regimes of different ocean basins in the Northern Hemisphere. The results reinforce the value of spatially distributed long-term research in understanding ecological responses.

SBC contributed to a LTER Network synthesis activity 'Ecological futures' that will be part of a series in Ecosphere. SBC's contribution focuses on the theme of connectivity and the value of long-term data in assessing species change in systems whose foundations are formed by relatively short-lived species.

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: marine, aquatic and terrestrial ecology, physical, biological and chemical

oceanography, hydrology, geology, geography, environmental history, science education and informatics. Investigators Guerrini and Dugan with PhD student D. Burnette are preparing an invited chapter entitled “Invisible landscapes: perception, heritage, and coastal change in Southern California,” on their results from historical research on SBC landscapes for an edited volume, *Coastal Heritage and Cultural Resilience*, (ed. Lisa Price and Nemer Marchi, publisher Springer).

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 117 undergraduate students, 32 graduate students, 9 post doctoral fellows were trained through substantial involvement in SBC research. The 9 REU students from 2016-17 worked closely with SBC researchers and graduate students on a wide range of topics. Many have plans to pursue an advanced degree following their undergraduate education. 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 not only provides valuable undergraduate training, but also affords SBC's graduate students and post docs with significant opportunities for mentorship training. In 2017, 31 UCSB undergraduate students received academic credit to participate in a structured SBC marine research training program that runs the entire academic year. Students in the program actively participate in the collection, processing and analysis of core data and many develop their own independent research projects. 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 reporting period post doc Max Castorani began a tenure track assistant professor position at the University of Virginia and former graduate student Dan Okamoto was hired as an assistant professor at Florida State University. Former graduate students Kevin Johnson is now an NSF postdoctoral fellow at Louisiana State University, Tom Bell began a postdoc at UCSB and Sloane Viola became a State Sea Grant Fellow.

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 (31 in 2016-17) 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. Several SBC investigators mentor middle and high school students in developing and executing science projects and conducting research each year. This year middle school student, S. Carlson, mentored by J. Dugan took her project on kelp consumption by beach hoppers to the Santa Barbara County and California State science fairs.

The success of SBC's outreach programs has led us to explore new methods for reaching larger audiences. To this end Investigators Blanchette and Dugan led SBC's efforts on an LTER children's book, *The Golden Forest*, that highlights the links between giant kelp forests and sandy beaches. The text and illustrations for the book have been finalized and the book will be published in Fall 2017. The book will be a focal K-12 resource in SBC Schoolyard programming. In addition, an iPhone application for sandy beach ecosystems developed with collaborative funding is due to be released on iTunes in Fall 2017. This new guide will complement the SBC LTER Kelp Forest Field Guide application, an interactive guide that provides information on >150 marine 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 are being used to maintain a custom 22' research vessel that was specifically designed for diving and oceanographic research and an autonomous ocean glider that is customized for coastal research. Both items were purchased with NSF funds awarded to SBC. Research groups collaborating with SBC have access to the vessel and glider for their research needs. Led by Investigator Hofmann, SBC partners with other research programs (e.g. Southern California Ocean Observing System (SCOOS), California's Ocean Protection Council, the Partnership for Interdisciplinary Study of Coastal Oceans (PISCO)) 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.

What is the impact on institutional resources that form infrastructure?

Nothing to report.

What is the impact on information resources that form infrastructure?

SBC's publicly available data holdings increased by about 10% during the past year. As in the recent past, new datasets often represent data from students or postdoctoral scholars, specifically designed to meet increasing requirements by journals to post data along with research papers. The number of datasets of this type is now large enough that patterns are becoming evident, and SBC is developing protocols for a consistent approach to naming and describing paper-related datasets which we hope will advance the community's ability to form linkages between papers and their data resources. SBC LTER also works regularly with repository developers at BCO-DMO to streamline cross-linkages between data from associated projects which are tightly coupled to SBC LTER, but which should also be visible through the BCO-DMO catalog (at the request of NSF). These linkages are facilitated by SBC LTER's experience with the DataONE system.

All metadata are available in the XML specification Ecological Metadata Language (EML), with data and metadata uploaded regularly to the repository of the Environmental Data Initiative (EDI), where it becomes available to the LTER Network catalog. SBC's own data catalog is based on this same corpus and organized into sampling collections, which are accessible from the website's research descriptions and sampling sites map. Our local infrastructure provides nightly backup for all data.

SBC LTER Information manager O'Brien is a co-Investigator of the new Environmental Data Initiative, EDI (NSF #1629233, #1565103) which will extend the LTER approach to data management to other ecosystem-level research endeavors funded by NSF, particularly MSB, LTREB and the Organization of Biological Field Stations (OBFS), and also will facilitate and coordinate data curation activities within the LTER Network. As these new responsibilities will detract from her ability to fully serve SBC LTER, in 2017, we transferred the data packaging tasks (e.g., EML metadata generation) to Li Kui (also at UCSB). O'Brien also continues to work on two other NSF funded projects, DataONE (DataNet, ACI) and GeoLink (EarthCube, GEO), specifically in the areas of semantics and data discovery, which highlights the usability of SBC data, and increases the visibility of all LTER data in federated systems.

What is the impact on technology transfer?

Significant portions of the SBC LTER Information Management System were duplicated to the Santa Barbara Channel Marine BON project (SBC MBON, <http://sbc.marinebon.org>, LPI R. Miller). This activity was directed by O'Brien, working closely with Kui. Leveraging SBC LTER's IMS had an immediate benefit to the MBON project by allowing them to be the first - and to date, only - US Marine BON with publicly available, fully curated datasets. Further, it has benefited SBC LTER by speeding the transfer of certain data management tasks from O'Brien to Kui during 2017.

O'Brien leads a LTER Network project on coordinated dataset design, which is initially focused on data manipulation and management for population, community, and biodiversity datasets to better serve reuse by data synthesis (with postdoc M. Castorani participating, June 2017). SBC LTER data were instrumental in: (1) helping to identify the best data formats, code, packaging patterns, metadata content, and vocabularies, and (2) building formal recommendations for data providers.

What is the impact on society beyond science and technology?

SBC investigators actively apply their knowledge of coastal ecosystems to inform, develop 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 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 investigators and students continue to contribute time and expertise to the ongoing NRDA (National Response Damage Assessment) investigation of the impacts of the May 2015 Refugio Oil Spill on the coastal ecosystems of the Santa Barbara Channel. SBC time series data are providing much needed information on some of the coastal ecosystems affected by the oil spill and are being used in the NRDA analyses.

SBC investigators and students are collaborating with the Bureau of Ocean Energy Management, National Marine Fisheries Service and the Channel Islands National Marine Sanctuary to assess factors affecting the spread and ecological consequences of two recent and rapidly spreading invasive species in southern California (the brown seaweed *Sargassum horneri* and the colonial bryozoan *Watersipora subtorquata*). These projects have resulted the development and testing of protocols and strategies for controlling invasive marine species in nearshore ecosystems such as kelp forests.

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 2016-17 we performed high quality nutrient chemistry analyses on water samples from local streams and rivers for Santa Barbara Channelkeeper. 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. As a result of climate change, natural and built coastal environments are expected to change considerably over the next century. Although some coastal states and municipalities are developing climate change vulnerability assessments, most focus on impacts to physical and built environments; they do not provide a comprehensive assessment of impacts to ecological resources and habitats. In collaboration with scientists from Scripps Institution of Oceanography and the USGS Pacific Coastal and Marine Science Center, SBC investigators Page, Melack and Dugan worked completed a 3-year study on climate adaptation planning for Santa Barbara County with a focus on the vulnerability of its wetland, watershed and beach ecosystems. The main objective was to provide information that assists the Cities of Santa Barbara, Carpinteria, and Goleta, the County of Santa Barbara in climate adaptation planning with a clear focus on coastal ecosystems. The scientists presented results to county and city planners in April 2017 at a public workshop and submitted the final report in July 2017 (available at <https://caseagrant.ucsd.edu/sites/default/files/SBA-CEVA-final-0917.pdf>). This report will be used by local land use planners and decision-makers to identify potential vulnerabilities of ecosystems to projected climate change impacts, and inform updates to coastal land use plans and sea level rise adaptation plans.

SBC research has led to a growing recognition of the unique biodiversity, functions and wildlife supported by sandy beaches and the role of kelp and other macroalgal wrack as an ecological resource by local and state agencies. SBC results are contributing to the development of new policies for conservation and management of sandy beach ecosystems worldwide. 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. In September 2016 Dugan, Miller, Page and SBC graduate students N. Schooler and K. Emery provided field support and protocol refinements for the ecological monitoring program for sandy beach ecosystems on Santa Rosa Island in Channel Islands National Park. This monitoring program, established in 1991 is the only comprehensive long term sandy beach monitoring program in the state of California.

Changes/Problems

Changes in approach and reason for change

Nothing to report.

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

Nothing to report.

Changes that have a 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.