**Annual Report for Period:** 12/2006 - 11/2007
**Submitted on:** 10/03/2007
**Principal Investigator:** Reed, Daniel C.
**Award ID:** 0620276
**Organization:** U of Cal Santa Barbara
**Title:**
LTER: Land/Ocean Interactions and the Dynamics of Kelp Forest Communities

## Project Participants

**Senior Personnel**

**Name:** Reed, Daniel
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**

**Name:** Melack, John
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**

**Name:** Holbrook, Sally
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**

**Name:** Gaines, Steven
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**

**Name:** Siegel, David
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**

**Name:** Dugan, Jenny
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
Project coordinator and sandy beach research

**Name:** Whitmer, Allison
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
Directs on campus marine outreach and education activities

**Name:** Page, Henry
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
Reef ecology research including stable isotope analyses

**Name:** Washburn, Libe
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
Oceanographic research

**Name:** Brzezinski, Mark
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**

Coastal Oceanography research

**Name:** Cooper, Scott
**Worked for more than 160 Hours:** No
**Contribution to Project:**
Stream ecology research

**Name:** Carlson, Craig
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
Marine microbial ecology

**Name:** Cardinale, Brad
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
Long term experiments and synthesis

**Name:** Guerrini, Anita
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
Historical research on coastal watersheds

**Name:** Zimmerman, Richard
**Worked for more than 160 Hours:** No
**Contribution to Project:**
Algal physiology and ecology research

**Name:** Schmitt, Russell
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
kelp forest community ecology

**Name:** Schimel, Joshua
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
Watershed nutrient research

**Name:** Nisbet, Roger
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
Ecological modeling

**Name:** McPhee-Shaw, Erika
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
Coastal oceanographic research

**Name:** MacIntyre, Sally
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
Limnologic and oceanographic research

**Name:** Even, Thomas
**Worked for more than 160 Hours:** No
**Contribution to Project:**
Stream ecology

**Name:** Gaylord, Brian

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
Kelp forest hydrodynamics and biomechanics

**Name:** Lenihan, Hunter

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
Reef ecology and fisheries

**Name:** Carr, David

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
Reef fisheries research

**Name:** Dudley, Tom

**Worked for more than 160 Hours:** No

**Contribution to Project:**
watershed and invasive plant research

**Name:** Beighley, Ed

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
Watershed  hydrology

**Name:** Freudenburg, William

**Worked for more than 160 Hours:** No

**Contribution to Project:**
Sociological studies

**Name:** Clarke, Keith

**Worked for more than 160 Hours:** No

**Contribution to Project:**
Land use research

**Post-doc**

**Name:** Miller, Robert

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
Develop apparatus and experiments investigating primary production of understory algae and phytoplankton in kelp forests

**Name:** Fram, Jonathan

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
Analysis of current, temperature, nutrient data for kelp forest and nearshore ocean

**Name:** Stewart, Hannah

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
Researched kelp forest dynamics in response to nutrient flow

**Name:** Revell, David

**Worked for more than 160 Hours:** No

**Contribution to Project:**
Sediment and sandshed dynamics of coastal beaches

**Name:** Miterai, Satoshi

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
ROMS modeling of larval connectivity with headlands

**Name:** Alberto, Filipe

**Worked for more than 160 Hours:** No

**Contribution to Project:**
Population genetics of kelps

**Name:** He, Yiping

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
watershed hydrology research

**Name:** Leydecker, Al

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
Watershed sampling and analyses

**Graduate Student**

**Name:** Arkema, Katie

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
Kelp forest community ecology, kelp primary production

**Name:** Rassweiler, Andrew

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
Kelp forest community ecology, kelp primary production

**Name:** Carney, Laura

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
kelp population genetics research

**Name:** Nickols, Kerry

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
kelp biomechanics research

**Name:** Hettinger, Anniliese

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
kelp biomechanics research

**Name:** Guenther, Carla

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
Fishery socioeconomics and management in kelp forests

**Name:** Simon, Scott

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
Coordinates on campus marine outreach and education activities

**Name:** Hammond, Latisha

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
Assists with on-campus marine outreach and education

**Name:** Klose, Kristie
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
Stream ecology research

**Name:** Shulman, Rachel
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
Long term experiments and synthesis

**Name:** Burnette, Don
**Worked for more than 160 Hours:** No
**Contribution to Project:**
History of botanical research on a coastal watershed

**Name:** Cavanaugh, Kyle
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
SPOT analysis of kelp cover/biomass

**Name:** Watson, James
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
modeling of larval & genetic connectivity for SBC-LTER

**Name:** Chaffey, Tim
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
ROMS modeling of larval connectivity with headlands

**Name:** Kostadinov, Tiho
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
coastal oceanographic research

**Name:** Anderson, Clarissa
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
coastal oceanographic research

**Name:** Wallner, Elisa
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
coastal oceanographic research

**Name:** Goldberg, Stuart
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
coastal oceanographic research

**Name:** Goodman, Jo
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**

coastal oceanographic research

**Name:** Levenbach, Stuart
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
Kelp forest community ecology

**Name:** Lester, Sarah
**Worked for more than 160 Hours:** No
**Contribution to Project:**
Kelp forests and population biology of urchins

**Name:** Brinkman, Jeff
**Worked for more than 160 Hours:** No
**Contribution to Project:**
Stream ecology

**Name:** Kinlan, Brian
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
ecology of kelp forests

**Name:** Kargar, Maryann
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
watershed hydrology research

**Name:** Bogonko, Michael
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
watershed hydrology research

**Undergraduate Student**

**Name:** Jolley, Margaret
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
Assisted with subtidal kelp forest research, data and lab sample processing

**Name:** Horii, Stephanie
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
Assisted with subtidal kelp forest research, data and lab sample processing

**Name:** Rompel, Jenna
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
Assisted with subtidal kelp forest research, data and lab sample processing

**Name:** Creason, Jamie
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
Assisted with subtidal  kelp forest research and lab sample processing

**Name:** Kondo, Emi
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**

Assisted with subtidal  kelp forest research and lab sample processing

**Name:** Zimmer-Faust, Amy
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
Assisted with subtidal  kelp forest research and lab sample processing

**Name:** James, Kelsey
**Worked for more than 160 Hours:** No
**Contribution to Project:**
Assists with on-campus marine outreach and education

**Name:** Le, Kevin
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
Assisted with subtidal  kelp forest research and lab sample processing

**Name:** Finstad, Sarah
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
Assisted with subtidal  kelp forest research and lab sample processing

**Name:** Santschi, Christen
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
Assisted with subtidal  kelp forest research and lab sample processing

**Name:** Quigley, Yasmin
**Worked for more than 160 Hours:** No
**Contribution to Project:**
Assists with on-campus marine outreach and education

**Name:** Naranjo, Vanessa
**Worked for more than 160 Hours:** No
**Contribution to Project:**
Assists with on-campus marine outreach and education

**Name:** Olsen, Lani
**Worked for more than 160 Hours:** No
**Contribution to Project:**
process stream samples, filter water samples for particulates, measure conductivity on stream samples

**Name:** Teeza, Inteema
**Worked for more than 160 Hours:** No
**Contribution to Project:**
process stream samples, filter water samples for particulates, measure conductivity on stream samples

**Name:** Minter, Thomas
**Worked for more than 160 Hours:** No
**Contribution to Project:**
Sample collection from streams during storm events

**Name:** Padilla, Emmanuel
**Worked for more than 160 Hours:** No
**Contribution to Project:**
Sample collection from streams during storm events

**Name:** Bowen, Kevin

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Performed nutrient analyses and data entry in laboratory for watershed, stream and beach samples, performed some quality control analyses.

**Name:** Moon, Evan

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

assisting in SPOT data analysis

**Name:** Fairbarn, KG

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

assisting in SPOT data analysis

**Technician, Programmer**

**Name:** Harrer, Shannon

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Assisted with reef and oceanographic research and data management

**Name:** Nelson, Clint

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Assisted with reef and oceanographic research and data management

**Name:** Fisher, Rachelle

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Assisted with reef and oceanographic research and data management

**Name:** Goodridge, Blair

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

: Assisted with reef, oceanographic and watershed research

**Name:** Kissinger, Michelle

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Assists with on-campus marine outreach and education

**Name:** Nakase, Dana

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Assists with on-campus marine outreach and education

**Name:** O'Brien, Margaret

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

IM coordinator

**Name:** Schooler, Nicolas

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Assists with reef and sandy beach research

**Name:** Setaro, Frank
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
Processing stream and watershed samples in laboratory

**Name:** Doyle, Allen
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
Analytical lab manager, performed and coordinated nutrient analyses for freshwater inorganic and total nutrients. Logged samples, created spreadsheets, performed quality analysis

**Name:** Fields, Erik
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
satellite image data processing

**Name:** Jones, Janice
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
coastal oceanographic research

**Name:** Gotschalk, Chris
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
coastal oceanographic research and data processing

**Name:** Court, David
**Worked for more than 160 Hours:** No
**Contribution to Project:**
remote sensing data analyses

**Name:** Emery, Brian
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
ocean surface currents research

**Name:** Ireson, Kirk
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
ocean surface currents research

**Name:** Guillocheau, Nathalie
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
Plumes and Blooms research

**Name:** Wiseman, Sheila
**Worked for more than 160 Hours:** No
**Contribution to Project:**
Stream ecology

**Name:** Morris, Jordan
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
server and database management

**Name:** Burt, Chad
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
information management

**Other Participant**

**Name:** Ralph, Yvette
**Worked for more than 160 Hours:** No
**Contribution to Project:**
Assisted with subtidal kelp forest research

**Research Experience for Undergraduates**

**Name:** Davenport, Lars
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
Assisted with subtidal kelp forest research

**Years of schooling completed:** Junior
**Home Institution:** Same as Research Site
**Home Institution if Other:**
**Home Institution Highest Degree Granted(in fields supported by NSF):** Bachelor's Degree
**Fiscal year(s) REU Participant supported:** 2007
**REU Funding:** REU supplement

**Name:** Craig, Alexandra
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
Assisted with subtidal kelp forest research

**Years of schooling completed:** Junior
**Home Institution:** Same as Research Site
**Home Institution if Other:**
**Home Institution Highest Degree Granted(in fields supported by NSF):** Bachelor's Degree
**Fiscal year(s) REU Participant supported:** 2007
**REU Funding:** REU supplement

**Name:** Heidelberger, Sara
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
Assisted with subtidal kelp forest sampling and lab sample processing

**Years of schooling completed:** Sophomore
**Home Institution:** Same as Research Site
**Home Institution if Other:**
**Home Institution Highest Degree Granted(in fields supported by NSF):** Bachelor's Degree
**Fiscal year(s) REU Participant supported:** 2007
**REU Funding:** REU supplement

**Name:** Cody, Tim
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**
Assisted with subtidal kelp forest sampling and lab sample processing

**Years of schooling completed:** Junior

**Home Institution:** Same as Research Site

**Home Institution if Other:**

**Home Institution Highest Degree Granted(in fields supported by NSF):** Bachelor's Degree

**Fiscal year(s) REU Participant supported:**

**REU Funding:** REU supplement

**Name:** Honig, Susanna

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Assisted with subtidal kelp forest research and lab sample processing

**Years of schooling completed:** Sophomore

**Home Institution:** Same as Research Site

**Home Institution if Other:**

**Home Institution Highest Degree Granted(in fields supported by NSF):** Doctoral Degree

**Fiscal year(s) REU Participant supported:** 2007

**REU Funding:** REU supplement

## Organizational Partners

**NOAA National Marine Sanctuary Program**

A major goal of the Channel Islands National Marine Sanctuary (http://www.cinms.nos.noaa.gov/home.htm)is to direct research and monitoring programs that will yield a body of information that can be used to evaluate existing management practices and provide improved understanding for future management decisions. CINMS has provided ship time and staff expertise to UCSB's Plumes and Blooms project and has offered similar support to the SBC LTER. CINMS has been an enthusiastic supporter of SBC because information generated by SBC will assist them in their efforts to manage and protect the Sanctuary. CINMS is currently considering expanding its boundaries to include much of the mainland coast in the Santa Barbara Channel and has been active in state-wide efforts to establish marine reserves. Both of these activities could greatly influence the level of protection afforded to marine habitats in the SBC LTER. Six SBC investigators served on a science advisory panel to CINMS to develop a plan to create marine protected areas.

**Santa Barbara Land Trust**

The Santa Barbara Land Trust has purchased the lower half of the Arroyo Hondo catchment, a parcel owned for generations by a couple of families and only slightly altered; the upper portion is administered by the US Forest Service as natural watershed. As part of a Bren School's Masters of Environmental Science and Management thesis project, we developed a natural resources management plan for the Land Trust. Further, the catchment is one of our intensive sites, and we will continue to provide useful information to the Land Trust as they protect and manage the property.

**University of California, Davis, CA**

**Old Dominion University**

collaborations on studies of kelp primary production

**Los Angeles Conservation Corps**

Collaborate on SBC-LTERs schoolyard program for K-12 education

**Santa Barbara Channel Keeper**

The Santa ChannelKeepers conduct monthly collections along the Ventura River, and we participate in this field work and complement their in situ measurements with high quality nutrient chemistry

**Ventura CoastKeeper**

Provides stream sampling volunteers and sample collections

**Carpinteria Creek Watershed Coalition**

**Univ.  California Natural Reserve System**

**Friends of the Santa Clara River**

**City of Santa Barbara**

The City of Santa Barbara recently obtained special funding through a voter approved tax increase to reduce polluted runoff that has resulted in beach closures. Two of our intensive catchments (Mission and Arroyo Burro) are within the City, and we are interacting with its staff to help them plan their restoration efforts.

**Santa Barbara County Project Clean Water**

Santa Barbara County's Project Clean Water in engaged in sampling local creeks during the initial rise of the hydrograph and measuring a suite of pollutants including metals, pesticides and herbicides. Our intensive sampling of nutrients and particulates during the whole hydrograph for most storms complements the County's effort, and we and they share data and interpretations. To further communication with Project Clean Water, we attend their monthly stakeholder meetings and have given public presentations of our results in that forum.

**Channel Islands National Park**

Since 1982 Channel Islands National Park (http://www.nps.gov/chis/) has collected data annually on the abundance of a wide variety of species that inhabit intertidal reefs and kelp forests at a multitude of sites on the five northern Channel Islands (http://www.nature.nps.gov/im/chis/index.htm). These data have proved extremely valuable in evaluating the response of nearshore reef communities to large disturbances (e.g. El Nino) that have occurred in the last 20 years. SBC has adopted sampling protocols similar to those used by NPS to examine long-term changes in reef populations on the mainland. When used in combination, NPS and SBC data provide large spatial resolution for evaluating changes in reef communities that occur in the future. This collaboration is important because it provides NPS with important information on the physical and biological oceaography of the Santa Barbara Channel, which otherwise would not be available to them. This information is useful in helping NPS manage and protect the unique and valuable resources of the Channel Islands.

**Santa Barbara Watershed Resource Center**

Santa Barbara Watershed Resource Center is a collaborative partner in SBC's outreach program

**Terra Image USA**

Recently, UC Santa Barbara and Terra Image USA, the company which owns the academic rights to SPOT data for the U.S., have entered into a research partnership which gives UCSB students and researchers [nearly] unlimited access to archived SPOT imagery and the ability to acquire new scenes (www.ia.ucsb.edu/pa/display.aspx?pkey=1311; also

www.spot.ucsb.edu). Currently we have 27 SPOT 4 & 5 multispectral scenes covering parts of the Santa Barbara Channel from October 2004 to Jan 2006. Beginning Jan 2006, the SPOT Corporation has
tasked its satellites to provide at least bi-monthly coverage of the entire Santa Barbara Channel in support of this agreement.

**Center for Integrative Coastal Observ.**

**Other Collaborators or Contacts**

The Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) is a large-scale marine science research program funded by the David and Lucile Packard Foundation that focuses on understanding the nearshore ecosystems of the U.S. West Coast. Representing a collaboration of scientists from four universities (including UCSB), the interdisciplinary research ranges from long-term monitoring of ecological and oceanographic processes at dozens of coastal sites to experimental work in the lab and field to explore how individual organisms and populations are affected by environmental change. PISCO research at UCSB (PIs Gaines, Warner, and Washburn) is tightly linked with the Santa Barbara LTER and considerable sharing of resources and data in studies pertaining to physical, chemical, and biological oceanography.
(http://www.piscoweb.org)

NASA funds a long-term (>10 yr) study at UCSB (referred to as Plumes and Blooms) (http://www.icess.ucsb.edu/PnB/PnB.html)that investigates marine plankton blooms associated with runoff. The goal of this project (Lead PI Siegel) is to develop new satellite ocean color algorithms to use in coastal waters influenced by terrigenous materials (sediments, dissolved organic materials, etc.). In situ optical quantities and in-water constituents are collected every two weeks along a 7 station transect crossing the Santa Barbara Channel and related to simultaneous ocean color images from the SeaWiFS satellite sensor. Siegel is also the lead PI on another NASA funded project whose research objective is to develop a predictive understanding of giant kelp forests in the nearshore waters of California using a combination of: (1) high-resolution remote sensing of kelp cover, biomass & its physiological state, (2) metapopulation modeling of kelp patch dynamics, and (3) Bio-optical modeling of kelp productivity. The project builds on the findings of SBC funded research and there is substantial coordination and information exchange between the two projects.

The San Onofre Nuclear Generating Station (SONGS) mitigation program was instituted by the California Coastal Commission as a means of compensating for the loss of coastal marine resources caused by the operation of the nuclear power plant, which is located on the coast in northern San Diego County. PI Reed and Associate Investigator Page are lead investigators on the SONGS mitigation program and are responsible for designing and implementing monitoring programs that evaluate the effectiveness of the various mitigation projects. One component of the mitigation program requires the restoration of tidal wetlands. Carpinteria salt marsh is one of the reference sites being used to evaluate the performance of San Dieguito Lagoon (the wetland to be restored, which is located in San Diego County). Data on water quality, tidal inundation, and species composition and abundance of wetland biota are being collected at Carpinteria and three other wetlands in southern California as part of this project. These data are available to us and nicely complement those that are being collected by SBC LTER. Another large component of the SONGS mitigation program involves mitigating the loss of kelp forest habitat via the creation of artificial reefs. The design of the long term-monitoring of the artificial reef and nearby natural kelp forests that are used for reference is similar to that used by SBC LTER to monitor changes in kelp forests in the Santa Barbara region and provides an excellent opportunity for regional comparisons.

SBC investigators are actively collaborating with researchers from the Centre of Marine and Environmental Research (CMER) at the Universidade do Algarve, Portugal on issues pertaining to gene flow, inbreeding depression and population connectivity in the giant kelp Macrocystis pyrifera. CMER is a member of the Marine Biodiversity and Ecosystem Functioning (MarBEF) program, which is a network of excellence funded by the European Union. It consists of 91 European marine institutes and is a platform to integrate and disseminate knowledge and expertise on marine biodiversity with links to researchers, industry, stakeholders and the general public. CMER is also a member of CORONA (Coordinating Research of the North Atlantic), an NSF-funded multidisciplinary research network to study the marine biota of the North Atlantic. The network includes 118 scientists from 13 countries across the North Atlantic. The major research and education goals of CMER, MarBEF, and CORONA are complimentary to those of SBC LTER, providing the ideal opportunity for collaboration.

SBC-LTER investigators are collaborating with the California Cooperative Extension/Sea Grant program on projects investigating aquatic invasive species and on collaborative fisheries research with fishing partners.

CALobster (http://www.calobster.org/), a new collaborative fishery research program recently initiated by an SBC investigator and his graduate students, focuses on the spiny lobster fishery with a goal of promoting and conducting community-based research that lead to the best management practices and help maintain working harbors.

## Activities and Findings

**Research and Education Activities: (See PDF version submitted by PI at the end of the report)**

**Findings: (See PDF version submitted by PI at the end of the report)**

**Training and Development:**

Training and Development 2007

Education and training are tightly integrated into all aspects of SBC research. In 2007, eight postdocs, 25 graduate students, 5 REU students and more than 19 undergraduate students participated in SBC research. Educational opportunities at SBC are not limited to university students and post docs. Teachers and numerous volunteers from the general public regularly participate in our stream sampling program and gain considerable knowledge on the constituents of runoff and of the processes that influence their concentrations. SBC students, postdoctoral fellows, and investigators participated in the 2007 SBC-LTER Spring Science Retreat in June. Results from SBC research were presented in an interactive poster session, and overview presentations.

SBC-LTER is hosting a SEEDS field trip for 24 undergraduate students from throughout the US and its surrounding territories in October 2007. SEEDS is an education program of the Ecological Society of America whose mission is to diversify and advance the profession of ecology through opportunities that stimulate and nurture the interest of underrepresented students. Focused at the undergraduate level, opportunities sponsored by the program include student field trips such as the one to SBC in October 2007, undergraduate research fellowships, ESA Annual Meeting travel awards, and campus ecology chapters. The SBC SEEDS field trip will focus on meeting with SBC ecologists and students at University of California, Santa Barbara and learning more about their research at the Santa Barbara Coastal LTER as well as the broader LTER network. Participants will be staying in

cabins situated in oak woodlands at a camp in the coastal mountains. Students will tour local coastal ecosystems with SBC investigators and graduate students. Activities will include a trip to a kelp forest on a university research vessel, the R/V Cormorant, a visit and historical overview of a working harbor, intertidal field observations at low tide, marine aquaria activities, a tour of watershed research sites, meeting and interacting with a variety of SBC-LTER researchers and graduate students and a UCSB campus tour.

**Outreach Activities:**

OUTREACH

The SBC-LTER Summer Diversity Program 2007

SBC's Schoolyard LTER (SLTER) program is organized around a theme of watershed ecology. This approach allows for an integrated program that includes K-12 students, K-12 teachers, undergraduate and graduate students. A highlight of our SLTER is the Summer Diversity Program (SDP), which is a collaborative effort with the Los Angeles Conservation Corps (LACC) that brings inner-city middle school students to Santa Barbara and the Santa Ynez Valley for an extensive, immersive science education experience. The SDP includes: a student and family visit to UCSB for campus tour and marine science education 'carousel,' a weekend camping trip at the Sedgwick Ranch (a UC Natural Reserve), and an immersive, weeklong residential program at UCSB, that includes trips through a local watershed and restoration site. These field experiences are interwoven with watershed ecology lesson plans that are based on SBC LTER research. Undergraduate and graduate students serve as docents and provide extensive mentoring. In addition, our program docents and UCSB and community college counselors provide continuous support to LACC students and their families throughout the year. Our SDP is also involved in a cross-site education research program lead by KBS LTER and in collaboration with the SGS and BES Schoolyard programs to examine learning about the water cycle in middle and high school-aged students. Utilizing a pre/post assessment survey developed by KBS LTER, data show that, on average, student's knowledge increased almost 20% (Fig. 1).

Research Experience & Education Facility (REEF)

The Santa Barbara Coastal (SBC) LTER outreach, education and training programs benefit from a close association with the University of California at Santa Barbara's Research Experience & Education Facility, better known as the REEF, an interactive aquarium facility. The REEF is equipped with state-of-the-art, aquaria and touch tanks, ranging from 2 to 2,000 gallons. The REEF also utilizes a high-tech life support system for the Research Tank, which highlights current, on-going research at UCSB and the Marine Science Institute, including SBC-LTER research.

One of the joint goals of the SBC LTER and the REEF program is to provide UCSB undergraduates, majoring in Aquatic Biology, with a solid foundation in temperate marine ecology and research. The REEF training provides them with the basis for communicating this knowledge in an educational format. To that end, the REEF develops its curriculum around a number of research programs at UCSB. The SBC LTER is a significant contributor to this endeavor. Support from the SBC LTER schoolyard program has allowed the REEF to obtain teaching supplies and equipment for curriculum and teacher professional development, as well as provide stipends for teachers, undergraduate and graduate internships. The REEF also utilizes graduate students from the SBC LTER to train REEF undergraduate staff, which, in turn, enhances their training as laboratory and field assistants and research divers for SBC LTER research.

The REEF program has been busy during 2007, between outreach visits to schools, community events and on-campus programs, the REEF provided marine science and environmental education to over 33,000 children and adults. This includes hosting educational visits from primary and secondary schools from King City in Monterey Co., to Sacramento and San Diego. The REEF also serves as a marine laboratory for many colleges

including Cal Lutheran Thousand Oaks, CSU Channel Islands, and UCSB. At UCSB, the REEF serves as an interdisciplinary adjunct laboratory for undergraduate courses including: Geology 4 (Intro to Oceanography), EEMB 3 (Intro Biology), EEMB 106 (Biology of Fishes), Writing 2 and Writing 109 ST. This year the REEF had over 3,000 on-campus visitors. The REEF also serves UCSB outreach and summer programs, including the SBC-LTER Schoolyard Program which involves inner-city Middle School youths in the Los Angeles Conservation Corps (LACC) Clean and Green Program. This year The REEF also supported international programs, including middle school students from Taiwan as part of the Yuan-Lin Cultural Exchange Program and Graduate students from Osaka Japan.

OceansAlive!
SBC LTER students participate in the OceansAlive! program of the UCSB Marine Science Institute (MSI), a collaboration with a number of UCSB departments and research programs to provide 125 local junior high, middle school and high school students with UCSB undergraduate and graduate student mentors for science fair projects. These secondary school students then compete at the local level with the opportunity to progress to the state and national levels.

Other SBC Outreach Activities
In 2007, SBC LTER investigator Jenny Dugan mentored a science fair project for 2 local high school students. The students, Andrew Sanchez and Esther Flores, competed in two science fairs with their project entitled 'How does the amount of acanthocephalan (thorny head worm) parasites affect the swimming and burrowing of the pacific mole crab, Emerita analoga'. Their study won best project in the Senior Life Science division and best senior ecology project and best senior marine science project as well as the best senior project in the fair at the Santa Barbara County Science Fair. At the California State Science Fair in May 2007, Andrew and Esther's project earned 2nd place in the senior zoology category.

Direct outreach to the public is an active area for many SBC investigators and students. Al Leydecker, a SBC post doc, assists and helps direct stream and river monitoring, education and sampling programs for several community environmental organizations including Santa Barbara Channel Keeper, Isla Vista Surf Rider and Ventura Surf Rider and the Friends of the Santa Clara River. SBC Investigator Scott Cooper gave a presentation and carried out training on stream ecology and the use of stream organisms as bioindicators to K- 12 docents from NRS (Sedgwick Ranch), Land Trust for Santa Barbara County (Arroyo Hondo Reserve), EEMB Biodiversity Center, Santa Barbara Botanic Gardens, and other organizations at Arroyo Hondo Creek in January, 2007. In May 2007 Scott also participated in a research project and public outreach event called 'BioBlitz' organized by the Santa Barbara Botanic Gardens and Natural History Museum. He collected invertebrates from Mission Creek, created a list of the collected invertebrates, set up demonstrations of stream organisms, and discussed stream ecology with the public. Investigator John Melack was interviewed about creeks and watersheds by a local television producer, Santa Barbara City TV, for a show on Santa Barbara creeks. John also served as a Panel member on 50 minute long UCTV program called 'Global Warming: Change Begins with Learning', part 2 - Lands, Lakes and Oceans: The Ecology of Climate Change.

SBC investigators also participated in several public groups to provide education and a scientific perspective including the Santa Barbara Community Environmental Council, Friends of the Santa Clara River, Santa Barbara Creeks Council and the UCSB Shoreline Preservation Fund.

2007 Public and K-12 Outreach Talks
SBC investigators routinely give lectures in local K-12 schools on LTER related topics. Listed below are the lectures given in 2007.

Dugan, J. E. public seminar: Hopping with life: the ecology of sandy beaches. Ty Warner Sea Center Arthropod Fair presentation.

Dugan, J.E. 2007. Sandy Beach Ecosystems: Storm Response versus Human Alterations Invited talk. Shoreline Preservation Annual Reception.

Dugan, J.E. 2007. Beach ecosystems on the brink, presentation to the Ocean Protection Council

McPhee-Shaw, E. 2007. public seminar entitled 'The Coastal Ocean: Dynamics where Land and Sea Meet' for the nonprofit organization 'Friends of Moss Landing Marine Laboratories.'

Melack, J. 2007. LTER research on creeks within City of Santa Barbara. Lecture to Santa Barbara Creeks Council.

Revell, D. 2007 Sandy Beach Ecosystems: Storm Response versus Human Alterations. Invited talk. Shoreline Preservation Annual Reception.

Schimel, J. Global Warming: Science and Society. April 2007. Panel discussant following Elizabeth Kolbert's public lecture: 'Field Notes from a Catastrophe'.

Schimel, J. Global Warming: Science and Society Public Discussions, organizer and participant: UCSB, Montecito, Goleta, Solvang, and Carpinteria libraries.

Washburn, L., 2006, presentation: Currents in the Santa Barbara Channel, Pacific and Corinthian Yacht Club, 18 August, Oxnard, CA.

Washburn, L., 2007, 4 presentations: Scientific Diving, Career Day, Dos Pueblos High School, 28 February, Goleta, CA.

Washburn, L., 2007. The oceanography of the Santa Barbara Channel. presentation to Volunteer Naturalist Corps, Channel Islands National Marine Sanctuary, Chase Palm Park, Santa Barbara, CA

Washburn, L., 2007. Overview of Montecito Outfall Study, presentation to Montecito Sanitation District Board, Montecito, CA

## Journal Publications

Behrenfeld, M. J. and D. A. Siegel, "Ocean productivity - Climate linkages imprinted in satellite observations", Global Change Newsletter (IGBP), p. 4, vol. 68, (2007). Published,

Gaylord, B. P., J. Rosman, D. C. Reed, J. R. Koseff, J. Fram, S. McIntyre, K. Arkema, C. McDonald, M. A. Brzezinski, J. L. Largier, S. G. Monismith, P. T. Raimondi and B. Mardian, "Spatial patterns of flow and their modification within and around a giant kelp forest", Limnology and Oceanography, p. 1838, vol. 52, (2007). Published,

Gross, K. and B. J. Cardinale, "Does species diversity drive ecosystem productivity or vice versa? Towards unification of the historical and contemporary paradigms", American Naturalist, p. 207, vol. 170, (2007). Published,

Kostadinov, T. S., D. S. Siegel, S. Maritorena and N. Guillocheau, "Ocean color observations and modeling for an optically complex site: Santa Barbara Channel, California, USA", Journal of Geophysical Research, Oceans, p. C07011, vol. 112, (2007). Published,

Lester, S. E., B. I. Ruttenberg, S. D. Gaines and B. Kinlan, "The relationship between dispersal ability and geographic range size", Ecology Letters, p. 745, vol. 10, (2007). Published,

Lester, S. E., E. D. Tobin and M. D. Behrens, "Disease dynamics and the potential role of thermal stress in the sea urchin, Strongylocentrotus purpuratus", Canadian Journal of Fisheries and Aquatic Sciences, p. 314, vol. 64, (2007). Published,

McPhee-Shaw, E. E., D. A. Siegel, L. Washburn, M. A. Brzezinski and J. A. Jones, "Mechanisms for nutrient delivery to the inner shelf: Observations from the Santa Barbara Channel", Limnology and Oceanography, p. 1748, vol. 52(2), (2007). Published,

Miller, L. P. and B. P. Gaylord, "Barriers to flow: The effects of experimental cage structures on water velocities in high-energy subtidal and intertidal environments", Journal of Experimental Marine Biology and Ecology, p. 215, vol. 344, (2007). Published,

Ohlmann, C. J., P. White, L. Washburn, E. Terrill, B. M. Emery and M. Otero, "Interpretation of coastal HF radar derived surface currents with high resolution drifter data", Journal of Atmospheric and Oceanic Technology, p. 666, vol. 24(4), (2007). Published,

Schlacher, T. A., J. Dugan, D. S. Schoeman, M. Lastra, A. Jones, F. Scapini, A. McLachlan and O. Defeo, "Sandy beaches at the brink", Diversity and Distributions, p. 556, vol. 13(5), (2007). Published,

Schmitt, R. R. and S. S. Holbrook, "Temporal co-variation between young-of-year class strength and the forage base of surfperch (Teleostei: Embiotocidae)", Raffles Bulletin of Zoology, p. 155, vol. 14, (2007). Published,

Anderson, C. R., D. A. Siegel, M. A. Brzezinski and N. Guillocheau, "Controls on Temporal Patterns in Phytoplankton Community Structure in the Santa Barbara Channel, California bloom in the Santa Barbara Channel, California", ournal of Geophysical Research, Oceans, p. , vol. , ( ). Accepted,

Beighley, R. E., T. Dunne and J. M. Melack, "Impacts of land use alterations on event runoff frequency distributions in southern California coastal watersheds", Journal of the American Water Resources Association, p. , vol. , ( ). Accepted,

Lester, S. E., S. D. Gaines and B. Kinlan, "Reproduction on the edge: large-scale patterns of individual performance in a marine invertebrate", Ecology Letters, p. , vol. , ( ). Accepted,

Mitarai, S., D. A. Siegel and K. B. Winters, "A numerical study of stochastic larval settlement in the California Current System", Journal of Marine Systems, p. , vol. , ( ). Accepted,

Page, H. M., J. E. Dugan, D. M. Schroeder, M. M. Nishimoto, M. S. Love and J. C. Hoesterey, "Trophic links and condition of a temperate reef fish: comparisons among offshore oil platform and natural reef habitats", Marine Ecology Progress Series, p. 245, vol. 344, (2007). Published,

Scapini, F. and J. E. Dugan, "Sun and landscape orientation in adult and juvenile sandhoppers Orchestoidea tuberculata (Amphipoda, Talitridae) from two beaches in south central Chile", Marine Ecology, p. , vol. , ( ). Accepted,

Dugan, J. E., D. M. Hubbard, I. F. Rodil, D. Revell and S. Schroeter, "Ecological effects of coastal armoring on sandy beaches", Marine Ecology, p. , vol. , ( ). Accepted,

Revell D. L., J. E. Dugan, D. M. Hubbard, "Physical and ecological responses to the 1997-98 El Nino", Journal of Coastal Research, p. , vol. , ( ). Accepted,

Sadro, S., M. Gastil-Buhl and J. M. Melack, "Characterizing patterns of plant distribution in a southern California salt marsh using topographic and hyperspectral data and local tidal hydrodynamics", Remote Sensing of the Environment, p. , vol. , ( ). Accepted,

Barth, J. A., B. A. Menge, J. Lubchenco, F. Chan, J. M. Bane, A. R. Kirincich, M. M. McManus, K. J. Nielsen, S. D. Pierce and L. Washburn, "Delayed upwelling alters nearshore coastal ocean ecosystems in the northern California current", Proceedings of the National Academy of Sciences, p. 3719, vol. 104(10), (2007). Published,

**Books or Other One-time Publications**

Washburn, L, "Coastal Currents", (2007). Book, Published
Editor(s): Denny, M. W. and S. D. Gaines
Collection: Encyclopedia of Tidepools and Rocky Shores
Bibliography: University of California Press, Berkeley and Los Angeles

Anderson, C. R., "Environmental controls of phytoplankton community structure in the Santa Barbara Channel: Application to the dynamics and detection of harmful diatom blooms", (2007). Thesis, Published
Bibliography: PhD dissertation, Interdepartmental Graduate Program in Marine Science, University of California, Santa Barbara, CA

Brinkman, M. A., "Influences of human disturbance and natural physical and chemical variables on biological community structure in streams of southern coastal Santa Barbara County, California, and an index of biological integrity", (2007). Thesis, Published
Bibliography: M.A. thesis, University of California, Santa Barbara, CA.

Lester, S. E., "Marine macroecology: The effects of dispersal and reproductive output on species' geographic distributions", (2007). Book, Published
Bibliography: PhD dissertation, University of California, Santa Barbara, CA

Levenbach, S, "Community-wide ramifications of an associational defense on shallow temperate reefs", (2007). Thesis, Published
Bibliography: PhD dissertation, Department of Ecology, Evolution and Marine Biology, University of California, Santa Barbara, CA

Revell, D, "Long Term and Storm Event Changes to the Santa Barbara Sandshed", (2007). Book, Published
Bibliography: PhD dissertation, University of California, Santa Cruz, CA

Rossiter, M., M. Debner, J. Siew, C. Ciarametaro and D. Beck, "Evaluation of rainfall-runoff relationships to inform development of an incentive program for stormwater pollution reduction in South Coast watersheds", (2007). Book, Published
Bibliography: Group Masters Thesis, Master of Environmental Science and Management, Bren School of Environmental Science and Management, University of California, Santa Barbara, CA

Harmon, M. E., D. L. Phillips, J. Battles, A.

Rassweiler, R. O. Hall and W. K. Lauenroth, "Quantifying uncertainty in net primary production measurements", (  ). Book, Accepted
Editor(s): ahey, T. J. and A. K. Knapp
Collection: Principles and Standards for Measuring
Net Primary Production in Long-Term
Ecological Studies.
Bibliography: Oxford University Press

## Web/Internet Site

**URL(s):**

http://sbc.lternet.edu/index.html

**Description:**

This is the project website which describes the research questions, progress, people, outreach. publications, presentations and data products of the Santa Barbara Coastal LTER. The SBC website was converted from a collection of static pages to a scripted system which streamlines the addition of new material and facilitates editing of dynamic menus or style changes. During the conversion, new material was added so that the website is now compliant with LTER recommendations.

## Other Specific Products

**Product Type:**

**Data or databases**

**Product Description:**

SBC publications database: Like our datasets, SBC publications are described by the EML schema. We have continued to extend EML for the reporting and multi-use needs of bibliographic references. We are also continuing work on the web application to accommodate searches and reports, and to increase speed.

**Sharing Information:**

SBC Publications database is available at http://sbc.lternet.edu/publications

**Product Type:**

**Software (or netware)**

**Product Description:**

Query interface for EML datasets: SBC's growing data time series requires tools for querying and sub-setting data tables. We have developed a generic web application which can be applied to many types of data tables described by EML. The application's use of the EML format means it can potentially be applied by many other research groups.

**Sharing Information:**

This query interface is available through links at http://sbc.lternet.edu/data).

**Product Type:**

**Data or databases**

**Product Description:**

SBC datasets on climate, hydrology, stream chemistry, watershed characteristics, coastal ocean currents and biogeochemistry, net primary production of kelp, historical kelp biomass, cover of sessile organisms on reefs, reef fish abundance, abundance and size of giant kelp, reef invertebrate and algal density and stable isotope data from kelp forest food webs are being collected and updated annually.

**Sharing Information:**

Available final datasets are listed in the metadata catalog on the site's website http://sbcdata.lternet.edu/catalog/

## Contributions

**Contributions within Discipline:**

Giant kelp forests have been the subject of numerous studies over the last four decades. The vast majority of this work has been done at the species, population, or community level. Despite learning much about the ecology of kelp forest communities, the understanding of ecosystem level processes in kelp forests remains quite primitive. Results from our reef studies are helping to fill this little studied, yet ecologically important area of research. Of particular significance are our studies of 1) primary production, 2) stable isotope analyses of kelp forest food webs, 3) the role of nutrients in altering these food webs and 4) links between kelp forests and sandy beach food webs.

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

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

Our extensive and intensive measurements of solute and particulate concentrations and export from the steep, flashy catchments along the central/southern coast of California provide important comparative information to the field of watershed science that is otherwise lacking.

**Contributions to Other Disciplines:**

The research mission of SBC is very interdisciplinary in scope. As such, contributions are being made to a wide range of disciplines including: terrestrial, aquatic and marine ecology, physical, biological and chemical oceanography, hydrology, geology, geography, toxicology, environmental history and informatics. Coordinated studies among the many disciplines represented in SBC are leading to an improved understanding of the patterns and processes that link land and ocean environments and their consequences for coastal ecosystems. This improved understanding is not only contributing to furthering the many disciplines listed above, but is of considerable value to those interested in studying the extent to which society is influenced by human impacts to coastal systems. SBC is actively initiating ties with the social science community. Investigator Siegel directs the Institute for Computational Earth System Sciences (ICESS) and is head of the SPOT Resource Center (http://www.spot.ucsb.edu/) to provide SPOT imagery (a high spatial resolution commercial data set) from the SPOT constellation of satellite sensors to UCSB researchers, including the LTER. To date over 35,000 high resolution scenes have been provided to UCSB investigators. Investigator Lenihan has initiated a collaborative fishery research program, CALobster (http://www.calobster.org/), focused on the spiny lobster fishery with a goal of promoting and conducting community-based research that lead to the best

management practices and help maintain working harbors. Investigators Page and Dugan conducted collaborative research on the recruitment of fishery species with trap and dive fishermen and are initiating a new collaborative research project on crab fisheries with local trap fisherman. Dugan and Guerrini continued preparation of an interdisciplinary multi-authored book on the deep history of a SBC coastal wetland and watershed.

**Contributions to Human Resource Development:**

Our project provides significant opportunities for research and teaching in science at multiple levels. In 2007 eight post docs, 25 graduate students, 5 REU students and more than 19 undergraduate students participated in SBC research. In addition to gaining valuable research experience, many of the undergraduate students earned academic credit or were given monetary compensation. SBC graduate students produced 6 dissertations and 1 group masters thesis in 2007. Graduate student Stu Levenbach received the John A. Knauss Marine Policy Fellowship in January 2007 and was initially placed with the staff for the SenateÆs Commerce Committee. In November 2007, Stu will begin work as the Program Examiner for the National Oceanic and Atmospheric Administration (NOAA) in the Office of Management and Budget. As an examiner for NOAA, he will review the agencyÆs annual budget request and help decide the level of funding that is referred to Congress as part of the PresidentÆs budget. In addition to budgetary responsibilities, the examiner performs in-depth program evaluations, reviews proposed regulations, approves agency testimony, and analyzes pending legislation. In essence the examiner is a ôone stop shopö within OMB and is often called upon to provide analysis for the Executive Office of the President.

Our project's research also finds its way into the classroom as SBC investigators routinely incorporate activities and findings of SBC-sponsored research into their teaching, thereby extending the project's contributions to the broader student body. Many SBC investigators give guest lectures and class demonstrations on SBC research to university courses. SBC investigators, graduate students and staff work with undergraduate students including interns and honors students and mentor independent research by undergraduates and high school students.

Educational opportunities at SBC are not limited to university students and post docs. Pre-college teachers and non-scientists from the local community routinely participate in our ongoing stream sampling program and gain considerable knowledge on the constituents of runoff and of the processes that influence their abundance.

Increased exposure to the SBC research activities has come by way of the LTER Schoolyard program. In 2007, SBC continued to increase the exposure of SBC research activities to K-12 students and teachers by repeating an exciting new environmental education program for middle school students. The new program brought underrepresented students from inner city Los Angeles to Santa Barbara-area sites for residential environmental education programs including field trips, an educational cruise and individual research projects

The Santa Barbara Coastal (SBC) LTER outreach, education and training programs benefit from a close association with the University of California at Santa BarbaraÆs Research Experience & Education Facility, better known as the REEF, an interactive aquarium facility. The REEF is equipped with state-of-the-art, aquaria and touch tanks, ranging from 2 to 2,000 gallons. The REEF also utilizes a high-tech life support system for the Research Tank, which highlights current, on-going research at UCSB and the Marine Science Institute, including SBC-LTER research. This program reaches thousands of students annually.

SBC-LTER is hosting a SEEDS field trip for 24 undergraduate students from throughout the US and its surrounding territories in October 2007. SEEDS is an education program of the Ecological Society of America whose goal is to diversify and advance the profession of

ecology by providing opportunities that stimulate and nurture the interest of underrepresented students. Focused at the undergraduate level, opportunities sponsored by the program include student field trips such as the one to SBC in October 2007.

**Contributions to Resources for Research and Education:**

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

Information Resources
SBC's web site contributes to information resources by providing the scientific community and the general public access to unique datasets that are of interest to a diverse array of people. Some examples of such datasets include: historical data on giant kelp abundance in the northeast Pacific, SST imagery from NOAA-AVHRR polar orbiters of the Santa Barbara Channel, high frequency radar data of surface currents in the Santa Barbara Channel, precipitation data and soil mapping and land-use coverage of the Santa Ynez Mountains. In 2007 access and format of these datasets were enhanced on our website which was redesigned to fit LTER network standards.

**Contributions Beyond Science and Engineering:**

SBC investigators have been very active in applying their knowledge of Santa Barbara's coastal ecosystems to inform and implement changes in local and regional policies. SBC 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.

Investigator Gaines serves on several committees and advisory groups concerned with fisheries and marine conservation including the Science Advisory Panel for the California Marine Life Protection Act, the advisory board for the California Oiled Wildlife Care Network, the Science Advisory Group for the Interagency Ecological Program of the California Department of Water Resources, the Marine Life Protection Act Baseline Science Management Panel and the University of California Marine Council. He is also a science advisor for the Joint Ocean Commission. He made numerous presentations to policy and agency groups this year including a talk entitled ôMarket Based Solutions to Fisheries Challengesö to the National Press Club, Washington DC in March 2007 and ôScience Guidelines for the Design of Marine Reserve Networksö to the MLPA Science Advisory Team in San Francisco in July 2007. He also spoke to the Gordon and Betty Moore Foundation Board on Unique Features of the Channel Islands during their May 2007 board retreat.

Investigators Reed and Page work with the staff of the California Coastal Commission (CCC) on a large multidimensional 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 PageÆs primary responsibilities are to consult with the employees of the power plant (Southern California Edison), the CCC and their staff, and other resource agencies on ecological issues relating to the design of the mitigation projects and to develop and implement monitoring programs capable of determining whether the biological and physical performance of these projects meet pre-determined standards. Much of the science done on these mitigation projects is quite complementary to that done by SBC LTER and there is considerable exchange of information and ideas between the two projects.

SBC research plays a prominent role in shaping policy towards local watershed issues as well. We have developed mutually beneficial, cooperative associations with local government departments and NGOs. Santa Barbara County's Project Clean Water is

engaged in sampling local creeks during the initial rise of the hydrograph and measuring a suite of pollutants including metals, pesticides and herbicides. Our intensive sampling of nutrients and particulates during the entire hydrograph for most storms complements the County's effort, and they and we share our data and interpretations. The Santa Barbara Channel Keepers conduct monthly collections along the Ventura River, and we participate in this fieldwork and complement their in situ measurements with high quality nutrient chemistry. Al Leydecker, a SBC post doc, continued to assist and help direct stream and river monitoring, education and sampling programs for several community environmental organizations including Santa Barbara Channel Keeper, Isla Vista Surf Rider and Ventura Surf Rider in 2007.

Investigator Melack serves on the Water Quality Committee (Hydrology Section) of the American Geophysical Union. He is also on the Standard Methods Committee of the American Water Works Association and the Technical Advisory Committee for Friends of Santa Clara River water quality monitoring program. In addition he was a consultant to Tetra Tech for development of water quality criteria called ænutrient numeric endpoints for TMDL developmentÆ. He also served as advisor for a Bren School Masters of Environmental Science and Management group project on runoff reduction for Santa Barbara Channel Keepers and Santa Barbara County (Clients).

Investigator Schimel is a member of the Kearney Foundation of Soil Science Advisory Committee and Chair of the Arctic System Science Steering Committee (Arctic Consortium of the US).

Investigator Washburn made a presentation to the Montecito Sanitation District Board on the local physical oceanography and its implications on the Montecito municipal waste outfall.

The California Coastal Commission is considering revising current policies on the practice of beach grooming and has sought consultation from Investigator Dugan on the ecological impacts associated with beach grooming. Dugan also provided input to the California State Ocean Protection Council on threats to beach ecosystems with respect to climate change and coastal development.

## Special Requirements

**Special reporting requirements:** None
**Change in Objectives or Scope:** None
**Unobligated funds:** $ 0.00

**Animal, Human Subjects, Biohazards:** None

## Categories for which nothing is reported:

## RESEARCH ACTIVITIES

### REEF STUDIES

*Kelp forest community dynamics*

The primary objectives of our long-term kelp forest monitoring are to: (1) determine patterns of regional variability in the structure and dynamics of kelp forest communities over short and long temporal scales, and (2) obtain data for assessing population and community level responses to variation in the magnitude and composition of terrestrial and oceanic inputs to coastal reefs. To achieve these objectives we initiated an annual kelp forest monitoring program in the summer of 2000 (the first year of our project) in which the abundance of kelp forest plants and animals are recorded along permanent transects at three sites located along the mainland coast in the Santa Barbara Channel at varying distances from sources of terrestrial runoff. Six additional mainland sites were added in the summer of 2001, and two sites at Santa Cruz Island were added in the summer of 2004. Two to eight 40 m long transects were installed at each site. The transects are marked with metal stakes fastened to the bottom at eight meter intervals. The abundance of relatively large solitary algae (e.g., kelps), invertebrates, and cryptic species of bottom-dwelling reef fish are counted in a 1 m wide area on both sides of each 40 m transect. Smaller species (and smaller individuals of large species) of algae, and invertebrates are counted in six permanently placed 1 $m^2$ quadrats that are located at eight meter intervals along each transect. The percentage cover of understory algae, sessile invertebrates, and various substrate types is determined along each transect by recording the biota and substrate intersecting an imaginary perpendicular line positioned at 1 m intervals located 0.5 m on both sides of each transect (n = 80 points per transect). The abundance and size of mobile reef fish are sampled on the bottom in a 2 m wide and 2 m high corridor along each transect. Sampling of all sites is done once per year in the summer (late July), with the exception of mobile reef fish which are sampled every time a site is visited (sampling frequency ranges between 2 to 20 times per year). Tidbit temperature loggers are positioned on the bottom at each site and sample at a frequency of once every 15 minutes.

We also continue to sample 11 reefs at Santa Cruz Island as part of a pre-SBC LTER ongoing effort. The goal of this component of our research is to assess abundances of certain demersal fish and their benthic crustacean food, and ascertain the state of each reef (forested by giant kelp and/or by understory algae, urchin barren, etc.). These reefs have been sampled yearly (or more often) since 1982, as part of ongoing research by Russell Schmitt and Sally Holbrook. At each reef, six key species of demersal fish are counted by divers along permanent 2 meter wide transects at depths of 3m, 6m, and 9m. Random point contact line transects are used to assess the composition of benthic substrates (rock, sand, and species of algae or invertebrate) along the band transects. Benthic samples are removed from 0.1$m^2$ quadrats, brought to the lab and processed to obtain counts and size structure of crustaceans and other invertebrates as well as species composition and biomass of algae. Adding two of these 11 sites to our core kelp forest monitoring program in the summer of 2004 allows us integrate the long-term nature of the Santa Cruz Island study with the more taxonomically comprehensive sampling of our mainland sites. Collectively, these data afford a rich opportunity to track long-term changes in these reef communities, and relate observed variation to large scale physical and biotic processes that occur in the Southern California Bight.

In 2002 we completed a field guide to the common kelp forest algae and invertebrates of the SBC LTER that contains photographs, key characteristics and habits of all the species sampled in our kelp forest monitoring program. During 2006 we produced the 3$^{rd}$ edition of the field guide which was expanded to include reef fish and nearshore marine mammals. This document is used to train students, staff and PIs in the identification of the species that are being monitored on the project, and helps to ensure quality control of the data being collected. It is available to the public at large on the SBC website, where it serves as a useful tool in describing the marine fauna and flora of the SBC LTER.

*Regional studies of giant kelp abundance*

ISP Alginates (formerly Kelco Co.) has collected information on the biomass of giant kelp in California and Mexico from routine (approximately monthly) aerial surveys since 1958. A standard protocol is used by an observer in a small fixed-wing aircraft to visually estimate the harvestable tonnage of giant kelp biomass for 109 designated kelp beds. Observations are recorded on data sheets and archived in notebooks housed at ISP Alginates. .In the summer of 2000 ISP Alginates provided us with copies of all their archived records. We used these records to create a digital database on the historical abundance of giant kelp throughout its range in California and Mexico. Quality control on this database was completed in 2001 and maps and other descriptive information on the kelp beds of Central, Southern, and Baja California

were added to the database in 2002. ISP alginates ceased operations in California in 2006 after more than fifty years of harvesting kelp. Mr. Dale Glantz, who performed the kelp surveys for ISP Alginates for the last 25 years, is continuing to conduct aerial kelp surveys and SBC LTER has entered into an agreement with him to purchase kelp data from these flights. All data and metadata are available on the SBC website at http://sbc.lternet.edu/data/research/reef/historical-kelp-data/. This database enables us to more easily evaluate long-term trends in the abundance of giant kelp and allows us to place our observations of kelp abundance within SBC into a much broader regional perspective.

We have also begun exploring regional dynamics of giant kelp using SPOT high spatial resolution (10 & 20 m) multispectral satellite imagery. UCSB was recently designated as a SPOT imagery research center, giving UCSB students and researchers nearly unlimited, nearly free access to SPOT imagery and the ability to acquire new scenes (details at http://www.spot.ucsb.edu). Recently we developed a robust method for delineating kelp-covered pixels by using a near-infrared to green band ratio in multispectral SPOT imagery. In 2007 SBC Investigators Siegel, Zimmerman and Gaines obtained funding from NASA for a collaborative project with SBC LTER that integrates kelp data from SPOT imagery and SBC diver surveys with physiological and population modeling with the goal of producing spatially explicit forecasts of kelp forest ecosystem responses to a suite of regional scenarios representing the range of anticipated changes in climate and human activities.

*Primary production of giant kelp forest ecosystems*

In 2001 we initiated field studies designed to examine long-term spatial and temporal patterns of variation in the net primary production (NPP) of the giant kelp *Macrocystis pyrifera* and the factors that control them. *Macrocystis* is the largest alga in the world and it is believed to be one of the most productive organisms on earth. A single individual can be more than 30 m tall and consist of over a 100 fronds. Plants may live up to four to six years, while individual fronds live about 3-5 months. In May 2002 we refined the methodology that we use to estimate changes in standing crop. The current methodology consists of estimating the standing crop of giant kelp monthly in fixed plots at three sites (Mohawk Reef, Arroyo Burro, and Arroyo Quemado) from diver measurements of the density and length of all fronds > 1 m tall. Allometric equations are used to convert these measurements into an estimate of the total length of all fronds in the water column and surface canopy portions of each plant and relationships generated from length and weight measurements of 55 adult *M. pyrifera* collected from our study sites are used to convert field estimates of total length to total wet weight. The wet weight of each plant is converted to dry weight, carbon weight and nitrogen weight based on the analyses of blades collected from 10 to 15 plants at each site during each monthly survey. Independent instantaneous loss rates for entire plants and for fronds on surviving plants each month from 10 to 15 tagged plants at each site. Using our estimates of the standing crop at the beginning and end of each sampling interval ($S_0$, $S_t$) and the loss rate ($l$) during the sampling interval we calculate the average growth rate $g$ of *M. pyrifera* as:

$$g = \frac{1}{T}\ln(\frac{S_t}{S_0}) + l$$

where $T$ is the number of days in the sampling interval. This exponential model implies that NPP at any moment is the product of $g$ and $S$. By assuming that growth is constant over the period and expressing $S$ at any time $t$ as a function of initial FSC, growth rate, and loss rate ( $S_t = S_0 e^{(g-l)t}$ ) we estimate daily NPP for each sampling interval by integrating instantaneous NPP over the interval and dividing by $T$:

$$NPP = \int_0^T g S_t dt$$

Seasonal NPP and seasonal growth rate of *M. pyrifera* are calculated as the mean NPP and mean growth rate for all days in the season.

We have been exploring the physical, chemical and biological factors controlling growth and NNP in giant kelp using regression analyses. Seawater temperature and nutrient concentration and physical disturbance from waves and standing crop are currently the focus of these investigations.

The methodology outlined above is quite labor intensive and difficult to apply over a broad region. With collaborative funding from the Center for Integrative Coastal Observations, Research and Education (CICORE) SBC investigator R. Zimmerman has been developing algorithms to evaluate the condition and

estimate the productivity, of giant kelp canopies along the California coast based on the analysis of PHILLS and SAMSON hyperspectral imagery. The consistent optical signature of the kelp canopy produces a Blade Area Index (BAI, identical to Leaf Area Index used in terrestrial vegetation studies) that is linearly related to SBC LTER diver measurements of kelp abundance (Figure 1a). The slope (0.1) indicates that the canopy structure exerts a strong package effect on the optical efficiency of light absorption. The ability to predict BAI allows retrieval of standing biomass and productivity from measurements of below-canopy irradiance and above canopy reflectance. Estimates of kelp blade area can be linearly related to standing biomass and daily productivity (Figures 1b and 1c).

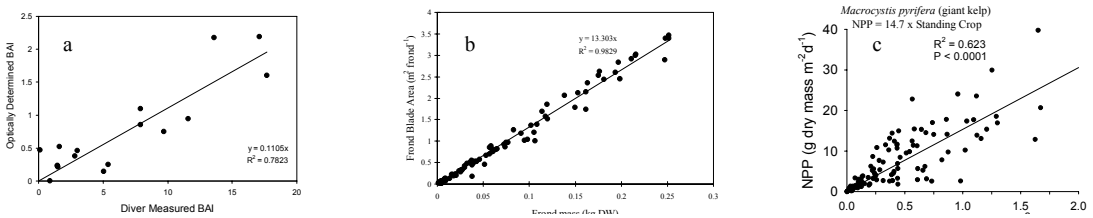


Figure 1. Relationships between (a) optical and direct diver-made counts of kelp blade area index, (b) frond mass and blade area per frond, and (c) kelp standing crop and net primary productivity.

The strong reflectance signal in the NIR allows absolute kelp abundance and productivity to be calculated and mapped across the habitat from remotely sensed hyperspectral imagery using the normalized difference vegetation index (NDVI). Knowledge of kelp blade optical properties (data not shown here), combined with linear regression of the relationships illustrated in Fig. Z provide a quantitative link between the remotely sensed reflectance signals from giant kelp canopies detected by the hyperspectral imager, optically determined NDVI, kelp blade area, standing crop and productivity.

Production of benthic macroalgae in the kelp forest understory, and of phytoplankton in the water column, may be affected by shading, flow attenuation, and other factors influenced by the primary canopy of Macrocystis. Since these factors, particularly shading, negatively affect understory algae and phytoplankton, the relative importance of primary production of these ecosystem components may be inversely related to that of giant kelp, potentially complementing it in space and time. Beginning in June 2006, we developed and refined a method of in-situ measurement of understory algal production by measuring oxygen evolution in closed chambers. The chambers are built of acrylic and Tefzel plastic, with electric pumps driving water circulation, and an optical probe with logger that records dissolved oxygen concentration and temperature once per minute. Light and dark incubations provide estimates of production and respiration, respectively, and the algae inside the chamber are harvested for biomass measurement. In 2006 we used this method to estimate production of two important understory assemblages, red algal turf and foliose red algae, at one of our long-term monitoring sites, Naples Reef. In 2007, we began using the method to measure understory production inside and outside the kelp forest at one of our monthly kelp production sites, Mohawk Reef. We are also measuring phytoplankton production monthly, inside and outside the kelp forest at the same site, using light and dark bottle incubations with $^{13}C$-labeled bicarbonate as a tracer. The overarching goal is to address the question: How does the negative effect of giant kelp on understory algae and phytoplankton interact with wave disturbance and N loading to affect the magnitude and interannual variability of NPP of the kelp forest ecosystem?

We have begun assembling components for a bio-optical model of understory algae production with the goal of modeling understory production inside and outside the kelp forest at our monthly kelp production sites (Mohawk Reef, Arroyo Burro, Arroyo Quemado) based on the standing crop of understory algae and amount of light available to them. Three key components of this model are 1) Spatially detailed and high-frequency photosynthetically active radiation (PAR) data 2) monthly estimates of understory biomass and 3) Photosynthesis vs. irradiance (P/E) curves describing species-specific responses of algae to the spectrum of available PAR. In June we deployed PAR loggers inside and outside the kelp forest at Mohawk Reef, logging PAR data every 2 minutes. We plan to deploy identical PAR loggers at the remaining monthly sites in late August. To estimate understory biomass for 2 species of dominant understory kelps, *Laminaria farlowii* and *Pterygophora californica*, we have developed relationships between plant allometry and biomass to enable non-destructive estimation of biomass at our monthly primary production sites. For the remaining components of the understory algae community, we are

developing a relationship between percent cover and biomass of dominant species by measuring percent cover in field quadrats, harvesting the quadrats, and measuring biomass in the lab. We are currently developing a laboratory setup to measure P/E curves for dominant understory species. The results from this model will be compared with the benthic chamber results, and could be used to extend these measurements into a long-term fine-scale dataset that would be logistically impossible otherwise.

*Gene flow, inbreeding depression and population connectivity in giant kelp*

Our prior NSF funded research examined the population dynamics of giant kelp (*Macrocystis pyrifera*) forests in southern California from a metapopulation perspective taking into account rates of colonization, extinction, and occupancy of discrete kelp patches, and the degree of connectivity (via spore dispersal) among them, and inbreeding depression (Raimondi et al. 2004, Reed et al. 2006, Gaylord et al. 2007). Our estimates of connectivity and rates of self-fertilization were based on empirical measurements from experimental populations, and physical modeling. Confirmation of our estimates of connectivity and inbreeding is best done using genetic analyses. With NSF funds we developed a molecular library for *Macrocystis* with greater than 90% polymorphism. In collaboration with Drs. Filipe Alberto and Ester Serrao from the Centre of Marine and Environmental Research (CMER) at the Universidade do Algarve, Portugal we are using this library to develop microsatellites that can be used to evaluate levels of connectivity and self-fertilization in giant kelp. With funding from Portugal, Alberto visited UCSB in summer 2006 to collaborate with us in developing a sampling protocol that would enable us to examine the genetic structure and dynamics of kelp populations in the Southern California Bight and elsewhere in the world. During his stay we used this sampling protocol to obtain kelp samples from each of our nine mainland long-term study sites. The samples were processed in our laboratory and the genetic analyses are being done in Dr. Alberto's laboratory at CMER. Alberto returned to UCSB in summer 2007 to work with us in interpreting the results of his genetic analyses and to collect additional samples that would provide further insight into the spatial patterns of genetic relatedness within and among kelp forests in the Santa Barbara Channel.

*Biological and physical coupling within giant kelp forests*

Currents impinging on the kelp forest transport nutrients, plankton and organic carbon that can substantially subsidize the kelp community. The kelp forest in turn modifies the flow around and within its boundaries, and forest producers and consumers alter the flux of nutrients and particulates within the forest. With collaborative funding from the University of California's Coastal Environmental Quality Initiative SBC investigators Gaylord, Brzezinski, Carlson, Holbrook, McIntyre, and Reed have been investigating the linkages between hydrodynamics and kelp forest function with a specific focus on determining: (1) the degree to which impinging flows enter the forest as opposed to being diverted around it, (2) rates of consumption and production of waterborne subsidies (i.e., nutrients, POM, DOM) by kelp forests, (3) the interaction of nutrients, light, and flow in determining kelp growth, and (4) the implications of forest-flow interactions for forest-dwelling suspension feeding invertebrates. Our efforts in this endeavor employ extensive measurements of flow and kelp forest community structure, geochemical and biochemical analyses, and experimental manipulations in exploiting a breadth of expertise in hydrodynamics, marine ecology, biological oceanography, and algal physiology.

SBC LTER is also actively collaborating with an NSF-funded project examining the ecomechanics of flexible marine organisms. This project (led by Brian Gaylord) is focusing on understanding the details of how important habitat-forming species like giant kelp interact with waves and currents, and how aspects of their mechanical design drive patterns of kelp mortality (via dislodgement) and subsequent population dynamics, which profoundly influence net primary production and trophic interactions of kelp forests. This research is largely being done at one of our kelp primary production sites (Mohawk Reef) and SBC LTER personnel and boats are actively involved in the collection of data for this project.

*Food web studies using stable isotope*

Potentially important food sources to primary consumers on shallow subtidal reefs include phytoplankton, macroalgae, and terrestrially-derived POM. We are using stable carbon and nitrogen isotope ratio analysis of producers and consumers of varying trophic status to evaluate the relative contribution of these sources to reef food webs. Our efforts thus far have focused on characterizing variability in the stable C and N isotope values of potential food sources (phytoplankton, giant kelp, understory algae and terrestrial POM)

and of different types of consumers on reefs that vary in their influence of freshwater runoff and in the biomass of giant kelp.

*Kelp subsides to sandy beach communities*

Kelp forests export large subsidies of drift macrophytes (>450 kg $m^{-1}$ $y^{-1}$) to sandy beach food webs in the SBC LTER. These subsidies are key resources for the beach food web supporting large numbers and a high diversity of consumers. With collaborative support from the State of California's Office of Oil Spill Prevention and Response, we have conducted field experiments on two spatial scales to investigate the responses of infaunal wrack-dependent macroinvertebrates to macrophyte subsidies from coastal reefs using kelp wrack additions to beach habitats. These data will be used in developing methods for recovery of beach ecosystems following oil spills and cleanup activities. Sample processing in the laboratory is ongoing for these experiments. We continued our research on nutrient cycling associated with the delivery and processing of drift macroalgae on a range of sandy beaches of the SBC-LTER coast by processing samples collected in 2003-2006 for DOC and DON. This effort is still ongoing with some analytical challenges to meet, including a lack of complete oxidation in pore water samples with very high ammonia concentrations as is typical of some of the study beaches.

OCEAN STUDIES

Three permanent reef sites are being monitored through a combination of sampling from small boats, instrumented moorings, and satellite imagery to provide baseline data for focused studies taking place within and the kelp forests and their surrounding waters of the Santa Barbara Channel. A primary objective for collecting these observations is to understand the inherent natural variability in the oceanographic conditions in this region, which is needed to detect sudden shifts or ongoing directional changes in climate and ocean properties that affect the structure and function of kelp forest ecosystems. The oceanographic conditions of primary interest to us include the sources and fluxes of nutrients to macrophytes in the kelp forest, the character and flux of particulate material that fuels the diverse assemblage of kelp forest suspension feeders, and the prevalence and consequences of freshwater plumes in kelp forests. During the past year budgetary constraints have caused us to adjust the level of oceanographic sampling done at our reef sites and to suspend basin wide surveys of oceanographic conditions and processes across the Santa Barbara Channel, although analyses of data from past cruises is currently underway.

*Moored instruments and monthly sampling*

We conduct monthly sampling of water properties from our 22' research vessel at Arroyo Quemado, Arroyo Burro and Mohawk, which are the three reef sites where we collect monthly measurements of giant kelp biomass and primary production. Monthly water sampling at two other sites (Carpinteria and Naples Reef) was discontinued in 2006 due to budgetary constraints. Water samples are collected from the surface down to 10 m adjacent to the offshore edge of the kelp forests at each site and in the interior of the kelp forests at Arroyo Quemado and Mohawk. Samples are analyzed for nitrate, silicate, ammonium and phosphate, particulate organic carbon, particular organic nitrogen, and chlorophyll concentration. Sampling for carbon and nitrogen isotopes in suspended particulates reported in previous years has been suspended for the time being. All water samples are filtered within hours of collection and stored frozen for analysis in the Marine Science Institute Analytical Laboratory at UCSB. During each sampling period a CTD equipped with a fluorometer and transmissometer is lowered at each station and data on temperature, salinity, chlorophyll fluorescence, and suspended sediments are recorded throughout the water column.

We continued to maintain long-term instrumented moorings at Carpinteria, Naples Reef, Arroyo Quemado, and Mohawk .in water depths ranging from 7 to 13 m. These moorings are equipped with sensors that allow us to sample conductivity, temperature, and depth more frequently (i.e., once every minutes) and over a wider range of ocean conditions than can be achieved using small boats. This is especially important during storm events and high winds when sampling from boats is not possible. High rates of bio-fouling and budgetary constraints have caused us to discontinue the deployment of fluorometers and backscatter sensors on these moorings. An Acoustic Doppler Current Profiler (ADCP) is deployed on the bottom adjacent to each mooring to measure vertical profiles of current velocity throughout the water column. Bottom temperature is also measured by the ADCPs. We also maintain an instrument package near the surface below mean lower low water on Stearns Wharf near downtown Santa Barbara, which consists of an array of sensors that measure conductivity, temperature, depth, chlorophyll fluorescence, and bio-luminescence. The maintenance of this instrument package is a collaborative effort

among SBC-LTER, the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO), and the Southern California Coastal Ocean Observing Systems (SCCOOS) and the data collected from it are publicly available in near-real time on our website at http://sbcdata.lternet.edu/data/stearns_wharf/index.php.

*Regional Surface Current Patterns*

With collaborative funding from several other projects LTER Investigator Libe Washburn has been operating an array of three to five high frequency (HF) radars on land boarding the Santa Barbara Channel to map the regional surface ocean circulation. These data provide an important link between synoptic circulation patterns in the channel and sub-surface property fields observed by moored instruments and ship board instrumentation. Currently there are five HF radars in operation, the latest on Santa Cruz Island. We are working to get additional sites to improve coverage in the SBC LTER study region. These include sites at: Vandenberg Air Force Base, Gaviota, Nicolas Canyon, San Nicolas Island, Point Arguello, and Point Mugu. Emery et al. 2004 describe an earlier configuration of the array and its performance in more detail. SBC LTER investigators have used surface current data from HF radars to examine a variety of phsyical and biological processes in the Santa Barbara Channel including the formation of small eddies, coastal trapped waves, larval fish distributions, and basin-wide circulation (e.g., Beckenbach and Washburn, 2004; Nishimoto and Washburn, 2002; Bassin et al. 2005; Anderson et al. 2007). Ongoing studies utilizing HF radar data are examining the effects of eddies on phytoplankton primary production, larval transport, and the propagating response of inner shelf circulation due to wind relaxation events, which may serve as an important trigger for poleward flows that connect kelp habitats in the Southern California Bight with kelp beds along the central California coast

*Cross Shelf Processes*

During the past year, we made substantial progress on a research campaign designed to improve our understand cross-shelf processes in the Santa Barbara Channel that transport materials to and from kelp forests. Much of our efforts on this topic focused on analyzing data from the sixteen SBC-LTER cruises in the Santa Barbara Channel conducted during 2000-2006. Data analysis procedures were employed to visualize and quantify sub-surface property distributions obtained from the extensive suite of shipboard, moored, and land-based instrumentation. Particular attention was given to processing acoustic Doppler current profiler (ADCP) data, which are critical for understanding the role of ocean currents in structuring density, nutrient, and phytoplankton distributions offshore of the kelp forests. Substantial progress was also made on interpreting patterns of phytoplankton primary productivity obtained during the cruises.

*Satellite Data*

Local area coverage SeaWiFS ocean color and AVHRR thermal imagery have been collected and analyzed as part of the SBC-LTER program. This provides 1-km scale synoptic views of ocean chlorophyll concentrations and sea surface temperature over the entire Santa Barbara Channel. Co-registered five-day composite fields for SST and chlorophyll concentration are created on a routine basis for the Santa Barbara Channel. All imagery is hand navigated and de-clouded (see http://www.icess.ucsb.edu/avhrr & http://www.icess.ucsb.edu/~fields/wifsTest for example imagery).

WATERSHED STUDIES

*Runoff, stream chemistry and fluxes*

Fluvial transport and processing of nutrients, organic matter, and sediment are the primary means by which land masses influence coastal ecosystems. The volume and geophysical/chemical properties of runoff are determined by the amount and pattern of rainfall, terrain, lithology, land use, vegetation, and perturbations to the watershed and adjoining estuary. As part of our long-term monitoring we have established stream gauging stations throughout the SBC LTER study region where stream stage and water temperature are recorded every five minutes throughout the year. To convert our measured stage values to discharge, we develop rating curves by measuring channel cross-sections and roughness to characterize the channel reaches, and then use the HEC-RAS (stream flow hydraulics) program. The dynamics of stream channels requires these rating tables be updated periodically with revised channel surveys and verified field measurements of stage and discharge. In addition to stream stage and temperature, we have installed three transducers that record conductivity. Continuous (5-min) conductivity data help discern the various sources (surface, soil and groundwater) of runoff contributing to storm hydrographs. To understand and

model the rainfall-runoff processes we have established a rainfall gauge network consisting of 12 sites with rainfall gauges. Gauges at five of our most remote sites are also equipped with spread spectrum telemetry.

On a weekly to bi-weekly and storm (hourly for rising limb and at 2-4 hour intervals on falling limb) basis, water samples from streams are collected and all or a subset are analyzed for (a) nitrate, ammonium, total dissolved nitrogen, and particulate nitrogen; (b) soluble reactive phosphorus, total dissolved phosphorus and particulate phosphorus; (c) particulate organic carbon; (d) total suspended sediments; and (e) conductivity.

The locations where samples for chemical analyses have been obtained have changed during the course of our studies. During the last year regular sampling was conducted at Gaviota, San Onofre (to follow post fire recovery), Arroyo Hondo, Refugio, Bell Canyon, Devereux, Atascadero, Rattlesnake and Mission. Additions to our regular hydrological sampling include:

- In collaboration with Channel Islands National Park, we have surveyed streams on Santa Rosa Island for chemical conditions, bacteria and macroinvertebrates.
- In collaboration with Santa Barbara Channelkeepers, we have conducted monthly sampling at a series of stations throughout the Ventura River catchment.
- In collaboration with the Friends of the Santa Clara River, we have conducted monthly sampling at a series of stations throughout the Santa Clara River catchment.
- In collaboration with the City of Santa Barbara, we have performed analyses of nutrients for quarterly samples in creeks within the City.

*Estuarine studies*

Studies of Carpinteria salt marsh, partly funded by NASA, combined remote sensing and ground-based methods to determine the vegetation patterns and to generate a digital elevation model, which was combined with stage measurements to calculate inundation dynamics and permit estimation of tidal exchanges with the coastal ocean. PhD student Darcie Goodman's ecological studies of Devereux Slough include measurements of nutrient loading from its catchment, vertical profiles of temperature, salinity and dissolved oxygen, transparency, bathymetry, and water levels as well as monitoring of macroinvertebrate, fish, vegetation and bird species assemblages.

*Stream ecology studies*

Two studies of stream ecology were completed: (1) The biotic effects of introduced crayfish were investigated as part of the PhD research of Kristie Klose. Her study used an experimental approach to delineate the effects of a widespread exotic species, the crayfish (*Procambarus clarkii*), on benthic invertebrates and primary producers in the Santa Ynez and Ventura Rivers. (2) As part of Juliet Simpson's PhD research, the effects of nutrients on species composition and biomass of benthic and floating algae and aquatic plants in coastal streams and rivers was investigated.

SBC investigators have been collaborating with several agencies and NGOs on a variety of conservation issues pertaining to watersheds in the SBC region. Tom Dudley has been working with Stillwater Sciences and the California Coastal Conservancy in characterizing floodplain vegetation in the Santa Clara River to determine conservation and restoration needs, including management of non-indigenous invasive species. The primary species of management concern is *Arundo donax* (giant reed), the dominant riparian species in much of the watershed. The presence and impacts of several specialist herbivores are being examined as part of a study to develop a biological control program against *Arundo.* Anadromous runs of steelhead trout are a high conservation priority and studies for California Fish & Game of smolt growth and survival in both the Santa Clara and Santa Ynez rivers are underway. Dudley is also working with the University of California Co-Operative Extension program to develop a monitoring plan for detecting expansion of New Zealand Mud Snail in Piru Creek, a major tributary to the Santa Clara River.

One of the oldest and richest questions in ecology is that of how species diversity relates to biological productivity. Historically, researchers have viewed differences in biodiversity among communities or ecoregions as being a consequence of differences in levels of productivity. In recent years, ecologists have begun to view the relationship between diversity and productivity from a fundamentally different angle, examining how biodiversity controls, rather than simply responds to, the production of biomass in ecosystems. These contrasting perspectives have led to nearly a decade of debate - Is biodiversity the cause or the consequence of productivity? In the summer of 2006 we performed an experiment to clarify how species diversity and productivity can simultaneously influence one another. We

hypothesized that the 'productivity-drives-diversity' and 'diversity-drives-productivity' perspectives can be unified by carefully distinguishing between three causal pathways that operate concurrently to influence biomass production: (1) a direct effect of nutrient supply on productivity, (2) a direct effect of species richness on productivity, and (3) an indirect effect of nutrient supply on production that is mediated through its control over species richness. This set of pathways postulates that nutrient supply rate places an upper bound on the number of species that can locally coexist, but the number of coexisting species ultimately determines how efficiently resources are utilized and converted into new biomass. To test this prediction, we used nutrient diffusing substrates to manipulate the supply rate of nitrate and phosphate by 6-orders of magnitude in 12 streams in the Santa Barbara Costal and Santa Ynez watersheds. These streams were chosen to span a gradient in algal species richness (33-89 species) that accompanies gradients in eutrophication previously established by LTER studies of stream nutrient dynamics. After allowing substrates to colonize with algae for six weeks, we measured species diversity and rates of 1º production on each substrate. The identification and counts of 75+ samples of algae were completed in July 2007, and we just beginning to analyze the data.

### Information Management

The primary objective of the SBC LTER IM system is to facilitate research and outreach efforts by focusing on data organization and integrity, ease of access, and long-term preservation. We maintain an open, cross-platform system that is based on Internet standards, leveraging existing systems where possible, and building new tools geared toward collaboration and integration between data collection and publication. The SBC LTER IM system is integrated with other research groups at MSI, particularly Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) and the Moorea Coral Reef LTER (MCR LTER) since these groups share several scientists and sampling protocols.

SBC has been closely involved with the recent installation of an information management system for the MCR LTER (also at MSI/UCSB), and in development of scripted processing methods which are of use to several groups of local researchers. SBC is also well-represented in the activities of the LTER Information Managers Committee (IMC). Since SBC has adopted community-vetted components for its IM system, its products are well suited to deployment elsewhere in the ecological informatics community.

### LTER Network and Synergistic Activities

As a lead PI Reed serves on the LTER Science Council. He is also member of the LTER Executive Board, Publications Committee, and the Writing Team which produced the LTER Strategic Plan. Reed along with investigators John Melack and Brad Cardinale were members of the LTER Network Planning Committee and active in the LTER Network's Planning Grant process. Melack also organized a special session on NSF's Long-term Ecological Research Program for the AGU Meeting in December 2006. Investigator Libe Washburn serves on the LTER Network Information Systems Advisory Committee (NISAC). SBC Information Manager Margaret O'Brien is extremely active in the LTER Network 's information management arena. She serves on the Executive committee of the LTER Network's IM committee. She is currently involved in the following IM working groups and activities: (1) a Network-level working group on quality control which held a workshop in winter 2007, (2) Units working group responsible for establishing a collection of vetted measurement units which can be consulted by sites during metadata creation, (3) Controlled Vocabulary working group that evaluates the usefulness of keyword thesauri for browsing and querying metadata, (4) IM committee meeting logistics coordinator, (5) editor of the metadata section of the IM Committee's website which facilitates content, recommendations and discussions regarding metadata standards and implementation, and (6) member of the EML Project Committee, which is a national-level informatics group that oversees the development and maintenance of the EML schema.

### Presentations

*2006*

Schimel, J. P. 2006. The role of microbial stress responses in regulating ecosystem-level responses to episodic pulse weather events. American Geophysical Union Annual Meeting Symposium: "Impact of Climate Variability and Extreme Weather on Ecosystem Structure and Function Across Spatiotemporal Scales." December 2006.

*2007*

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Anderson, C. R. 2007. Towards the remote detection of toxic diatom blooms. Poster, SBC-LTER Annual Meeting June 2007.

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Arkema, K. 2007. Temporal variability in giant kelp abundance influences benthic community structure. Poster, SBC-LTER Annual Meeting, June 2007.

Brzezinski, M.A, L. Washburn, and D.A. Siegel. 2007. Physical drivers of spatial patterns in phytoplankton primary productivity in the Santa Barbara Channel, USA, Aquatic Sciences Meeting, 4-9 February, Santa Fe, NM.

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Cavanaugh, K. 2007. Remote Sensing of Giant Kelp Forests in the Santa Barbara Channel using SPOT Imagery"-Poster, SBC Annual Meeting, June 2007.

Chaffey, T. F.; Mitarai, S.; Siegel, D. A.2007: A description of the effects of headlands on marine larval dispersal using computational models. Poster, ASLO Aquatic Sciences Meeting, Santa Fe, NM, February 7, 2007.

Chaffey, T. 2007. A description of the effects of headlands on marine larval dispersal using computational models. Poster, SBC Annual Meeting, June 2007.

Coombs, S, J. Melack 2007. Export of nutrients after a fire. Poster, SBC-LTER Annual Meeting, June 2007.

Dudley, T., A.M. Lambert, P. Dalin, et al. 2007. Invasive species and riparian ecosystem linkages in the Santa Clara watershed, Santa Barbara County, Poster, SBC-LTER Annual Meeting, June 2007.

Dugan, J., M. Page, D. Hubbard and M. Lastra 2007. Exchanges between kelp forests and sandy beaches: macroalgal wrack input, processing and fate. Poster, SBC-LTER Annual Meeting, June 2007.

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Gaines, S. D. 2007. The Role of Science in California's Marine Life Protection Act, AAAS meetings, February 2007.

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Gaines, S. D. 2007. The Emerging Science of Marine Reserve Networks, UCLA, May 2007.

Gaines, S. D. 2007. The Role of Science in California's Marine Life Protection Act, Arizona State University, June 2007.

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Gaylord, B., D.C. Reed, P.T. Raimondi, and L. Washburn. 2007. Ecomechanics of macroalgal spore dispersal in coastal environments: Insights from theory and experiment. Society of Integrative and Comparative Biology Conference, Phoenix, Arizona, January 2007.

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Kostadinov, T 2007. Coastal Ocean Optics in the Santa Barbara Channel, California. Poster, SBC-LTER Annual Meeting, June 2007.

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Mitirai, S. D. Siegel B, Kendall, R. Warner, S. Gaines, C. Costello, K. Winters 2007. Hydrodynamic Connectivity in Nearshore Marine Population Dynamics Poster, SBC Annual Meeting, June 2007.

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Rassweiler, A. 2007. Filter-feeding leads to thresholds and alternate stable states in communities of space competitors. ESA/SER joint meeting. San Jose, CA, August 2007.

Rassweiler, A. 2007. Filter feeding generates patchiness in systems of marine space competitors Poster, SBC-LTER Annual Meeting, June 2007.

Rassweiler, A., D. Reed, and K. Arkema. 2007. Net primary production of giant kelp. Oral presentation, LTER Science Council Meeting, Portland, OR, May 2007.

Reed, D. 2007. Social - Ecological Interactions in Coastal Marine Ecosystems. LTER/NSF symposium. Washington D.C. March 2007.

Reed, D. 2007. Environmental drivers and biological sources of inter-annual variation in net primary production by giant kelp. Departmental seminar. Bodega Marine Laboratory, UC Davis. 23 May 2007.

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Reed, D. 2007. Social-ecological interactions in the Santa Barbara Coastal region. Guest Lecture, NCEAS, Santa Barbara, CA, September 2007.

Revell, D. 2007. Long Term and Storm Event Changes to the Santa Barbara Sandshed. PhD. Seminar. University of California, Santa Cruz.

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Robinson, M. 2007. Heterogeneous fishing effort and catch: Effects on stocks & yields" Poster, SBC-LTER Annual Meeting, June 2007.

Schimel, J. P. 2007. Linking from microsite microbial processes to catchment biogeochemistry. Gordon Research Conference on Catchment Science: Interactions of Hydrology, Biology & Geochemistry. New London, NH. July 2007.

Schimel, J. P. 2007. Soil structure and chemistry: the mediators between microorganisms and ecosystem function. Keynote address: Workshop– Microscale approaches to macroscale issues in ecology. Washington, D.C., April 2007.

Schimel, J. P. 2007. Regulating denitrification: Regulating denitrification: linking physiology and physics in soil N cycling. Keynote Address: COST 856 Conference– Denitrification: A challenge for Pure and Applied Science. Aberdeen, Scotland. March 2007.

Schimel, J. P. 2007. Microbial function in nature: connecting physiology and physics. Keynote address: EuroDiversity workshop: Microbial Diversity and Ecosystem Functioning. Lunz am See, Austria. March 2007.

Shulman, R. 2007. Effects of press and pulse drivers on kelp forest structure and function. Poster, SBC Annual Meeting, June 2007.

Siegel, D.A., and S. Mitarai, 2007: Mixing and Stirring in Aquatic Ecosystems: A Micro-Review. Invited mini-review 2007 ASLO Aquatic Sciences Meeting, Santa Fe, NM, February 8, 2007.

Siegel, D. A., N. Guillocheau, S. Maritorena, M. Brzezinski, L. Washburn 2007. Plumes and Blooms: seasonal to [nearly] time scale decadal ocean water mass variability in the SB Channel Poster, SBC-LTER Annual Meeting, June 2007.

Siegel, D. A., Costello, C., Gaines, S., R. Hilborn 2007. Flow, Fish & Fishing Biocomplexity Project Poster, SBC-LTER Annual Meeting, June 2007.

Siegel, D. A., S. Gaines, Hill, B. Kinlan, Kyriakidis, D. Reed and D. Zimmerman 2007. NASA Kelp Dynamics Interdisciplinary Science Project Poster, SBC-LTER Annual Meeting, June 2007.

Simon, S. 2007. Poster, "SBC-LTER Watershed Education Program"-SBC-LTER Annual Meeting ‚June 2007.

Stewart, H 2007. Physical-biological interactions in nearshore marine systems Guest Lecture, Marine zoology/botany course, Friday Harbor Labs, University of Washington.

Stewart, H 2007 Biological response of kelp individuals to habitat modification by the bed. North West Algal Symposium.

Stewart, H. 2007 The interplay between seaweed morphology, physiology and performance across barrier reefs and kelp beds Invited seminar, Dept of Botany, University of British Columbia.

Stewart, H. 2007. Growth and physiological response of M. pyrifera to alteration of physical factors in Mohawk kelp bed." Poster, SBC-LTER Annual Meeting, June 2007.
Truesdale-Carney, L. 2007. Delayed development of *Macrocystis* gametophytes. Poster, SBC-LTER Annual Meeting, June 2007.
Verdin, K., E. Beighley, Y. He and Y. Gummadi 2007. Automated Pfafstetter watershed subdivision: an assessment of hydrologic characteristics at varying spatial scales and topographic settings. Poster, SBC-LTER Annual Meeting, June 2007.
Wallner, E and C. Carlson 2007. Distribution and bioavailability of dissolved organic carbon in the Santa Barbara Channel. Poster, SBC-LTER Annual Meeting, June 2007.
Washburn, L., B.M. Emery, K. Laws, J.D. Paduan, 2007, Recent experiments on data procedures, algorithm development, and antenna modifications, using an array of current-measuring radars on the South-Central California Coast, Seventh Radiowave Oceanography Workshop, 28-31 May 2007, Cancun, Mexico.
Washburn L. and M. Brzezinski. 2007. Control of primary production by mesocale features in the Santa Barbara Channel. Poster, SBC Annual Meeting, June 2007.
Watson, J.R., D.A. Siegel, S. Mitarai. 2007: Simulating larval dispersal in the Santa Barbara Channel using different velocity field resolutions with a Lagrangian fluctuating component. Poster ASLO Aquatic Sciences Meeting, Santa Fe, NM, February 7, 2007.
Watson, J.R. 2007. Simulating Larval Dispersal in the Santa Barbara Channel. Poster, SBC Annual Meeting, June 2007.
Zimmerman, D. 2007. Modeling and mapping the productivity of giant kelp. Poster, SBC Annual Meeting, June 2007.

## RESEARCH FINDINGS

### REEF STUDIES

*Kelp forest community dynamics*

Results from our annual subtidal community surveys show that the kelp forest ecosystems in the Santa Barbara Channel are extremely dynamic in both space and time. Site specific differences in the timing and intensity of sea urchin grazing, exposure to wave disturbance and sand accretion caused the abundance of giant kelp at the nine mainland sites to vary asynchronously over time and independently in space. Understory algae and sessile invertebrates also displayed substantial variation among sites and years, which is not surprising given the large fluctuations seen in giant kelp, which is known to influence other components of the kelp forest community. For example, a dense *Macrocystis* canopy can reduce light levels near the bottom inhibiting understory algal recruitment and growth. This in turn may affect the distribution and abundance of sessile invertebrates, which may compete with understory algae for space. These different species interactions are tempered by physical and biological disturbances that indiscriminately reduce the abundance of all algae and sessile invertebrates. Such interactions among giant kelp understory algae and sessile invertebrates are evident from analyses of our long term monitoring data, which show a significant positive relationship between interannual variation in the density of giant kelp and interannual variation in the relative abundance of understory algae and sessile invertebrates (Figure 1). This relationship reflects the substantial heterogeneity in community dynamics present among our permanent transects. Transects characterized by high interannual variation in giant kelp abundance were also locations where the structure of the benthic community was highly variable. Conversely, transects with low interannual variability in giant kelp abundance showed less variation in the relative abundance of understory algae and sessile invertebrates.

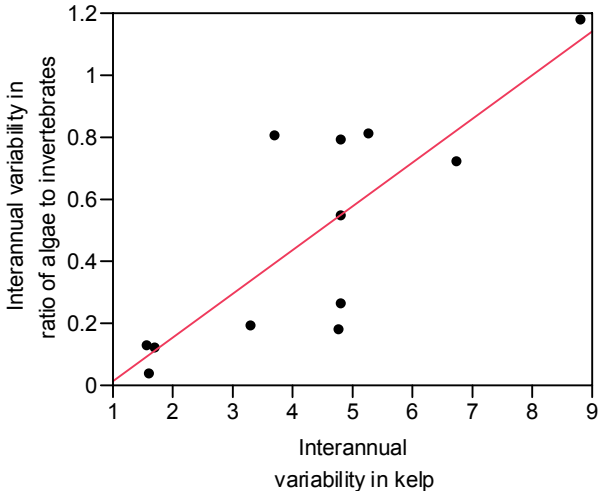



Figure 1. Relationship between interannual variability in the ratio of % cover algae to % cover invertebrates and interannual variability in kelp abundance measured as fronds/$m^2$ ($r^2 = 0.66$, $p<0.0013$). Interannual variability was calculated as the standard deviation in the abundance of kelp and ratio of algae to invertebrates among six years of data (2000-2005).

In addition to continuing our long term monitoring we are investigating relationships between understory algae and sessile invertebrates in greater detail with experiments and mathematical models. For example, the PhD research of Andrew Rassweiler is investigating dramatic shifts between two very different benthic communities, one in which *Pachythyone rubra,* a filter feeding sea cucumber, persists at high density (>1000 per $m^2$) and one which is dominated by algae and other invertebrates. Spatial and temporal distribution of these communities suggests that they may represent alternate stable states, in which mechanisms reinforce each phase once it is established. He is investigating competition with algae as one such mechanism. Rassweiler has used mathematical models to show that space competition with algae can cause alternate stable states when filter feeders are also consuming algal spores. He has also shown experimentally that the sea cucumbers are competing with algae, and that algal settlement is more than twice as high when the sea cucumbers are removed, indicating that spore predation may be strong. Not all interactions between understory algae and sessile invertebrates are negative. Graduate student Stu Levenbach found that the sessile colonial anemone, *Corynactis californica*, creates a refuge for benthic macroalgae on rocky reefs that are intensively grazed by sea urchins. Within areas heavily grazed by sea urchins, benthic macroalgae and small mobile invertebrates were relatively more abundant among *Corynactis* colonies. Results from field experiments showed that *Corynactis* facilitated the recruitment of macroalgae and tubicolous amphipods in barren areas subjected to intensive grazing. In areas forested by

giant kelp where grazing intensity was low, *Corynactis* suppressed algal recruitment, but facilitated tubicolous amphipods. A manipulation of fish and sea urchins suggested that grazing by urchins, as opposed to predation from fish (primarily surfperch), suppressed tubicolous amphipods and this activity was hindered by the presence of *Corynactis*.

*Regional studies of giant kelp abundance*
SBC LTER grad student Kyle Cavenaugh is leading an effort to develop a method for the remote assessment of giant kelp (*Macrocystis pyrifera*) canopy cover and biomass using multispectral data from the SPOT 4 and 5 satellites. A time series of 11 dates of satellite imagery for the Santa Barbara Channel was collected between October of 2004 and January of 2007. An algorithm used to determine the surface canopy area identifies kelp-covered pixels using the near-infrared to green band ratio after atmospheric correction by the dark pixel method. A series of common satellite vegetation indices are applied to the imagery and compared to SCUBA diver measurements of frond density and biomass, which are measured monthly at three sites (Arroyo Burro, Arroyo Quemado, and Mohawk) where we are collecting long-term measurements of NPP by giant kelp. The Normalized Difference Vegetation Index (NDVI) obtained from the satellite images was highly correlated with diver measurements of kelp biomass (Figure 2. $r^2 = 0.71$). The relationship we found between biomass and NDVI was used to transform maps of kelp canopy cover into maps of area specific biomass. We are continuing to build our database of satellite imagery with bi-monthly collections over the entire Santa Barbara Channel, and we are using our recently developed remote sensing techniques to tracked large scale changes in giant kelp biomass along the Santa Barbara coastline. Satellite data of kelp canopy area and validated with diver measurements of area specific biomass will be used to make regional scale analyses of kelp population dynamics in response to various biophysical forcings.

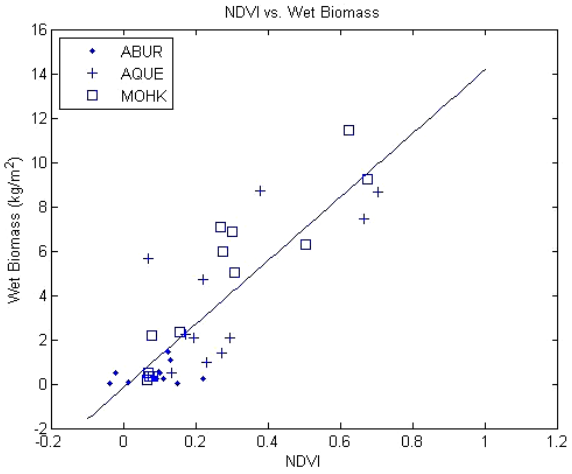



Figure 2. Linear regression of NDVI and biomass measurements ($r^2 = 0.71$; $p < 1*10^{-10}$). The different symbols represent the three sites: ABUR = Arroyo Burro, AQUE = Arroyo Quemado, and MOHK = Mohawk.

*Primary production of giant kelp forest ecosystem*
Net primary production (NPP) is influenced by disturbance-driven fluctuations in foliar standing crop (FSC) and resource-driven fluctuations in rates of recruitment and growth, yet most studies of NPP have focused primarily on factors influencing growth. We quantified NPP, FSC, recruitment, and growth rate for the giant kelp, *Macrocystis pyrifera* at three kelp forests in southern California over a 54 month period and determined the relative roles of FSC, recruitment and growth rate in contributing to variation in annual NPP. NPP averaged between 0.42 to 2.38 kg dry mass $m^{-2}$ $y^{-1}$ at the three sites. The initial FSC present at the beginning of growth year and the recruitment of new plants during the year explained 63% and 21% of the inter-annual variation observed in NPP, respectively (Figure 3a). The previous year's NPP and the loss rate (caused primarily by disturbance from waves) collectively accounted for 80% of the inter-annual variation in initial

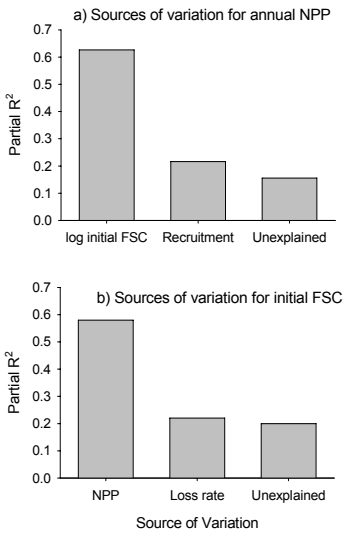



Figure 3. Results from stepwise multiple regression analyses investigating the relative contributions of: (a) standing crop at the start of the growing season (log initial FSC) and annual recruitment density of giant kelp to variation in annual net primary production (NPP), and (b) previous year's NPP and loss rate of kelp biomass in autumn of the previous year (loss) to initial FSC.

FSC (Figure 3b). No correlation was found between annual growth rate and annual NPP, largely because annual growth rate was consistent compared to initial FSC and recruitment, which fluctuated greatly among years and sites. Although growth rate was a poor predictor of variation in annual NPP, it was principally responsible for the high mean values observed for NPP by *Macrocystis*. These high mean values reflected rapid growth (~ 2% $^{-d}$) of a relatively small standing crop (maximum annual average = 444 g dry mass $m^{-2}$) that replaced itself an average of about seven times per year. Disturbance-driven variability in FSC may be generally important in explaining variation in NPP, yet is rarely examined because cycles of disturbance and recovery occur over timescales of decades or more in many systems. Considerable insight into how variation in FSC drives variation in NPP may be gained by studying systems like giant kelp forests that are characterized by frequent disturbance and rapid rates of growth and recruitment.

The algorithms developed to explore regional estimates of giant kelp productivity were applied to hyperspectral images of the Carmel Bay region in central California. Analyses of these images revealed 1.74 $km^2$ of identifiable kelp canopy along from Cypress Point to Yankee Point (Figure 4) in Monterey County. Regions of highest biomass and productivity were found at the west entrance to Stillwater Cove, along the rocky shore south of Carmel Beach and the south side of Pt. Lobos. The identified aerial coverage of giant kelp exceeded 1.7 $km^2$ over the 15 km stretch of coastline. This represents a standing giant kelp biomass of 1.3 million Kg (dry mass) and a daily production rate of 20,000 Kg (dry mass) $d^{-1}$. The annualized production based on this daily rate is equivalent to 7.1 million Kg (dry mass) and 2.1 million Kg carbon exported to adjacent beaches, the coastal ocean and the deep sea.

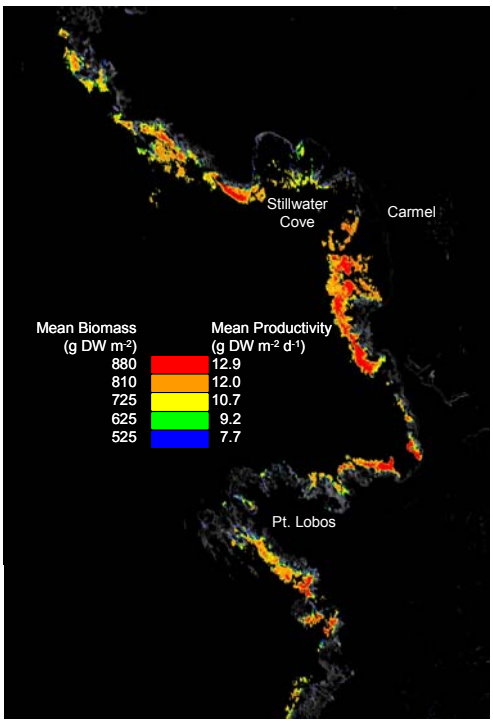



Figure 4. Map of giant kelp biomass and productivity along the Carmel Bay region calculated from NDVI analysis of the PHILLS imagery collected in 2004. Color bars indicate levels of productivity ranging from highest (red) to lowest (blue).

Measurements of oxygen evolution in chambers placed on the bottom under a sparse canopy of giant kelp at Naples Reef showed that production of foliose red algal assemblages was approximately twice that of red turfing algae on a per area basis (GPP foliose red = 12.3 $\pm$ 2.2 (S.E.). mmol $O_2$ $m^{-2}hr^{-1}$, turfing red = 5.4 $\pm$ 0.7 mmol $O_2$ $m^{-2}hr^{-1}$). These values are similar to rates previously measured for benthic macroalgae. Assuming a photosynthetic quotient of 1 and that these measurements (which were taken in fall) represent the entire year, we estimate that foliose red algae at Naples Reef produce net ~0.4 kg C $m^{-2}yr^{-1}$, which is comparable to the estimates that we have obtained for sparse populations of giant kelp. These results support the idea that understory algae may be a significant component of kelp forest production, particularly when kelp biomass is low. Although lower in net primary production, turf communities had significantly higher biomass-specific production rates (ANOVA df = 1,21, F=5.9, p= 0.02), suggesting that temperate turf assemblages, like their counterparts on tropical coral reefs, have relatively high growth rates, and may be heavily cropped by grazers. Kelp forests, however, lack the diversity of grazing fishes found on reefs, suggesting that the abundant micrograzers, (e.g. amphipods) found in these turfs may be important in controlling turf biomass.

Monthly chamber measurements of oxygen evolution for understory communities, using 1-hour incubations throughout the day, have shown thus far no significant diel variation in macroalgal production, suggesting photosynthetic saturation at very low light levels. For spring 2007, mean GPP outside the kelp forest at Mohawk Reef was 17.8 $\pm$ 5.3 (S.E.) mmol $O_2$ $m^{-2}hr^{-1}$, while rates inside the forest averaged 5.1 $\pm$ 1.0 mmol $O_2$ $m^{-2}hr^{-1}$, affirming a strong affect of the kelp canopy on understory algal production. Phytoplankton production was even more strongly affected by the presence of kelp, with rates outside the forest >50 fold higher than rates inside the kelp forest (275 vs. 5 mg C $m^{-3}day^{-1}$). We are continuing these

monthly measurements to better understand: (1) how seasonal variations in kelp canopy may affect primary production of understory algae and phytoplankton, (2) the extent that production by these ecosystem components complements each other, and (3) the primary sources of variation in their production.

*Gene flow, inbreeding depression and population connectivity in giant kelp*
We found extensive polymorphism in the microsatellite markers that we tested, which was indicated by the high allelic richness found within each of our nine long-term study sites. Preliminary results to date show that kelp populations along the mainland coast of the Santa Barbara Channel have a low genetic structure, which is indicative of high gene flow. Despite this apparent high gene flow we still found a significant pattern of isolation by distance. Moreover, all nine of the populations sampled showed high $F_{IS}$ values, which is consistent with high levels of inbreeding. We are in the process of testing alternative explanations for these patterns (e.g., frequency of other alleles or other genotyping related problems).

*Biological and Physical coupling within giant kelp forests*
Findings from the deployment of extensive arrays of flow sensors within and around the kelp forest at Mohawk Reef indicated a clear reduction of current speeds within the forest that is dependent on the density of kelp individuals, a visible downstream wake characterized by slower flows, a zone of marked flow acceleration along the offshore boundary of the forest, and strong effects of water depth on velocity. These features have implications for understanding the degree to which nearshore flows pass through kelp forests as opposed to being diverted around them. This in turn bears on the capacity of kelp forest ecosystems to influence a variety of nearshore waterborne commodities, including nitrate, dissolved and particulate carbon, phytoplankton, and zooplankton, each of which may be produced or consumed by members of the kelp forest community.

To determine the relative importance of different sources of nitrate to the annual nitrogen demand by *Macrocystis pyrifera*, we: (1) quantified ambient nitrate concentrations in the kelp forest at our Mohawk study for 13 months using an in situ nitrate analyzer, and (2) characterized physical supply mechanisms using water column thermal structure and flow regime data obtained in the forest's interior and at its outside edge. Monthly nitrate supply varied by a factor of 50 over the 13 month study, while measured net uptake of nitrogen varied only five fold. Maximum net nitrogen acquisition rates for fronds in the interior of the forest were 0.18 mmol N $g^{-1}$ $month^{-1}$ during spring upwelling in 2005 and declined to 0.04 mmol N $g^{-1}$ $month^{-1}$ during autumn until upwelling resumed the following year. The net nitrogen acquisition rate for growing canopy fronds at the edge of forest averaged 22% higher than for those in the forest's interior. Modeled gross nitrogen uptake with consideration of Michaelis-Menten uptake kinetics for nitrate and mass transfer limitation was higher than measured acquisition throughout the study except during the highly stratified summer and autumn months when observed net uptake exceeded modeled gross uptake (Figure 5). The late summer and fall shortfall in modeled nitrogen uptake suggested that the kelp forest received

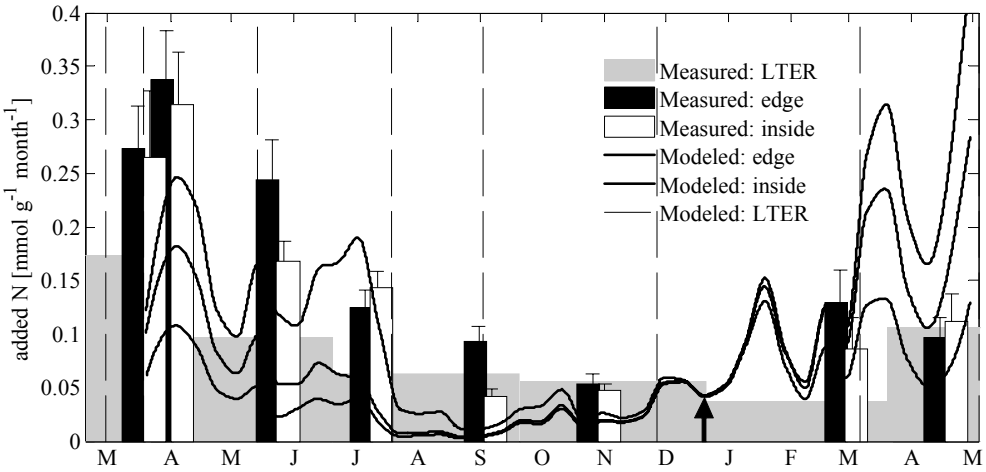



Figure 5. Time series of measured acquisition and modeled uptake of nitrogen in mmol g_$wet^{-1}$ $mo^{-1}$ by growing canopy fronds at the edge and inside the Mohawk kelp forest, and of all fronds in a 40 m x 40 m area of the interior of the forest (LTER) for the period 21 March 2005 through 30 April 2006.

over half of its nitrogen from sources other than seawater nitrate, possibly ammonium from epibionts. Internal waves and local streams supplied less than 9% of the total annual nitrate supply, but internal waves contributed 20% of the supply during stratified periods. Calculations of nitrate flux into the forest relative to both measured and modeled uptake indicate that kelp utilized < 7% of the nitrate supplied to the forest throughout the study. Nitrate supply to this modest sized kelp forest was roughly equivalent between alongshore (45%) and cross-shore flows (55%), which distinguishes it from large kelp forests in which cross-shore flows dominate exchange.

Reduced flow, nutrients and PAR in the interior of the forest appear to have significant effects on kelp physiology and growth. We found that kelp fronds grew faster and into bushier shapes at the edge of the Mohawk kelp bed relative to the interior. Differences in growth between fronds at the edge and interior of the bed appear to be more pronounced at higher frond densities. Data collected on flow velocities, light, temperature, and seawater nitrate from moored instruments coupled with semi-monthly analyses of kelp tissue nitrate and carbohydrate storage compounds (mannitol, laminarin) are being used to investigate the specific mechanisms that cause kelp growth to differ at the edges and interior of the forest.

Sessile suspension feeding invertebrates rely on water flow to bring them food particles. Thus, their short term rates of food capture and longer term rates of growth may be affected by current speed. LTER graduate student Katie Arkema is using field transplant experiments and laboratory analyses of gut fullness to investigate the effects of current speed on food capture and colony growth rate in the encrusting bryozoan *Membranipora tuberculata*. *Membranipora* feeds on phytoplankton and is arguably the most abundant suspension feeder in southern California kelp forests, where its colonies occur mostly as an epiphyte on giant kelp. Results to date show that food capture rates (as indicated by gut chlorophyll *a* concentrations) are greatest at intermediate flow speeds (Figure 6). Previous laboratory flume studies have shown that the feeding structures of *Membranipora* are inhibited in fast flows, which is consistent with Arkema's finding of low concentrations of chlorophyll *a* in the guts of *Membranipora* at high flow sites. The relationship between colony growth rate and current speed was similar to that between food capture and current speed; growth rates were slowest at sites where current speeds were consistently low (<5cm/s) or consistently high (>20 cm/s) and fastest at sites with intermediate current speeds (5-20 cm/s).Growth rates also varied within sites Position in the forest also affected *Membranipora* growth rates as colonies transplanted to the edges of kelp forests grew faster than colonies transplanted to the interiors of kelp forests. This last finding is consistent with the results of our hydrodynamic studies done at Mohawk Reef where we found a significant reduction in current speeds within the forest that was dependent on the density of kelp (see above) and suggests that the slow growth rates observed for *Membranipora* colonies in the interiors of kelp forests relative to the edges result from reduced food capture in slower water flows created by the dampening effect of giant kelp.

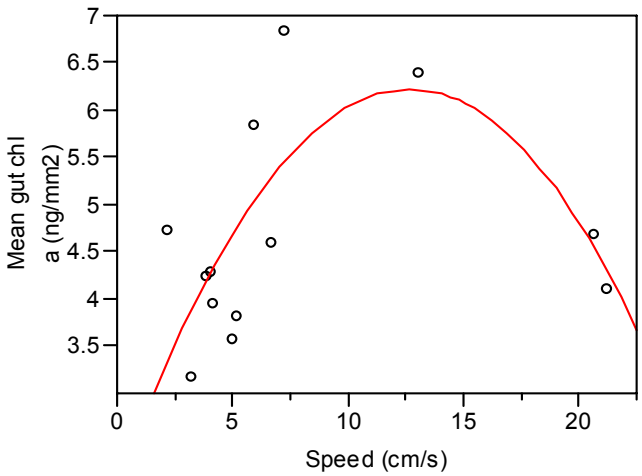



Figure 6. Mean gut chlorophyll *a* concentration (ng/mm2) as a function of ambient current speed (cm/s). Current speed explains 42% of the variation in gut chlorophyll *a* concentration ($r^2 = 0.45$, $p<0.05$).

As part of the research collaborative on the ecomechanics of kelp, extensive second-by-second recordings were made of hydrodynamic forces imposed on two important and common seaweeds: *Macrocystis pyrifera* (the giant kelp) and *Egregia menziesii* (the feather boa kelp). These measurements demonstrated that forces due to waves impinging directly on emergent organisms and forces arising from flexible organisms whiplashing in flow often greatly exceeded forces imposed by classic velocity-dependent drag. Such impingement and inertial forces routinely exceeded those imposed by drag by over a factor of three. Findings from the force measurements have also informed patterns of kelp dislodgement

quantified via a 3-year monitoring program that tracked the fate of several hundred tagged giant kelp individuals at Mohawk Reef. It is well known that wave-driven flows associated with winter storms create strong seasonal patterns of kelp disturbance. However, the potential roles of wave-induced dislodgement in modulating size and age-structure in kelp forests have not been examined. Results of this project reveal strong effects of shape and size on the susceptibility of giant kelp to physical disturbance. Such size and shape-dependent consequences cascade to influence the interaction of overall forests with arriving flows, the degree of exchange of interior waters with exterior fluid masses, and levels of uptake and production of limiting ecosystem-level constituents such as nitrate and carbon.

*Food web studies using stable isotope* $\delta^{13}C$ values of suspended particulate organic matter (POM) on reefs tended to decrease following periods of significant rainfall at the reef site most influenced by freshwater runoff, increase with phytoplankton standing crop at all reefs, and generally decline in both wet and dry years in late fall-early winter at all reefs in the absence of obvious drivers. Stable isotope values of reef consumers indicated little direct use of terrestrially-derived POM. However, a pattern of $^{15}N$-enrichment in two common species, the sea urchin, *Strongylocentrotus purpuratus* and annelid, *Diopatra ornata*, with increasing influence of watershed runoff suggested that terrestrially-derived nitrogen may enter the food web indirectly through a trophic intermediate such as microbes or algae (Figure 7). The importance of giant kelp to the reef food web varied with consumer feeding mode. In contrast to previous studies, $\delta^{13}C$ values of suspension-feeders suggested little use of kelp-derived material, based on the similarity in isotope values of these consumers among reefs during the first two years of the study when kelp biomass was low, and the absence of a directional shift in isotope values that would indicate the use of more $^{13}C$-enriched production during the last two years of the study when kelp biomass was higher at two of the reefs. However, isotope values for herbivores were generally $^{13}C$-enriched relative to suspension-feeders, reflecting the use of local giant kelp or other $^{13}C$-enriched benthic algal production. Thus, spatial and temporal fluctuations in the biomass of giant kelp would be least likely to impact the food resources of suspension-feeders and have greatest effect on benthic herbivores.

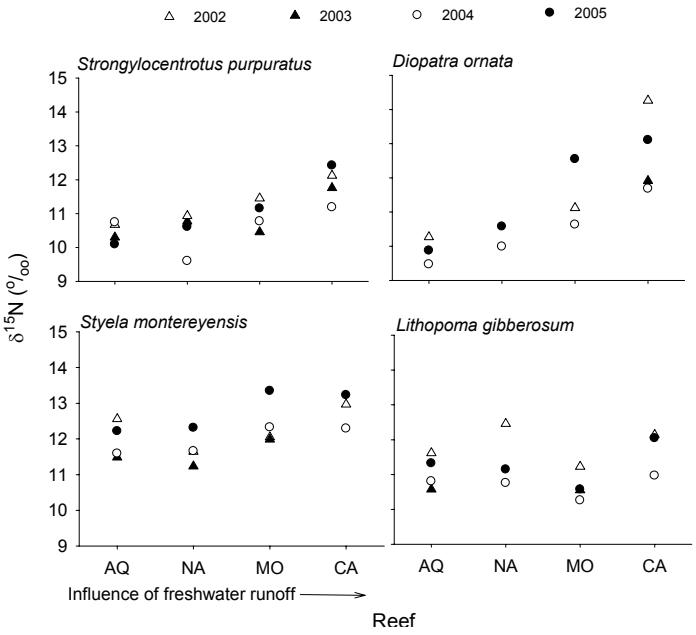



Figure 7. Variation in the $\delta^{15}N$ values of selected consumers among reefs. Reefs are arranged from left to right relative to increasing influence of freshwater runoff as measured by variation in salinity (AQ= Arroyo Quemado, NA = Naples, MO = Mohawk, CA = Carpinteria).

OCEAN STUDIES

*Moored instruments and monthly sampling* – Data from the time series of monthly water column sampling and moored observations continue to support ongoing activities including assessments of mechanisms of nutrient delivery to kelp forests (McPhee Shaw et al. 2007, Fram et al. in prep.), the affect on kelp forests on current flow through and around kelp forests (Gaylord et al.2007) and the carbon and nitrogen isotopic composition of suspended particulate matter in the past (Page et al. in review). These findings are largely detailed in the section entitled *"Biological and Physical Coupling within Giant Kelp Forests"*. Data are used by SBC investigators, post docs, graduate students and in collaborative efforts with other projects. An example of a new collaborative effort that is making use of these data is work that the SBC LTER is doing with Drs. Grace Chang and Tommy Dickey of UCSB and Erika McPhee Shaw of Moss Landing Marine Laboratory to further examine cross-shelf physical processes that deliver nutrients to the inner shelf.

UCSB's ocean physics laboratory has deployed moorings on the shelf in the Santa Barbara Basin for several years, but at greater depths than those deployed adjacent to kelp forests by us. By combining data from the SBC LTER and these moorings we obtain a more comprehensive cross-shelf instrument array. The data from these mooring are being combined and used to assess cross-shelf processes on a larger spatial scale that previously done using only SBC LETR data from moorings adjacent to reefs.

*Surface Current Patterns*

Surface current data from HF radars are being used to understand a number of imporant dynamical processes in the Santa Barbara Channel. As described in the section on analysis of SBC-LTER cruise data, surface current patterns are being incorporated into the ongoing analysis of on primary productivity in the channel. They provide an important link between synoptic circulation patterns in the channel and sub-surface property fields observed by ship board instrumentation. HF observations are also being used to examine the response of inner shelf currents to changes in wind forcing along the mainland coast from Carpinteria to Point Sal. A hypothesis of this research is that wind relaxation events are an important trigger for poleward flows that connect kelp habitats in the Southern California Bight with kelp beds along the central California coast.

*Cross Shelf Processes*

The deep velocity structure of a cyclonic eddy is shown in Figure 8 (right-hand panel). The surface flow of the eddy observed by the HF radars (Figure 8 left-hand panel) extended to about 400 m depth, which indicates eddies transport phytoplankton over the full range of depths spanning the euphotic zone. The rotation of the eddy also causes uplift of the density surface which may drive primary production processes in the eddy.

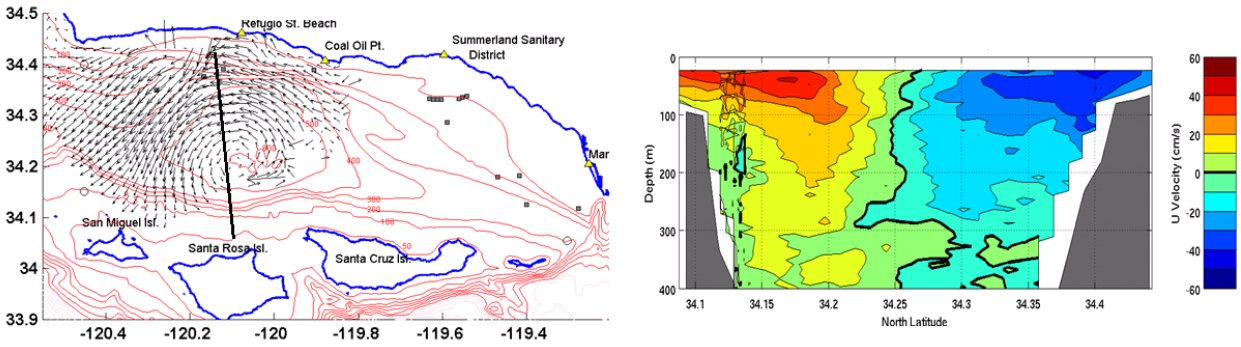



Figure 8. Left-hand panel shows mean velocity field during Sept. 2002 cruise. Shipboard ADCP section shows subsurface velocity field along ship track in left-had panel.

We assembled the 5 meter productivity data from all the cruises to obtain a better understanding of phytoplankton distributions in the Santa Barbara Channel and the processes that control their rates of primary productivity. Results show that regions of high chlorophyll (red and yellow shades in Figure9) are concentrated in areas where the 25.52 density surface is uplifted due to ocean currents. Our analyses to date indicate that the euphotic zone is 20 m deep or less, and the presence of fluorescence at greater depths suggests isopycnal transport processes may be important in re-distributing phytoplankton vertically. Jo Goodman, a graduate student, participated in these analyses along with Chris Gotschalk, a staff research associate.

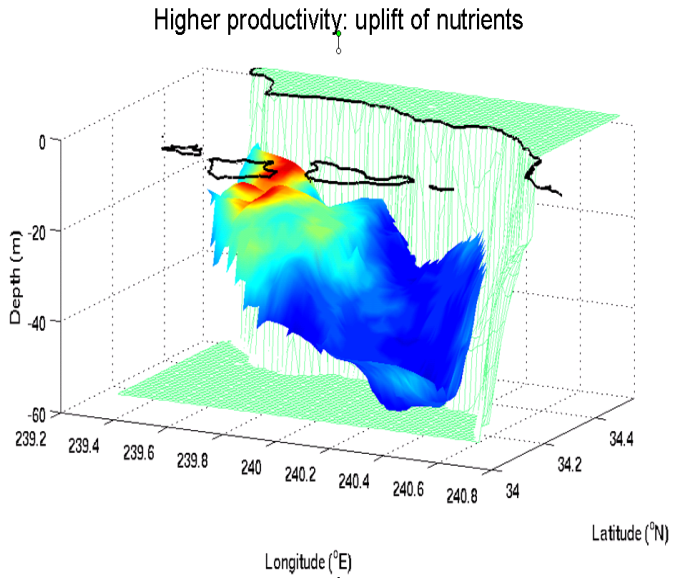
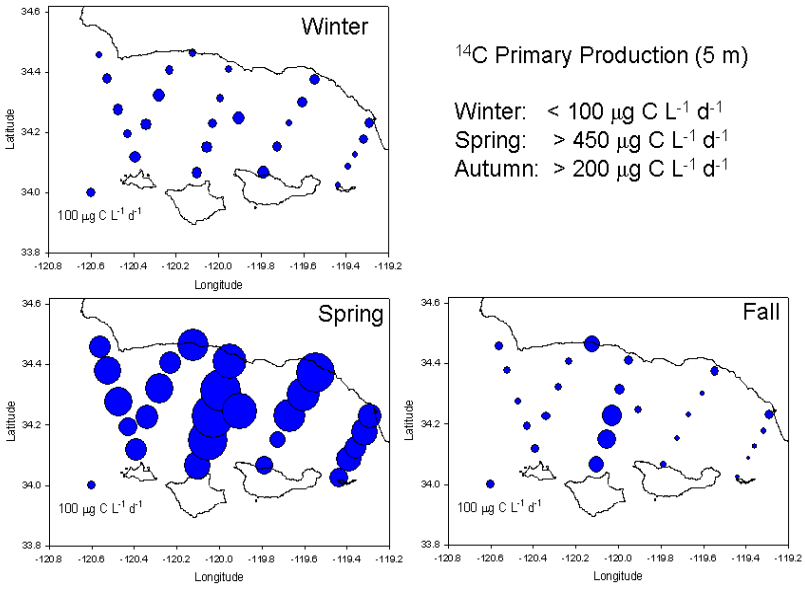



Figure 9. 3-dimensional image of fluorescence, an indicator of phytoplankton concentration, draped on the 25.52 kg $m^{-3}$ potential density surface during SBC-LTER Cruise #5 for the period 9-12 Sept 2002. The coastline is in light blue and bathymetric data are truncated at 60 m depth

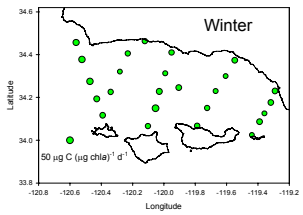
Analysis of the productivity data resulted in several important findings over the past year. Grouping of cruises according to season revealed that seasonal upwelling drives a maximum during spring in phytoplankton biomass and productivity in the SBC as shown in Figure 10. A second maximum occurs in the western basin during fall. These biological patterns appear linked to cyclonic rotation that develops in the western Santa Barbara Basin during spring and fall. Primary production and chlorophyll biomass are significantly elevated within the cyclonic flow (Figure c), but carbon assimilation numbers, a measure of primary productivity per unit mass of chlorophyll, is not (Figure 11). This suggests that accumulation of phytoplankton by convergence within the cyclonic flow, rather than nutrient injection, is the dominant process affecting primary production. These and other results from this analysis were presented by Mark Brzezinski at the ASLO meeting in February 2007.




$^{14}$C Primary Production (5 m)

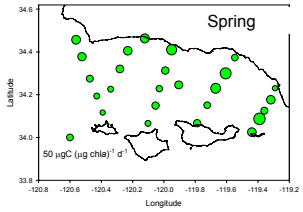
Winter: < 100 µg C $L^{-1}$ $d^{-1}$
Spring: > 450 µg C $L^{-1}$ $d^{-1}$
Autumn: > 200 µg C $L^{-1}$ $d^{-1}$

Figure 10. Upper, and lower two panels show seasonal composites of primary productivity at 5 m depth from fifteen cruises for which data are available. The size of the blue dots indicates the magnitude of productivity according the scale in each panel.




Carbon Assimilation Number (5 m)

Similar for all seasons
50 – 90 µg C (µg chl*a*)$^{-1}$ d$^{-1}$



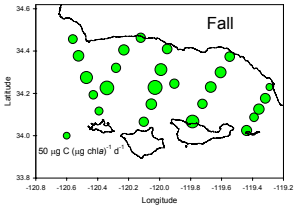




Figure 11. Upper and lower two panels show seasonal composites of carbon assimilation number at 5 m depth from fifteen cruises for which data are available. The size of the green dots indicates the magnitude of the assimilation number according the scale in each panel.

*Satellite Data*)

Satellite ocean-color and sea-surface temperature (SST) imagery are used to assess the occurrence, extent and duration of surface sediment plumes from discharged stormwater and phytoplankton blooms in the Santa Barbara Channel (Otero and Siegel, 2004; Warrick et al. 2004). Monthly mean annual cycles of SST, chlorophyll (Chl) and the water-leaving radiance at 555nm (LwN(555)), an index for sediment-affected waters, show plumes associated with runoff in winter, while blooms occur in the late spring–early summer and are associated with cool SST and upwelling favorable winds. Interannual variations are consistent with remote forcing by El Niño cycles (Figure 12). During the 1997–1998 El Niño, Chl concentrations are moderate, and El Niño-induced floodwater discharges result in high LwN (555) values throughout the Santa Barbara Channel. However, a correspondence between El Niño–La Niña a state and Chl is not found for the Santa Barbara Channel due to what appears to be the advection of nutrient-depleted waters from the east. Empirical orthogonal function analysis is used to spatially and temporally deconvolve processes regulating SST, Chl and LwN (555).

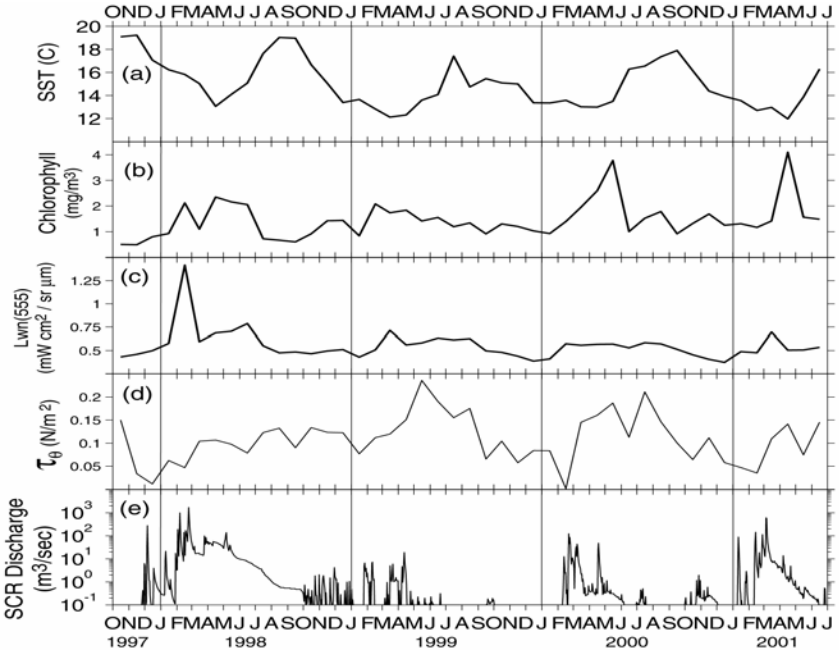



Figure 12. Santa Barbara Channel (SBC) regional mean time-series of (a) SST, (b) Chl and (c) LwN(555) averaged on a monthly basis. Only scenes with a minimum of 70% coverage (88% coverage for SST) are used in computing spatial averages over the SBC. Local forcing by (d) wind stress at the west channel buoy along the principal axis (aligned 1221 clockwise from north) and (e) daily discharge from the Santa Clara River as measured by the USGS.

## WATERSHED STUDIES

*Nutrient concentrations and fluxes as a function of land use and variations in runoff*

The coastal watersheds of the Santa Barbara Channel experience a Mediterranean climate with mild, moist winters and moderately warm, generally rainless summers and offer a rich range of conditions for experimental and observational study. The mainland drainage areas are comprised of three watershed scales: 74 small coastal catchments draining from the Santa Ynez Mountains varying in size from 1 $km^2$ to ~ 50 $km^2$ with a total area of 790 $km^2$; the Ventura River draining 590 $km^2$; and the Santa Clara River draining 4200 $km^2$. Steep mountain slopes composed of readily eroded material over shallow bedrock layers and strongly seasonal rainfall create large sources of sediments. The catchments differ widely in the proportion of agricultural and urban development. The topography of the coastal watersheds is characterized as mountainous headwaters and gently sloping coastal plains separated by transitional foothills. From west to east, there are both elevational and land use gradients. Headwater elevations increase from approximately 300 to 1400 m, and land uses on the coastal plain and foothills change from mostly rangeland to a combination of urban and agricultural lands. Most of the annual precipitation and corresponding runoff occurs in only a few large events resulting in high peak discharges and a rapid return to near baseflow conditions.

Water year (WY) 2007 had very low rainfall and consequently small amounts of export of nutrients to the coastal ocean. We observed much lower concentrations of nitrate and ammonium in comparison to WY 2005 in the San Onofre catchment, as it continues to recover from a wildfire that buried nearly the entire area. Results from WY 2005 indicated that nitrate concentrations during storm runoff from burned catchments increased by as much as 7 times, and phosphate concentrations increased by 4 to 5 times. A large ammonium flush occurred during the first two storms of the season, and ammonium concentrations were greater than nitrate concentrations in the first storm.

The Ventura River ranges in flow from near 0 to 11 $m^3 s^{-1}$. Monthly synoptic sampling, in collaboration with the Santa Barbara Channelkeepers, of nutrients at 15 locations indicates nitrate peaks in early winter, presumably from mineralization and mobilization after the advent of the rainy season, with concentrations decreasing to a minimum by late summer. Phosphate follows a similar pattern. Variation in nitrate (0 to 550 μM) and phosphate (0 to 35 μM) in the river and its tributaries is considerable. During winter stormflow, nitrate concentrations in the lower, urbanized portion of the catchment are decreased by dilution from surface runoff, while phosphate concentrations increase throughout the basin coincident with sediment mobilization.

The Santa Clara River has been sampled monthly at 5 to 6 sites since November 2005 in collaboration the Friends of the Santa Clara River. The sites span the length of this large watershed and include forest service lands, extensive orchards and urban reaches. Nitrate concentrations ranged from 0.7 to 182 μM and phosphate ranged from 1.1 to 5.8 μM.

*In-stream and estuarine processing of and responses to nutrients and invasive species*

Biological processing of nitrogen and phosphorus in streams can alter both the form and the total amounts of N and P that are delivered to coastal systems. Understanding the structure and function of the stream biota with regard to nutrient processing is therefore necessary in order to understand the transport and fate of these nutrients. The organisms principally responsible for uptake and transformation of N and P include algae, vascular plants, and microscopic heterotrophs. PhD student, Julie Simpson has found that algal biomass varies greatly depending on the surrounding land use, ranging from 1.6 mg $m^{-2}$ chlorophyll a in an undeveloped watershed site to 4000 mg $m^{-2}$ chlorophyll a at an urban site. Dissolved nutrient concentrations were highly variable across sites and had a broad range of N:P ratios. Results from nutrient diffuser experiments showed that the accrual of algal growth at the sites in watersheds with little to no development was consistently nitrogen limited. Benthic communities at these sites included diverse diatom assemblages, red algae, and N-fixing cyanobacteria. However, algal growth on the nutrient diffusers did not show a significant positive response to either N or P addition at most of the anthropogenically influenced sites.

*Ludwigia hexapetala* is an invasive, emergent vascular plant on the lower Ventura River. Presence of this plant appears to inhibit filamentous green macroalgae, while facilitating growth of shade-tolerant diatoms and has ecosystem-level effects. Wastewater effluent enters the river and produces stream water nitrate concentrations of 100-200 μM. Nitrate uptake rates downstream of the treatment plant inputs averaged 5 kg N/km/day, and direct uptake by *Ludwigia* could account for 20-40% of this nitrate

drawdown. Further nitrate removal from the water column may be indirectly facilitated by the presence of *Ludwigia* through facilitation of diatom population growth.

Coastal marshes can modify nutrient-rich runoff from upland catchments and can augment export of organic matter to near-shore communities via tidal exchanges. To understand these influences, PhD student Steve Sadro characterized vegetation, flushing rates and residence time of water within Carpinteria salt marsh. Vegetation mapping from airborne hyperspectral data permitted discrimination of the dominant vegetation classes. Analysis of tidal fluctuations have yielded inundation-elevation curves that indicate *S. virginica* and *J. carnosa* are dominant in areas that are inundated for periods of 14-17 % while multi-species mixtures and grasses are dominant in areas that are inundated for periods of 6-9 %.

PhD student Darcie Goodman continues to study the Devereux Slough ecosystem, a seasonally closed canyon mouth estuary located just west of Coal Oil Point. The purpose of this research is to obtain an in-depth understanding of the ecological conditions of the estuary through intensive monitoring conducted over a four-year period. WY 2007 was the first year of the study in which the slough did not flush and there was no exchange with the ocean, which resulted in peculiar conditions. Of the nine most common fish species recorded at the slough, only three species have been abundant this spring and fall following the dry storm season: *Fundulus parvipinnis (*California Killifish), *Gillichthys mirabilis* (Longjaw Mudsucker) and the endangered tidewater goby. *Atherinops affinis* (topsmelt), which is usually very abundant during the spring and early summer, has been rare this year. *Gammarus* (freshwater shrimp) and *Baetis* (mayfly) are the most abundant invertebrates found in sediment samples. *Salicornia virginica* is the most common vegetation found in the slough system, and the salt grass *Distichlis spicata* and *Frankenia salina* (Alkali Heath) are the most common species in the riparian zone.

The red swamp crayfish, *Procambarus clarkii*, is an invasive macroinvertebrate in many lakes and streams throughout the western U.S., including Santa Barbara and Ventura Counties, California. Because this species is a generalized omnivore, determining its potential impacts on native taxa is important for predicting community responses to this widespread exotic species in California and elsewhere. PhD student, Kristie Klose performed field and lab experiments to examine several aspects of the ecological interactions of the crayfish in southern California. The first part of her field research entailed field experiments delineating the effects of a *P. clarkii* density gradient on benthic invertebrate biomass and diversity, basal resources, and sediment levels in two disparate Californian stream communities. These experiments showed that habitat type, invertebrate composition, and dominant trophic linkages influenced the effects of omnivory in both streams, ranging from effects on large benthic invertebrates in the Santa Ynez River to indirect effects on small consumers in the Ventura River. The second part incorporated field experiments delineating the individual and combined effects of *P. clarkii* on two native consumers, snails (*Physella gyrina*) and atyid shrimp (*Atyoida bisulcata*). The results indicated that *P. clarkii* generated complex and different effects, probably mediated through multiple trophic interactions involving benthic invertebrates, periphyton, leaf litter, and non-trophic activities including effects on sedimentation and snail behavior. The third part included laboratory experiments examining the effects of species interactions (i.e., crayfish vs. snails) on consumer behavior and survival through snail spatial and temporal microdistributional changes as a consequence of crayfish movement limitations and foraging activities at night. These results indicate that cues produced by predators (e.g., chemical, mechanical) altered prey microdistributions, but that prey responses (e.g., moving above the water line or to horizontal refugia without crayfish) depended on the intensity and nature of cues.

Preliminary analyses of stream experiments testing bi-directional relationships between algal diversity and primary production suggest strong direct effects of both nutrient loading and algal species richness on primary production, but that nutrient loading and richness did not interact to influence production as expected. This may be due to the fact that nutrient levels in streams around Santa Barbara are already excessively high due to eutrophication and, as a result, nutrient loading did not alter richness as many studies predict.

## INFORMATION MANAGEMENT

### *Publications database*

Like our datasets, SBC publications are described by the EML schema and are available online http://sbc.lternet.edu/publications. We have continued to extend EML for the reporting and multi-use needs of bibliographic references. We are also continuing work on the web application to accommodate searches and reports, and to increase speed.

*Query interface for EML dataset*
SBC's growing data time series requires tools for querying and sub-setting data tables. We have developed a generic web application which can be applied to many types of data tables described by EML(available through links at http://sbc.lternet.edu/data). The application's use of the EML format means it can potentially be applied by many other research groups.

*SBC-LTER Website*
The SBC website (http://sbc.lternet.edu) was converted from a collection of static pages to a scripted system which streamlines the addition of new material and facilitates editing of dynamic menus or style changes. During the conversion, new material was added so that the website is now compliant with LTER recommendations.