

Annual Report for Period:03/2002 - 03/2003

Submitted on: 01/26/2003

Principal Investigator: Reed, Daniel C.

Award ID: 9982105

Organization: U of Cal Santa Barbara

Title:

LTER: Land/Ocean Interactions and the Dynamics of Kelp Forest Ecosystems

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:

Serves on our executive committee, directed research on hydrological and hydrochemical aspects in streams.

Name: Holbrook, Sally

Worked for more than 160 Hours: Yes

Contribution to Project:

Name: Cooper, Scott

Worked for more than 160 Hours: Yes

Contribution to Project:

Serves on our executive committee. Directs studies of in-stream processing of nutrients and organic matter.

Name: Gaines, Steven

Worked for more than 160 Hours: Yes

Contribution to Project:

Name: Washburn, Libe

Worked for more than 160 Hours: Yes

Contribution to Project:

Served on Executive Committee, participates in UNOLS cruises (including occasionally serving as Chief Scientist. Directs research on physical oceanography.

Name: Brzezinski, Mark

Worked for more than 160 Hours: Yes

Contribution to Project:

Serves on Executive Committee. Active participant on UNOLS cruises, and frequently serves as the chief scientist. Directs research on phytoplankton ecology and physiology.

Name: Page, Henry

Worked for more than 160 Hours: Yes

Contribution to Project:

Directed wetland ecology research.

Name: Schimel, Joshua

Worked for more than 160 Hours: No

Contribution to Project:

serves on our Executive Committee and directs soil ecology research.

Name: Siegel, David

Worked for more than 160 Hours: Yes

Contribution to Project:

Serves on our executive committee, directs ocean remote sensing work and participates on UNOLS cruises.

Name: Zimmerman, Richard

Worked for more than 160 Hours: Yes

Contribution to Project:

Investigates primary production in giant kelp

Name: Shima, Jeff

Worked for more than 160 Hours: Yes

Contribution to Project:

Research and outreach coordinator for SBC LTER. Investigates recruitment processes in reef fishes.

Name: Lenihan, Hunter

Worked for more than 160 Hours: Yes

Contribution to Project:

Reef ecologist investigating trophic interactions

Name: Schmidt, Russell

Worked for more than 160 Hours: Yes

Contribution to Project:

Dr. Schmidt is a reef ecologist collaborating on SBC kelp forest studies

Name: Nisbet, Roger

Worked for more than 160 Hours: No

Contribution to Project:

Dr. Nisbet is a theoretical ecologist working on food web models

Name: Kendall, Bruce

Worked for more than 160 Hours: No

Contribution to Project:

Dr. Kendall is a theoretical ecologist working on food web models

Name: Dugan, Jenny

Worked for more than 160 Hours: Yes

Contribution to Project:

Sandy beach ecologist. examines influence of kelp wrack on beach consumers. Serves as the project's Research and Education coordinator.

Name: Warner, Robert

Worked for more than 160 Hours: No

Contribution to Project:

reef ecologist

Name: Frew, James

Worked for more than 160 Hours: No

Contribution to Project:

Oversees project's information management

Name: Mertes, Leal

Worked for more than 160 Hours: No

Contribution to Project:

works on sediment transport from watersheds to the coastal ocean

Name: Keller, Arturo

Worked for more than 160 Hours: No

Contribution to Project:

Studies pollutants and models hydrochemistry of watersheds

Name: Dunne, Tom

Worked for more than 160 Hours: No

Contribution to Project:

Contributes to hydrological modeling

Name: Holden, Patricia

Worked for more than 160 Hours: No

Contribution to Project:

Works on the ecology of stream microbes

Name: Reichman, Jim

Worked for more than 160 Hours: No

Contribution to Project:

Helped facilitate the implementation of our information management system. Conducts research on soil disturbance by gophers

Name: Carlson, Craig

Worked for more than 160 Hours: Yes

Contribution to Project:

Works on dissolved Organic Carbon release in coastal ocean including kelp forest ecosystems

Post-doc

Name: Leydecker, Al

Worked for more than 160 Hours: Yes

Contribution to Project:

Participated in design and execution of chemical sampling and hydrological measurements for coastal streams and analysis of data.

Name: Busse, Lilian

Worked for more than 160 Hours: No

Contribution to Project:

Conducting studies of nutrient-grazer relations in Mission Creek and studies of diatoms and nutrients in Carpinteria Marsh

Name: Beighley, Ed

Worked for more than 160 Hours: Yes

Contribution to Project:

responsible for hydrological modeling

Name: Mcphee-Shaw, Erika

Worked for more than 160 Hours: Yes

Contribution to Project:

Analyzes physical-oceanographic data sets from fixed moorings and cruises, investigates inner-shelf dynamics and mechanisms for cross-shelf nutrient delivery.

Graduate Student

Name: Levenbach, Stuart

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted in subtidal field research.

Name: Robinson, Tim

Worked for more than 160 Hours: Yes

Contribution to Project:

participated in chemical sampling of streams and coordination of GIS of coastal catchments

Name: Simpson, Julie

Worked for more than 160 Hours: Yes

Contribution to Project:

Conducts studies of nutrients and aquatic plants in streams

Name: Beherens, Michael

Worked for more than 160 Hours: No

Contribution to Project:

Assisted in subtidal field research

Name: Anderson, Clarissa

Worked for more than 160 Hours: Yes

Contribution to Project:

Participated UNOLs cruises, collection and laboratory processing of monthly water samples. Analyzes phytoplankton species composition in the SB Channel using microscopy and HPLC. Examines the effects of plankton community composition on rates of nutrient cycling as well as the potential effects of freshwater runoff on phytoplankton distributions.

Name: Rassweiler, Andy

Worked for more than 160 Hours: Yes

Contribution to Project:

works on kelp forest ecology, participates in kelp forest community surveys and giant kelp primary production studies. Assists in data management and analyses.

Name: Harrison, Lee

Worked for more than 160 Hours: No

Contribution to Project:

Assists in data entry, stream sampling and GIS work

Name: Brinckman, Jeff

Worked for more than 160 Hours: Yes

Contribution to Project:

conducted surveys of water chemistry, physical factors, and benthic algae and invertebrates at approximately 30 coastal stream sites between Gaviota and Carpinteria

Name: Demarest, Mark

Worked for more than 160 Hours: No

Contribution to Project:

works on ocean primary production

Name: Anghera, Michelle

Worked for more than 160 Hours: No

Contribution to Project:

works on saltmarsh invertebrate assemblages

Name: Kelner, Julie

Worked for more than 160 Hours: No

Contribution to Project:

studies spatial and temporal variation in the infauna of sandy beach communities near to and far from sources of terrestrial runoff

Name: Katie, Arkema

Worked for more than 160 Hours: Yes

Contribution to Project:

works on kelp forest ecology, participates in kelp forest community surveys and giant kelp primary production studies.

Name: Bassin, Corinne

Worked for more than 160 Hours: Yes

Contribution to Project:

Analyzed oceanographic data, participated in one UNOLS cruise

Name: Beckenbach, Edwin

Worked for more than 160 Hours: Yes

Contribution to Project:

Analyzed surface current data from high frequency radars

Name: Otero, Mark

Worked for more than 160 Hours: Yes

Contribution to Project:

Analyzed satellite ocean color and SST imagery. Completed MS degree partially supported by the

Name: Kinlan, Brian

Worked for more than 160 Hours: Yes

Contribution to Project:

Works on spatial dynamics of kelp forests using the historical kelp data base

Name: Bose, Rajenda

Worked for more than 160 Hours: No

Contribution to Project:

works on database technology

Name: Broitman, Bernardo

Worked for more than 160 Hours: No

Contribution to Project:

works on recruitment of reef organisms

Name: Goldman, Darcie

Worked for more than 160 Hours: Yes

Contribution to Project:

Name: Klose, Kristie

Worked for more than 160 Hours: Yes

Contribution to Project:

Conducts studies of impact of exotic crayfish on stream biota

Name: Lester, Sarah

Worked for more than 160 Hours: No

Contribution to Project:

Name: Nelson, Craig

Worked for more than 160 Hours: No

Contribution to Project:

Name: Parker, Sophie

Worked for more than 160 Hours: Yes

Contribution to Project:

Conducts studies of impact of exotic crayfish on stream biota

Name: Senyk, Natalie

Worked for more than 160 Hours: Yes

Contribution to Project:

Works on spatial dynamics of kelp

Name: Petrey, Danielle

Worked for more than 160 Hours: Yes

Contribution to Project:**Undergraduate Student**

Name: Galst, Carey

Worked for more than 160 Hours: Yes

Contribution to Project:

Assists in subtidal data collection, monthly water sampling and data management and support.

Name: Boch, Charles

Worked for more than 160 Hours: Yes

Contribution to Project:

Prepared and managed kelp database and assisted with subtidal field work.

Name: Deward, Amy

Worked for more than 160 Hours: No

Contribution to Project:

assisted with filtration of water samples

Name: Pau, Staphanie

Worked for more than 160 Hours: No

Contribution to Project:

conducted GIS analysis and stream sampling as part of a senior thesis

Name: Quinn, Andy

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted in subtidal field research and the laboratory processing of samples collected in the field

Name: Fuchs, Maria

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted in subtidal field research and the laboratory processing of samples collected in the field

Name: Ecker, John-Michael

Worked for more than 160 Hours: No

Contribution to Project:

Assisted in subtidal field research and the laboratory processing of samples collected in the field

Name: Jones, Julia

Worked for more than 160 Hours: No

Contribution to Project:

Assisted in subtidal field research and the laboratory processing of samples collected in the field

Name: Bradford, Stephen

Worked for more than 160 Hours: No

Contribution to Project:

Assisted in subtidal field research and the laboratory processing of samples collected in the field

Name: Kendall, Daniel

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted in subtidal field research and the laboratory processing of samples collected in the field

Name: Green, Kristen

Worked for more than 160 Hours: No

Contribution to Project:

Assisted in subtidal field research and the laboratory processing of samples collected in the field

Name: Seruto, Cherlyn

Worked for more than 160 Hours: No

Contribution to Project:

Assisted in assembling field guide to marine plants and animals of the SBC LTER

Name: Doty, Kevin

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted in the laboratory processing of samples collected in the field and on UNOLS cruises

Name: DeMent, Andrea

Worked for more than 160 Hours: No

Contribution to Project:

Assisted in subtidal field research

Name: White, Jada

Worked for more than 160 Hours: No

Contribution to Project:

Assisted in subtidal field research

Name: Benson, Jeremy

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted in subtidal field research and the laboratory processing of samples collected in the field

Name: Blythe, Jonathan

Worked for more than 160 Hours: No

Contribution to Project:

Assisted in subtidal field research and the laboratory processing of samples collected in the field

Name: Briggs, Amanda

Worked for more than 160 Hours: No

Contribution to Project:

Assisted in the deployment and retrieval of moored oceanographic instruments

Name: Scalliett, Helene

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted in the deployment and retrieval of moored oceanographic instruments, UNOLs cruises, collection and laboratory processing of monthly water samples

Name: Nimmer, Andrew

Worked for more than 160 Hours: No

Contribution to Project:

assisted in stream sampling

Name: Blum, Marguerite

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with lab processing of stream samples

Name: Nguyen, John

Worked for more than 160 Hours: No

Contribution to Project:

assisted with lab processing of stream samples

Name: Jung, Katrina

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with lab processing of stream samples

Name: Jones, Jamie

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with lab processing of stream samples

Name: Asao, Shinichi

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with lab processing of stream samples

Name: Collins, Craig

Worked for more than 160 Hours: No

Contribution to Project:

Assists in chemical analyses of stream samples

Name: Grisafe, Michael

Worked for more than 160 Hours: No

Contribution to Project:

Assists in chemical analyses of stream samples

Name: Kostadinov, Tiho

Worked for more than 160 Hours: No

Contribution to Project:

Name: Guebels, Caroline

Worked for more than 160 Hours: Yes

Contribution to Project:

Assists in processing of stream samples

Name: Moore, Kelly

Worked for more than 160 Hours: No

Contribution to Project:

Assists in processing of stream samples

Name: Reed, Aimee

Worked for more than 160 Hours: No

Contribution to Project:

Assists in processing of stream samples

Name: Dias, Kristen

Worked for more than 160 Hours: No

Contribution to Project:

Assists in processing of stream samples

Name: Tiff, Lubren

Worked for more than 160 Hours: No

Contribution to Project:

Assists in processing of stream samples

Technician, Programmer

Name: Evans, Bryn

Worked for more than 160 Hours: Yes

Contribution to Project:

Bryn works full time collecting and processing ocean and reef data

Name: Anghera, Mike

Worked for more than 160 Hours: Yes

Contribution to Project:

Mike works full time collecting and processing ocean and reef data

Name: Salazar, David

Worked for more than 160 Hours: Yes

Contribution to Project:

David- prepares and services oceanographic instruments for deployment in the field.

Name: Jones, Janice

Worked for more than 160 Hours: Yes

Contribution to Project:

participates on UNOLS cruises, monthly sampling of water column properties around kelp forests, deployment of in situ nitrate analyzers on targeted reefs.

Name: Emery, Brian

Worked for more than 160 Hours: Yes

Contribution to Project:

Managed and performed data collection using CODAR-type high frequency radar systems.

Name: Lertcheraonyong, Krisada

Worked for more than 160 Hours: Yes

Contribution to Project:

Analyzed data collected by CODAR-type high frequency radar.

Name: Setaro, Frank

Worked for more than 160 Hours: Yes

Contribution to Project:

oversees processing of stream samples for chemical analyses

Name: Doyle, Alan

Worked for more than 160 Hours: Yes

Contribution to Project:

oversees chemical analyses of stream samples

Name: Seydel, Keith

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted in subtidal field research and the laboratory processing of samples collected in the field

Name: Kay, Matt

Worked for more than 160 Hours: Yes

Contribution to Project:

worked on kelp production studies and nutrient addition experiments on reef community structure

Name: Polyakov, Olga

Worked for more than 160 Hours: Yes

Contribution to Project:

Participated on UNOLS cruises.

Name: Mutz, Stephen

Worked for more than 160 Hours: No

Contribution to Project:

Assisted in subtidal field research

Name: Gotschalk, Chris

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted in subtidal field research and in the deployment and retrieval of moored oceanographic instruments

Name: Luan, Wei-yee

Worked for more than 160 Hours: Yes

Contribution to Project:

Data manager for SBC LTER

Name: Goodman, Darcie

Worked for more than 160 Hours: No

Contribution to Project:

community volunteer who assists in stream sampling

Name: Fields, Erik

Worked for more than 160 Hours: Yes

Contribution to Project:

writes programs for analyzing oceanographic data

Name: Menzies, David

Worked for more than 160 Hours: Yes

Contribution to Project:

Helped maintain oceanographic instrumentation. Participated on UNOLS cruises

Name: Polyakov, Olga

Worked for more than 160 Hours: Yes

Contribution to Project:

Participated on UNOLS cruises.

Name: Jones, Chris

Worked for more than 160 Hours: Yes

Contribution to Project:

helped direct data management system for project

Name: Woods, Jim

Worked for more than 160 Hours: Yes

Contribution to Project:

provided IT support for the project

Name: Coombs, Scott

Worked for more than 160 Hours: Yes

Contribution to Project:

Conducts and manages field sampling, operates gauging stations and conducts data analysis

Other Participant

Name: Killion, Lisa

Worked for more than 160 Hours: No

Contribution to Project:

assists in stream sampling

Name: Barkley, Andre

Worked for more than 160 Hours: No

Contribution to Project:

assists in stream sampling

Name: Melkonian, Al

Worked for more than 160 Hours: No

Contribution to Project:

assists in stream sampling

Research Experience for Undergraduates

Name: Willis, Allan

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted in subtidal field 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): Doctoral Degree

Fiscal year(s) REU Participant supported: 2001

REU Funding: REU supplement

Name: Ow, Leah

Worked for more than 160 Hours: Yes

Contribution to Project:

assisted in the analysis of physical oceanographic data

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): Doctoral Degree

Fiscal year(s) REU Participant supported: 2002 2001

REU Funding: REU supplement

Name: Ecker, John-Michael

Worked for more than 160 Hours: Yes

Contribution to Project:

surveyed biodiversity and community dynamics in reef ecosystems. Assisted in studies on primary production in kelp.

Years of schooling completed: Freshman

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: 2002

REU Funding: REU supplement

Name: Blum, Marguerite

Worked for more than 160 Hours: Yes

Contribution to Project:

Participated in studies of the ecology of stream biota

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): Doctoral Degree

Fiscal year(s) REU Participant supported: 2002

REU Funding: REU supplement

Name: McMillan,, Jeffrey

Worked for more than 160 Hours: Yes

Contribution to Project:

Participated in studies of ecology of stream biota

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): Doctoral Degree

Fiscal year(s) REU Participant supported: 2002

REU Funding: REU supplement

Organizational Partners

University of California, Office of the President, Oakland

The UC Office of the President funds the UC Toxic Substances Research & Teaching Program. One component of this program is the UC Coastal Toxicology Program (UCCTP) whose mission is to help resolve pollution-related problems in California's coastal ecosystems. UCCTP accomplishes this mission by facilitating new research endeavors by UC faculty, and by providing students with research support and interdisciplinary training in the broad area of environmental toxicology. UCCTP is providing support for two graduate students (including salary and the cost of student fees and health insurance) for each year of our project to work on SBC LTER related issues.

The Minerals Management Service

The Minerals Management Service funds a large study of ocean circulation in the Santa Barbara Channel region. The program is run through Scripps Inst. of Oceanography and includes extensive arrays of moorings to measure and ultimately model ocean swells and circulation in this region (http://cdip.ucsd.edu/models/sb_channel.gif).

In addition, MMS supports a large interdisciplinary research program at UCSB to investigate the effects of the offshore oil and gas industry on coastal marine resources (<http://www.mms.gov/omm/pacific/enviro/cmi.htm>). Investigators funded by this program are collaborating with LTER scientists on a wide range of projects in the SBC site including, ocean circulation in the Santa Barbara Channel, long-term monitoring of rocky intertidal shores, sea otter foraging behavior, trophic interactions in sandy communities, and seagrass ecology

Department of Interior National Park Service

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 oceanography 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.

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.

ISP Alginates

ISP Alginates (formerly Kelco Co.) has collected information on the abundance of giant kelp in California and Mexico from routine (approximately monthly) aerial surveys since 1958. They have supplied us with copies of all their archived records and we have converted them into a digital database that will allow us to more easily evaluate long-term trends in the abundance of giant kelp. Kelps surveys by ISP Alginates are ongoing and we are continuing to work closely with them to keep the database on giant kelp current.

University of Colorado at Boulder

We are collaborating with Mark Williams and Diane McKnight (ISTAAR, Univ. of Colorado) on a LTER cross site comparison grant to investigate dissolved organic N in streams.

University of New Hampshire

We are collaborating with Bill McDowell (Univ. of NH) on a LTER cross site comparison grant to investigate dissolved organic N in streams.

Moss Landing Marine Laboratories

Dr. Richard Zimmerman a research biologist at MLML is collaborating with SBC on research pertaining to primary production in marine algae

Santa Barbara Watershed Resource Center

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

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 the Land Trust as they protect and manage the property.

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

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 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 whole hydrograph for most storms complements the County's effort, and we and they share data and interpretations. To further communication with Project Clean

Other Collaborators or Contacts

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 and Warner) 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 (>6 y) study at UCSB (referred to as Plumes and Blooms) that investigates the interaction of marine plankton blooms and terrestrial runoff. The goal of this project (awarded to 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 and MODIS satellite sensors. (<http://www.icess.ucsb.edu/PnB/PnB.html>)

With funding from the Los Angeles Regional Water Quality Control Board (RWQCB), Arturo Keller has developed a detailed nutrient (N and P) source loading and water quality model for the Santa Clara River watershed, the largest watershed (> 4,000 km²) in our LTER study area. It has supported significant agricultural activity for more than a century, although it is transitioning to suburban and urban land uses. The project involves developing a decision-support model for determining a Total Maximum Daily Load for nutrients, allocating the TMDL to point and non-point sources (including agriculture), and evaluating various Best Management Practices. We have implemented the Watershed Analysis Risk Management Framework model, using data from local (e.g. United Water Conservation District, Ventura County Flood Control District, Los Angeles County Department of Public Works, Ventura County Farm Bureau, four large wastewater treatment plants, city governments, agricultural associations, environmental organizations, land developers), regional/state (e.g. Southern California Association of Governments, RWQCB, State Water Resources Control Board, California Air Resources Board) and national (e.g. USEPA, USGS, NOAA, USFWS) sources for meteorology, land use, fertilizer application rates, atmospheric deposition, point source flow and concentrations, water quality and gauged flow.

The Environmental Protection Agency funds the Western Center for Estuarine Ecosystem Indicator Research (CEEIR) whose primary objective is to develop a suite of biological, ecological, and chemical indicators of wetland ecosystem health for the California Coast. Several key scientists (Nisbet, Holden, Kendall, Page) working on this program are closely aligned with SBC and there is much interest in establishing common study sites, sharing data, and developing a joint curricula for graduate students working on the two projects. The estuarine focus of CEEIR nicely compliments the kelp forest focus of SBC. Collectively, the two programs will provide an in-depth assessment of the natural and human processes affecting two of the most important and conspicuous coastal ecosystems in California.

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 for our project and nicely complement those that are being collected by SBC and CEEI. Another major component of the SONGS mitigation program is the creation of kelp forests on artificial reefs to replace kelp habitat destroyed by the power plant. Large-scale (i.e. 10 ha) experiments are being done to determine how reef topography and size influence the colonization and development of kelp and other reef associated organisms. There is considerable exchange of ideas, information and personnel between SBC and the SONGS mitigation project on all issues pertaining to kelp forest research.

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:

Education and training are tightly integrated into all aspects of SBC research. In 2002, four post docs, 23 graduate students, four REU students

and more than 25 additional undergraduate students participated in SBC research. Educational opportunities at SBC are not limited to university students and post docs. 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 abundance. In November 2001, SBC organized and sponsored a symposium titled 'The effects of human activities on ecosystems at the land/ocean margin' for the annual meetings of the Western Society of Naturalists. The symposium was attended by more than 400 people (scientists, students, and the general public) and included speakers from all over the U.S.

The SBC-LTER program has jointly developed a graduate student training program with three other existing programs on the UCSB campus: the Center for Estuarine Indicator Ecosystem Research (CEIER) funded by U.S. Environmental Protection Agency, the UC Coastal Toxicology Program funded by University of California, and the Partnership for Interdisciplinary Studies of Coastal Oceans funded by the Packard Foundation. This program emphasizes interdisciplinary research to examine how coastal ecosystems change in response to natural and human-induced alternations in the environment, and seeks to create a diverse scientific community of students that have a respect and appreciation for other disciplines. In 2002, the program included 23 graduate students and four postdoctoral fellows, with research interests spanning terrestrial, aquatic, and marine ecology, physiology, geology, oceanography, and policy. Students and postdoctoral fellows participated in a quarter-long seminar that student and post doc research projects. In April, 2002 three SBC graduate students presented posters on their research at the 15th Annual UC Toxic Substances Research and Teaching Program Symposium, Long Beach, California. In September 2002, five SBC graduate students, Co-PI Holbrook and three Associate Investigators, attended the Annual Coastal Toxicology Retreat at the Bodega Marine Laboratories to discuss research integration among faculty and graduate students. Topics covered included research needs, on-going research projects, and future research collaborations between the Toxicology Program and the SBC LTER. Three of the students attended a week long interdisciplinary short course on eco-toxicological research. In addition, students, postdoctoral fellows, and Senior Investigators participated in the second Annual SBC-LTER Science Meeting, where results from SBC research were presented.

Outreach Activities:

Growing concern over frequent beach closures due to high bacterial pollution continues to focus public attention on the declining water quality of Santa Barbara's creeks and beaches. SBC-LTER has partnered with the Community Environmental Council to develop sets of educational tools and resources housed at the South Coast Watershed Resource Center (SCWRC) to inform the public about: (1) the importance of our watershed resources, (2) the connections between watersheds and coastal ocean ecosystems, (3) how these resources are impacted by human activities, (4) the role watershed restoration plays in improving water quality, and, (5) ways that the community can actively protect our creeks, wetlands, and ocean. SCWRC opened its doors in August 2001 and has since provided education programs for numerous elementary schools, organized public workshops on a variety of environmental issues, and hosted numerous meetings and tours for a wide variety of non-profit environmental awareness groups. SBC researchers worked with SCWRC staff to develop displays depicting ongoing research in the watersheds and nearshore waters in the Santa Barbara area. Schoolyard funds supplied by NSF have been used to purchase start-up equipment for the school programs as well as the production of student journals that were used by all the students who participated in the programs.

In 2002 the main focus of the SBC's Schoolyard program was the develop an interactive computer animation model of the Arroyo Burro Watershed, which empties into the ocean at the site of SCWRC.. The computer animation model will provide an interactive tool for 4-8th grade students, instructors, and the general public using SCWRC. The animation model, which will be made available on CD as well as on-line through SBC LTER's website has two main components: 1) an animated fly over tour coupled with static pages that allow the user to view images and information of the various ecosystems and land uses characteristic of the Arroyo Burro watershed; and 2) an interactive animated water surface response of the Arroyo Burro Creek as it flows by the SCWRC that allows the user to alter various land use and rainfall configurations. The animation program provides an interactive educational tool that emphasizes both the spatial distribution of the various ecosystems and land uses within the Arroyo Burro Watershed, and the effects of land use change on flooding.

Common Ground is a group of stakeholders who are developing a consensus on management for the Gaviota coast. We are involved to provide a scientific perspective.

The SBC-LTER outreach program also played host to Eagle Scout Tim Brox, selected by NSF's Polar Programs to visit US research stations in Antarctica. A 'cross-site' LTER outreach effort (in conjunction with the Palmer Station LTER) introduced Tim to ongoing studies at the SBC-LTER and emphasized the value of long-term research efforts.

Several SBC investigators routinely give lectures in local k-12 schools on LTER related topics (e.g. kelp forest ecology, watershed processes, ocean circulation, etc.). In addition to these many lectures, post doc Erika McPhee-Shaw co-taught a classroom project through the 'Kids do Ecology' program, which is run through NCEAS, and has some direct ties with Los Marineros (http://www.nceas.ucsb.edu/nceas-web/kids/main_pages/classweb.htm). Additional outreach activities done by SBC investigators include: a segment on live TV for Project Oceanography (<http://www.marine.usf.edu/pjocean/>) on SBC research in the Santa Barbara Channel, assisting the Channel Islands Marine Sanctuary in developing curriculum on associations between terrestrial runoff and phytoplankton blooms, and giving several public presentations on LTER related research to non-scientist groups.

The JASON PROJECT (<http://www.jason.org/jason14/home>) is a multi-disciplinary educational program that sparks the imagination of students and enhances the classroom experience by developing and supporting curricula that enable students and their teachers to do field work from the classroom and exposes students to leading scientists and their research as they examine basic biological and geological questions. SBC-LTER investigators worked with the JASON PROJECT in the development of JASON XIV: From Shore to Sea, which is now available for school year 2002-03. In this new and exciting program, the JASON team explores the terrestrial and marine ecosystems that extend from California's coast to the Channel Islands Marine Sanctuary.

Journal Publications

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- Allison, G. W., S. D. Gaines, J. Lubchenco, and H. P. Possingham, "Ensuring persistence of marine reserves: Catastrophes require adopting an insurance factor", *Ecological Applications*, p. , vol. , (). Accepted
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- Sagarin, R., and S. D. Gaines, "The "abundant center" distribution: to what extent is it a biogeographic rule?", *Ecology Letters*, p. 137, vol. 5, (2002). Published
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- Holbrook, S. J., D. C. Reed, D. C., and J. S. Bull, "Survival experiments with outplanted seedlings of surfgrass (*Phyllospadix torreyi*) to enhance establishment on artificial structures", *ICES Journal of Marine Science*, p. 350, vol. 59, (2002). Published
- Shima, J.S., and A.M. Findlay, "Pelagic larval growth rate impacts benthic settlement and survival of a temperate reef fish.", *Marine Ecology Progress Series*, p. 303, vol. 235, (2002). Published

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- Washburn, L., K. A. McClure, B. H. Jones, and S. M. Bay, "Spatial Scales and Evolution of Stormwater Plumes in Santa Monica Bay ,", *Marine Environmental Research.*, p. , vol. , (). Accepted
- Bay, S., B. H. Jones, K. Schiff, and L. Washburn, "Water Quality Impacts of Stormwater Discharges to Santa Monica Bay", *Marine Environmental Research*, p. , vol. , (). Accepted
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Books or Other One-time Publications

Robinson, T. H., Al Leydecker, J. M. Melack, and A. A. Keller, "Nutrient Concentrations in Coastal Streams and Variations with LandUse in the Carpinteria Valley, California.", (2002). Conference Proceedings, Accepted
Collection: California and the World Ocean '02.
Bibliography: Santa Barbara, CA, USA

Robinson, T. H., A.Leydecker, J. M. Melack, and A. A. Keller, "Nutrient Concentrations in Southern California Streams related to Landuse", (2002). Proceedings, Published
Editor(s): Lesnick, John R.
Collection: . Coastal Water Resources, AWRA 2002 Spring Specialty Conference Proceedings, American Water Resources Association
Bibliography: Middleburg, Virginia, TPS-02-1, pp 339-343

Bull, J. S., "An Experimental Evaluation of Different Methods of Restoring Phyllospadix torreyi (Surfgrass)", (2002). Thesis, Published
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Warrick, J. A., "Short-term (1997-2000) and long-term (1928-2000) observations of river water and sediment discharge to the Santa Barbara Channel.", (2002). Thesis, Published
Bibliography: Dissertation. University of California, Santa Barbara

Otero, M. P., "Spatial and Temporal Characteristics of Sediment Plumes and Phytoplankton Blooms in the Santa Barbara Channel.", (2002). Thesis, Published
Bibliography: Thesis. University of California, Santa Barbara, CA 113 pp.

Web/Internet Site

URL(s):

<http://sbc.lternet.edu>

Description:

This is our project's website that was created to describe the activities and results of this award

Other Specific Products

Product Type: Data or databases

Product Description:

ISP Alginates (formerly Kelco Co.) has collected information on the abundance 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. ISP Alginates has provided us with copies of all their archived records. We have 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. Kelps surveys by ISP Alginates are ongoing and we are continuing to work closely with them to keep the database on giant kelp current.

Sharing Information:

Our historical kelp database can be accessed on the SBC website at <http://sbc.lternet.edu/data/research/reef/historical-kelp-data/>.

Product Type: Data or databases

Product Description:

SST imagery from NOAA-AVHRR polar orbiters of the Santa Barbara Channel

Sharing Information:

The database is available at <http://www.icess.ucsb.edu/avhrr/ViewSBchnlGifs.html>

Product Type: Data or databases

Product Description:

Surface currents by high frequency radar around Point Conception California

Sharing Information:

The data are available at <http://www.icess.ucsb.edu/iog/codar.htm>

Product Type: Teaching aids

Product Description:

Field guide to the common subtidal plants and animals. Santa Barbara Coastal Ecosystem Long-Term Ecological Research Program.

Sharing Information:

available online at: <http://sbc.lternet.edu/data/research/reef>.

Contributions

Contributions within Discipline:

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.

Our stream experiments have shown that the relative importance of nutrient and grazer limitation to algal biomass changes across habitats and through the seasons. This temporal and spatial variation needs to be considered in examining controls on algal biomass and in examining the effects of stream organisms on nutrient processing. The stable isotope work indicates that stable isotope techniques can be used to delineate food webs across streams draining basins experiencing different types of land use. The Carpinteria Salt Marsh work suggests that marsh diatoms can be used as bioindicators of nitrogen inputs.

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, our understanding of ecosystem level processes 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 primary production, of stable isotope analyses of kelp forest food webs, and of the role of nutrients in altering these 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 begun to quantitatively assess the flux of nutrients due to each mechanism. This research is providing valuable information about transport processes on the inner shelf, which is 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 fills an important gap in that it 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.

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, and informatics. SBC is now completing its third year of research and the major contributions of our research have yet to be realized. It is our intent that coordinated studies among the many disciplines represented in SBC will lead to an improved understanding of the patterns and processes that link land and ocean environments and their consequences to coastal ecosystems. Such an improved understanding will not only contribute to furthering the many disciplines listed above, but should be of considerable value to those in the social sciences interested in studying the extent to which society is influenced by human impacts to coastal systems. SBC hopes to attract social scientists in future years to investigate such issues.

Contributions to Human Resource Development:

Our project provides significant opportunities for research and teaching in science at multiple levels. In 2002, four post docs, 23 graduate students, two REU students and more than 20 additional 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. One of our past REU students is Hispanic and recently graduated from UCSB in biology. He continued to work on our project as a research technician while actively exploring his options for furthering his education in graduate school. He recently was accepted into the graduate program at Columbia University beginning spring 2003. Several of our undergraduate students have applied for and received funding to pursue independent studies associated with SBC research activities. One of these students recently graduated and she has been accepted into a Ph.D program at UC Riverside. 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. Educational opportunities at SBC are not limited to university students and post docs. Two pre-college teachers and several 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. Using supplemental Schoolyard funds from NSF we developed a partnership with the South Coast Watershed Resource Center, a local non-profit group that promotes conservation of coastal ecosystems through education and training. Built at the request of Santa Barbara County in response to growing concerns about the South Coast's water quality, the Watershed Resource Center makes the connection between healthy watersheds and each of our own personal habits such as cleaning up after pets, landscaping with native plants, and properly disposing of everyday chemicals. It gives school kids an opportunity to experience our environment first-hand, provides information to educators about watershed-related subjects (including those studied by SBC), and educates the general public about coastal ecosystems and their conservation. NSF funds have been used to enhance hands-on school and public programs, teacher workshops, and computer based activities at the Center.

SBC investigators have also worked closely with the Channel Islands National Marine Sanctuary and the Santa Barbara Maritime Museum in developing curricula and exhibits that expose non-scientist members of the public to SBC research activities.

Contributions to Resources for Research and Education:

NSF funds from our project were used to purchase 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.

Our project contributed to institutional resources and education by way of providing support to the Western Society of Naturalists, which is one of only a handful of societies that provide a forum for young marine ecologists and naturalists to present their work. PI Reed was invited to organize a symposium on human effects on ecosystems at the land/ocean margin for the annual meetings of WSN. WSN specifically asked that the symposium be broad in scope, but it did not have funds to pay for all the travel costs of attracting speakers from areas outside of the west coast. We used NSF funds from this project to pay the travel expenses of some of the symposia speakers. The result was a symposium that featured speakers from all over the continental US and Hawaii speaking on a wide variety of topics. The society received many compliments on the symposium and was very appreciative of NSF's support.

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, and soil mapping and land-use coverage of the Santa Ynez Mountains. Significant effort was spend during 2002 upgrading our website to better convey the wide range of reseach and education activities being done by our project

Contributions Beyond Science and Engineering:

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

The Channel Islands National Marine Sanctuary (NOAA) and the California Department of Fish and Game have developed a joint state and federal process to consider marine reserves in the Channel Islands National Marine Sanctuary (<http://www.cinms.nos.noaa.gov/nmpreserves.html>). This joint federal and state process stems from a shared concern for sustaining California's marine resources, as well as areas of overlapping and complimentary jurisdiction. The public process is based on both extensive stakeholder input and the best available science. A Science Panel was formed to assimilate, analyze and interpret all scientific data pertinent to the process. Seven of the 15 member Science Panel are senior investigators associated with SBC. Many of the recommendations made by the Science Panel were based, in part, on first-hand knowledge obtained by SBC investigators. Relying heavily on information compiled by the Science Panel, the California Fish and Game Commission voted to implement a no-take marine reserve system in the Channel Islands beginning January 1, 2003. The pending marine reserve at the Channel Islands will be one of the largest ones in the country. The process of establishing marine reserves in the Santa Barbara Channel is ongoing and SBC investigators are continuing to play an important and active role in working with state and federal agencies on these issues.

Santa Barbara Channel has a long history of oil and gas development. Many of the platforms in the channel are nearing the end of their operating lives and there is much controversy over whether decommissioned platforms should be dismantled and removed or abandoned in place to serve as artificial reefs for fish and other reef associated organisms. Co-PI Holbrook chaired the UC Marine Council committee that wrote a report commissioned by the California State Legislature on scientific issues related to decommissioning California oil platforms. She and other committee members drew upon their knowledge of reef ecosystems in the Santa Barbara Channel and evaluated all other existing information on issues relating to production on artificial and natural reefs. The report was released in fall 2000, and can be found at http://www.ucop.edu/research/ucmc_decommissioning/

SBC research is playing 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 we and they share our 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. 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 working with city staff to help them plan their restoration efforts. 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 UCSB 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 the sites that we sample intensively, and we will continue to provide useful information to the Land Trust as they protect and manage the property. The Santa Barbara Channel Keepers 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. Tim Robinson, an SBC graduate student doing his dissertation research in the Carpinteria watershed is an active participant in the Carpinteria Creek Watershed Coalition, whose mission is to restore and preserve Carpinteria Creek sufficiently to reestablish a steelhead run (steelhead is an endangered species in California). Tim also serves on the Technical Advisory Committee to the Santa Barbara County Task Force, Southern California Wetlands Recovery Project. Melack serves on Common Ground, a stakeholder group formulating plans for long-term preservation and economic viability for the Gaviota coast.

Special Requirements

Special reporting requirements: None

Change in Objectives or Scope: None

Unobligated funds: less than 20 percent of current funds

Animal, Human Subjects, Biohazards: None

Categories for which nothing is reported:

RESEARCH ACTIVITIES

The research focus of SBC is on ecological systems at the land-ocean margin. Although there is increasing concern about the impacts of human activities on coastal watersheds and nearshore marine environments, there have been few long-term studies of linkages among terrestrial, estuarine, nearshore, and oceanic habitats. The primary research objective of SBC is to help fill this gap by determining the relative contributions of land vs. ocean-derived constituents in structuring kelp forest ecosystems, which are among the most productive systems in the world. SBC research involves interdisciplinary studies coordinated among more than twenty investigators working in watersheds, subtidal reefs, and the coastal ocean. These studies are designed to determine the effects of land use patterns on the distribution and movement of nutrients, sediments, and organisms across landscapes, their transport and modification by streams and estuaries, and the effects of stream outflows and coastal ocean processes (e.g., upwelling, currents, waves, and water column productivity) on population, community and ecosystem level processes in giant kelp forests.

Below we detail our research activities as they pertain to land, reef and ocean processes.

WATERSHED STUDIES

In water year 2002, we modified our first year strategy of studying a large number of streams representing broad land-use or geographic categories to intensively studying a few selected creeks. The selected streams were sampled as they cross land-use boundaries, as well as at the previously sampled tidal limit. We also sampled a few, well-defined, smaller drainages tributary to single land uses (e.g., residential, agricultural drains, and light commercial) in an effort to better define the effect of land-use on nutrient export. We sampled both baseflow and stormflow for dissolved inorganic nutrients (nitrate, phosphate and ammonium), total dissolved nitrogen, particulate N, P and C, and total suspended solids

Our 2003 sampling goals are to regularly sample stormwater chemistry at Gaviota, Refugio, Arroyo Hondo, Arroyo Burro, Mission, Santa Monica, Franklin and Carpinteria creeks, and to sample at least one storm on the Ventura River. This selection is derived from a number of considerations: (1) the need to sample the same creeks as in 2002 and 2001 because of the absence of a storm large enough to generate whole-catchment runoff in 2002 and only one such storm in 2001; (2) to expand coverage in the western LTER region by adding auto-sampling at Refugio and Gaviota; and (3) include the Ventura as both an eastern LTER location and to supplement the on-going "point in time" monthly river sampling program. Sampling at Gaviota, Arroyo Hondo and Ventura is being done at a single sampling point. All the other creeks are being sampled at multiple locations. The reasons for multiple sampling on a single creek are to determine how export varies with land use, and to model south-coast export and its probable variation with changing land use.

We have established 30 stream gauging stations in the LTER study region. At these sites, stream stage and water temperature are recorded at a 5-min temporal resolution. To convert our measured stage values to discharge we are developing rating curves by measuring channel cross-sections and roughness to characterize the channel reaches, and then, using the HEC-RAS (streamflow hydraulics) program, the channel properties are used to simulate rating tables that associate stage and discharge for a given site. 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 also record conductivity. Continuous (5-min) conductivity data will 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. Currently, we have installed 7 rainfall gauges (3 of the remotes gauges are equipped with spread spectrum telemetry). The additional sites have been identified, and we are currently in the process of gaining access to those sites.

Hydrologic modeling of the catchments requires detailed spatially distributed data. The following datasets have been compiled and subsetted for our catchments:

Digital Elevation Models: 3, 30 and 60 meter grid cell resolution.
National Hydrography Dataset (NHD) contains information about surface water features such as lakes, ponds, streams, rivers, springs and wells.
Soil Survey Geographic (SSURGO) data base, which is the most detailed level of soil mapping done by the Natural Resources Conservation Service (NRCS).
State Soil Geographic Database (STATSGO) is a soil map made by generalizing the detailed SSURGO data.
National Land Cover Data derived from the early to mid-1990s Landsat Thematic Mapper satellite data with a 21-class land cover classification scheme.
Land Use/Land Cover derived from digital 1:42,000 scale orthophotos taken in 1998.
Various coverages from the City of Santa Barbara and Santa Barbara County: zoning, parcels, storm drains, roads, etc.

Using the SBC-LTER and existing gauging networks, we calibrated and validated two rainfall-runoff models for streams in the study region for the recent 14-year period (10/1/1988 through 9/30/2002). The recent 14-years are well suited for studying climate variability in the region because there are 4, 4 and 6 years classified as having El Nino, La Nina and normal climatic conditions, respectively. Initially, the HEC-HMS rainfall-runoff model was used to simulate runoff for the current land use conditions for the 14-year period. Then historical and future land use conditions were obtained, and the model was used to simulate the effects of land use change on the annual distribution of streamflow.

Building on the initial modeling effort, we have developed a model better suited to the SBC-LTER region. The model simulates runoff from three sources (surface, steep shallow soils and groundwater) and is designed to integrate nutrient and sediment export modules, which represents the future research direction of the terrestrial component of the SBC-LTER. The SBC rainfall-runoff model has been calibrated and validated for one watershed for the recent 14-year period using the current land use conditions. Predevelopment and future development land use conditions have also been simulated.

We have used supplemental NSF funding to establish on-line access to archived and on-going hydrologic and environmental datasets from the SBC-LTER by linking to both the CLIM-DB and HYDRO-DB.

Four studies of stream ecology were conducted: (1) The biotic effects of introduced crayfish are under investigation. (2) Stable isotope analyses are being used to decipher trophic structure in different seasons and habitats. (3) Surveys of water chemistry, physical factors, and benthic algae and invertebrates were conducted at approximately 30 coastal stream sites between Gaviota and Carpinteria. The purpose of this study is to examine correlations between the distribution of invertebrates and physical-chemical factors in coastal streams and to examine the use of stream invertebrates as bioindicators for stream "health". This work may form the basis for long-term LTER collaborations with the County of Santa Barbara, which is interested in developing assays for measuring stream "health". (4) To assess the effects of nutrients on species composition and biomass of benthic and floating algae in coastal streams, the relationship between in-stream nutrient concentrations and algal growth is being investigated in several streams. Surveys of water chemistry and algal abundance and species composition were conducted throughout the watersheds, and N and P supply were experimentally manipulated using nutrient diffusers to assess algal growth responses

REEF STUDIES

Kelp forest community monitoring

The primary objectives of our 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 sites close to and far from sources of terrestrial runoff. In the summer of 2001, we increased the number of sites that we sample from three to nine. Two to eight 40 m long transects were installed at each site. The transects were marked with metal stakes fastened to the bottom at five meter intervals. The abundance of relatively large solitary algae (e.g.,

kelps) and invertebrates 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, invertebrates, and cryptic species of fish are counted in six permanently placed 1 m² quadrats that are located at eight meter intervals along each transect. The percentage cover of understory algae, sessile invertebrates, and various substrate types along each transect is determined at 80 uniformly positioned points along each 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. All nine reef sites were sampled in the summer of 2002. We installed temperature loggers that record the temperature on the bottom every 30 minutes at each site.

We also continue to sample 11 reefs at Santa Cruz Island. 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 band 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 0.1m² 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. 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. 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. Efforts to include sections in the Field Guide on reef fish and marine mammals are underway.

Historical database on giant kelp abundance

ISP Alginates (formerly Kelco Co.) has collected information on the abundance 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. ISP Alginates has provided us with copies of all their archived records. We have 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 the data 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. In 2002 we added maps and other descriptive information on the kelp beds of Central, Southern, and Baja California to the database. Additional plans are underway to include over 1000 images of kelp canopies taken over the last 30 years. Aerial kelp surveys by ISP Alginates are ongoing and we are continuing to work closely with them to keep the database on giant kelp current.

Primary production in giant kelp

In 2001 we initiated field studies designed to examine spatial and temporal patterns of variation in the production 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 are thought to live about 6-8 months. In 2002 we refined the methodology that we use to estimate changes in standing stock over time and we have implemented this new methodology in our monthly surveys since May 2002. The methodology consists of: (1) estimating the length of all fronds > 1 m tall along fixed transects at three sites (Mohawk Reef, Arroyo Burro, Arroyo Quemado (lengths are estimated separately for the water column and canopy portion of each frond because the canopy portion of fronds tend to have greater biomass per given length than water column portions); (2)

measuring frond turnover (birth, growth and death) on 15 marked plants at each site; and (3) plant dissections for estimating weight-length relationships for the water column and canopy portions of different types of fronds (growing, not growing, senescent) and for determining the chemical composition (C, N) of different tissue types. These data are being used to estimate net primary production in two ways: (1) as the growth of surviving fronds + the biomass of new fronds in a population, and (2) as the change in the standing stock + the loss of initial biomass. When used in combination, these two approaches will be useful in determining the relative contributions of the birth of new fronds vs. the death of old fronds (i.e., population turnover) to NPP.

The methodology outlined above is quite labor intensive, and thus is difficult to apply over a broad region. We are exploring the potential for estimating plant standing crop and productivity using in situ spectroscopy. In this method a radiometrically calibrated HydroRad spectroradiometer fitted with cosine collectors is mounted to a portable frame for underwater operation by a SCUBA diver. Downwelling irradiance spectra are being measured inside and outside our three kelp forest sites where we are measuring kelp productivity. Canopy absorbance of spectral irradiance is determined by differences in downwelling irradiances measured inside and outside the kelp forest. The resulting absorbance spectra are compared to spectrophotometrically determined absorbances of individual kelp blades measured in the laboratory. Optical data collected in the field are taken concurrently with more labor intensive diver measurements of kelp biomass. The optical data are used to calculate a Blade Area Index (BAI) for use in estimating standing crop. Estimates of standing crop based on BAI are compared to those obtained from diver measurements to determine the validity of using optical data for assessing standing crop in giant kelp.

Kelp forest community metabolism

In collaboration with Dr. Sally MacIntyre and Brian Gaylord of UCSB, Amatzia Genin of Elat University in Israel, and Drs. Steve Monosmith and Jeff Koseff, and Rob Dunbar of Stanford University, SBC conducted preliminary studies to investigate how the kelp forest modifies the flow around and within its boundaries, and how forest producers and consumers alter the flux of nutrients and particulates within the forest. The ultimate objective of this collaboration is to: (1) determine, for the first time, the net community production (NCP) and biogeochemical fluxes within a kelp forest.; (2) establish the linkages between net community production, nutrient and particle fluxes, and hydrodynamics; and (3) quantify the spatial (across the forest) and temporal (seasonal) changes in NCP, biogeochemical fluxes and hydrodynamics to fully characterize the kelp forest ecosystem.

Food web studies using stable isotope

Potentially important food sources to primary consumers on shallow subtidal reefs include phytoplankton-dominated seston, kelp-derived detritus, and for locations adjacent to sources of freshwater runoff, terrestrially-derived POM. We plan to use stable carbon and nitrogen isotope ratio analysis of consumers of varying trophic status to evaluate the relative contribution of these sources to reef food webs. Research activity during the reporting period has focused on beginning to characterize variability in the isotope values of potential food sources (phytoplankton, kelp, and terrestrial POM). This information is needed to evaluate whether these isotopic values differ enough from one another to permit the use of mixing models to estimate the contribution of each source to the reef food web.

Field experiments: the role of nutrients in trophic interactions

Kelp forests have two major food webs: a well studied one in which macroalgae are consumed directly by large grazers (i.e. sea urchins), which in turn are consumed by large predators (i.e., sea otters), and a little studied one in which macroalgae serves as a substrate for a periphyton and small crustacean grazers, which are preyed upon extensively by benthic reef fish. A question of interest to SBC is the degree to which nutrients control species interactions within each food web. To address this question, we began devising a suite of short and long-term experiments in 2002 to investigate how changes in nitrogen supply influence trophic interactions in the little studied macroalgal/periphyton based food web. The experiments feature a multi-factor design in which nutrients, primary producers (macroalgae, and periphyton), and consumers are manipulated and responses in the species composition, numerical abundance, and biomass of different trophic levels are being followed. We plan to follow these experiments through time to track both short-term (weeks-months) and long-term (years-decades) responses.. Much of the work done in 2002 focused

on testing various techniques of delivering nutrients to reef benthos and measuring the response of microalgae and macrofaunal crustacean, polychaete, and molluscan fauna

In summer 2002, we initiated an experiment to investigate the main and interactive effects of elevated nutrient supply and sea urchin grazing on benthic community structure at one of our experimental reef sites, Naples Reef (12-13 m water depth). The experiment consists of fourteen 15 m² plots, seven of which sea urchins are excluded from. Three 0.5 m² plots were established in the center of each of the 15 m² plots and were randomly assigned one of three nutrient treatments (diffuser with nutrients, diffuser without nutrients, and no-diffuser). At the beginning of the experiment the species composition, abundance, and biomass of algal and invertebrate fauna of benthic community were sampled using the same methods employed in the reef community monitoring section described above.

Two short-term experiments were set up to test whether the addition of nutrients, sea urchin grazing, and fish predation interact to influence the species composition, abundance, and biomass of microalgae and invertebrate grazers, which form the basis of the food chain for many reef fish. In the first experiment, microalgae/invertebrate recruitment substrates (1 cm x 15 cm x 8 cm plastic "Dobbie" dish scrubber pads) were placed on two of the three nutrient diffusers treatments (the diffusers with and without nutrients) located within three plots containing sea urchins and three plots without urchins. This experiment ran for two-weeks and tested whether nutrient addition and urchin grazing interact to influence microalgae/invertebrate recruitment. In the second experiment, we examined whether the effects of nutrient addition and fish predation on the abundance of microalgae and mesofauna colonizing experimental substrates. This was done by placing "Dobbie" recruitment substrates within fish exclusion cages (20 cm x 20 cm x 10 cm rectangular cages made of 1-cm Vexar plastic mesh) on two of the three diffuser treatments (the diffusers with and without nutrients) in plots containing sea urchins. The fish exclusion cages consisted of three treatments, a full cage, a cage control, and a no-cage treatment. One of each cage type was placed on each of the two diffuser treatments within each plot. The second experiment ran for a two weeks on two separate occasions and for one month on another occasion. We are in the process of determining what type of recruitment substrate and cage design will work best, and we are analyzing the results of the second experiment.

Kelp subsidies to sandy beach communities

The condition and productivity of kelp forests may directly affect that of other coastal habitats which depend on subsidies of kelp drift material. Exposed sandy beaches are a dominant coastal habitat in the SBC-LTER region, making up over 50% of the mainland shoreline. The rich macroinfauna of beaches in the region depend largely upon allochthonous sources of organic matter and carbon because relatively little primary production occurs on the beach itself. Kelp forests are important sources of organic matter and can provide large subsidies of drift macrophytes (>450 kg m⁻¹ y⁻¹) to sandy beach food webs in the SBC-LTER. With collaborative support from University of California Sea Grant, we are studying the responses of infaunal invertebrates, shorebird predators, sediments and dune vegetation to macrophyte subsidies from coastal reefs using comparative surveys and manipulative field experiments.

OCEAN STUDIES

We are using a combination of time series measurements at reef sites, survey cruises over the entire Santa Barbara Channel and satellite observations to examine the transport of nutrients and other constituents to and from the reef ecosystem. Three permanent reef sites are being monitored through a combination of sampling from small boats, instrumented moorings, and satellite imagery. The principal goal of these observations is to establish baseline data for detecting key events that can affect the reef ecosystem. These include the prevalence of freshwater plumes at each reef site, the flux of nutrients to the macrophytes, and the character and flux of particulate material that fuel the sessile invertebrate community. We have also undertaken a series of channel-wide cruises on the R.V. Point Sur, to monitor the seasonal characteristics of physical, chemical, and biological parameters in the offshore waters that are the source of these materials to the reef.

Channel surveys

We conducted three channel-wide surveys of hydrographic and biological parameters during February, March, and September of 2002, and will conduct three more during 2003. Each cruise includes using an

undulating towed vehicle called a Scanfish to obtain high resolution, two-dimensional maps of temperature, salinity, beam attenuation at 660 nm (a measure of water turbidity), and chlorophyll from the surface to ~ 100 meters depth. A set of cross-channel transects of CTD profiles along the Scanfish tracks provides vertical profiles of the same water properties measured by the Scanfish, but from the surface to the bottom. Additional parameters such as nutrient and particle characteristics are derived from bottle samples obtained during the CTD surveys. Depth profiles of primary production are also done to assess the relative roles of phytoplankton vs. macrophyte production. Other instruments on the CTD platform measure optical properties used to characterize the particle fields and dissolved components of the water column. The spatial variability of currents is measured continuously during the cruises with a ship-board Acoustic Doppler Current Profiler (ADCP).

The data from these cruises provide a valuable measure of the “background state” of the Channel with respect to water characteristics, nutrient concentration, phytoplankton biomass and primary productivity. It is necessary to characterize seasonal patterns in these properties, as well as changes at shorter time scales due to oceanic dynamics, in order to assess the role of “open channel” nutrient delivery to kelp reefs, and to adequately compare it to delivery from terrestrial sources. Valuable complementary data on the seasonal evolution of water masses, nutrients and particle fields is obtained from twice-monthly cruises of the Plumes and Blooms project (funded by NASA). We are developing a series of computer programs to automate the processing of the Scanfish and other survey data. Currently we have completed the work on the ScanFish processing allowing near real time data processing and graphical visualization of the data while at sea. Efforts continue to streamline and automate the processing of other data sets.

Monthly sampling

We continued monthly sampling of water properties at two reef sites (Carpinteria Reef and Naples Reef) that we initiated in November 2000 and began additional sampling at a third reef site (Arroyo Quemado) in March 2001. Sampling at the three reefs is conducted with small boats. We have reduced the number of stations samples at each site to a single site at each reef due to budgetary constraints. Last year we sampled three locations near each reef site. Sampling stations were located inshore of each reef, halfway between the surf zone and the reef, immediately adjacent to each reef, and about a kilometer offshore of each reef. This year we have reduced our sampling effort to the single site at each reef due to budgetary constraints. A CTD equipped with a chlorophyll fluorometer and transmissometer is lowered at each station and data on temperature, salinity, chlorophyll, and suspended sediments are recorded throughout the water column. Pumped water samples are collected from the surface down to 25 m (depending on water depth) and analyzed for nutrient concentrations (nitrate, silicate, and phosphate). Samples of particulate mater are collected at each depth and analyzed for carbon and nitrogen isotopes, particulate organic carbon, organic nitrogen, and silica concentrations, and chlorophyll concentration. All water samples are filtered within hours of collection and stored frozen for analysis in the Marine Science Institute Analytical Laboratory at UCSB. This year we stopped collecting samples of particulate silica concentration due to budgetary constraints.

Moorings

We continue to maintain a permanent mooring at each core reef site (Carpinteria, Naples Reef, and Arroyo Quemado). These permanent moorings allow us to sample ocean conditions at a higher frequency and in a wider range of conditions than can be achieved using small boats. This is especially important during storm events when sampling from boats is not possible. Each mooring is equipped with a conductivity sensor, temperature sensor, pressure sensor, and fluorometer and backscatter meter deployed at 2 m. An ADCP is deployed on the bottom adjacent to each mooring to monitor ocean current patterns. During 2002 we deployed an automated nutrient analyzer manufactured by WS Oceans near the Naples and Arroyo Quemado moorings. This nutrient analyzer allows us to obtain a time series of nitrate concentration with at sampling intervals as low as 20 minutes, and allows detailed investigations of the role of inner shelf processes, such as upwelling and internal tides, in supplying nutrients to the reef. The nitrate analyzer has been deployed nearly continuously from July 2002 through December 2002. We were successful in timing one of the winter deployments to coincide with the first major rainstorm of the year allowing us to examine the effects of a first flush of nitrate on the reefs. We were also successful in obtaining funds through the ONR DURIP program to purchase two additional nutrient analyzers. An additional WS Oceans device has been ordered and was received in December 2002. We plan to purchase a new optical nitrate analyzer from

Satlantic Corporation for us on the undulating vehicle to define the variance in nitrate concentration along isopycnal surfaces that impinge on the reefs.

Surface Current Patterns

Over the past year we continued to operate an array of high frequency (HF) radars to monitor surface currents in the Santa Barbara Channel. Data are available in the western Channel for most of 2002 from the five site array centered on Point Conception. We are now reconfiguring the radar array to have better coverage over the LTER study area. Sites at Point Conception and Point Arguello are being moved to sites in the eastern Santa Barbara Channel: one site will be the Rincon Island (We are awaiting permit approvals on this site), the other is not yet determined but may be the Mandalay Generating Station near Oxnard, CA. The HF radars provide hourly maps of surface currents around-the-clock out to a distance of about 42 km offshore. This array presently encompasses two of our three reef sites and will cover the third when the new sites are established in the eastern channel. We are using data from the HF radar array to examine how the larger scale circulation patterns in the Channel influence flow over the inner shelf and through the reef ecosystem.

Satellite Data

Local area coverage imagery from the SeaWiFS and AVHRR missions are 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. 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.

We have focused our initial studies on assessing the space/time characteristics of the chlorophyll imagery from SeaWiFS and the processes which control phytoplankton blooms. This work was presented at the 2001 ASLO Aquatic Science meetings in Albuquerque. We find good relationships among upwelling indices (wind and SST) and chlorophyll distribution and strong east to west differences in chlorophyll are apparent. Ocean color imagery is also used to assess the dispersion of sediment plumes within the Santa Barbara Channel. These data provide a unique large scale view of ocean processes in the Santa Barbara Channel. We plan to submit a manuscript using these data to the special issue of Deep-Sea Research, Part II on SeaWiFS applications.

Runoff "Event" Sampling

We have initiated the "event" sampling described in last year's annual report. Thus far we have sampled the first major storm of the year and are poised to sample subsequent significant runoff events. Currently we are sampling with a CTD and transmissometer, and sample for dissolved nutrients and suspended particulate matter. This sampling is coordinated between the ocean and watershed groups to ensure changes in the ocean can be related to terrestrial runoff. Our current efforts focus on the outflow from the Carpinteria salt marsh. We will broaden our event sampling to include other watersheds once we gain a better understanding of the fate and transport of runoff plumes.

PRESENTATIONS

2002

- Beckenbach, E.H. and L. Washburn, 2002: Observations of Wavelike Phenomena in the Santa Barbara Channel Using HF Radar, Ocean Sciences Meeting, 11-15 February, Honolulu, HI.
- Beighley, R.E. 2002. (Invited), Advancements in GIS and Hydrologic Modeling: Adjusting Measured Flow Data from Urbanized Watersheds and a case study of the SBC-LTER, Water Science Group, University of California, Santa Barbara, CA, February 19, 2002.
- Beighley, R.E. 2002. Hydrologic modeling for the SBC-LTER. Water Science Group Meeting, UCSB.
- Beighley, R.E., and J.M. Melack, 2002. Spatial Database Development and Integration into Hydrologic Modeling in Coastal Watersheds for the Santa Barbara Channel – Long Term Ecological Research Project, California and the World Ocean 2002, Santa Barbara, CA, October 28, 2002.
- Beighley, R.E., T. Dunne, and J.M. Melack, 2002. Annual and Interannual Streamflow Variability for Mountainous Coastal Catchments in a Mediterranean Climate in Relation to Land Use Change and

- Climate Variability, American Geophysical Union, Fall Meeting, San Francisco, CA, December 9, 2002.
- Cudaback, C., and L. Washburn, 2002. Circulation near Pt. Conception California, PISCO Symposium, Monterey, CA, 10 March.
- Cudaback, C., L. Washburn, E.P. Dever, 2002, Inner-Shelf Circulation Near Point Conception, California. Ocean Sciences Meeting February, Honolulu, HI, 11-15 Feb.
- Cudaback, C., L. Washburn, J. Caselle, C. Blanchette, B. Gaylord. 2002. High frequency sampling of nearshore coastal circulation and invertebrate settlement near Santa Barbara California, Eastern Pacific Ocean Conference, Timberline Lodge, OR, 25-28 Sept.
- DiGiacomo, B. Holt, and L. Washburn, 2002. Pollution Hazards Off the Southern California Coast: Satellite and In Situ Observations of Naturally Occurring Oil Seepage, Storm Water Runoff and Wastewater Plumes. Water Quality: Ocean Modeling, Observations and Remote Sensing, California and the World Ocean, Santa Barbara, CA, 27-30 Oct.
- DiGiacomo, P. M., B. Holt, and L. Washburn, 2002, Pollution Hazards off the Southern California Coast: Satellite and In-Situ Observations of Naturally Occurring Oil Seepage and Storm Water Runoff Plumes. Ocean Sciences Meeting February, Honolulu, HI, 11-15.
- DiGiacomo, P.M., B. Holt, and L. Washburn, 2002, An Examination of Small-Scale Coastal Eddies and Pollution Hazards off California Using an Integrated Multi-Sensor/In-Situ Approach. AIRSAR Workshop, Jet Propulsion Laboratory, Pasadena, CA, 5 March.
- Dugan, J. E. 2002. Ecological effects of grooming on exposed sandy beaches in southern California. Invited Seminar, California State University Northridge.
- Dugan, J. E. 2002. Ecological impacts of grooming on exposed sandy beaches in southern California. Paper presentation, California and the World Ocean '02, Santa Barbara, CA
- Dugan, J. E. 2002. Response of sandy beach ecosystems to macrophyte wrack subsidies. Presented at NOAA Hazardous Materials Response Division annual meeting, Santa Barbara, CA
- Dugan, J.E. 2002. Effects of beach grooming on sandy beaches in California. Presented to San Diego City Council, Natural Resources and Culture Committee, San Diego, CA
- Gaines, S. D. 2002. Fluid connections. Seminar for the UCSB Board of Trustees, University of California, Santa Barbara. October 2002
- Gaines, S. D. 2002. Large scale perspectives on marine ecology . Department seminar. University of California, Santa Barbara. November 2002.
- Gaines, S. D. 2002. Large scale perspectives on marine ecology. Department seminar, California State University, Fullerton. November 2002.
- Lenihan, H.S. 2002. Santa Barbara Channel LTER: an example of multidisciplinary coastal marine research at UCSB. UCSB Bren School of Environmental Science and Management Fall Student Orientation.
- Levenbach, S. 2002. Human and Natural Causes of Variation in Benthic Community Composition on Nearshore Rocky Reefs. UCTSR&TP 15th Annual Symposium, April 5-6, 2002, Long Beach, CA
- Leydecker, A. and J. Altstatt. 2002. Nutrient response of the Ventura River to drought conditions in southern California. . American Geophysical Union, Fall Meeting (San Francisco.)
- McPhee-Shaw, 2002. Internal waves over continental slopes: implications for the suspension and transport of sediment. Invited presentation. American Geophysical Meeting, San Francisco, CA, December, 2002.
- McPhee-Shaw, E, Siegel D, Washburn, L, and M. Brzezinski, 2002. The Santa Barbara Channel LTER. Oceanographic data from near-shore stations, 2001, with implications for nutrient delivery to kelp reefs. Departmental seminar at the Applied Physics Laboratory at the University of Washington.
- McPhee-Shaw, E. 2002. Inner-Shelf Observations from the Santa Barbara Channel LTER. Departmental seminar, UCSB.
- McPhee-Shaw, E., M. Brzezinski, D. Siegel, and L. Washburn, 2002. The Santa Barbara Channel LTER: Oceanographic data from near-shore stations, 2001-2002, with implications for nutrient delivery to kelp reefs. California and World Ocean '02 Conference, Santa Barbara, CA, October 27-30, 2002.
- McPhee-Shaw, Washburn, Siegel, and Brzezinski, 'The Santa Barbara Channel LTER (Long-term ecological research) study. Oceanographic time-series data from nearshore stations, 2001, with implications for nutrient delivery to kelp reefs. Talk given at EPOC (Eastern Pacific Ocean Conference) meeting, Mt Hood, OR, September 25-28, 2002.
- Otero, M.P., 2002: Physical Forcing of Plumes and Blooms in the Santa Barbara Channel: Department seminar, UCSB. November 2002

- Otero, M.P., D.A. Siegel and E. Fields, 2002: Physical Forcing of Plumes and Blooms in the Santa Barbara Channel: An Integrated Satellite Approach. Poster presented at 2002 AGU/ASLO Ocean Sciences meeting, Honolulu HI, February 2002.
- Robinson, T. 2002. Santa Barbara Coastal Long Term Ecological Research (LTER); Nutrient Concentrations in Coastal Streams, Variations with Land Use in the Carpinteria Valley, California. Paper presentation, California and the World Ocean '02, Santa Barbara, CA
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RESEARCH FINDINGS

WATERSHED STUDIES

While the SBC-LTER is relatively new (i.e., < 3 years of data), there is sufficient water quality information to characterize storm response and assess the annual fluxes for water and nutrients. From an analysis of the first two years, variation in chemical concentration with the storm flow hydrograph requires the modeling of nutrient export in these “flashy” relatively short and steep coastal streams at a time step significantly less than one day. For example, Figure 1a shows that nitrate, SRP and particulate organic nitrogen (PON) vary with the hydrograph, albeit in different patterns: SRP varies in phase with outflow, nitrate exhibits the opposite pattern, and PON concentrations, along with other particulates, reach a maximum on the rising limb of the first storm pulse. Different patterns imply different mechanisms and/or sources for the various species. Concentration-discharge (C-D) plots for constituents provide insight into what these mechanisms and sources may be. Figure 1b shows the C-D plot for nitrate and silica for the storm and stream in 1a; the arrows indicate variation with time. A counter-clockwise loop, as shown in Figure 1b, requires a minimum of three sources. Assuming surface runoff dominates on the rising hydrograph limb, shallow soilflow is predominant on the falling limb, and that groundwater exerts an influence at hydrograph peaks and controls baseflow concentrations, the magnitude of nitrate concentrations in the various source waters must be soilwater > groundwater > surface runoff. The silica pattern, while similar, exhibits relative concentrations of groundwater > soilwater > surface runoff. However source concentrations may vary both between storms and within a storm, e.g., due to the flushing and exhaustion of dry-season deposition, or end of growing season mineralization and reduced residence time of stormflow. The effect of different source waters on total dissolved nitrogen (TDN) concentrations and their decline with time can be seen in Figure 1c.

The cumulative annual flux for water year 2001 is shown in Figure 1d for the Carpinteria Creek watershed. The rainy season was characterized by two major storms of similar rainfall magnitude: one in early January, the other in early March. The March storm generated approximately 60 % of the annual export of dissolved constituents since little upland runoff resulted from the January storm due to low antecedent soil moisture conditions. Further, the March storm produced over 90 % of the annual particulate export; annual particulate P export exceeded dissolved P export by a factor of 2-3. In 2000-2001 (Sep-Aug) on the Ventura River, nitrate and SRP exports were 1.73 and 0.07 kg/ha; in 2001-2002 (Sep-Aug) the export decreased to 0.07 and 0.01, or 96 and 81% less. In drought years particulate export is low, as sediment is appreciably mobilized only in large storms and dissolved export dominates; in El Niño years the situation is reversed, particulate export exceeds dissolved export by more than an order of magnitude.

Given the effects of El Niño and La Niña conditions on rainfall and runoff, interannual variability is large. We reviewed 14 years of records for the Atascadero Creek watershed and found that the maximum 10 days of flow from an average El Niño year accounts for 10-15 percent of the total 14-year discharge compared with 2-3 percent for an average La Niña year. In a given year, the maximum 1-day of flow can account for over 50 percent of the annual discharge.

The three streams in the Carpinteria region exhibit a wide range of nutrient concentrations (Figure 2). Baseflow nitrate concentrations in Franklin Creek are three orders of magnitude greater than in Carpinteria Creek. Stormflow nutrient concentrations vary both spatially and temporally. Streams with low levels of agricultural or urban development (Santa Monica) have increased nutrient concentrations during storms; while more intensively developed watersheds (Franklin) show a decrease. Carpinteria Creek exhibits an increase in nitrate concentrations while phosphate decreases during stormflow.

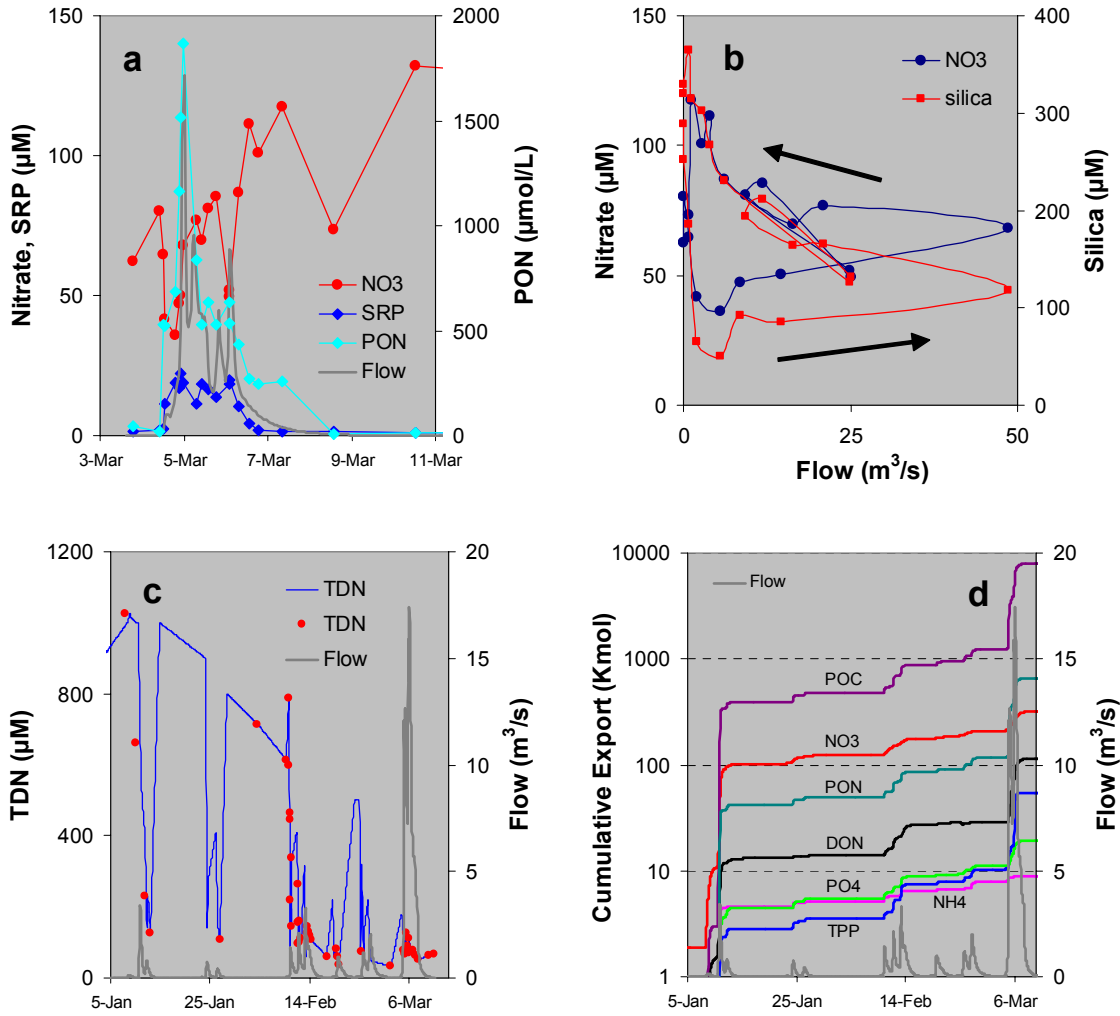


Figure 1: (a) Variation in nitrate, soluble reactive phosphorus (SRP) and particulate organic nitrogen (PON) at the outflow of Arroyo Burro during the storm of March 4-9, 2001; (b) Concentration-discharge relationship for nitrate and silica at Arroyo Burro during the same storm; (c) modeled and sampled (points) total dissolved nitrogen (TDN) at the outflow of Carpinteria Creek during the rainy season: 2000-2001; (d) Cumulative export of Carpinteria Creek during the winter of 2000-2001.

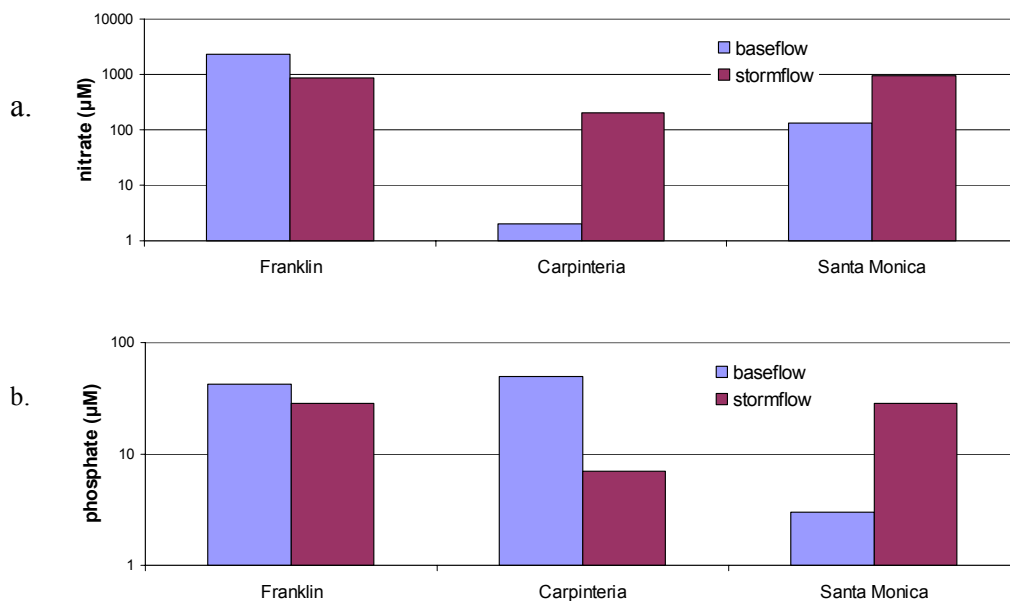


Figure 2: (a) Mean (WY2001) stormflow and baseflow nitrate concentrations (b) Mean stormflow and baseflow phosphate (SRP) concentrations.

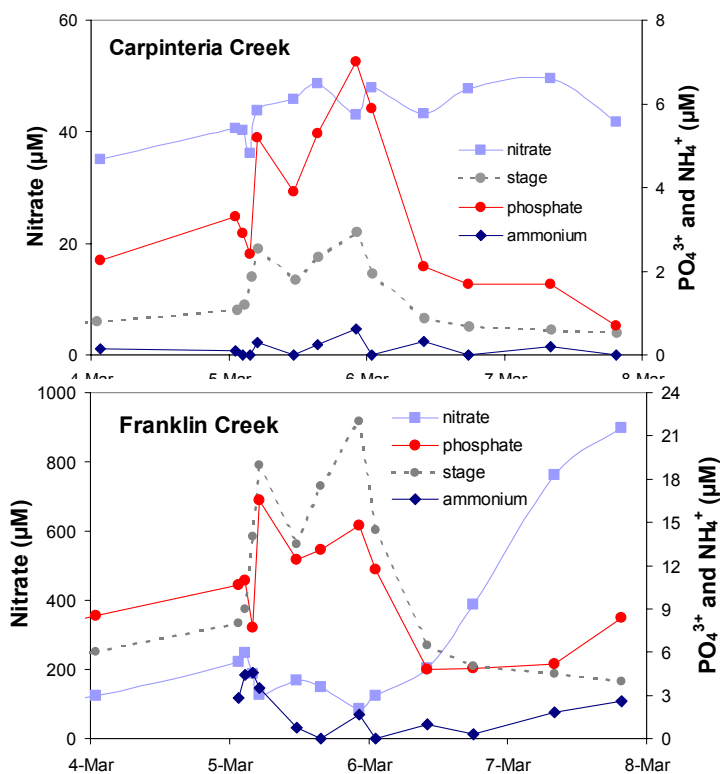


Figure 3. Nutrient concentrations at Carpinteria and Franklin creeks during the largest storm of the winter of WY2001. Stage is included as an indication of variations in stormflow (no scale). The EPA safe drinking water standard is $714 \mu\text{M NO}_3^-$ ($10 \text{ mg/l NO}_3\text{-N}$).

During the largest storm in WY2001, nitrate concentrations in Franklin Creek were four times higher than in Carpinteria Creek, while phosphate was higher by a factor of 2 (Figure 3). The similarity of the temporal variation in phosphate concentrations with the hydrograph in both streams indicates that phosphate is probably being exported from the entire catchment and not from any particular land use. In contrast, the decrease in nitrate concentrations with increased stormflow in Franklin Creek points to dilution, probably from impervious area runoff, as the primary mechanism reducing concentrations. Avocado orchards may be responsible for increased nitrate in Carpinteria Creek during the storm. Ammonium concentrations in Carpinteria Creek remained low throughout the storm and peaked at $0.6 \mu\text{M}$ with the crest of the hydrograph. In Franklin Creek, ammonium rose rapidly at the initiation of the rising limb of the hydrograph only to fall off quickly and stay at relatively low concentrations until a day after the storm when it began to rise back to base flow levels.

The Ventura River drains 580 sq. km of mountainous coastal watershed 100 km northwest of Los Angeles, Ca. The climate is Mediterranean with an average annual rainfall of 500 mm and extreme seasonal and inter-annual variations in runoff; more than 90 % of the rain falls between Nov. and April and most of the annual flow (range: 0 to 11 cu.m/sec) occurs over a few days. Monthly synoptic sampling of nutrients at 15 locations (from Nov. 2000) shows nitrate peaking 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) on 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.

Rainfall in the winter of 2001-02 was only 40 % of the annual mean, insufficient to meet end-of-dry-season soil moisture deficits and generate runoff from upland areas; subsequent groundwater inflows to rivers and creeks were severely diminished. Average flow this past winter was 0.15 cu.m/sec, in contrast with a 72 yr mean of 4.6. In the absence of stormflows, which usually scour the channel, exuberant plant growth overwhelmed the lower river and macrophytes have replaced algae as dominant primary producers. Phosphate concentrations following the drought winter have remained similar to those measured during the previous, normal rainfall, year of 2000-2001 (1-5 μM), except below km 9, where treated sewage effluent is discharged.

With lower flows, effluent has become the dominant source of water below the treatment plant, increasing the relative nutrient loading; 3 km below the plant, phosphate and nitrate concentrations increased by late summer to ~ 30 and $200 \mu\text{M}$, respectively. In contrast with phosphate, nitrate concentrations elsewhere are reduced, falling below detection limits in many sections. These sections have now become N-limited, as further evidenced by the increased presence of N-fixing plants and *chara* alga. While some nitrate reduction is undoubtedly due to lower ground and soilwater inflows, uptake by aquatic vegetation has played a significant role. More rapid and dense vegetative growth in the absence of winter channel scouring, lower than normal drought-year flows, and velocity inhibiting beds of macrophytes have led to enhanced uptake and denitrification. In effect, the lower river has become a linear wetland; by km 1, high nitrate concentrations in discharged effluent have decreased to zero. These relative normal-to-dry-year changes are common, the discharge record indicates even drier conditions 27 % of the time.

Initial results from the Santa Clara River work indicate that loading of nutrients to the land surface is dominated by agriculture and atmospheric deposition, but that a large fraction (typically > 90%) is assimilated or transformed so that it is not available for transport during storm events. The relative contributions from point and non-point sources vary along the watershed for each nutrient. Although ammonium salts are used as fertilizer and are also found in atmospheric deposition, NH_4^+ is transformed relatively fast to NO_3^- , resulting in little in-stream ammonium loading from non-point sources. Nitrite inputs are low, mostly from the wastewater treatment plants. NO_3^- is reaching the river from a number of sources, from direct releases, through stormflow and shallow subsurface flow, and from deeper groundwater that intersects the river at various locations.

In order to determine the effects of anthropogenic development on algal communities in streams, we selected sites in four streams draining small watersheds in the Santa Barbara area, and multiple sites within a single larger watershed near Malibu, CA. Each site was located in a stream which drained a watershed or sub-watershed predominantly influenced by a single type of development (e.g. agricultural, urban, or

commercial). At each site we performed a survey of algal species composition, percent cover, and biomass, and also measured nutrient availability (nitrogen and phosphorus) and physical conditions which might influence algal growth (light availability and current speed). In addition, we investigated the response of benthic algal communities to N and P enrichment using an in-stream nutrient diffuser apparatus. In a separate experiment, we measured the growth response of floating algae to a light gradient.

Our surveys showed a broad range of algal biomass in these streams, from 1.6 mg m⁻² chlorophyll a in an unimpaired site to 4000 mg m⁻² chlorophyll a at an urban site. The growth of floating algae responded strongly to experimental light reduction. Preliminary results from the nutrient diffusers indicate that the response of algal biomass to N and P enrichment changes substantially across sites with differing anthropogenic influence.

We are using 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 River and neighboring streams along the Santa Barbara coast. Although previous experiments have demonstrated the important effects of crayfish on benthic stream communities, no studies have examined the effects of invasive crayfish on the abundance and distribution of local stream invertebrate, plant, and algal assemblages. Our first year's results are in agreement with similar studies detailing the effects of other crayfish species on benthic invertebrate prey, suggesting that crayfish have strong impacts on snails (e.g., *Physella* sp.).

We have sampled in riffles and pools, separately, for stable isotope analyses (¹³C and ¹⁵N) in spring, summer, fall and winter in Rattlesnake Creek. The results from our initial studies indicated that the analysis of stable isotopes can be used in local streams for tracing aquatic food webs. Leaf litter, FPOM and periphyton often had different $\delta^{13}\text{C}$ signatures; consequently, we were able to trace carbon sources for different herbivores. Only pure *Cladophora* samples showed clean signatures for algae, whereas periphyton samples were probably contaminated with detritus. $\delta^{15}\text{N}$ values of herbivores were elevated by 1-2 ‰ relative to the $\delta^{15}\text{N}$ of their diets. Heptageniid and baetid mayfly nymphs used algae as their primary food source, whereas the caddisflies *Lepidostoma* and *Gumaga* used a mixture of leaf litter and FPOM. $\delta^{15}\text{N}$ of the predators was enriched by ca. 2 ‰ relative to the $\delta^{15}\text{N}$ of the herbivores

REEF STUDIES

Kelp forest community monitoring

To date, we have collected data on the abundance of over 150 species of kelp forest plants and animals. Data collected in summer 2000 showed Carpinteria and Naples Reefs are dominated by actively grazing sea urchins and are largely deforested of kelp and understory foliose algae. Nonetheless, there are striking differences in the benthic species composition at these two sites. Carpinteria Reef has little foliose algae (< 1%) and is dominated by encrusting coralline algae with relatively few reef-associated fish. In contrast, the abundance of understory algae (mainly red algal turf) and fish on Naples Reef are relatively high. Interestingly, the algal turf on Naples Reef is usually associated with aggregations of the clonal sea anemone, *Corynactis californica*. The mechanisms causing the species assemblages at Carpinteria and Naples to differ are unclear. One possibility is that sea urchins avoid the stinging tentacles of sea anemones. As a consequence, sea anemones provide a spatial refuge from grazing and allow patches of red algae to persist despite high densities of grazing sea urchins. The conspicuously low abundance of clonal anemones at Carpinteria Reef could result from high rates of sedimentation, which can inhibit suspension feeders as well as turf algae. One important source of sedimentation on nearshore reefs is terrestrial runoff, which likely differs between the two sites. Unlike Naples Reef, which is offshore far from sources of runoff, Carpinteria Reef is located at the outfall of a major drainage system in a heavily developed watershed. Thus sedimentation from runoff could reduce algal abundance and the forage base for fishes on Carpinteria Reef directly via burial, or indirectly by reducing the abundance of sea anemones that provide them refuge from grazing sea urchins. We have obtained matching funds from the University of California Marine Council for stipend support for a graduate student (Stu Levenbach) to work on testing these and other related hypotheses for his dissertation. Mr. Levenbach's results to date indicate that sea urchins do indeed avoid clonal sea anemones. Experiments are underway to determine (1) threshold densities of *Corynactis californica* needed to illicit an avoidance response in sea urchins, and (2) the role of sediment in determining the distribution and abundance of *Corynactis californica*.

Our long-term sampling of reef systems on Santa Cruz Island has provided evidence of ecosystem changes associated with ocean warming at the decadal scale. We have seen shifts to dominance by southern species in kelp forest fish at these sites. Since the early 1970's, the proportion of species in fish assemblages that are cold-water, northern species has dropped by about half, while the proportion of southern, warm-water species has increased nearly 50 percent. Overall, there has been a substantial decline in total fish abundance, which correlates closely with declines in productivity. These patterns suggest an ongoing redistribution of marine species along the coast of California that is consistent with predicted northward shifts in species' ranges in response to ocean warming.

Primary production in giant kelp

The production of new fronds of giant kelp varied greatly among seasons. Frond production in the fall was three to four times greater than that in late spring and early summer. Spatial variability in the production of new fronds was relatively small as similar patterns were observed at all sites. Elongation rates of new fronds were measured at two sites (Mohawk and Arroyo Burro) during November and December 2001 and January 2002. During this period growth rates averaged 10 and 14 cm day⁻¹ peaking in December at 12 and 19 cm day⁻¹, for Mohawk and Arroyo Burro, respectively. Tremendous variation in growth rates were observed among fronds with elongation rates of some fronds averaging nearly 90 cm per day. The relationship between frond length and frond weight was generally consistent over time and among sites, which greatly simplifies the conversion of data on frond length to estimates of frond biomass.

Spectral shapes of the calculated canopy absorbance spectra showed similarities with laboratory measurements of individual blades and provided a simple means for calculating the horizontally projected blade area index (*BAI*) of the overlying canopy. Optical estimates of horizontally projected *BAI* were correlated to the more laborious direct counts and harvest estimates, but the slope of the relationship was 0.22, perhaps in part due to our relatively low sample size at this point in time. Application of the cosine law to this slope suggests the average angular distribution of kelp blades within the canopy to be about 13° with respect to the nadir. We are continuing to evaluate the utility of in situ spectroscopy for rapid, non-destructive evaluation of submerged plant canopies in optically shallow waters and plan to obtain more data under a wider range of canopy densities.

Kelp forest community metabolism

Our preliminary measurements show a remarkable decrease of chlorophyll *a*, POC, and PON, primarily near the bottom, and a similarly remarkable decrease of nitrate, nitrite and phosphate in the upper water column inside the kelp forest. These trends indicate the occurrence of intense, previously undocumented grazing on phytoplankton and other organic particles near the bottom and pronounced uptake of nutrients closer to the surface where most of the kelp biomass was located. The large increase in phaeophytin near the bottom corroborates the conclusion that grazing was intense, while the corresponding near-bottom increase in silicate suggests significant benthic regeneration of silica. These results formed the basis for a collaborative proposal between UCSB and Stanford University that was submitted to NSF in summer 2002.

Food web studies using stable isotope

Preliminary data are encouraging in showing separation in the isotopic composition of terrestrially-derived POM, marine POM, and kelp (Figure 4). In the coming months, we will continue to collect and analyze samples of these materials to extend our data set. We will also investigate potential sources of variability in values of marine POM, including contributions from phytoplankton, kelp detritus and terrestrial inputs. This will be accomplished by collecting samples of POM further offshore, at locations less likely to be influenced by inputs from kelp or terrestrial runoff and more likely reflect primarily a phytoplankton source. During the upcoming year, we also plan to sample for isotopic analysis representative deposit-feeding (e.g., sea cucumbers), filter-feeding (e.g., barnacles), and predatory (e.g., starfish) species at four reef sites during the rainy season (most likely in February or March) and during the dry season (in August) to assess the contribution of terrestrial and marine sources to the reef food web.

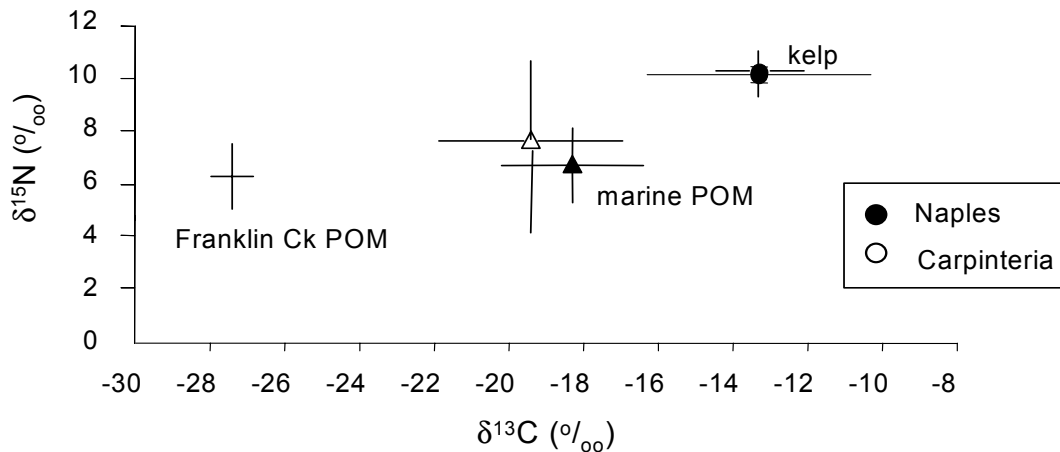


Figure 4. Isotopic composition of terrestrially-derived POM (from Franklin Creek in Carpinteria, May-June 2001, n=2), and nearshore marine POM (Jan-June 2001, n=6), and kelp (Dec 2000-May 2001, n=4) from Naples and Carpinteria Reefs. Data are means \pm 1 SD.

Field experiments: the role of nutrients in trophic interactions

To date, we have developed a diffuser system that will deliver nutrients to the reef benthos, and we initiated a set of experiments to determine how increases in nutrients interact with grazing and predation to influence benthic community structure and trophic interactions. Our nutrient diffuser consists of a flexible 2.5-cm diameter PVC pipe with large screen mesh windows that contains a slow release plant fertilizer (Osmocote; by wt. = 10 % ammonium, 9% nitrate, 6% phosphate, and 12% potassium). Laboratory tests determined that the optimal diffuser design (PVC pipes with ½ surface area covered with 2 mm screen mesh openings) provided a substantial and linear increase in ammonium and nitrate concentrations in the mesocosms. We are in the process of collecting field samples of nitrogen (ammonium and nitrate) concentrations in 0.10 m² areas surrounding the plots to determine if nitrogen values measured in laboratory aquarium tests reflect concentrations delivered to benthos on reefs.

Preliminary results from the experiment investigating the effects of added nutrients and sea urchin grazing on the abundance of periphyton and mesograzers show that the total number of crustacean grazers (amphipods, cumaceans, tanaids, and isopods) on recruitment substrates varied with the addition of nutrients, but was unaffected by sea urchin grazing. There were significantly more crustaceans on caged recruitment substrates placed on diffusers without nutrients than on substrates with nutrients regardless of whether sea urchins were present (Figure 5). These results indicate that nutrient additions can have complex effects on the microalgae/invertebrate/fish food web. We plan to identify the nature of these complex interactions by proceeding with a series of similar recruitment/fish exclusion experiments.

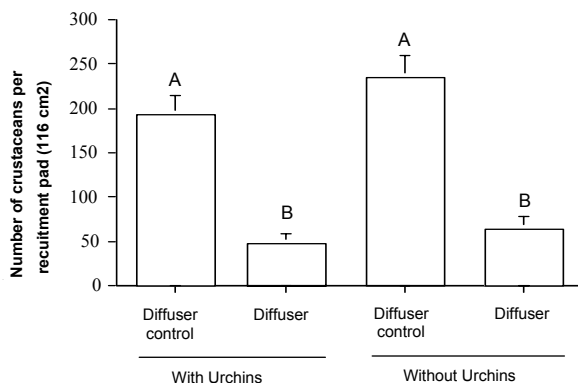


Figure 5. Results of a short-term experiment designed to test whether nutrient addition and urchin grazing interact to influence the recruitment of crustaceans within the microalgae/invertebrate/fish food web on rocky reefs. Recruitment of crustaceans was measured on plastic “Dobbie” dish scrubber pads placed on nutrient diffusers and nutrient diffuser controls located within plots with and without urchins (N=3 of each treatment combination). Letters above bars represent results of SNK post-hoc tests (A>B at $P<0.05$).

Kelp subsidies to sandy beach communities

Macrophyte wrack deposited on beaches in the SBC-LTER study area consisted primarily of giant kelp, *Macrocystis pyrifera*, and surfgrass, *Phyllospadix spp.*. The standing crop of macrophyte wrack was estimated monthly by measuring the cover of wrack in the intertidal zone of the study beaches. Mean cover of macrophyte wrack varied over an order of magnitude among beaches in the SBC-LTER region. Standing crop of wrack also varied among months and years (Figure 6). Variation in the standing crop of wrack on beaches may be closely linked to the dynamics and condition of kelp forests and coastal reef ecosystems. For example, the standing crop of wrack was consistently very low at a beach adjacent to our core reef site at Carpinteria. This reef has been dominated by sea urchins the last several years and it supported little foliose macroalgae during this study.

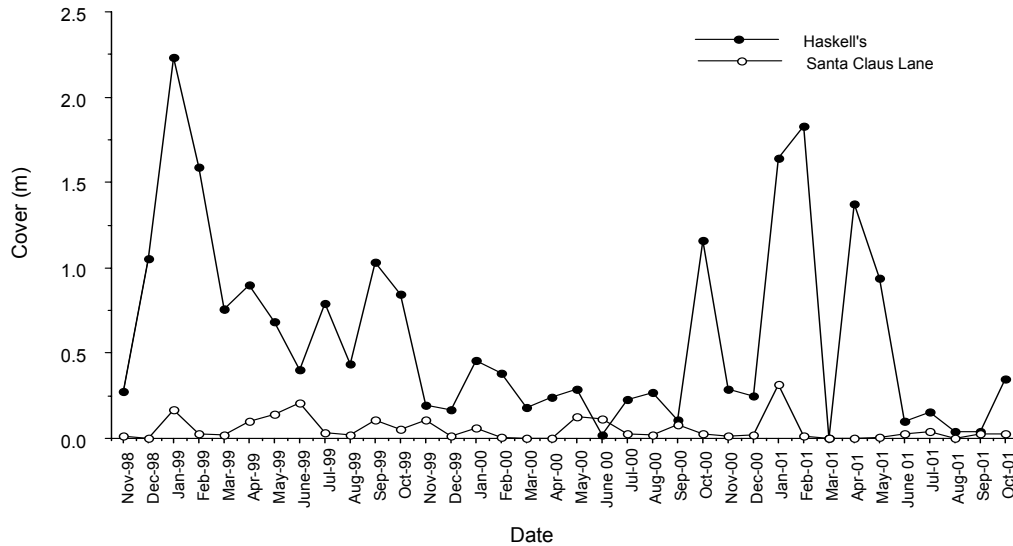


Figure 6. Time series of the mean cover of *Macrocystis pyrifera* wrack at two beaches, Haskell's and Santa Claus Lane, located near core reef sites, Naples and Carpinteria, respectively, from October 1998 – October 2001.

Results of our field studies suggest that changes in the amount and type of macrophyte wrack available significantly affects infaunal community biodiversity, structure and dynamics, and alters prey availability to higher trophic levels, such as shorebirds, on sandy beaches. Wrack-associated invertebrates, including amphipods, isopods, and insects, made up an average of >37% of the macrofaunal species on natural beaches. Overall species richness and abundance, and the species richness, abundance, and biomass of wrack-associated fauna and taxa were significantly correlated with the standing crop of macrophyte wrack. The abundance of two shorebird species that forage visually, Black-bellied Plovers and Western Snowy Plovers, was positively correlated with the standing crop of wrack and with the abundance of wrack-associated invertebrate prey. Surveys of beaches that are regularly groomed to remove wrack provided an opportunity to assess the importance of wrack subsidies to macrofauna communities in a large scale "experiment". The species richness, abundance, and biomass of wrack-associated macrofauna were significantly depressed on groomed beaches compared to natural beaches with high or low standing crops of macrophyte wrack (Figure 7).

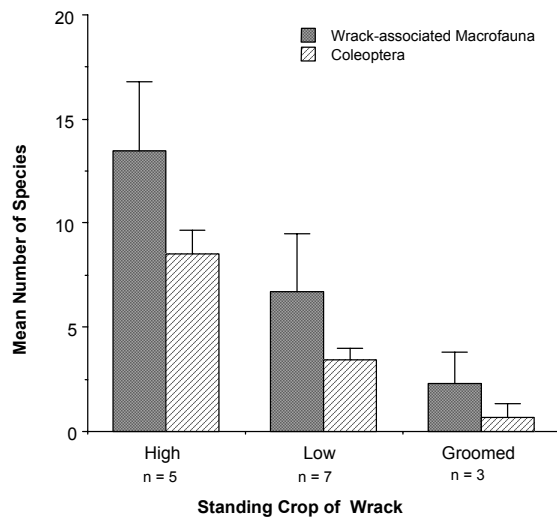


Figure 7. Mean species richness of wrack-associated macrofauna (solid bars) and Coleoptera (hatched bars) for beaches with high and low standing crop of macrophyte wrack, and for groomed beaches. Error bars represent standard errors.

OCEAN STUDIES

Ongoing measurements at the three reef mooring sites provide an extended time series describing oceanographic conditions and dynamics of the inner shelf. Nearly two years of data now allow us to identify clear seasonal regimes. The addition of the in-situ nitrate analyzer to our suite of measurements over the past year has led to a much better understanding of how nitrate concentration varies seasonally and in response to specific oceanographic conditions. In-situ measurements of nitrate concentration, along with concurrent measurements of currents, temperature, density, pressure, optical scattering, and fluorometer, allow us to characterize the “type” of nutrient delivery mechanism based on the response of the water column and the currents.

A seasonal pattern is clearly observed in temperature, and is consistent over the two years of measurements. Winter surface temperatures ranged between 12.5° and 14.3° between mid-February and the end of March, 2001. Winter of 2002 was slightly warmer at Carpinteria, with surface water temperatures ranging between 13.5° and 14.9° between December 13 and March 6. The range was 12.8° to 14.1°, at both Naples and Arroyo Quemado for the same time period. During both years, the oceanographic winter “season” ended with the onset of spring upwelling, which caused water temperatures to drop as low as 10°C for periods of almost a week in duration. The upwelling regime started in early April in 2001, and in 2002 it started a few weeks earlier. Temperatures rose throughout May, reaching levels between 15 and 19 degrees between June and September. This summer period is characterized by energetic variability at tidal frequencies and by strong thermal stratification. Temperatures transition to the colder, winter regime between October and December.

Nitrate concentration at reef sites

Figure 8 shows the time series of temperature (both near-surface (4 m) and 3 meters above the bed) and nitrate concentration from Naples, for the year-long period between July 2001 and July 2002. Temperature and salinity characteristics did not vary much among the three sites, so data from the mid-coast station, Naples, can be used to represent temporal changes that occur elsewhere. The middle panel shows nitrate concentration measured in-situ with the moored nitrate auto-analyzer. We do not have completely continuous temporal coverage of nitrate measurements (this will soon be corrected with the acquisition of the additional nitrate analyzers described above), but with combined data from the nitrate-sensor deployments and the channel-wide hydrographic surveys, we can estimate a temperature-nitrate relationship. This was used to generate a time series of approximate nitrate concentration for the whole year, based on the near-surface temperature. This time series is shown in the bottom panel (Figure 7), with the in-situ nitrate concentration superimposed. Although the error in this method is high (at least $\pm 1.5 \mu\text{M}$)

it does capture the overall seasonal trend in nitrate concentration, and does a good job of reproducing the peaks observed in December 2001 and in April/May 2002. The temperature-nitrate prediction under-predicts nitrate for July 2002, but that is because near-surface temperature was used to construct this estimated time series. During the highly-stratified conditions of summer, surface temperatures are much warmer than near-bed temperatures. During the summer of 2002, the nitrate sensor was deployed near the bed in order to sample the deeper, colder water. Thus, nitrate measured near the bed was substantially elevated over predictions based on surface temperatures.

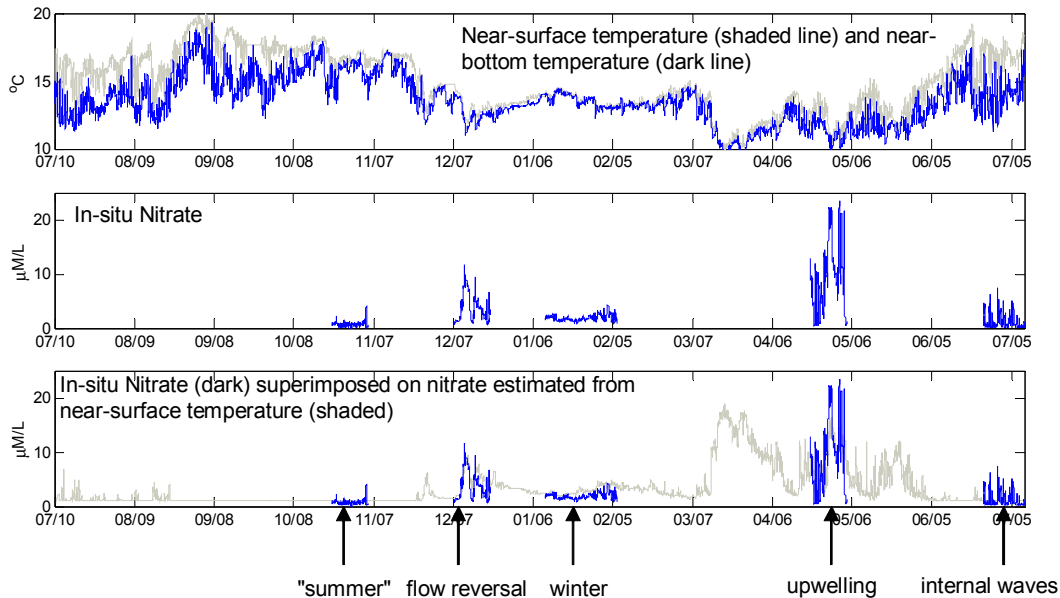


Figure 8. Time series of temperature and nitrate between July 2001 and July 2002. The top panel shows near-surface (4 m depth) and near-bottom (3 m above bed) temperature from the Naples mooring. The second panel shows nitrate concentration, measured with the in-situ nitrate sensor, during all of its deployments throughout this period. The bottom panel shows a comparison of in-situ nitrate with nitrate estimate from the longer time series of near-surface temperature.

Nitrate delivery mechanisms

The highest nitrate concentrations occurred during the upwelling events of March through May. Peak values were $> 20 \mu\text{M}$. High nutrient levels were also observed during December 2001, and were associated with a cold water mass and with a flow reversal whereby the alongshore currents, which are westward in the mean, reversed to eastward flow for several days. This advective event appears to have been associated with an eddy, based on the HF radar and ADCP time series. Such events would likely affect the coast between Naples and Arroyo Quemado given the size of the eddy (~ 20 km diameter). In this case the eddy was anti-cyclonic (clockwise) with its center on the 500 m isobath on northern side of the Santa Barbara Basin. The eddy produced up to an order of magnitude increase in nitrate concentration along with a 2 C temperature decrease. Similar nutrient and cold water transport may frequently occur along the coast between our Naples and Arroyo Quemado sites due to anti-cyclonic eddies of this size and smaller, which appear to be common. Significant eddy-transport of nutrients to the inner shelf (~ 10 m depths) was surprising so we will investigate this further over the next year.

During summer through early fall, background nutrient levels are low, and are possibly nitrate limiting for *Macrocystis* (Reed et al. 1996). However, pulses of cold water and high nutrients were observed near the bottom during the nitrate-sensor deployments of June/July (Figure 7), and in August and September (not shown). These pulses of high nitrate appear to be associated with internal waves at tidal and diurnal frequencies. These tidal-frequency internal motions are associated with periods of high stratification, and are a common feature in the Channel and elsewhere in the Southern California Bight. They have been

observed during summers at all of the LTER mooring sites, as well as at the nearby moorings maintained by the Partnership for Interdisciplinary Studies of the Coastal Ocean (PISCO) program.

Comparison of nitrate delivery mechanisms

Using the mooring time series, we can extract a nitrate-delivery budget characterizing the year between July 2001 and July 2002. The mooring time series are used to characterize the oceanographic condition of each day of the year, and the in-situ nitrate measurements are used to determine an average nitrate-concentration supply rate ($[N(t)-N_0]/T$, in $\mu\text{M}/\text{day}$, is approximately equal to the divergence of nitrate flux, where N_0 is the minimum nitrate concentration over the event, $N(t)$ is the measured nitrate concentration, T is the duration of the event being sampled) characterizing each of the following mechanisms: spring upwelling, flow-reversal (or “advective”), events, internal waves, “background winter” conditions (when vertical mixing and other small-scale advective processes add nitrate to the already relatively-high surface levels), and “summer background” conditions. The supply rate for each mechanism is given in Table 1. During the spring of 2002, 74 days were characterized by upwelling. The high supply rate combined with the duration of spring upwelling, suggests that approximately 76% of the annual nitrate supply to the kelp reefs (for July 2001 to July 2002) came during spring upwelling. Eddies and associated flow reversals also introduce cold, high-nutrient water masses to the reef. Although these events were somewhat rare,

Mechanism for nutrient delivery	Time (%of year)	Nitrate Supply Rate ($\mu\text{mol}/\text{l}/\text{day}$)	Contribution to annual nitrate flux
Spring Upwelling	74 days 21%	0.7	76%
Flow reversal events	19 days 5%	0.4	13%
Summer internal waves	48 days 13%	0.07	5%
Terrestrial input (Storm events)	0 days 0% (6 days in 2001 - 2%)	0.1	0% (~ 1% in 2001)
<u>Extra during Background conditions</u>			
Winter	127 days 27%	0.03	5%
Summer/Fall	97 days 34%	0.01	1%

Table 1. An annual nitrate delivery budget for the year July 2001 to July 2002.

occurring over about 19 days of the year, the contribution to the annual nitrate budget was sizeable. Internal waves during the summer contributed approximately 5% of the annual nitrate delivery budget. We hypothesize that this mechanism may be important for kelp ecosystems because it delivers nitrate to reef depths during summer and early fall, when conditions could otherwise be nitrate-limited (Zimmerman and Kremer, 1984).

There were no sizeable rain storms during July 2001 to July 2002, and the moorings recorded no freshwater runoff events, so the contribution to the annual nitrate supply from terrestrial runoff events was negligible for that year. However, for comparison, we have added to the table an estimate based on the March, 2001, storm, which was the biggest storm in the previous year. A nitrate delivery rate characterizing this storm was estimated from mooring measurements of freshwater dilution and from stream nitrate concentration measurements provided by the terrestrial/watershed group. We estimate maximum nitrate concentrations in the surface waters to have been approximately 5 to 8.3 $\mu\text{mol}/\text{l}$. This estimate corresponded fairly well with surface-water measurements of 5.6 $\mu\text{mol}/\text{l}$ at the Carpinteria reef, and 3.0 $\mu\text{mol}/\text{l}$ at the Naples reef, made

1.5 days into the storm. The resulting delivery rate is shown in the table: had this storm occurred during the year 2002 budgeted here, it would have contributed approximately 1% of the total nitrate contribution. Newly-acquired measurements from the in-situ nitrate sensor moored at Arroyo Quemado show that the sensor captured the response of the reef water column to a storm that occurred the night of November 7, 2002. Preliminary data suggest that nitrate concentration rose immediately, and then remained high for approximately 12 hours, but attained a maximum of only 3.0 to 3.5 $\mu\text{mol/l}$. This response suggests that our estimates above, for times when in-situ nitrate data were not available, are valid. A peak in nitrate of 8 to 11 μM occurred approximately two days after the storm, however, the duration of this nitrate peak was at least 60 hour, and was associated with significant water column cooling. The comparison of these two events again suggests that the advection of cold water masses up into reef depths is the process dominating nitrate delivery to the reef.

Channel Surveys

During the channel survey of April-May 2002, we caught the onset of a local upwelling event, which was simultaneously recorded by the moored instruments at the reef sites (Figure 8). Surface temperatures as low as 10.5° were observed along the Gaviota Coast to Santa Barbara, and were associated with high fluorometer and bottle chlorophyll levels. Primary productivity estimates were as high as $842 \text{ mg C m}^{-3} \text{ d}^{-1}$. Satellite sea surface temperature and Chlorophyll estimates suggest that a deep water mass upwelled locally at the coast within the western channel and spread southward across the channel. Measurements made during this cruise will be extremely valuable for characterizing the biological response to the high influx of nutrients brought in by spring upwelling events.

High-Frequency Radar Data

One of the most interesting results from the HF radars over the past year was the discovery of small, near shore anti-cyclonic eddies which may be important transport mechanisms from the mid to inner shelf (discussed above). A presentation was also made at the 2002 Ocean Sciences Meeting in Honolulu describing what we hypothesize are topographic Rossby waves in the western Santa Barbara Channel (Beckenbach and Washburn, 2002). These appear as trains of alternating cyclonic and anti-cyclonic eddies, lasting for up to several weeks, which span the Santa Barbara Basin. We speculate that they may be important for transporting materials to and from the inner shelf as well as periodically disrupting the prevalent cyclonic circulation in the western channel. An archive of gif images from the HF radar array is available at <http://www.icess.ucsb.edu/iog/codar.htm>.

Satellite Data

Example imagery is available at <http://www.icess.ucsb.edu/avhrr> and at http://www.icess.ucsb.edu/~motero/monthly_composites.html. A poster presenting many of the preliminary results of the satellite program was presented at the 2001 ASLO Aquatic Sciences Meeting. The satellite analysis program is tightly linked with the NASA supported Plumes and Blooms program (<http://www.icess.ucsb.edu/PnB/PnB.html>).