Annual Report for Period:04/2001 - 03/2002
Submitted on: 02/10/2002
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:

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:

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:
Directed oceanographic samplimg operations.

Name: Brzezinski, Mark
Worked for more than 160 Hours: Yes
Contribution to Project:
Directed phytoplankton ecology and physiology research.

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:

Directed optical oceanographic research.

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. Invetigates 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: No
Contribution to Project:
Sandy beach ecologist. examines influence of kelp wrack on beach consumers

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:

Name: Dunne, Tom

Worked for more than 160 Hours: No
Contribution to Project:

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

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.

Name: Busse, Lilian
Worked for more than 160 Hours: Yes
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:
Analyzed physical-oceanographic data sets from fixed moorings and cruises, helped with upcoming cruise planning, working on simple ecosystem responses to nitrate flux estimated for various physical mechanisms

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:
conducting studies of marsh plant nutrition at Carpinteria Marsh

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: No

Contribution to Project:

marine ecologist

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 d far from sources of terrestrial runoff

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 managment 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: No

Contribution to Project:
Assisted in the laboratory processing of samples collected in the field and in cruise preparation

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: No
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: No
Contribution to Project:
assisted with lab processing of stream samples

Name: Jones, Jamie
Worked for more than 160 Hours: No
Contribution to Project:
assisted with lab processing of stream samples

Name: Asao, Shinichi
Worked for more than 160 Hours: No
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

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:
assisting in annalysis 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

Organizational Partners

University of California, Office of the President, Oakland

The UC Office of the President funds the UC Toxic Substances Resesarch & 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 oceaography of the Santa Barbara Channel, which otherwise would not be available to them. This information is useful in helping NPS manage and protect the unique and valuable resources of the Channel Islands.

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 with Mark Williams and Diane McKnigt (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 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 are developing 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 in engaged in sampling local creeks during the initial rise of the hydrograph and measuring a suite of pollutants including metals, pesticides and herbicides. Our intensive sampling of nutrients and particulates during the whole hydrograph for most storms complements the County's effort, and we and they share are 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.

Other Collaborators or Contacts

The Partnership for Interdisplinary 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 marine plankton blooms associated with runoff. The goal of this project (awarded to Seigel, Brzezinski, Mertes, and Wasburn) is to develop new satellite ocean color algorithms to use in coastal waters influenced by terrigenous materials (sediments, dissolved organic materials, etc.). In situ optical quantities and in-water constituents are collected every two weeks along a 7 station transect crossing the Santa Barbara Channel and related to simultaneous ocean color images from the SeaWiFS satellite sensor. (http://www.icess.ucsb.edu/PnB/PnB.html)

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 compliment those that are being collected by SBC and CEEI.

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:

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 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 2001, 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 examined patterns, processes, and ecosystem services of coastal wetlands that may act as 'filters' between terrestrial and coastal marine ecosystems. In April, 2001 three SBC graduate students presented posters on their research at the 14th Annual UC Toxic Substances Research and Teaching Program Symposium, Lake Tahoe, California. In September 2001, four SBC graduate students, Co-PI Holbrook and two 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. In addition, students, postdoctoral fellows, and Principal/Associate Investigators participated in an 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 were 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.

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.). 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.

Journal Publications

Airame, S., J. E. Dugan, K. D. Lafferty, H. M. Leslie, D. A. McArdle, and R. R. Warner., "Applying ecological criteria to marine reserve design: a case study from the California Channel Islands", Ecological Applications, p. , vol. , ( ). Accepted

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

Blanchette, C. A., S. D. Gaines, and B. Miner, "Geographic variability in form, size, and survival of Egregia menziesii (Turner) Areschoug around Point Conception, California.", Marine Ecology Progress Series, p. , vol. , ( ). Accepted

Botsford, L. W., A. Hastings, and S. D. Gaines., "Dependence of sustainability on the configuration of marine reserves and larval dispersal distance", Ecology Letters, p. 144, vol. 4, (2001). Published

Gaines, S. D., B. Gaylord, and J. L. Largier, "Avoiding current oversights in marine reserve design.", Ecological Applications, p. , vol. , ( ). Accepted

Gaylord B., D. C. Reed, P. T. Raimondi, L. Washburn, and S. R. McLean, "A physically-based model of macroalgal spore dispersal in the wave and current-dominated nearshore", Ecology, p. , vol. , ( ). Accepted

Gerber, L. R., S. J. Andelman, L. W. Botsford, S. D. Gaines, A. Hastings, S. R. Palumbi, and H. P. Possingham, "Population models for marine reserve design: A retrospective and prospective synthesis.", Ecological Applications, p. , vol. , ( ). Accepted

Mertes L. A. K., and J. A. Warrick, "Measuring flood output from 110 coastal watersheds in California with field measurements and SeaWiFS", Geology, p. 659, vol. 29, (2001). Published

Phillips, N. E., and S. D. Gaines, "Spatial and temporal variability in size at settlement of intertidal mytilid mussels from around Pt. Conception, California", Invertebrate Reproduction and Development, p. , vol. , ( ). Accepted

Sagarin, R. and S. D. Gaines, "The many forms of species' abundance distributions.", Journal of Biogeography, p. , vol. , ( ). Accepted

Sagarin, R., and S. D. Gaines, "The "abundant center" distribution: to what extent is it a biogeographic rule?", Ecology Letters, p. , vol. , ( ). Accepted

Schroeter S. C., D. C. Reed, D. J. Kushner, J. A. Estes, and D. S. Ono, "The use of marine reserves in evaluating the dive fishery for the warty sea cucumber (Parastichopus parvimensis) in California, U.S.A.", Canadian Journal of Fisheries and Aquatic Science, p. 1773, vol. 58, (2001). Published

Wares, J., S. D. Gaines, and C. Cunningham., "A comparative study of asymmetric migration events across a marine biogeographic boundary", Evolution, p. 295, vol. 55, (2001). Published

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. , vol. , ( ). Accepted

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. , vol. , ( ). Accepted

Books or Other One-time Publications

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

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 infomatics. SBC is now completing its second 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 the past year, four post docs, 11 graduate students, two REU students and 27 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 REU students is Hispanic and recently graduated from UCSB in biology. He is continuing to work on our project as a research technician while actively exploring his options for furthering his education in graduate school. 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.

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. 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 are developing 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.

Special Requirements

Special reporting requirements: None
Change in Objectives or Scope: None
Unobligated funds: $ 500,000.00

Animal, Human Subjects, Biohazards: None

Categories for which nothing is reported:

Any Book

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

During water year 2001 we monitored nutrient and sediment concentrations in 19 coastal streams in Santa Barbara and Ventura counties. 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. The selected catchments varied in area, topography, vegetation, soils, geology and land use, and displayed a wide range of baseflow nutrient concentrations. In water year 2002, we modified our 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 are being sampled as they cross land-use boundaries, as well as at the previously sampled tidal limit. We are also sampling 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.

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 in the Malibu Creek watershed was investigated in summer and fall of 2001. Surveys of water chemistry and algal abundance and species composition were conducted throughout the watershed, and N and P supply were experimentally manipulated using nutrient diffusers to assess algal growth responses.

Three additional studies of stream ecology were conducted: (1) Effects of nutrients and grazers on species composition and biomass of periphyton. Two experiments in stream channels and one experiment in experimental pools in Mission Creek, Santa Barbara were completed. (2) Stable isotope analyses were used to trace food on four sampling dates in different seasons and habitats in Rattlesnake Creek. (3) Surveys of water chemistry, physical factors, and benthic algae and invertebrates were done 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 very interested in developing assays for measuring stream “health”.

The use of diatoms as bioindicators in a salt marsh was evaluated by sampling for water chemistry and diatoms in Carpinteria Salt Marsh.

Hydrologic modeling of the catchments in our study requires detailed spatially distributed data. The following datasets have been compiled and are being 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.

Rainfall data are also a significant factor in hydrologic modeling. We have developed working relationships with Santa Barbara and Ventura Counties and the National Weather Service and have developed GIS coverages showing the locations and temporal resolution for all the gauges maintained by these agencies. We have access to both their historical and future data. Using both the watershed and rainfall data, we have developed a GIS application that relates elevation, aspect, and gauges locations to spatially distribute rainfall over a watershed. This relationship is required to deal with the significant orographic enhancement of rainfall in this region, where rainfall at the watershed divide can be twice that of near shore area. In addition, we identified other existing data sources (Doppler radar and mesoscale model forecasts), their spatial and temporal coverage, and problems associated with them.

To calibrate and verify a hydrologic model, stream flow data is required. Santa Barbara and Ventura Counties and the US Geological Survey maintain several gauges along the south coast, and we have access to all the available data. To augment the existing gauging network, we have installed 24 pressure transducers to record stage at our priority sampling sites. We are currently surveying the gauge locations and developing rating curves to relate stage with discharge.

Using the GIS, discharge and rainfall data for WY 2001, we setup and calibrated hydrologic models on Mission and Carpinteria Creeks, two SBC-LTER study watersheds which have USGS stream gauges. In addition to these watersheds, we setup models on three other nearby watersheds, which also have USGS stream gauges. We are using the HEC-HMS model, which is the US Army Corps of Engineer's Hydrologic Modeling System (HMS) computer program developed by the Hydrologic Engineering Center (HEC). This model simulates rainfall-runoff and routing processes from both undisturbed and urban land and is spatially averaged at the sub-basin scale. For these five watersheds, we calibrated the model with USGS flow data. The model shows how the initial watershed conditions change from dry to wet as the rainy season progress. While this model is useful for assessing the basic hydrologic signal from our study watersheds, we are currently developing a better distributed continuous simulation model that will be integrated with water quality modules to simulate the discharge of water, associated solutes, and sediments from the land to ocean.

We are working with Charles Jones, an Associate Researcher at the Institute for Computational Earth System Science (ICESS) at the University of California, Santa Barbara, who is using the Pennsylvania State University/ National Center for Atmospheric Research (PSU/NCAR) Mesoscale Model (MM5-V3) to provide precipitation forecasts for the SBC-LTER region. We are currently working to link the MM5 forecasts to our hydrologic model.

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 scale, 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 m^2 quadrats that are located at eight meter intervals along each transect. The percentage cover of understory algae, sessile invertebrates, and various substrate types 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.

We also continue to sample 15 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 $0.1m^2$ quadrats, brought to the lab and processed to obtain counts and size structure of crustaceans and other invertebrates as well as species composition and biomass of algae. 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.

We are creating a field guide to the common kelp forest species of the SBC LTER that will contain photographs, key characteristics and habits of all the species sampled in our kelp forest monitoring program. This document is being used to train students, staff and PIs in the identification of the species that are being monitored on the project and will help to ensure quality control of the data being collected. When completed, it will be made available to the public at large on the SBC website, where it will serve as a useful tool in describing the marine fauna and flora of the SBC LTER.

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 will help us to more easily evaluate long-term trends in the abundance of giant kelp and will allow us to place our observations of kelp abundance within SBC into a much broader regional perspective. Kelps 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. Most of our work so far has focused on refining the methodology that we will use to estimate rates of change in standing stock over time. At present this is being done by**:** (1) measuring the sizes and numbers of fronds on marked individuals over time, (2) developing frond length/weight

regressions for different seasons and sites, and (3) estimating changes in population density over time. We hope to use these data 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.

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.

Fish Recruitment Studies

Kelp canopies provide critical habitat for the recruitment of many species of reef fish. In 2001, we began investigating the extent to which the physiological condition of pelagic reef-fish larvae recruiting to the kelp canopy is modified by land vs. ocean sources to influence the growth and survival of benthic juveniles. Using standardized larval collectors to simulate kelp canopies, we quantified spatio-temporal variation in recruitment of an obligate canopy species, the kelp bass (*Paralabrax clathratus*). Our collections also allowed us to characterize spatio-temporal variation in the *quality* of settling larvae, using otoliths (fish "ear stones") that provide estimates of growth histories of larval fishes. The standing-stock of forage on a subset of our collectors at Carpinteria Reef was manipulated to simulate different productivity regimes. Results from this experiment will be used to: (1) examine potential interactive effects of larval "quality" and reef "quality" that may ultimately contribute to recruitment success of kelp bass at our sites and (2) determine the extent to which the quantity and quality of kelp bass recruitment is related to a varying oceanographic conditions.

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 2001 to investigate how changes in nitrogen supply influence trophic interactions in the little studied macroalgal/periphyton based food web. The experiments will feature a multi-factor

design in which nutrients, primary producers (macroalgae, and periphyton), and consumers will be manipulated in an orthogonal design and responses in the species composition, numerical abundance, and biomass of different trophic levels will be followed. We plan to follow these experiments through time to track both short-term (weeks-months) and long-term (years-decades) responses. Work done to date has focused on technique development and site selection. We have spent considerable time designing and testing methods for delivering nutrients to experimental plots on shallow subtidal reefs in the wave-and current dominated nearshore.

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 deep water offshore of the reef.

Channel surveys

We conducted two channel-wide surveys of hydrographic and biological parameters during March and September of 2001, and will conduct another in February, 2002. 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 complimentary 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).

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. Sampling stations are 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. 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.

Moorings

In addition to the moorings installed in the first year at two permanent Carpinteria and Naples reef sites, a new mooring was installed at 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. Each mooring is equipped with a conductivity sensor, temperature sensor, pressure sensor, fluorometer and backscatter meter deployed at 2 m. An ADCP is deployed on the bottom adjacent to each mooring to monitor ocean current patterns.

In summer 2001 we deployed an automated nutrient analyzer near the Naples mooring. This nutrient analyzer allows us to obtain a time series of nitrate concentration with at sampling intervals as low as 2 minutes, and will allow detailed investigations of the role of inner shelf processes, such as upwelling and internal tides, in supplying nutrients to the reef. The nitrate analyzer was deployed at the Naples site from late-summer through early-winter. It was recently moved to the Carpinteria site in anticipation of the winter-storm signal being strongest at the site nearest the Carpinteria watershed.

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 2001, but since December 2001 we were able to re-establish two former sites thanks to an equipment loan from the NOAA Environmental Technology Laboratory in Boulder Colorado. Currently the radar array has five sites extending from Coal Oil Point to Pt. Sal. The array provides 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 we are actively pursuing funding to expand the array to provide coverage at the third site. 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 prepared the sampling equipment, personnel, and boat in anticipation of a storm discharge event in which we will map the runoff plume at Carpinteria with CTD and transmissometer, and sample for dissolved nutrients and suspended particulate matter. Our offshore sampling will be coordinated with the watershed group. 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

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RESEARCH FINDINGS

WATERSHED STUDIES

Baseflow concentrations of nitrate and phosphate in creeks with appreciable urban sub-catchments in their lower basins are approximately an order of magnitude above streams with little human impact (ca. 150 and 5 μM nitrate and phosphate, respectively, for urban streams vs. 15 and 1 μM for lightly impacted watersheds); concentrations in streams tributary to "greenhouse" agriculture are an additional order of magnitude higher (ca. 2000 and 50 μM nitrate and phosphate). Stormflow generally increases phosphate concentrations in all streams, except those heavily impacted by greenhouse agriculture. Stormflow decreases nitrate concentrations in streams with human impacts, but increases nitrate concentration in little disturbed streams.

All urban streams exhibit a similar response to stormflow: variations in phosphate concentrations rise and fall in parallel with the hydrograph, nitrate is fully out of phase with phosphate, and ammonium declines exponentially after a sharp peak at the beginning of storms. The stormflow response of "non-urban" streams lacks a common pattern, but, in general, nitrate and phosphate concentrations follow variations in the hydrograph, and ammonium concentrations remain low. The nutrient concentration-discharge relationships for the urban streams show hysteresis and fit a 3-compartment baseflow/surface-flow/soilwater model. However, the pattern for each species is different in shape or temporal variation, indicating the lack of a common source or hydrologic response. Dissolved silica concentrations during stormflow exhibit the same pattern as nitrate, reinforcing the conclusion that soil and groundwater inputs are the primary sources of high nitrate, and that urban surface runoff generally dilutes stream concentrations.

The relative export associated with urban streams was consistent: phosphate export at least 5-times that of ammonium and nitrate at least 5-times that of phosphate. Export on the rising hydrograph limb was most important for ammonium (where 30 to 50 % of the ammonium is lost), somewhat important for phosphate (~25 % of total export) and relatively unimportant for nitrate (10 to 15 %). Export to the Santa Barbara channel from all coastal streams is dominated by "flashy" runoff occasioned by only one or two large winter storms; typically, only a single day's runoff produces well over half of the annual export.

Sediment levels are high in all streams during major storms, and after the initial hydrograph rise, remain high throughout the storm. However, particulate N and C exhibit a "flushing" effect: concentrations are highest on the rising limb and peak with the hydrograph, concentrations then decline and remain low during the remainder of the storm. Maximum particulate concentrations during the largest storm of water year 2001 varied from 0.3 to 2.4 mmol/L for nitrogen, and 3 to 22 mmol/L for carbon. Streams with short or non-engineered (concrete canalization, channel straightening, rip-rap) coastal plain segments exhibit the highest particulate concentrations.

From October 2001 through January 2002, a series of 10 small storms, all with 2.5 cm or less rainfall, presented an opportunity to analyze coastal plain nutrient contributions since little or no upper basin runoff was generated. At urban sampling points, nitrate concentrations generally followed the pattern described previously: a decrease during

storms caused by, stormflow dilution of high nitrate in baseflow. The first storm of the season (following 6 months of dry weather) was a major exception, and generated a substantial nitrate (and phosphate) pulse. While major storms are characterized by consistent variations in nutrient concentrations, smaller storms are variable due to differences in antecedent conditions and rainfall/runoff patterns.

Urban phosphate concentrations during the October to January series of storms exhibited two contrasting patterns: decreasing with runoff where impervious surfaces dominated, and increasing in areas with significant urban green space (parks, open space, lawns and gardens). The increasing phosphate concentrations were seen mainly on the falling hydrograph limb, indicative of soil water drainage. Both maximum and minimum urban phosphate concentrations have decreased with successive storms indicating depletion of the urban reservoir. A similar pattern of phosphate decreases over time was also seen in agricultural runoff.

Preliminary results of studies of effects of nutrients on species composition and biomass of algae in coastal streams suggest that algal growth in the extensively developed lower watershed of Malibu Creek is limited by phosphorus availability. Creeks in the upper watershed, with less human influence, appear to be nitrogen limited. We also observed a shift in dominance from benthic microalgae in oligotrophic sites to floating macroalgae in more eutrophic sites.

The most promising approach in delineating the simultaneous effects of top-down and bottom-up processes on periphyton communities is to conduct experiments in which both resources and consumers are manipulated. We studied the effects of manipulations of nutrients and grazers on periphyton biomass and species composition in experimental arenas placed in different habitats (riffles and pools) and conducted during different seasons (summer and fall) in Mission Creek, Santa Barbara. Our results showed that nutrient effects on algal biomass and species composition were greater in summer than in fall, and that grazer impacts on algae were able to override nutrient effects in the fall. We conclude that the magnitudes and relative importance of top-down and bottom-up controls differ from season to season.

In 2001, we took biological samples in riffles and pools, separately, for stable isotope analyses (^{13}C and ^{15}N) in spring, summer, fall and winter in Rattlesnake Creek. The results from our preliminary studies indicated that the analysis of stable isotopes can be used productively in local streams (Rattlesnake Creek) for tracing aquatic food webs. Leaf litter, FPOM and periphyton often had different $\delta^{13}C$ 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. $\delta^{15}N$ values of herbivores were elevated by 1-2 ‰ relative to the $\delta^{15}N$ 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. $\delta^{15}N$ of the predators was enriched by ca. 2 ‰ relative to the $\delta^{15}N$ of the herbivores. In 2002 we will work on methods for more cleanly separating periphyton and detritus signatures, and will sample small invertebrates (chironomids, mites, microcrustaceans) more thoroughly to complete the pictures of food webs in local

streams. We plan to compare food web structures in streams draining urban, agricultural, and natural catchments using these methods.

We took surface water samples and pore water samples for chemical analyses, as well as diatom samples, from 12 different sites in Carpinteria Salt Marsh in 2000 - 2001. The nutrient concentrations within the marsh fluctuated greatly over both space and time. Nutrient concentrations of surface water at the west side of the marsh are lower in N and P than on the east site of the marsh. Franklin Creek showed higher nitrate concentrations and lower phosphate concentrations than Santa Monica Creek. East and West Estero channel showed intermediate nutrient concentrations. Cluster analysis of the diatom composition showed that we can distinguish between groups that are correlated with nitrate concentrations.

Using the GIS, discharge and rainfall data for WY 2001, we setup and calibrated hydrologic models for Mission and Carpinteria Creeks, two of our intensive sites, which have USGS stream gauges. In addition to these watersheds, we setup models for three other nearby watersheds, which also have USGS stream gauges. Currently, we are using the HEC-HMS model, which is the US Army Corps of Engineer's Hydrologic Modeling System (HMS) computer program developed by the Hydrologic Engineering Center (HEC). This model simulates rainfall-runoff and routing processes from both undisturbed and urban lands. This model is spatially averaged at the sub-basin scale. We calibrated the model for these five watersheds using USGS flow data. The calibrated model shows how the initial watershed conditions change from dry to wet as the rainy season progresses. This model is useful for assessing the basic hydrologic signal from our study watersheds. We are currently developing a more distributed continuous simulation model that will be integrated with water quality modules to simulate the discharge of water, associated solutes, and sediments from the land to ocean.

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 to 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.

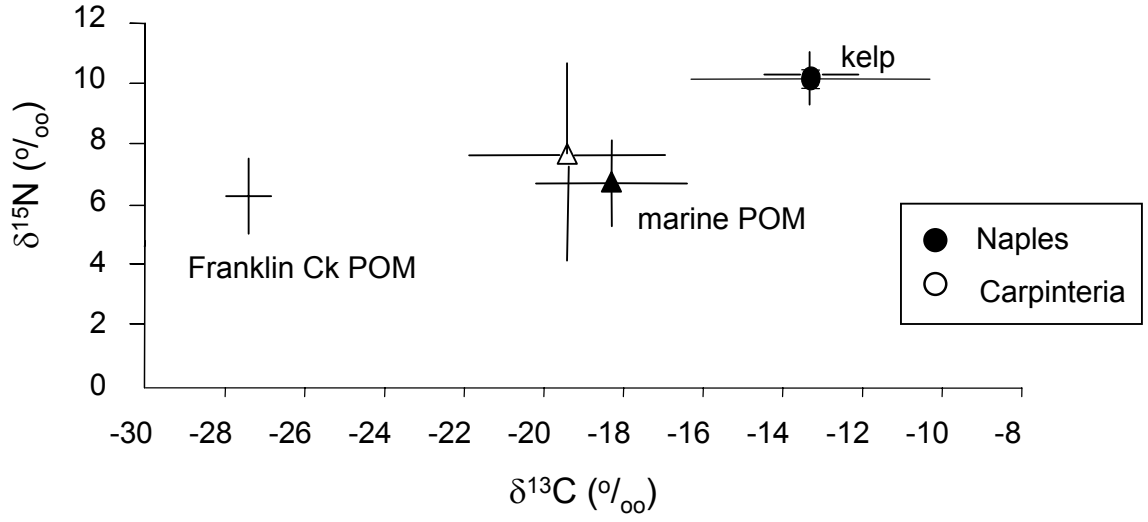
Our long-term sampling of reef systems on Santa Cruz Island has provided evidence of ecosystem changes associated with ocean warming at the decadal scale. We have seen shifts to dominance by southern species in kelp forest fish at these sites. Since the early 1970's, the proportion of species in fish 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.

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 1). 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

Figure 1. 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.

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.

Fish recruitment studies

We were able to sample and recover otoliths from ~200 newly recruited kelp bass, and analyses are currently underway to explore the patterns and consequences of variation in larval growth rates, and how larval experience may interact with post-larval habitat quality to determine the magnitude of recruitment events. We received substantial recruitment to Carpinteria Reef, a site that lacked kelp canopies during this period, suggesting that kelp bass populations may be habitat limited at some places and times within the Santa Barbara Channel. SBC-LTER resources have also allowed us to re-analyze archival samples of kelp bass otoliths, and results of this effort confirm the importance of *larval quality* on *post-larval survival*—such effects that "carry-over" through metamorphosis are only now becoming apparent for marine reef organisms, and may help to explain notoriously variable recruitment in marine reef systems. A paper detailing this work is currently in press (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*).

Field experiments: the role of nutrients in trophic interactions

To date, we have developed a diffuser system that will deliver nutrients to the benthic macroalgae. Our diffuser consists of a perforated flexible 2.5-cm diameter PVC pipe that contains a slow release plant fertilizer (Osmocote; by wt. = 10 % ammonium, 9% nitrate, 6% phosphate, and 12% potassium). To determine the optimal diffuser design, we compared the diffusion rate of ammonium and nitrate (the nutrients that most commonly limit algal growth at our sites) from diffusers with varying combinations of diffuser port (i.e., perforations in the pipe that allow leakage of nutrients) diameter (1-3 mm) and density (0.6-9.0 holes/cm of pipe). Three separate experimental runs were conducted in which diffusers with different combinations of port diameter and density were placed in separate 75 L mesocosms. Ammonium and nitrate concentrations were measured every 24 hours or more frequently in each mescocosm during a 150-200 hr period.

The optimal diffuser design (1 mm diameter holes; 1.8 holes/cm) provided a substantial and linear increase in ammonium and nitrate concentrations in the mesocosms (Figure 2). Background ammonium and nitrate concentrations rose from an ambient 2-4 umol to

about 42,000 umol ammonium and 45,000 umol nitrate in only 24 hrs (note: most of the diffused nutrients will be rapidly diluted in seawater when the diffusers are deployed on reefs). In addition, our optimal diffuser lost 15% of its total load of ammonium and 60% of its of nitrate over a 5 day period, thus assuring that the diffusers once deployed on reefs will not have to be replaced any more frequently than once per week . We plan to initiate our first field experiments using the nutrient diffusers in spring 2002.

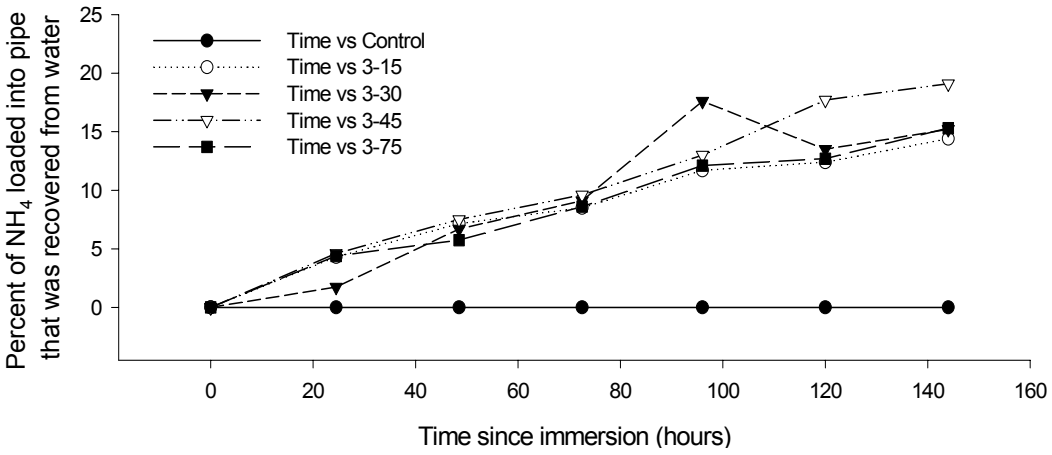


Figure 2. Dissolution rate of Ammonium from diffusers with 1 mm diameter holes at densities of 0-3.0 holes/cm of diffuser flexible PVC pipe. The legend refers to the third trial ("3") and the number of holes for each 25–cm long pipe (0-75).

OCEAN STUDIES

Channel surveys

In March 2001 there was strong cross-channel variability in nutrient concentration, both from north to south, and from east to west. For example, surface water (~ 0-20 m) on the south side of the channel, near the islands, had NO_3 concentrations of 3-6 µmol, while across the Channel at the coast, surface concentrations were typically near zero. Nutrient and chlorophyll concentrations were higher in the surface waters of the western end of the Channel, near Point Conception, than in the southern side of the Channel. These patterns are consistent with counterclockwise circulation of nutrient-rich waters into the Channel from the upwelling region north of Point Conception. Distributions of currents and isopycnals measured during the cruise support this interpretation. However, the high-concentrations distributed through the surface may be linked to low surface stratification in the southern portion, and possibly an indication of higher levels of vertical mixing near the islands than in other regions of the channel

Cross-channel contours of beam attenuation showed maxima at depths between 60 and 400 meters. These were associated with the continental slope bordering the northern side of the channel, and are presumably lithogenic, particulate matter suspended in intermediate nepheloid layers detaching from the continental slope. The September data also suggest a strong gradient in suspended particulate mass (SPM) from the eastern

(equatorward) end of the Channel to the west (poleward). The high levels of beam c in the eastern Channel suggest a fundamentally different particle field compared to the west Channel. In particular, we found a close spatial correlation between chlorophyll and beam c patterns in the western Channel, but not in the east. We will investigate the hypothesis that this difference results from extensive re-suspension of bottom sediments in the eastern Channel.

Moorings

Our moored time series from the Carpinteria and Naples sites started at the end of the winter runoff season of 2001. This has allowed us to observe some of the seasonal characteristics of the inner–shelf waters. From this time series we can identify several different types of dynamics which *may* prove important for delivering nutrients to the kelp reef. These regimes can be classified into the following three categories: (1) runoff events, (2) "cold water" events, and (3) internal tide events. Examples of observations of these regimes follow.

1) Runoff events. Our moored instrumentation was in place for the biggest rainstorm (highest stream discharge) of winter 2001, which occurred in the first week of March. A strong freshwater signal was observed at the Carpinteria mooring located adjacent to the mouths of Santa Monica and Franklin Creeks as well as at the Naples mooring, which is relatively far from creek outflows. At Carpinteria, the salinity dropped from approximately 33 to 31 ppt. Using this observed salinity change and a representative in-stream value of 50 μmol nitrate concentration for Carpinteria Creek, we can estimate that this volume of freshwater mixed through the inner shelf might result in an increased NO_3 concentration of order 10 μmol for a duration of approximately 5 days. NO_3 levels in streams are typically higher earlier in the season, so an equally large runoff event occurring in the early winter might contribute twice as much nitrate. We hope that the nutrient analyzer currently moored at the Carpinteria site will provide better a better estimate of the magnitude of nutrient pulses associated with runoff events this winter and spring. Our event sampling should also produce better estimates of the nutrient levels in runoff plumes.

2) "Cold Water," or "upwelling" events. Temperature records from Carpinteria and Naples showed two periods of low temperature in April 2001. In each case, the temperature dropped from approximately 14 ^{o}C down to 10.5 ^{o}C, and the duration of these cool events was about 8 to 10 days. If the cold water had been advected into the Channel after an upwelling event near Point Conception, it may already have been nutrient depleted by the time it reached our study site. However, if the cold water were brought to the reef by *local* upwelling, it may have had the potential to deliver a large supply of nutrients to the reef for the duration of the event. For example, based on data from our 2001 cross-channel surveys and from a compilation of Plumes and Blooms data, we estimate that replacing 15 ^{o}C water with upwelled 12 ^{o}C water can elevate reef NO_3 concentrations by approximately 8-10 μmol. In 2001, this type of "upwelling" event occurred more often than high-discharge runoff events, so this process may contribute as much or more nitrate to the reef than do terrestrial runoff events. Very recent data from the nutrient sampler deployed at Naples during December 2001 showed a temperature

decrease from 15 to 12 ^{o}C over December 10-13, associated with a nitrate peak going from 2 to 10-12 µmol. This is consistent with our prediction that these "cold events" can lead to a dramatic increase in nutrient concentration over kelp beds. Our continuing analysis of these events will focus on the relationship between local winds and upwelling over the inner shelf.

3) Internal tide events. During the summer, the surface waters were generally between 15 and 20 ^{o}C. Data obtained from instruments deployed at our sites by the Partnership for Interdisciplinary Studies of the Coastal Ocean (PISCO) showed that the low-frequency temperature variability was modulated by changes of ~ 4 ^{o}C at the diurnal tidal frequency due to internal tides. The temperature changes extended inshore to the shallowest measurement locations (on the 4 m isobath) indicating that internal tide transport extends to the coast. Internal tide energy is generally more pronounced in summer due to increased shallow stratification. Consequently, during nitrate-limited periods such as in summer, cold water brought up-shelf by internal tides may deliver pulses of elevated nutrients to macrophyte and plankton communities on the reefs. This has been hypothesized to be an important mechanism for sustaining kelp communities in southern California (Zimmerman and Kremer, 1984. Episodic nutrient supply to a kelp forest ecosystem in Southern California. *J. Mar. Res*. **42:** 591-604) and we will be investigating this mechanism by monitoring nitrate, temperatures, and currents on the reef during the upcoming year.

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