

Annual Report for Period:12/2009 - 11/2010

Submitted on: 09/03/2010

Principal Investigator: Reed, Daniel C.

Award ID: 0620276

Organization: U of Cal Santa Barbara

Submitted By:

Reed, Daniel - Principal Investigator

Title:

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

Project Participants

Senior Personnel

Name: Reed, Daniel

Worked for more than 160 Hours: Yes

Contribution to Project:

Name: Melack, John

Worked for more than 160 Hours: Yes

Contribution to Project:

Name: Holbrook, Sally

Worked for more than 160 Hours: Yes

Contribution to Project:

Name: Gaines, Steven

Worked for more than 160 Hours: Yes

Contribution to Project:

Name: Siegel, David

Worked for more than 160 Hours: Yes

Contribution to Project:

Name: Dugan, Jenny

Worked for more than 160 Hours: Yes

Contribution to Project:

Project coordinator and sandy beach research

Name: Whitmer, Allison

Worked for more than 160 Hours: Yes

Contribution to Project:

Directs on campus marine outreach and education activities

Name: Page, Henry

Worked for more than 160 Hours: Yes

Contribution to Project:

Reef ecology research including stable isotope analyses

Name: Washburn, Libe

Worked for more than 160 Hours: Yes

Contribution to Project:

Oceanographic research

Name: Brzezinski, Mark

Worked for more than 160 Hours: Yes

Contribution to Project:

Coastal Oceanography research

Name: Cooper, Scott

Worked for more than 160 Hours: No

Contribution to Project:

Stream ecology research

Name: Carlson, Craig

Worked for more than 160 Hours: Yes

Contribution to Project:

Marine microbial ecology

Name: Cardinale, Brad

Worked for more than 160 Hours: Yes

Contribution to Project:

Long term experiments and synthesis

Name: Guerrini, Anita

Worked for more than 160 Hours: Yes

Contribution to Project:

Historical research on coastal watersheds

Name: Zimmerman, Richard

Worked for more than 160 Hours: No

Contribution to Project:

Algal physiology and ecology research

Name: Schmitt, Russell

Worked for more than 160 Hours: Yes

Contribution to Project:

kelp forest community ecology

Name: Schimel, Joshua

Worked for more than 160 Hours: Yes

Contribution to Project:

Watershed nutrient research

Name: Nisbet, Roger

Worked for more than 160 Hours: Yes

Contribution to Project:

Ecological modeling

Name: McPhee-Shaw, Erika

Worked for more than 160 Hours: Yes

Contribution to Project:

Coastal oceanographic research

Name: MacIntyre, Sally

Worked for more than 160 Hours: Yes

Contribution to Project:

Limnologic and oceanographic research

Name: Even, Thomas

Worked for more than 160 Hours: No

Contribution to Project:

Stream ecology

Name: Gaylord, Brian

Worked for more than 160 Hours: Yes

Contribution to Project:

Kelp forest hydrodynamics and biomechanics

Name: Lenihan, Hunter

Worked for more than 160 Hours: Yes

Contribution to Project:

Reef ecology and fisheries

Name: Carr, David

Worked for more than 160 Hours: Yes

Contribution to Project:

Reef fisheries research

Name: Dudley, Tom

Worked for more than 160 Hours: No

Contribution to Project:

watershed and invasive plant research

Name: Beighley, Ed

Worked for more than 160 Hours: Yes

Contribution to Project:

Watershed hydrology

Name: Freudenburg, William

Worked for more than 160 Hours: No

Contribution to Project:

Sociological studies

Name: Clarke, Keith

Worked for more than 160 Hours: No

Contribution to Project:

Land use research

Name: Holden, Patricia

Worked for more than 160 Hours: Yes

Contribution to Project:

Microbial Ecology including bacterial and water quality research in coastal watersheds

Name: Tague, Christina

Worked for more than 160 Hours: No

Contribution to Project:

Research and modeling on how eco-hydrologic systems are altered by changes in land use and climate

Name: Bennett, Danuta

Worked for more than 160 Hours: Yes

Contribution to Project:

Algal sampling and identification for stream samples

Name: Roberts, Dar

Worked for more than 160 Hours: No

Contribution to Project:

Remote sensing of vegetation, geology, ecology, and ecophysiology with specific interests in wildfire effects and dynamics in SBC watersheds

Name: Bookhagen, Bodo

Worked for more than 160 Hours: No

Contribution to Project:

Remote sensing of fire scars and earth surface processes in SBC watersheds

Name: Even, Tom

Worked for more than 160 Hours: No

Contribution to Project:

Assist with stream ecology research

Name: Simons, Rachel

Worked for more than 160 Hours: No

Contribution to Project:

research on larval transport and population connectivity in the Southern California Bight, including the Santa Barbara Channel

Post-doc

Name: Miller, Robert

Worked for more than 160 Hours: Yes

Contribution to Project:

Develop apparatus and experiments investigating primary production of understory algae and phytoplankton in kelp forests

Name: Fram, Jonathan

Worked for more than 160 Hours: Yes

Contribution to Project:

Analysis of current, temperature, nutrient data for kelp forest and nearshore ocean

Name: Stewart, Hannah

Worked for more than 160 Hours: Yes

Contribution to Project:

Researched kelp forest dynamics in response to nutrient flow

Name: Klose, Kristie

Worked for more than 160 Hours: Yes

Contribution to Project:

Stream ecology research, responsible for algal sampling and processing, NDS and leaf decomposition studie

Name: Revell, David

Worked for more than 160 Hours: No

Contribution to Project:

Sediment and sandshed dynamics of coastal beaches

Name: Miterai, Satoshi

Worked for more than 160 Hours: Yes

Contribution to Project:

ROMS modeling of larval connectivity with headlands

Name: Alberto, Filipe

Worked for more than 160 Hours: No

Contribution to Project:

Population genetics of kelps

Name: He, Yiping

Worked for more than 160 Hours: Yes

Contribution to Project:

watershed hydrology research

Name: Leydecker, Al

Worked for more than 160 Hours: Yes

Contribution to Project:

Watershed sampling and analyses

Name: Fewings, Melanie

Worked for more than 160 Hours: Yes

Contribution to Project:

Physical Oceanography

Name: Nelson, Craig

Worked for more than 160 Hours: No

Contribution to Project:

Physical-chemical measurements and bacterial analyses

Name: Byrnes, Jarrett

Worked for more than 160 Hours: Yes

Contribution to Project:

Research on disturbance and community structure of benthic communities

Name: Figueroa, Dijanna

Worked for more than 160 Hours: Yes

Contribution to Project:

research on science education as part of the MSP program

Name: Kinlan, Brian

Worked for more than 160 Hours: Yes

Contribution to Project:

Kelp forest ecosystem research

Graduate Student

Name: Arkema, Katie

Worked for more than 160 Hours: Yes

Contribution to Project:

Kelp forest community ecology, kelp primary production

Name: Rassweiler, Andrew

Worked for more than 160 Hours: Yes

Contribution to Project:

Kelp forest community ecology, kelp primary production

Name: Carney, Laura

Worked for more than 160 Hours: Yes

Contribution to Project:

kelp population genetics research

Name: Nickols, Kerry

Worked for more than 160 Hours: Yes

Contribution to Project:

kelp biomechanics research

Name: Hettinger, Annliese

Worked for more than 160 Hours: Yes

Contribution to Project:

kelp biomechanics research

Name: Guenther, Carla

Worked for more than 160 Hours: Yes

Contribution to Project:

Fishery socioeconomics and management in kelp forests

Name: Harrer, Shannon

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with reef and oceanographic research and data management

Name: Goodridge, Blair

Worked for more than 160 Hours: Yes

Contribution to Project:

research on watershed and nearshore nutrient sources for kelp forests

Name: Simon, Scott

Worked for more than 160 Hours: Yes

Contribution to Project:

Coordinates on campus marine outreach and education activities

Name: Hammond, Latisha

Worked for more than 160 Hours: Yes

Contribution to Project:

Assists with on-campus marine outreach and education

Name: Schooler, Nicolas

Worked for more than 160 Hours: Yes

Contribution to Project:

Assists with reef and sandy beach research

Name: Shulman, Rachel

Worked for more than 160 Hours: Yes

Contribution to Project:

Long term experiments and synthesis

Name: Burnette, Don

Worked for more than 160 Hours: No

Contribution to Project:

History of botanical research on a coastal watershed

Name: Cavanaugh, Kyle

Worked for more than 160 Hours: Yes

Contribution to Project:

SPOT analysis of kelp cover/biomass

Name: Watson, James

Worked for more than 160 Hours: Yes

Contribution to Project:

modeling of larval & genetic connectivity for SBC-LTER

Name: Chaffey, Tim

Worked for more than 160 Hours: Yes

Contribution to Project:

ROMS modeling of larval connectivity with headlands

Name: Kostadinov, Tiho

Worked for more than 160 Hours: Yes

Contribution to Project:

coastal oceanographic research

Name: Anderson, Clarissa

Worked for more than 160 Hours: Yes

Contribution to Project:

coastal oceanographic research

Name: Wallner, Elisa

Worked for more than 160 Hours: Yes

Contribution to Project:

coastal oceanographic research

Name: Goldberg, Stuart

Worked for more than 160 Hours: Yes

Contribution to Project:

coastal oceanographic research

Name: Goodman, Jo

Worked for more than 160 Hours: Yes

Contribution to Project:

coastal oceanographic research

Name: Levenbach, Stuart

Worked for more than 160 Hours: Yes

Contribution to Project:

Kelp forest community ecology

Name: Lester, Sarah

Worked for more than 160 Hours: No

Contribution to Project:

Kelp forests and population biology of urchins

Name: Brinkman, Jeff

Worked for more than 160 Hours: No

Contribution to Project:

Stream ecology

Name: Kinlan, Brian

Worked for more than 160 Hours: Yes

Contribution to Project:

ecology of kelp forests

Name: Kargar, Maryann

Worked for more than 160 Hours: Yes

Contribution to Project:

watershed hydrology research

Name: Bogonko, Michael

Worked for more than 160 Hours: Yes

Contribution to Project:

watershed hydrology research

Name: Shields, Catherine

Worked for more than 160 Hours: Yes

Contribution to Project:

Watershed research and modeling

Name: Smyth, Robyn

Worked for more than 160 Hours: Yes

Contribution to Project:

Research on biogeochemical responses to physical processes in the coastal ocean.

Name: Finger, Helene

Worked for more than 160 Hours: Yes

Contribution to Project:

Research on biogeochemical responses to physical processes in the coastal ocean.

Name: Landgren, Kristin

Worked for more than 160 Hours: Yes

Contribution to Project:

Research on coastal ocean productivity

Name: Goodman, Darcie

Worked for more than 160 Hours: Yes

Contribution to Project:

Research on coastal watersheds and estuaries

Name: Melton, Christopher

Worked for more than 160 Hours: Yes

Contribution to Project:

Research on coastal ocean productivity and conditions

Name: Sadro, Steve

Worked for more than 160 Hours: No

Contribution to Project:

Physical-chemical measurements and analyses of stream samples.

Name: Cano, Aubrey

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted in K-12 program coordination and execution (Schoolyard?Floating Lab Component, MSP?teacher PD)

Name: Rathbone, Sarah

Worked for more than 160 Hours: No

Contribution to Project:

assisted in K-12 program coordination and execution (Schoolyard?Floating Lab Component, MPS?Teacher professional development).

Name: Rodriguez, Gabe

Worked for more than 160 Hours: Yes

Contribution to Project:

Kelp forest research

Name: Dellaripa, Nicholas

Worked for more than 160 Hours: Yes

Contribution to Project:

Working on SBC-LTER cruise data and other regional oceanographic data sets

Name: Okamoto, Daniel

Worked for more than 160 Hours: Yes

Contribution to Project:

Kelp forest research

Name: Valencia, Sarah

Worked for more than 160 Hours: Yes

Contribution to Project:

Collaborative fishery research

Name: Kay, Matthew

Worked for more than 160 Hours: Yes

Contribution to Project:

Collaborative fishery research

Name: Wilson, Jono

Worked for more than 160 Hours: Yes

Contribution to Project:

Collaborative fishery research

Name: Rush, Tanique

Worked for more than 160 Hours: Yes

Contribution to Project:

Research on remote sensing of kelp forests

Name: Hanan, Erin

Worked for more than 160 Hours: Yes

Contribution to Project:

Research on soil nutrient dynamics

Name: Barron, Rebecca

Worked for more than 160 Hours: Yes

Contribution to Project:

research on inherent optical properties (IOP) in the Santa Barbara Channel

Undergraduate Student

Name: Jolley, Margaret

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with subtidal kelp forest research, data and lab sample processing

Name: Horii, Stephanie

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with subtidal kelp forest research, data and lab sample processing

Name: Rompel, Jenna

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with subtidal kelp forest research, data and lab sample processing

Name: Creason, Jamie

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with subtidal kelp forest research and lab sample processing

Name: Kondo, Emi

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with subtidal kelp forest research and lab sample processing

Name: Zimmer-Faust, Amy

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with subtidal kelp forest research and lab sample processing

Name: James, Kelsey

Worked for more than 160 Hours: No

Contribution to Project:

Assists with on-campus marine outreach and education

Name: Le, Kevin

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with subtidal kelp forest research and lab sample processing

Name: Finstad, Sarah

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with subtidal kelp forest research and lab sample processing

Name: Santschi, Christen

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with subtidal kelp forest research and lab sample processing

Name: Quigley, Yasmin

Worked for more than 160 Hours: No

Contribution to Project:

Assists with on-campus marine outreach and education

Name: Naranjo, Vanessa

Worked for more than 160 Hours: No

Contribution to Project:

Assists with on-campus marine outreach and education

Name: Olsen, Lani

Worked for more than 160 Hours: No

Contribution to Project:

process stream samples, filter water samples for particulates, measure conductivity on stream samples

Name: Teeza, Inteema

Worked for more than 160 Hours: No

Contribution to Project:

process stream samples, filter water samples for particulates, measure conductivity on stream samples

Name: Minter, Thomas

Worked for more than 160 Hours: No

Contribution to Project:

Sample collection from streams during storm events

Name: Padilla, Emmanuel

Worked for more than 160 Hours: No

Contribution to Project:

Sample collection from streams during storm events

Name: Bowen, Kevin

Worked for more than 160 Hours: Yes

Contribution to Project:

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

Name: Moon, Evan

Worked for more than 160 Hours: Yes

Contribution to Project:

assisting in SPOT data analysis

Name: Fairbarn, Kenneth

Worked for more than 160 Hours: Yes

Contribution to Project:

assisting in SPOT data analysis

Name: Nielsen, Jessica

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with kelp forest research and lab sample processing

Name: Cady, Samantha

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with kelp forest research and lab sample processing

Name: Madras, Marie

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with kelp forest research and lab sample processing

Name: Silbert, Matthew

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with kelp forest research and lab sample processing

Name: You, Jiayang

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with information management, database construction and web applications

Name: Griffiths, Marc

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with kelp forest research and lab sample processing

Name: Allman, Erin

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with kelp forest research and lab sample processing

Name: Miller, Kate

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with kelp forest research and lab sample processing

Name: Jew, Gregory

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with kelp forest research and lab sample processing

Name: Most, Mackenzie

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with kelp forest research and lab sample processing

Name: Hazen, Michael

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with kelp forest research and lab sample processing

Name: Barkley, Yvonne

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with kelp forest research and lab sample processing

Name: Artis, Austin

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with kelp forest research and lab sample processing

Name: Linard, Erica

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with kelp forest research and lab sample processing

Name: Dilley, Eric

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with kelp forest research and lab sample processing

Name: Schwarzkopf, Zacary

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with kelp forest research and lab sample processing

Name: Lever, Jeremie

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with kelp forest research and lab sample processing

Name: Chanco, Michael

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with kelp forest research and lab sample processing

Name: Edwards, Kristen

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with kelp forest research and lab sample processing

Name: Gower, Yvonne

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with kelp forest research and lab sample processing

Name: Judge, Jenna

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with kelp forest research and lab sample processing

Name: Gherardi, Kristyn

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with kelp forest research and lab sample processing

Name: Karm, Debi

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with kelp forest research and lab sample processing

Name: Swann, Justine

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with kelp forest research and lab sample processing

Name: McAlexander, Laurie

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with kelp forest research and lab sample processing

Name: Phares, Natalie

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with kelp forest research and lab sample processing

Name: Stroud, Ashley

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with kelp forest research and lab sample processing

Name: Novoa, Anai

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with kelp forest research and lab sample processing

Name: Flores, Jonathan

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with kelp forest research and lab sample processing

Name: Borchart, Sinaed

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with kelp forest research and lab sample processing

Name: Boccio, Gina

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with kelp forest research and lab sample processing

Name: Nicholson, Lisa

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with kelp forest research and lab sample processing

Name: Gibson, Carolyn

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with kelp forest research and lab sample processing

Name: Yu, Gordon

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with maintenance of the SBC-LTER real-time data display system on Stearns Wharf.

Name: Villanueva, Karie

Worked for more than 160 Hours: No

Contribution to Project:

Processed stream water and sediment samples

Name: West, Laura

Worked for more than 160 Hours: No

Contribution to Project:

Processed stream water and sediment samples

Name: Gonter, Lauren

Worked for more than 160 Hours: No

Contribution to Project:

Processed stream water and sediment samples

Name: Svete, Lindsey

Worked for more than 160 Hours: No

Contribution to Project:

Collected stream chemistry samples during storms. Processed stream water and sediment samples

Name: Journales, Mary

Worked for more than 160 Hours: No

Contribution to Project:

Processed stream water and sediment samples

Name: Paine, Christina

Worked for more than 160 Hours: No

Contribution to Project:

Processed stream water and sediment samples

Name: Flavin, Kimberly

Worked for more than 160 Hours: No

Contribution to Project:

Processed stream water and sediment samples

Name: Buffington, Gary

Worked for more than 160 Hours: No

Contribution to Project:

Assist in collecting stream chemistry samples during storms

Name: Smith, Chris

Worked for more than 160 Hours: No

Contribution to Project:

Assist in collecting stream chemistry samples during storms

Name: Lipps, Megan

Worked for more than 160 Hours: No

Contribution to Project:

Assist in collecting stream chemistry samples during storms

Name: Gluchowski, David

Worked for more than 160 Hours: No

Contribution to Project:

Assist in collecting stream chemistry samples during storms

Name: Rosser, Nathan

Worked for more than 160 Hours: No

Contribution to Project:

Assist in collecting stream chemistry samples during storms

Name: Patton, Judd

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with laboratory and field research on streams

Name: Hurtado, Vivian

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with laboratory and field research on streams

Name: Baxter, Catherine

Worked for more than 160 Hours: Yes

Contribution to Project:

assisted in K-12 program coordination and execution (Schoolyard?SBC-LTER curriculum and Floating Lab)

Name: Rink, Laura

Worked for more than 160 Hours: Yes

Contribution to Project:

assisted in K-12 program coordination and execution (Schoolyard?SBC-LTER curriculum and Floating Lab)

Name: Aguanno, Kristen

Worked for more than 160 Hours: No

Contribution to Project:

assisted in K-12 program coordination and execution (Schoolyard?SBC-LTER curriculum and Floating Lab)

Name: Allmann, Erin

Worked for more than 160 Hours: No

Contribution to Project:

assisted in K-12 program coordination and execution (Schoolyard?SBC-LTER curriculum and Floating Lab)

Name: Beckler, Michael

Worked for more than 160 Hours: No

Contribution to Project:

assisted in K-12 program coordination and execution (Schoolyard?SBC-LTER curriculum and Floating Lab)

Name: Bonsell, Christina

Worked for more than 160 Hours: No

Contribution to Project:

assisted in K-12 program coordination and execution (Schoolyard?SBC-LTER curriculum and Floating Lab)

Name: Choy, Robynn

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with kelp forest research, data, and lab processing
 Assisted in K-12 program coordination and execution (Schoolyard?SBC-LTER curriculum and Floating Lab)

Name: Cowen, Jane

Worked for more than 160 Hours: No

Contribution to Project:

assisted in K-12 program coordination and execution (Schoolyard?SBC-LTER curriculum and Floating Lab)

Name: Fong, Carrie

Worked for more than 160 Hours: No

Contribution to Project:

assisted in K-12 program coordination and execution (Schoolyard?SBC-LTER curriculum and Floating Lab)

Name: Frietas, Elyse

Worked for more than 160 Hours: No

Contribution to Project:

assisted in K-12 program coordination and execution (Schoolyard?SBC-LTER curriculum and Floating Lab)

Name: Keller, Kaely

Worked for more than 160 Hours: No

Contribution to Project:

assisted in K-12 program coordination and execution (Schoolyard?SBC-LTER curriculum and Floating Lab)

Name: Lam, Laurel

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with subtidal kelp forest research, data, and lab processing

Assisted in K-12 program coordination and execution (Schoolyard?SBC-LTER curriculum and Floating Lab)

Name: McFarlin, Michael

Worked for more than 160 Hours: Yes

Contribution to Project:

assisted in K-12 program coordination and execution (Schoolyard?SBC-LTER curriculum and Floating Lab)

Name: Ophanon, Justine

Worked for more than 160 Hours: No

Contribution to Project:

assisted in K-12 program coordination and execution (Schoolyard?SBC-LTER curriculum and Floating Lab)

Name: Schorrock, Kait

Worked for more than 160 Hours: No

Contribution to Project:

assisted in K-12 program coordination and execution (Schoolyard?SBC-LTER curriculum and Floating Lab)

Name: Xue, Yun Feng

Worked for more than 160 Hours: No

Contribution to Project:

assisted in K-12 program coordination and execution (Schoolyard?SBC-LTER curriculum and Floating Lab)

Name: Logan, Rebekah

Worked for more than 160 Hours: Yes

Contribution to Project:

assisted in K-12 program coordination and execution (Schoolyard?SBC-LTER curriculum)

Name: Anton, Cassidy

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with kelp forest research, data, and lab processing

Name: Amenta, Allison

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with kelp forest research, data, and lab processing

Name: Collins, Haley

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with kelp forest research, data, and lab processing

Name: Foster, Matt

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with kelp forest research, data, and lab processing

Name: Heindel, Sara

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with kelp forest research, data, and lab processing

Name: Lin, Mike

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with kelp forest research, data, and lab processing

Name: Nadal, Ana

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with kelp forest research, data, and lab processing

Name: Ramos, Kim

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with kelp forest research, data, and lab processing

Name: Shen, Erika

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with kelp forest research, data, and lab processing

Name: Torres, Stephanie

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with kelp forest research, data, and lab processing

Name: Kirkey, Matthew

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with field and laboratory studies of sandy beaches

Name: Barrows, Mercer

Worked for more than 160 Hours: Yes

Contribution to Project:

assists with SBC-LTER field work and has been working on calibration of newly developed pressure sensors for use in the SBC-LTER

Name: Langenback, Tony

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with processing invertebrate samples from SBC reefs

Name: Kahn, Alena

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with processing invertebrate samples from SBC reefs

Name: Iwanicki, Suzanne

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with processing invertebrate samples from SBC reefs

Name: Fox, Beth

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with processing invertebrate samples from SBC reefs

Name: Rich, Andrew

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with processing invertebrate samples from SBC reefs

Name: Winners, Brett

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with kelp forest research, data, and lab processing

Name: Ake, Hannah

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with kelp forest research, data, and lab processing

Name: Nielsen, Craig

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with kelp forest research, data, and lab processing

Name: James, Tayler

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with kelp forest research, data, and lab processing

Name: Hranek, Brian

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with kelp forest research, data, and lab processing

Name: Soccodato, Alice

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with kelp forest research, data, and lab processing

Name: Benes, Alexandra

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with kelp forest research, data, and lab processing

Name: Treiberg, Krystal

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with kelp forest research, data, and lab processing

Name: Koda, Samantha

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with kelp forest research, data, and lab processing

Name: Duplisia, Breanna

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with kelp forest research, data, and lab processing

Name: Nava, Gabriela

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with kelp forest research, data, and lab processing

Name: Gee, Sean

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with kelp forest research, data, and lab processing

Name: Green, Ian

Worked for more than 160 Hours: Yes

Contribution to Project:

Working on determining the temperature sensitivity of the wave-measuring pressure sensors developed with SBC-LTER funding

Name: Alvarado, Paola

Worked for more than 160 Hours: No

Contribution to Project:

Assist with Informal Science Education for SBC LTER Schoolyard Program (Oceans-to-Classrooms/REEF)

Name: Anderson, Benjamin

Worked for more than 160 Hours: No

Contribution to Project:

Assist with Informal Science Education for SBC LTER Schoolyard Program (Oceans-to-Classrooms/REEF)

Name: Bland, Erika

Worked for more than 160 Hours: No

Contribution to Project:

Assist with Informal Science Education for SBC LTER Schoolyard Program (Oceans-to-Classrooms/REEF)

Name: Chang, Young

Worked for more than 160 Hours: No

Contribution to Project:

Assist with Informal Science Education for SBC LTER Schoolyard Program (Oceans-to-Classrooms/REEF)and MSP program

Name: Chubb, Corinne

Worked for more than 160 Hours: No

Contribution to Project:

Assist with Informal Science Education for SBC LTER Schoolyard Program (Oceans-to-Classrooms/REEF)

Name: Doran, Rachel

Worked for more than 160 Hours: No

Contribution to Project:

Assist with Informal Science Education for SBC LTER Schoolyard Program (Oceans-to-Classrooms/REEF)

Name: Dover, Christina

Worked for more than 160 Hours: Yes

Contribution to Project:

Assist with Informal Science Education for SBC LTER Schoolyard Program (Oceans-to-Classrooms/REEF)

Name: Eccles, Emily

Worked for more than 160 Hours: No

Contribution to Project:

Assist with Informal Science Education for SBC LTER Schoolyard Program (Oceans-to-Classrooms/REEF)

Name: Foster, Cody

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with Informal Science Education for SBC LTER Schoolyard Program (Oceans-to-Classrooms/REEF)and with SBC LTER research

Name: Garrett, Casey

Worked for more than 160 Hours: No

Contribution to Project:

Assist with Informal Science Education for SBC LTER Schoolyard Program (Oceans-to-Classrooms/REEF)

Name: Gibson, Alexis

Worked for more than 160 Hours: No

Contribution to Project:

Assist with Informal Science Education for SBC LTER Schoolyard Program (Oceans-to-Classrooms/REEF)

Name: Gibson, Harrison

Worked for more than 160 Hours: No

Contribution to Project:

Assist with Informal Science Education for SBC LTER Schoolyard Program (Oceans-to-Classrooms/REEF)

Name: Ginther, Samuel

Worked for more than 160 Hours: Yes

Contribution to Project:

Assist with Informal Science Education for SBC LTER Schoolyard Program (Oceans-to-Classrooms/REEF)

Name: Karevoi, Adam

Worked for more than 160 Hours: Yes

Contribution to Project:

Assist with Informal Science Education for SBC LTER Schoolyard Program (Oceans-to-Classrooms/REEF)

Name: Koenig, Laura

Worked for more than 160 Hours: No

Contribution to Project:

Name: Stamme, Mishelle

Worked for more than 160 Hours: No

Contribution to Project:

Assist with Informal Science Education for SBC LTER Schoolyard Program (Oceans-to-Classrooms/REEF)and SBC research

Name: Kolbauer, Jennifer

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with Informal Science Education for SBC LTER Schoolyard Program (Oceans-to-Classrooms/REEF), the MSP Program and SBC LTER research

Name: Miller, Ahna

Worked for more than 160 Hours: Yes

Contribution to Project:

Assist with Informal Science Education for SBC LTER Schoolyard Program (Oceans-to-Classrooms/REEF)

Name: Reneault, Liana

Worked for more than 160 Hours: No

Contribution to Project:

Assist with Informal Science Education for SBC LTER Schoolyard Program (Oceans-to-Classrooms/REEF)

Name: Sakai-Hart, Michelle

Worked for more than 160 Hours: No

Contribution to Project:

Assist with Informal Science Education for SBC LTER Schoolyard Program (Oceans-to-Classrooms/REEF)

Name: Schmidt, Devon

Worked for more than 160 Hours: No

Contribution to Project:

Assist with Informal Science Education for SBC LTER Schoolyard Program (Oceans-to-Classrooms/REEF)

Name: Shorrock, Kaitlyn

Worked for more than 160 Hours: No

Contribution to Project:

Assist with Informal Science Education for SBC LTER Schoolyard Program (Oceans-to-Classrooms/REEF)

Name: Standerfer, Katherine

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with Informal Science Education for SBC LTER Schoolyard Program (Oceans-to-Classrooms/REEF) and the MSP program.

Name: Tien, Peter

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with Informal Science Education for SBC LTER Schoolyard Program (Oceans-to-Classrooms/REEF)

Name: Tirona, Ashley

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with Informal Science Education for SBC LTER Schoolyard Program (Oceans-to-Classrooms/REEF)

Name: Burgess, Joey

Worked for more than 160 Hours: No

Contribution to Project:

Assist with stream ecology research

Name: Simpson, Mark

Worked for more than 160 Hours: No

Contribution to Project:

Assist with stream ecology research

Name: Ng-Parish, Jonathon

Worked for more than 160 Hours: No

Contribution to Project:

Assist with stream ecology research

Name: Tay, Jason

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with research on kelp forest food web

Name: Durr, Rebecca

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with research on sandy beach food webs

Name: Schultz, Dana

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with research on sandy beach food webs

Name: Frame, Rachel

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with research on sandy beach food webs

Technician, Programmer

Name: Nelson, Clint

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with reef and oceanographic research and data management

Name: Fisher, Rachelle

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with reef and oceanographic research and data management

Name: Kissinger, Michelle

Worked for more than 160 Hours: No

Contribution to Project:

Assists with on-campus marine outreach and education

Name: Nakase, Dana

Worked for more than 160 Hours: No

Contribution to Project:

Assists with on-campus marine outreach and education

Name: O'Brien, Margaret

Worked for more than 160 Hours: Yes

Contribution to Project:

IM coordinator

Name: Setaro, Frank

Worked for more than 160 Hours: Yes

Contribution to Project:

Processing stream and watershed samples in laboratory

Name: Doyle, Allen

Worked for more than 160 Hours: Yes

Contribution to Project:

Analytical lab manager, performed and coordinated nutrient analyses for freshwater inorganic and total nutrients. Logged samples, created spreadsheets, performed quality analysis

Name: Fields, Erik

Worked for more than 160 Hours: Yes

Contribution to Project:

satellite image data processing

Name: Jones, Janice

Worked for more than 160 Hours: Yes

Contribution to Project:

coastal oceanographic research

Name: Gotschalk, Chris

Worked for more than 160 Hours: Yes

Contribution to Project:

coastal oceanographic research and data processing

Name: Court, David

Worked for more than 160 Hours: No

Contribution to Project:

remote sensing data analyses

Name: Emery, Brian

Worked for more than 160 Hours: Yes

Contribution to Project:

ocean surface currents research

Name: Ireson, Kirk

Worked for more than 160 Hours: Yes

Contribution to Project:

ocean surface currents research

Name: Guillocheau, Nathalie

Worked for more than 160 Hours: Yes

Contribution to Project:

Plumes and Blooms research

Name: Wiseman, Sheila

Worked for more than 160 Hours: No

Contribution to Project:

Stream ecology

Name: Morris, Jordan

Worked for more than 160 Hours: Yes

Contribution to Project:

server and database management

Name: Burt, Chad

Worked for more than 160 Hours: Yes

Contribution to Project:

information management

Name: Meyerhof, Matthew

Worked for more than 160 Hours: Yes

Contribution to Project:

Coordinated undergrads for storm sampling, conducted both storm and baseflow chemistry sampling, and assisted us with our chemistry data analysis and processing

Name: Donahue, Christine

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with reef and oceanographic research

Name: Moy, Shannon

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with historical sandy beach data and imagery and field studies

Name: Berry, Heather

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with storm sampling coordination, storm sample collection, laboratory processing, and data entry and analysis

Name: Hubbard, David

Worked for more than 160 Hours: No

Contribution to Project:

Assist with monthly shorebird surveys of SBC beaches

Other Participant

Name: Ralph, Yvette

Worked for more than 160 Hours: No

Contribution to Project:

Assisted with subtidal kelp forest research

Name: Reifel, Stanley

Worked for more than 160 Hours: Yes

Contribution to Project:

Developed the circuit board now being used in the new wave-measuring pressure sensors developed for the SBC-LTER.

Name: Johnson, Cyril

Worked for more than 160 Hours: No

Contribution to Project:

Helped design and who fabricated the new wave-measuring pressure sensors developed for the SBC-LTER

Research Experience for Undergraduates

Name: Davenport, Lars

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with subtidal kelp forest research

Years of schooling completed: Junior

Home Institution: Same as Research Site

Home Institution if Other:

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

Fiscal year(s) REU Participant supported: 2007

REU Funding: REU supplement

Name: Craig, Alexandra

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with subtidal kelp forest research

Years of schooling completed: Junior

Home Institution: Same as Research Site

Home Institution if Other:

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

Fiscal year(s) REU Participant supported: 2007

REU Funding: REU supplement

Name: Heidelberger, Sara

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with subtidal kelp forest sampling and lab sample processing

Years of schooling completed: Sophomore

Home Institution: Same as Research Site

Home Institution if Other:

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

Fiscal year(s) REU Participant supported: 2007

REU Funding: REU supplement

Name: Cody, Tim

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with subtidal kelp forest sampling and lab sample processing

Years of schooling completed: Junior

Home Institution: Same as Research Site

Home Institution if Other:

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

Fiscal year(s) REU Participant supported:

REU Funding: REU supplement

Name: Honig, Susanna

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with subtidal kelp forest research and lab sample processing

Years of schooling completed: Sophomore

Home Institution: Same as Research Site

Home Institution if Other:

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

Fiscal year(s) REU Participant supported: 2007

REU Funding: REU supplement

Name: Christie, Jocelyn

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with kelp forest research, data and lab sample processing

Name: Nolan, Ryan

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with information management, database construction and web applications

Years of schooling completed: Junior
Home Institution: Same as Research Site
Home Institution if Other:
Home Institution Highest Degree Granted(in fields supported by NSF): Bachelor's Degree
Fiscal year(s) REU Participant supported: 2009
REU Funding: REU supplement

Name: Stolzenbach, Kevin

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with kelp forest research, data, and lab processing as REU and hourly student assistant. He previously assisted in K-12 program coordination and execution (Schoolyard?SBC-LTER curriculum and Floating Lab)

Name: Henry, Rachel

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted with kelp forest research, data, and lab processing

Years of schooling completed: Junior
Home Institution: Same as Research Site
Home Institution if Other:
Home Institution Highest Degree Granted(in fields supported by NSF): Doctoral Degree
Fiscal year(s) REU Participant supported: 2009
REU Funding: No Info

Organizational Partners

NOAA National Marine Sanctuary Program

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

Santa Barbara Land Trust

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

University of California, Davis, CA

Old Dominion University

Research collaborations on studies of kelp primary production

Los Angeles Conservation Corps

Collaborators on SBC-LTER's schoolyard program for K-12 education

Santa Barbara Channel Keeper

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

Ventura CoastKeeper

Provides stream sampling volunteers and sample collections for watershed research.

Carpinteria Creek Watershed Coalition

Univ. California Natural Reserve System

Friends of the Santa Clara River

City of Santa Barbara

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

Santa Barbara County Project Clean Water

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

Channel Islands National Park

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

Terra Image USA

Center for Integrative Coastal Observ.

La Cumbre Junior High School

The mission of LCJHS is to promote and support academic excellence and the well-being of each student; to promote and provide equity in education; to provide technological skills necessary to compete as students and workers; to create life-long, confident, independent learners that are prepared for high school and beyond. SBC-LTER is collaborating with LCJHS through MSP.

American Assoc. Univ. Women Tech Trek

Tech Trek is a math/science camp designed to develop interest, excitement and self-confidence in young women who will enter eighth grade in the fall. It features hands-on activities in math, science and related fields. All sleeping, eating, instructional and recreational facilities are located on a university campus where camps are held. Tech Trek is a new SBC Schoolyard partner.

LTER Math-Science-Partnership (MSP)

The project connects the research and education prowess in the environmental sciences of universities and sites within LTER with teacher professional development in science and mathematics of partner middle schools and high schools. It extends across the nation and involves four LTER research sites—the Shortgrass Steppe, Baltimore Ecosystems Study, Kellogg Biological Station, and Santa Barbara Coastal—and their

partnering institutions, the LTER Network Office, and a group of 22 K-12 schools and districts that will directly impact over 250 science and mathematics teachers and 70,000 students from diverse backgrounds.

UCSB's Office of Acad. Prep. + Education

Scripps Institution of Oceanography

University of Southern California

University of Calif. San Diego

Cal Poly San Luis Obispo

S. Calif. Coastal Ocean Observing System

MIRADA LTERs

Other Collaborators or Contacts

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

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

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

SBC investigators are actively collaborating with researchers from the Centre of Marine and Environmental Research (CMER) at the Universidade do Algarve, Portugal on issues pertaining to gene flow, inbreeding depression and population connectivity in the giant kelp *Macrocystis pyrifera*. CMER is a member of the Marine Biodiversity and Ecosystem Functioning (MarBEF) program, which is a network of

excellence funded by the European Union. It consists of 91 European marine institutes and is a platform to integrate and disseminate knowledge and expertise on marine biodiversity with links to researchers, industry, stakeholders and the general public. CMER is also a member of CORONA (Coordinating Research of the North Atlantic), an NSF-funded multidisciplinary research network to study the marine biota of the North Atlantic. The network includes 118 scientists from 13 countries across the North Atlantic. The major research and education goals of CMER, MarBEF, and CORONA are complimentary to those of SBC LTER, providing the ideal opportunity for collaboration.

The University of California, Santa Barbara's Academic Preparation and Equal Opportunity (APEO) program mission is to serve a diverse population by supporting and providing pathways of high-quality P-20 academic preparation and equal opportunity programs consistent with university, state and federal policies related to student enrollment and retention and faculty and staff hiring through partnerships within the university and the larger community. APEO has provided additional funds for undergraduate student salaries for Schoolyard related programming.

CoastLines is a three-year comprehensive Project for students and teachers funded by the Information Technologies for Students and Teachers program at the National Science Foundation (<http://www.coastlines.ws/>). It introduces fundamental concepts about information technologies (IT) to grade 7-12 schools. The project involves teachers and students in using geographic information systems (GIS) and global positioning systems (GPS) to conduct scientific studies of coastal ecosystems in the National Science Foundation's Long-Term Ecological Research (LTER) network. CoastLines builds on lessons learned by the Center for Image Processing in Education and other practitioners about offering GIS-based training to K-12 educators. SBC co-hosted a 2 week educator workshop for this program in Summer 2010.

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

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

Activities and Findings

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

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

Training and Development:

Education and training are tightly integrated into all aspects of SBC research. As of August 2010, 14 post docs, 46 graduate students, 8 REU students and more than 165 undergraduate students have participated in SBC research during the last 4 years. SBC provides research training opportunities to more than 25 undergraduate students each year. In addition to gaining valuable research experience, many of the undergraduate students earn academic credit or received monetary compensation for participating in SBC research as interns and honors students. SBC investigators, graduate students and staff train mentor independent research by undergraduates and local high school students. SBC LTER is an active participant in NSF's Research Experience for Undergraduates program and in several other mentorship programs sponsored by the University of California. REU students work closely with SBC researchers on both core measurements and experimental studies in the kelp forest. In addition to its pivotal role in SBC's K-12 and public outreach programs (see above), the Schoolyard program (SLTER) at SBC provides our undergraduate interns with a rigorous and pedagogically sound program of training in marine science and science education through The REEF (Research Experience and Education Facility) and other programs. These interns engage directly with middle school students as teachers and role models. Our project's research regularly finds its way into the classroom as SBC investigators routinely incorporate activities and findings of SBC-sponsored research into their teaching, thereby extending the project's contributions to the broader student body. Many SBC investigators give guest lectures and class demonstrations on SBC research in university courses.

SBC graduate student and postdoctoral training is integrated with a variety of other programs on the UCSB campus including the Bren School of Environmental Science and Management, The Institute for Computational Earth System Science, The Interdepartmental Marine Science Program and the Partnership for Interdisciplinary Studies of the Coastal Ocean. With the SBC LTER, these programs promote interdisciplinary research to examine how coastal ecosystems change in response to natural and human-induced alterations in the environment. SBC training includes students and post docs working in terrestrial, aquatic, and marine environments with interests ranging across ecology, physiology, geology, hydrology, oceanography, modelling and coastal policy. This enables valuable cross-training on environmental issues pertaining to

coastal ecosystems, provides a common language for communicating scientific information on these issues, and contributes to the creation of a diverse scientific community of students and postdocs that fosters a respect and appreciation for other disciplines. SBC students, postdoctoral fellows, and investigators participated in the LTER All Scientists Meeting in September 2009 and the site review in October 2009. At these meetings, results from SBC research and collaborative projects were presented in poster sessions and oral presentations. SBC graduate students also participated in the first UC-LTER graduate postdoc symposium organized by the CCE-LTER in May 2008.

Educational opportunities at SBC are not limited to university students and post docs. Teachers and numerous volunteers from the general public regularly participate in our stream sampling program and gain considerable knowledge on the constituents of runoff and of the processes that influence their concentrations.

Outreach Activities:

The SBC-LTER Summer Program 2010

SBC's Schoolyard LTER (SLTER) program is organized around a theme of watershed ecology. This approach allows for an integrated program that includes K-12 students, K-12 teachers, undergraduate and graduate students, and staff. For the last few years we have focused on developing long-term connections with local, regional and state middle and junior high schools through a partnership with the American Association of University Women's Tech Trek Program. Tech Trek is a math/science summer program designed to develop interest, excitement and self-confidence in young women who will enter eighth grade in the fall. It features hands-on activities in math, science and related fields. Tech Trek is a campus residential program that includes educational and recreational activities, all of which are located on a university campus where camps are held. Tech Trek is part of an interdisciplinary partnership involving science, technology, engineering, and math departments at UCSB through the Office of Academic Preparation and Education Outreach (APEO). The goal of APEO is to build college-going communities that improve student learning, increase college-going rates in underrepresented populations, and provide equal access to higher education for California's diverse students. With the infrastructural support of Tech Trek and APEO, the SBC SLTER program also aims to engage middle school students and teachers through the academic year and summers, and throughout their secondary school education.

Program Format: We are using the successes we had with our LACC summer program (2004-2007) and Pathways program (2008) to guide development of our SBC SLTER program. First, we continue to work with our undergraduate interns in a rigorous and pedagogically sound program of training in marine science and science pedagogy. These interns engage directly with middle school students as teachers and role models. Second, we continue to develop and adapt marine science lesson plans that engage students with learning about the local environment. These lesson plans incorporate ongoing SBC LTER research and include working with data generated by monitoring and experiments. The program is developed to build student's skills in scientific inquiry through a series of activities that move from structured or guided investigation to open-ended experimentation. Third, our program includes a combination of school-based activities, field trips, and an on-campus residential experience that immerse students in the environment of a college campus.

In working with Tech Trek, the SBC SLTER program engages a group of over 90 girls from junior high and middle schools from across the state. The participants are diverse, representing a broad range of socioeconomic and demographic groups. During their week-long residential immersion at UCSB, students participate in "core" courses that focus on science basics: physics, math, chemistry, and biology. These courses are then complimented with practical application activities where students are engaged in SBC LTER research- based learning activities, conduct field activities, and explore the possibility of attending a 4-year college. Activities include explorations of ecology and adaptation at the UCSB aquarium, SBC LTER research site monitoring protocols, and a Floating Lab trip, on a 75' catamaran, into the Santa Barbara Channel. An additional benefit expected in future years is the long-term connection we will maintain with participating students both through APEO support (they work with some of these same students throughout their high school years) and through continued engagement with students as they move into high school and college. We envision a program that supports interested students with science fair projects, summer research opportunities, and mentoring opportunities with our middle school program.

Research Experience & Education Facility (REEF)

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

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

The REEF program has been busy during 2010, between outreach visits to schools, community events and on-campus programs, The REEF provided marine science and environmental education to over 15,000 children and adults. This includes hosting educational visits from primary and secondary schools from King City in Monterey Co., to San Diego, and as far east as Las Vegas, Nevada! The REEF also serves as a marine laboratory for many colleges including Cal Lutheran Thousand Oaks, CSU Channel Islands, and UCSB. At UCSB, The REEF serves as an interdisciplinary laboratory for undergraduate courses including: Geology 4 (Intro to Oceanography), EEMB 3 (Intro Biology), EEMB 106 (Biology of Fishes), Writing 2 and Writing 109 ST. This year the REEF had over 3,200 on-campus visitors.

Math-Science-Partnership (MSP) Project: Pathways to Environmental Literacy

The MSP project, which was launched in October 2008, connects the research and education strengths in the environmental sciences of universities and sites within LTER with teacher professional development in science and mathematics of partner middle schools and high schools. It extends across the nation and involves four LTER research sites—the Shortgrass Steppe (SGS), Baltimore Ecosystems Study (BES), Kellogg Biological Station (KBS), and Santa Barbara Coastal (SBC) and their partnering institutions, the LTER Network Office, and a group of 22 K-12 schools and districts that will directly impact over 250 science and mathematics teachers and up to 70,000 students from diverse backgrounds. The SBC LTER site is currently working with La Cumbre Junior High School in providing teacher professional development to develop in-class science curriculum based on SBC LTER field study sites, data and ecological principles.

The MSP project provided funds to support a program coordinator, a post-doctoral fellow, and 2 SBC LTER graduate student fellows. The project participants worked with science teachers at a local school, La Cumbre Junior High School, implementing programming that impacted all 450 junior high schools students. In particular, the fellows worked in the 7th and 8th grade science classrooms developing and implementing LTER science based curriculum. All participants were actively engaged in developing and leading two field trips that brought all students to a nearby LTER monitoring site and on-campus for a visit to The REEF. A number of SBC graduate students, post-docs and investigators gave talks on their research and led activities for the MSP field trips and programs.

SBC co-hosted a 2 week workshop for 30 educators from all over the country as part of the CoastLines (<http://www.coastlines.ws>) project in Summer 2010. CoastLines is a three-year comprehensive project for students and teachers funded by the Information Technologies for Students and Teachers program at the National Science Foundation. It introduces fundamental concepts about information technologies (IT) to grade 7-12 schools by involving teachers and students in using geographic information systems (GIS) and global positioning systems (GPS) to conduct scientific studies of coastal ecosystems in the National Science Foundation's Long-Term Ecological Research (LTER) network. The focus of the CoastLines project in 2009-2010 was research being conducted at the SBC LTER. During Spring 2010 teachers participated in several online webinars during which they were introduced to the SBC LTER research themes, sites, and data. The online work was in preparation for the 2-week workshop held on the UCSB campus. During the workshop teachers worked with existing SBC LTER data to build GIS maps in order to virtually explore the SBC LTER research sites. Teachers also collected and geo-located their own environmental data to import into their GIS software. SBC LTER researchers and staff gave presentations, led field trips, and assisted teachers in developing research questions of their own. The workshop culminated with the development of GIS-based lesson plans that will be implemented in their classrooms in the fall semester. SBC LTER staff will continue to support teachers in their efforts throughout the fall semester.

Other SBC Outreach Activities

Direct outreach to the public is an active area for many SBC investigators and students. Al Leydecker, an SBC post-doctoral fellow, assists and helps direct stream and river monitoring, education and sampling programs for several community environmental organizations, including Santa Barbara Channel Keeper, Ventura Surf Rider and the Friends of the Santa Clara River. He also gave a lecture as part of a UC Cooperative Extension seminar series "More Than You Ever Wanted to Know About Algae in the Ventura River?". SBC investigators Bradley Cardinale and Jenifer Dugan gave talks to the local groups including Audobon Society and the Santa Ynez Natural History Society. Investigator Washburn gave a lecture on the oceanography of the Santa Barbara Channel to the docents of the Santa Barbara Maritime Museum. Investigator Cooper gave a talk at the Fire Forum on the effects of fire on stream ecology to the County of Santa Barbara Project Clean Water Stakeholders group. He also presented a lecture to the Ventura River Watershed Council on land use, nutrient inputs, and algal blooms in the Ventura River. SBC investigators also serve as participants and advisers to several community groups to provide educational and scientific perspectives including the Santa Barbara Community Environmental Council, Friends of the Santa Clara River, Santa Barbara Creeks Council, and the UCSB Shoreline Preservation Fund.

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Web/Internet Site

URL(s):

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

Description:

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

Other Specific Products

Product Type:

Data or databases

Product Description:

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

Sharing Information:

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

Product Type:

Software (or netware)

Product Description:

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

Sharing Information:

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

Product Type:

Data or databases

Product Description:

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

Sharing Information:

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

Contributions

Contributions within Discipline:

The understanding of ecosystem level processes in giant kelp forests has lagged behind the increasing body of knowledge at the species, population, or community level of kelp forests over the last four decades. Results from our reef studies are helping to address the growing need for research at the ecosystem level in kelp forests. Of particular significance are our studies of 1) primary production, 2) integrating kelp forest population dynamics and genetics on local to basin-wide spatial scales and across temporal scales 3) kelp forest food webs using stable isotope analyses, 4) the role of nutrients from multiple sources, including N-recycling, in altering these food webs and meeting nutrient demands of kelp forest ecosystems 5) the effects of wave disturbance on the complexity and diversity of kelp forest food webs and 6) links between kelp forests and sandy beach food webs.

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

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

Our extensive and intensive measurements and models 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. The hydrologic model that we are developing will aid in predicting how climate, land-use, and the physical and biological structure of coastal streams influence the runoff of material constituents. The model simulates rainfall-runoff and routing processes from three sources (surface, shallow soils and groundwater) for both undisturbed and urban lands and will ultimately be integrated with water quality modules to simulate the discharge of water, associated solutes, and sediments from the land to the ocean.

Contributions to Other Disciplines:

The research mission of SBC is very interdisciplinary in scope. As such, our research contributes to a wide range of disciplines including: terrestrial, aquatic and marine ecology, physical, biological and chemical oceanography, hydrology, geology, geography, toxicology, environmental history, science education and informatics. Coordinated studies among the many disciplines represented in SBC are leading to an improved understanding of the patterns and processes that link land and ocean environments and their consequences for coastal ecosystems. This improved understanding is not only contributing to furthering the many disciplines listed above, but is of considerable value to those interested in studying the extent to which society is influenced by human impacts to coastal systems. SBC is actively initiating ties with the social science community. Investigator Melack served as the acting dean of the Bren School of Environmental Science and Management until 2010 and has played a pivotal role in the development of the School, including chairing the committee that wrote the original proposal for the school. Investigator Gaines became the dean of the Bren School in January 2010. The Bren School's graduate training programs integrate science, management, law, economics, and policy as part of an interdisciplinary approach to environmental problem-solving. Investigator Siegel directs the Institute for Computational Earth System Sciences (ICESS) which is a leader in ocean color and remote sensing research. Investigator Lenihan leads a collaborative fishery research program, CALobster (<http://www.calobster.org/>), focused on the spiny lobster fishery with a goal of promoting and conducting community-based research that lead to the best management practices and help maintain working harbors. Investigators Melack, Schimel, Cooper, and Roberts are investigating the effects of fires in SBC watersheds with a multidisciplinary team of researchers and agency scientists. Investigators Page and Dugan conducted collaborative research on crab fisheries with local trap fisherman and are investigating aquatic invasive species in southern California harbors in cooperation with state marine advisors. Dugan and Guerrini are writing an interdisciplinary multi-authored book on the deep human and environmental history of a SBC coastal wetland and watershed.

Contributions to Human Resource Development:

Our project provides significant opportunities for research and teaching in science at multiple levels. As of August 2010 14 post docs, 46 graduate students, 9 REU students and more than 165 undergraduate students have participated in SBC research during this funding cycle. In addition to gaining valuable research experience, many of the undergraduate students earned academic credit or were given monetary compensation.

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

In summer 2010, Investigator Carlson taught an Immersion Course on Microbial Oceanography: The Biogeochemistry, Ecology and Genomics of Oceanic Microbial Ecosystems at the Bermuda Institute of Ocean Sciences. This lecture laboratory course provided training in various techniques in microbial ecology and oceanography used in both the LTER programs and the Microbial observatory program. Students from SBC LTER attended in summer 2010.

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

Increased exposure to the SBC research activities has come by way of the LTER Schoolyard program. SBC has continued to increase the exposure of SBC research activities to K-12 students and teachers by developing exciting new environmental education program for middle school students. The new program partners with local middle schools through a partnership with UCSB's Office of Academic Preparation and Education Outreach (APEO) for environmental education programs including field trips, an educational cruise and individual research projects. The goal of APEO is to build college-going communities that improve student learning, increase college-going rates, and provide equal access to higher education for California's diverse students.

The Santa Barbara Coastal (SBC) LTER outreach, education and training programs benefit from a close association with the University of California at Santa Barbara's Research Experience & Education Facility, better known as the REEF, an interactive aquarium facility. The REEF is equipped with state-of-the-art, aquaria and touch tanks, ranging from 2 to 2,000 gallons. The REEF also utilizes a high-tech life support system for the Research Tank, which highlights current, on-going research at UCSB and the Marine Science Institute, including SBC-LTER research. This program reaches thousands of K-12 students annually through special programs, school group tours and school visits.

SBC-LTER hosted a number of workshops for an innovative NSF funded project on targeted partnerships in math and science in 2009 -2010. These targeted partnerships focus on the critical education junction of middle school through high school to develop a program of teacher professional development in science and mathematics driven by framework of environmental science literacy surrounding the learning progressions of core science and math concepts. The goal is to connect the research capabilities of partner universities and LTER sites with K-12 teacher professional development in science and math at partner schools.

SBC co-hosted a two week CoastLines workshop for 30 educators from all over the country in Summer 2010. CoastLines is a three-year comprehensive project for students and teachers funded by the Information Technologies for Students and Teachers program at the National Science Foundation. It introduces fundamental concepts about information technologies (IT) to grade 7-12 schools by involving teachers and students in using geographic information systems (GIS) and global positioning systems (GPS) to conduct scientific studies of coastal ecosystems in the National Science Foundation's Long-Term Ecological Research (LTER) network. CoastLines builds on lessons learned by the Center for Image Processing in Education and other practitioners about offering GIS-based training to K-12 educators.

Contributions to Resources for Research and Education:

Physical resources

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

Information Resources

SBC's website contributes to information resources by providing the scientific community and the general public access to unique datasets that are of interest to a diverse array of people. Some examples of such datasets include: historical data on giant kelp abundance in the northeast Pacific, SST imagery from NOAA-AVHRR polar orbiters of the Santa Barbara Channel, high frequency radar data of surface currents in the Santa Barbara Channel, precipitation data and soil mapping and land-use coverage of the Santa Ynez Mountains. In 2009 access and format of these datasets were enhanced on our website which was redesigned to fit LTER network standards and updated for content.

Contributions Beyond Science and Engineering:

SBC investigators are very active in applying their knowledge of Santa Barbara's coastal ecosystems to inform and implement changes in local and regional policies. SBC investigators serve as advisors and committee and board members for a number of local and national groups concerned with conservation and management of natural resources as well as with local and state agencies.

Investigator Gaines serves on several committees and advisory groups concerned with fisheries and marine conservation including the Science Advisory Panel for the California Marine Life Protection Act, the Science Advisory Group for the Interagency Ecological Program of the California Department of Water Resources, the Joint Ocean Commission and the Marine Life Protection Act Baseline Science Management Panel. Other SBC investigators are actively working with the Science Advisory Panel and stakeholder groups to integrate SBC data and core measurements, provide information needed to develop the regional profile and evaluate proposals for reserve network design for the south coast region.

Investigators Reed and Page work with the staff of the California Coastal Commission (CCC) on a large multidimensional program designed to mitigate for the loss of coastal marine resources caused by the operation of the San Onofre Nuclear Generating Station (SONGS), a coastal power plant located in north San Diego County. The major emphasis in this program is compensation for lost marine resources via wetland and kelp forest restoration. Reed and Page's primary responsibilities are to consult with the employees of the power plant (Southern California Edison), the CCC and their staff, and other resource agencies on ecological issues relating to the design of the mitigation projects and to develop and implement monitoring programs capable of determining whether the biological and physical performance of these projects meet pre-determined standards. Much of the science done on these mitigation projects is quite complementary to that done by SBC LTER and there is considerable exchange of information and ideas between the two projects.

SBC research plays a prominent role in shaping policy towards local watershed issues as well. We have developed mutually beneficial, cooperative associations with local government departments and NGOs. Santa Barbara County's Project Clean Water is engaged in sampling local creeks during the initial rise of the hydrograph and measuring a suite of pollutants including metals, pesticides and herbicides. Our intensive sampling of nutrients and particulates during the entire hydrograph for most storms complements the County's effort, and they and we share our data and interpretations. We perform nutrient analyses on water samples from local streams and rivers for Santa Barbara Channelkeepers, the City of Santa Barbara and the Friends of the Santa Clara River. The Santa Barbara Channelkeeper program conducts monthly collections along the Ventura River, and we participate in this fieldwork and complement their in situ measurements with high quality nutrient chemistry. Co-Investigator Melack is on the Technical Advisory Committee for Friends of Santa Clara River water quality monitoring program and the Board of Directors for the Santa Barbara Community Environmental Council. Al Leydecker, a SBC post doc, continued to assist and help direct stream and river monitoring, synthesis, education and sampling programs for several community environmental organizations including Santa Barbara Channel Keeper, and Ventura Surfrider in 2009. He also provided regular reports on the status of algal blooms and eutrophication to interested parties involved in the TMDL regulatory process managed by the Regional Water Board. Investigator Cooper advised the City of Santa Barbara on the impacts and design of studies related to UV treatment of Laguna Creek waters before their discharge into the Laguna/Mission Creek estuary, reviewed and edited a 2009 report for the Southern Coastal Santa Barbara Creeks Bioassessment Program, to the City of Santa Barbara's Creek Division and the County of Santa Barbara's Project Clean Water, participated in stakeholders' meeting on Storm Water Management Plan for the City of Goleta. He also provided comments on the Southern California Steelhead Recovery Plan to NMFS, on statewide fish stocking policies to the DFG, and on proposed activities related to the removal of the Matilija Dam to the Army Corps of Engineers and is a member and consultant for the Tidewater Goby Working Group of the City of Santa Barbara, Public Works Department.

Three major fires, the Gap Fire in July 2008, Tea Fire in November 2008 and the Jesusita Fire in May 2009, have occurred in the Santa Barbara area, resulting in large scale evacuations of residents and the loss of nearly 300 homes and. The total acreage burned in less than one year in these three fires exceeds 20,000 acres of watershed lands located in and above the cities of Santa Barbara, Montecito and Goleta. SBC collects data that will help evaluate the effects of these 3 major fires on the composition of runoff and stream discharge in a variety of catchments. SBC investigators Cooper and Melack are working with NGOs and county and federal agencies to document effects of the fires and contribute to planning and preparation for post fire impacts. They have provided input and advice to County of Santa Barbara Flood Control personnel and environmental organizations on post-fire mitigation activities and hydromulch experiments in meetings and field trips and coordinated interactions between UCSB and the County of Santa Barbara. A group of SBC investigators are building collaborations and have obtained support for more intensive studies of the burned catchments, which were initiated in 2009.

The conservation and management of sandy beach ecosystems lags behind that of coastal wetlands and riparian habitats. SBC research on kelp wrack in these ecosystems has led to the recognition of wrack as an ecological resource by local and state agencies and contributed to the development of new policies for coastal management. SBC investigators Dugan and Page are working with California State Parks to develop and evaluate new restoration strategies for wrack-associated invertebrates on beaches that support breeding snowy plovers, a federally listed shorebird. Dugan plays an active advisory role with coastal consortiums and groups concerned with improving the conservation and management of beach ecosystems. She was invited to become part of the NSF-funded Coastal Barrier Island Network (CBIN) which is developing an interdisciplinary network to address the effective management of barrier island ecosystems under the pressure of global climate change (e.g., sea level rise and increased hurricane activity) and continued urbanization. She works with the California Coastal Commission on developing policies for beach management practices that incorporate key ecological components of beach ecosystems. She is also a member of the Beach Ecology Coalition, a new professional organization for beach managers, that provides a forum for education, outreach, training and development of best practices and cooperative research on sandy beach ecosystems in California.

Conference Proceedings

Special Requirements

Special reporting requirements: None

Change in Objectives or Scope: None

Animal, Human Subjects, Biohazards: None

Categories for which nothing is reported:

Any Conference

Research Activities

The Santa Barbara Coastal Long Term Ecological Research (SBC LTER) program (<http://sbc.lternet.edu/index.html>) was established in April 2000 and is housed at the University of California Santa Barbara. Its overarching mission is to understand the linkages among ecosystems at the land-ocean margin through interdisciplinary research, education and outreach with a focus on developing a predictive understanding of the structural and functional responses of giant kelp forest ecosystems to environmental forcing from the land and the sea. Giant kelp forests occur on shallow rocky reefs that fringe temperate coastlines throughout the world and are extremely important to the ecology and economy of the regions in which they occur. Our principal study site is the semi-arid Santa Barbara coastal region, which includes steep watersheds, small estuaries, sandy beaches, and the neritic and pelagic waters of the Santa Barbara Channel and the habitats encompassed within it (e.g., giant kelp forests, deep ocean basins, pelagic waters and offshore islands).

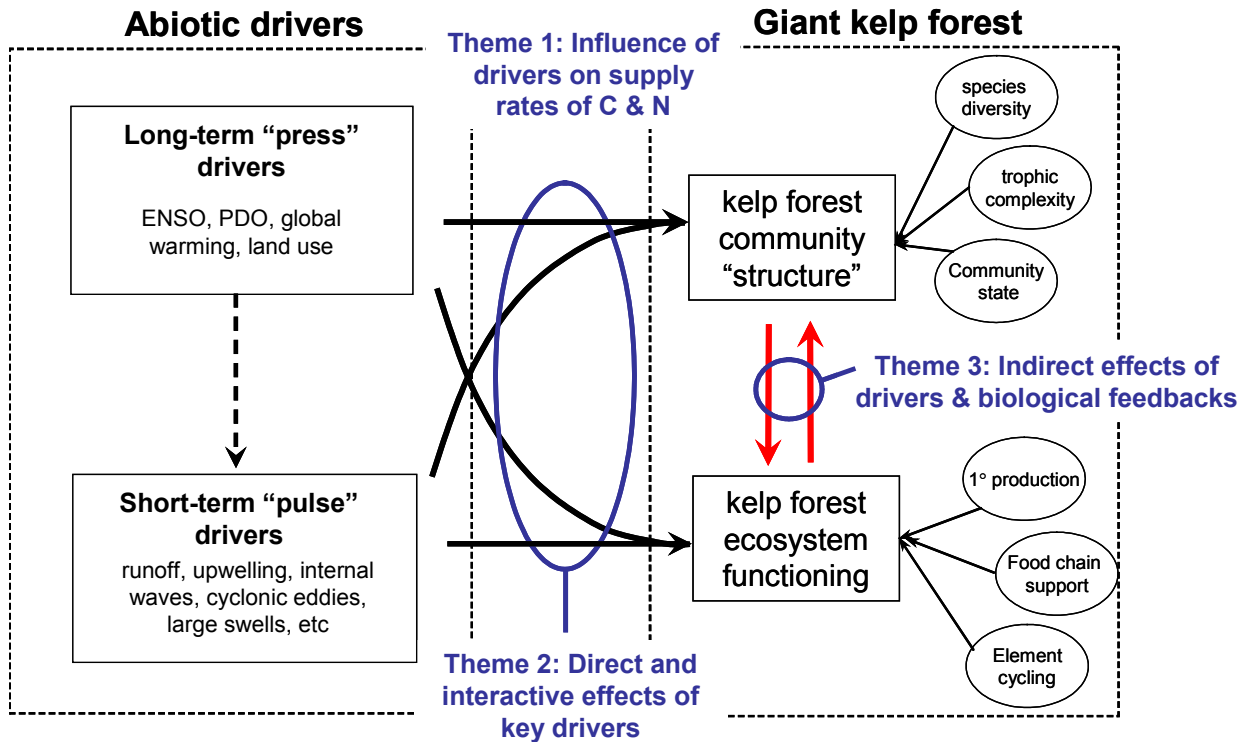
During our first six-year funding cycle our research focused on testing hypotheses and addressing questions relating to the role of terrestrial, oceanic and atmospheric forcing in accounting for the dynamics that we observed in kelp forest structure and function. Much of this work centered on; (1) determining the dynamics of production and food web structure in kelp forests, (2) identifying the important processes on land and in the coastal ocean that drive changes in the nature and quantity of subsidies delivered to kelp forests, and (3) establishing sampling programs to generate long-term data sets that could address questions and hypotheses relating to the core areas of LTER research. This research led to substantial increases in our knowledge of our study system. Armed with this increased knowledge we followed the advice of our first mid-term review and reduced our sampling effort in a number of these areas in our second cycle of funding in order to more intently pursue linkages among ocean, reef and land components and their propensity to change under different environmental conditions.

Our ability to predict how coastal ecosystems will respond to environmental change requires a recognition that the drivers of change (e.g., climate, disease, human actions) typically act over different temporal and spatial time scales. This inevitably results in a complex set of interactions among the biotic responses that these forcings elicit. The LTER Network has long been interested in environmental drivers that span a range of temporal and spatial scales and have recently formalized this interest into a pulse/press framework in which abiotic drivers act in a chronic long-term (i.e., “press”) or periodic short-term (i.e., “pulse”) fashion to influence biotic structure and ecosystem function (LTER Decal Plan 2007). We adopted this framework for our current funding cycle which seeks to obtain a more predictive understanding of the importance of land and ocean processes in determining the structure and function of giant kelp (*Macrocystis pyrifera*) forest ecosystems. The overarching question motivating our current research is:

How do abiotic drivers acting over different spatial and temporal scales interact to influence kelp forest structure and function?

To address this question we have focused our research around three general themes (Figure 1): (1) The influence of abiotic press and pulse drivers on exchange rates of N and C between giant kelp forests and adjacent land and ocean habitats, (2) The direct and interactive effects of key press and pulse drivers on kelp forest community structure and function through the modification of nutrient supply and wave disturbance, and (3) The indirect effects of pulse and press drivers on kelp forest community structure and function and the feedbacks between structure and function.

Figure 1. Conceptual framework of SBC LTER research. Specific research questions and hypotheses are organized under one of three central themes. The solid black arrows represent the influx of physical disturbance and chemical subsidies as influenced by abiotic press and pulse drivers. The ecological consequences of interactions between press and pulse drivers (dashed arrow) are manifested over a time period that is greater than the current six-year funding cycle, which necessitates the need for long-term research



THEME 1: The influence of abiotic press and pulse drivers on the rates of delivery of N and C to giant kelp forests

- *QUESTION 1a. How are the rates of delivery of N and organic C to giant kelp forests from terrestrial and oceanic environments altered by press and pulse drivers?*
- *QUESTION 1b. What are the sources and fate of dissolved and particulate organic matter in the nearshore zone?*

THEME 2: The direct and interactive effects of key press and pulse drivers on kelp forest community structure and function through the modification of nutrient supply and wave disturbance

- *QUESTION 2. How do wave disturbance and N loading act and interact to influence the structure, function, and resilience of the kelp forest ecosystem?*

THEME 3: Indirect effects of pulse and press drivers on kelp forest community structure and function and the feedbacks between them.

- *QUESTION 3a. How does the negative effects of giant kelp on understory algae and phytoplankton interact with wave disturbance and N loading to affect the magnitude and interannual variability of NPP of the kelp forest ecosystem?*
- *QUESTION 3b. How does the forest interact with its flow environment to modify the delivery of N and C and influence the species composition and performance of kelp forest biota?*

Short-term (hours to weeks) abiotic drivers that affect the delivery of nutrients and organic matter to kelp forests (e.g., upwelling, runoff) are embedded within a climatic regime (i.e., press driver) that fluctuates over much longer time scales (years, decades or more). The rate at which nutrients and organic matter are exchanged between kelp forests and adjacent habitats will depend not only on the direct effects of the pulse and press drivers, but also on the interactions among them (Theme 1, Figure I.1). Abiotic drivers not only influence supply rates of N and C to kelp forests, but also the frequency and intensity of physical disturbance. Because the return interval of some of the key press drivers occurs on decadal and longer time scales, long-term research is needed to evaluate the ecological consequences of the direct and interactive effects of pulse and press drivers on the structure and function of giant kelp forests (Theme 2, Figure 1). Like most natural systems, the structure and function of a giant kelp forest are inextricably linked. Thus, abiotic pulse and press drivers that directly affect the abundance and species composition of a kelp forest community will indirectly influence the system's capacity to fix carbon and take up nutrients used to support the complex kelp forest food web (Theme 3, Figure 1). Similarly, the amount and form of organic matter produced by the forest and made available to kelp forest consumers will in turn influence the abundance and species composition of organisms inhabiting the forest. Positive and negative feedbacks between kelp forest structure and function may arise from these indirect effects.

Site characteristics

SBC LTER is ideally suited to explore issues of connectivity between terrestrial and marine ecosystems and the actions and interactions of pulse and press drivers on kelp forest structure and function. Our site is bounded by the Transverse Ranges of central and southern California to the north, the Channel Islands to the south, Pt. Conception to the west, and the Santa Clara River to the east (Figure 2). The catchments draining into the Santa Barbara Channel offer a rich diversity of watersheds that are characterized by a wide variety of land covers and uses.

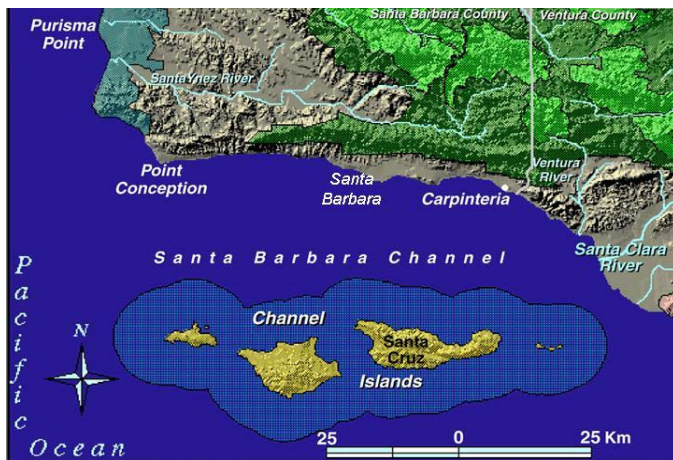


Figure 2. Regional map of SBC LTER. The site boundaries extend from Pt. Conception in the west to the Santa Clara River in the east, from the top of the Santa Ynez Mountains in the north out to the Channel Islands.

to the west, and the Santa Clara River to the east (Figure 2). The catchments draining into the Santa Barbara Channel offer a rich diversity of watersheds that are characterized by a wide variety of land covers and uses. Giant kelp forms expansive forests on shallow rocky reefs, which dominate the nearshore in this region. Because of their close proximity to shore, kelp forests are influenced by physical and biological processes that occur on the land as well as in the open ocean. Streams and rivers transport nutrients, dissolved and particulate organic matter (DOM and POM), sediments, and pollutants from

coastal watersheds to kelp forests, while ocean currents, internal waves, and other oceanographic processes supply nutrients, DOM, POM, larvae and plankton from adjacent offshore waters. In return, kelp forests export large amounts of DOM and POM to inshore intertidal habitats, as well as to offshore deep-water habitats. The transport of nitrate into the euphotic zone and disturbance from storm-generated waves are arguably the two most important factors regulating the standing crop and production of macroalgae (including giant kelp) in the coastal waters of southern California, and our research themes emphasize these two aspects. Short-term (i.e., pulse) and long-term (i.e., press)

changes in climate, oceanography and land use that directly or indirectly alter the disturbance regime and/or the supply of nutrients can have a profound influence on the structure of kelp forest communities and on the flow of materials to and from them.

The Santa Barbara region has a Mediterranean climate characterized by relatively calm, dry conditions in summer and autumn, prevailing winds in the spring, and episodic rain storms in the winter. This environmental setting creates strong seasonality in bottom-up forcing (via variation in the supply of nitrogen) and top-down control (via physical disturbance from storm generated waves). A number of “pulse” drivers operating on seasonal time scales influence these bottom-up and top-down forces including terrestrial runoff, large oceanic swells, wind-driven upwelling, internal waves, and other less understood oceanographic processes that supply nitrogen to otherwise depleted surface waters in summer and fall, and are thought to be important in enabling giant kelp to persist and grow year round in most years.

Aside from the seasonal cycle, the El Niño Southern Oscillation (ENSO) is the dominant climatic signal over most of the Pacific Ocean. The two phases of ENSO are generally termed El Niño (the warm, nutrient-poor phase) and La Niña (the cool nutrient-rich phase). The strengths of the various pulse drivers are El Niño dependent causing the relative contributions of land- and ocean-derived nitrogen and carbon to kelp forests in southern California to vary between El Niño and La Niña years, while the strength and intensity of El Niños vary with longer-term climatic cycles that have return frequencies of decades (e.g. the Pacific Decadal Oscillation).

General Research Approach

Certain abiotic drivers of kelp forest ecosystems are easily manipulated (e.g., physical disturbance that removes kelp), while others are difficult or practically impossible to manipulate on a meaningful scale (e.g., sea surface temperature, water column productivity, elevated runoff, land use change). Because of this, our research relies on a variety of approaches that include: (1) Coordinated long-term measurements of key abiotic drivers and ecological response variables. The purpose of our long-term measurements is to unveil spatial and temporal patterns in the structure and function of giant kelp forests in the Santa Barbara Channel and in the physical and chemical forcing variables that influence them. Because kelp forests occur at the land-ocean margin, we collect long-term measurements on land and intertidal beaches, in the offshore ocean, and in the shallow coastal zone where kelp forests occur (Table1), (2) Manipulative field experiments designed to isolate the causal mechanisms underlying the patterns observed in long-term measurements, (3) Measurement-intensive process studies aimed at obtaining a mechanistic understanding of processes that cannot be isolated using manipulative experiments, and (4) Integrated synthesis using modeling and analyses that allow for predictions beyond the spatial and temporal scope of our data, and that help guide the direction of our future research. Collectively, these elements provide a powerful basis for building a greater understanding of the direct and indirect effects of pulse and press drivers on kelp forest ecosystems, which is essential for predicting how giant kelp forests will respond to ongoing changes in the environment.

Table 1. Long-term core monitoring performed by Santa Barbara Coastal LTER (data available via the SBC LTER website <http://sbc.lternet.edu/data/>.)

Title	Summary of measurements	Year initiated
<i>Watershed Hydrology and Stream Chemistry:</i>		
Precipitation	Rainfall at 12 stations	2003
Stream Discharge	Stream stage and discharge at 16 stations	2002
Stream Chemistry	Storm-flow and base-flow sampling of nutrients, major anions and cations at 8 stations	2001
<i>Ocean Physics & Biogeochemistry:</i>		
Nearshore Ocean Water Chemistry Profiles	Profiled CTD and seawater nutrients, organic matter, & chlorophyll collected monthly at 5 reefs	2001
Moored Hydrography and Currents	Near continuous measurements of conductivity, temperature, & currents (ADCP) at 4 reefs	2001
Temperatures	Bottom temperature every 15 min at 11 reefs	2001
Irradiance	Bottom and surface irradiance every minute at 4 reefs	
<i>Kelp Forest Ecology</i>		
Kelp forest Community Structure	Annual data on the abundance (density or % cover), species composition and size structure of fishes, macroinvertebrates, giant kelp and understory algae at 11 reef sites	2000
Long-term Kelp Removal Experiment	Twice per season sampling (every 6 weeks) in kelp-removal and kelp-control plots at 4 reef sites. Sampled variables include: the abundance, species composition and size structure of fish, macroinvertebrates, and macroalgae, standing and detrital biomass of macroalgae.	2008
Kelp Net Primary Production	Monthly data on standing biomass, stoichiometry and biomass loss rates of giant kelp. Seasonal data on giant kelp NPP.	2002
<i>Sandy Beach Ecology</i>		
Macroalgal Wrack	Composition, cover and biomass of macroalgal wrack at 5 beaches	2008
Shorebirds	Shorebird density and species composition at 5 beaches	2008

*Other long-term data available from third parties include meteorology, ocean swell height and period, surface currents, satellite imagery (color, SST, kelp cover), and hydrology.

Research Presentations

SBC Investigators, students and postdocs gave more than 55 presentations or posters at scientific meetings, workshops and seminars in 2009-2010. A list of presentations on SBC research can be viewed at: <http://sbc.lternet.edu/catalog/presentations.jsp>

Information Management

The primary objective of the SBC LTER IM system is to facilitate research and outreach efforts by focusing on data organization and integrity, ease of access, and long-

term preservation. We maintain an open, cross-platform system that is based on Internet standards, which leverages existing systems where possible, and we focus on tools which integrate data publication with collection and processing. The SBC LTER IM system is integrated with other research groups at MSI with whom we share scientists and protocols. During 2010, we began migrating computing services from an in-house, lab-contributed system (PISCO) to the more centralized IT system at the Marine Science Institute. At MSI we are also closely aligned with the Moorea Coral Reef LTER (MCR LTER), and are working closely with several other LTER sites on specific data management issues.

SBC LTER's IM activities have continued to focus on metadata components which facilitate management of our major products (i.e., datasets and bibliography), and also which provide the basis for general website subject areas such as maps or description of projects (e.g., experiments). Additionally, we are taking advantage of opportunities to collaborate in two new areas, a) planning has begun on the development of a common relational data model with three other LTER sites (MCR, CWT, GCE), and b) we are applying innovative ontological approaches to the descriptions of our measurement.

Our metadata system continues to be closely aligned with the network data exchange specification, Ecological Metadata Language (EML), and contributes to the broader Network efforts. Our work with the query interface for EML datasets ("EDQ") has been partly responsible for the establishment of a network-wide work group to direct the development of software tools for metadata quality control and data-metadata congruency. The tool, called the "EML Congruency Checker" will be part of the PASTA suite, and also available to anyone creating code designed to work with EML metadata, such as the EDQ. Further work on our bibliographic database has been suspended during the redesign of LTER Network databases, which is currently in progress at the LNO. Ideally, improvements to central databases will supplant the need to duplicate this sort of work at the site level. Results of recent information management projects at SBC are summarized below.

SBC LTER has approximately 75% of its sampling sites entered into standardized forms which will allow us to use descriptive site information in multiple ways, e.g., reports for field teams, inclusion into EML datasets for publication, map display on the web site and contributions to the network databases and applications (e.g. siteDB and LTERMapS). Our schema is compatible with EML and the relational schema planned for other SBC metadata (mentioned above).

We continue to develop scripts to create EML datasets. In 2010, we began planning for further development of these tools for use with the relational metadata database mentioned above. As part of our migration from the PISCO IT system to MSI, we began using the LTER Network metadata catalog (Metacat) as our primary repository, and developed our own interface for displaying EML datasets. Our system is composed of Perl CGI, Javascript and XSL transformation stylesheets, and presents datasets in a modular "tabbed" view. By using the Network repository as the source, the search results in SBC's catalog are identical to those at the Network. The system is easily portable, and has already been adopted by MCR LTER for their data catalog. The stylesheets have been deliberately generalized and decoupled from scripting to enable their further development as a network resource.

We began development of a dictionary of measurements as part of the OBOE ontology developed by a related NSF project, Semantic Tools for Data Management (Semtools, DBI-0743429). The Semtools project is providing software for increased data access, discovery, and integration using semantically annotated metadata. By providing datasets for the development process, SBC can take advantage of knowledge modeling experts to build a detailed dictionary of its own ecological and environmental measurements. In addition to their use in the ontology, these measurement descriptions can be included in SBC EML metadata, and also will contribute to the broader measurement standardization efforts in the LTER network.

Lastly, SBC LTER is also well-represented in the activities of the LTER Network's Information Managers Committee (IMC), and information manager (O'Brien) is currently the IMC co-chair. Since SBC has adopted community-vetted components for its IM system, its products are well suited for use elsewhere in the ecological informatics community. SBC's proximity to the NCEAS ecoinformatics programming group has facilitated our early adoption of several programming tools, and in the process SBC has provided valuable feedback for products such as Metacat and Morpho, for the development of new tools such as the OBOE ontology and the EML data manager library, and for development of the EML schema itself.

LTER Network and Synergistic Activities

As a lead PI Reed serves on the LTER Science Council. He is also a member of the Publications Committee, and served on the LTER Executive Board (2006-2009) and the writing team that produced the LTER Integrated Research Plan (2006-2007). Reed along with investigators John Melack and Brad Cardinale were members of the LTER Network Planning Committee and active in the LTER Network's Planning Grant process (2004-2007) of which SBC outreach Coordinator Ali Whitmer was a co-Principal Investigator. Libe Washburn serves on the LTER Network Information Systems Advisory Committee (NISAC). SBC Information Manager Margaret O'Brien is extremely active in the LTER Network's information management arena. She serves as co-chair of the Executive Committee of the LTER Network's IM committee. She is currently involved in several network working groups charged with: (1) developing standards for data quality control, (2) establishing a collection of vetted measurement units, and (3) evaluating the usefulness of keyword thesauri for browsing and querying metadata. She is editor of the metadata section of the IMC website, which facilitates content, recommendations and discussions regarding metadata standards and implementation. With another information manager (Corinna Gries, CAP) she led an IMC group in developing a database for managing project descriptions using the EML schema with content delivered via web services.

Research Findings

Below we summarize our major research findings in the three general thematic areas upon which our current award is structured. We note that much additional research not reported below has been and continues to be done with support from the Santa Barbara Coastal LTER. A full list of SBC LTER's publications and products can be found at:

<http://sbc.lternet.edu/catalog/publications.jsp>

THEME 1: The influence of abiotic press and pulse drivers on rates of delivery of N and C to giant kelp forests

Oceanic transport and exchange of C and N between the inner shelf and offshore

Phytoplankton primary productivity and ocean circulation: A major effort of the oceanographic component of the SBC LTER has been to understand ocean circulation processes that exchange C and N between kelp forests and offshore waters. The approach has been to analyze observations from 16 UNOLS cruises during 2001-2006 in the Santa Barbara Channel and from an extensive array of moorings maintained by the SBC LTER, Partnership for Interdisciplinary Science of Coastal Oceans (PISCO), and other funding. Other critical data come from SBC LTER-funded small boat sampling, from the NOAA-funded Plumes and Blooms project, and from UCSB HF radar array which is part of the Southern California Coastal Ocean Observing system (SCCOOS). Two main lines of inquiry are: (1) quantifying the relationship between phytoplankton primary productivity and offshore circulation processes; and (2) understanding exchange processes between the near shore areas containing kelp forests and the open ocean offshore. Additional external funding from NSF, NASA, and NOAA has been obtained to leverage SBC LTER research in these directions. Results from the analysis of the oceanographic data bear directly on Questions 1a and 1b of Theme 1, because they quantify offshore oceanic sources of dissolved and particulate organic matter.

A paper currently in revision by Brzezinski and Washburn (2010, submitted to L&O) describes the relationship between chlorophyll biomass and phytoplankton productivity and the pulse drivers of wind-driven upwelling, eddy circulation, and water mass variability. An objective analysis of measured productivity using empirical orthogonal functions (EOFs) found that the strongest driver was seasonal upwelling. The analysis also revealed that eddy rotation as quantified by the relative vorticity ζ and the circulation Γ is important in driving productivity. Recently, nutrient uplift due to cyclonic rotation in eddies has been found to stimulate phytoplankton production in the open ocean. In contrast to the open ocean, our results suggest a more complex relationship between productivity and flow rotation in the coastal regime of the SBC LTER. Strong rotation is a necessary, but insufficient condition for stimulating productivity. It is important to understand this relationship because rotation can drive production during fall when wind-driven upwelling is reduced or

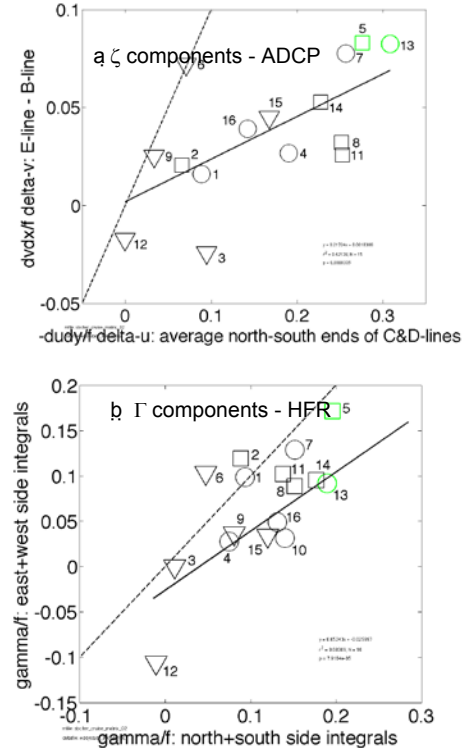


Figure 1. a) Sub-surface relative vorticity ζ measured by shipboard ADCPs during the UNOLS cruises. The x, y axes are the two components of ζ and positive values are cyclonic (counter-clockwise). b) Surface circulation Γ measured by HF radars. The x, y axes are components of Γ along the northern & southern and eastern & western segments of a box in the western Santa Barbara Channel. Positive values are cyclonic (counter-clockwise). Green symbols indicate high ppp localized in cyclonic eddies. Symbols indicate cruise season: circles for spring, squares for fall, triangles for winter.

ineffective. Figure 1 shows components of surface Γ and subsurface ζ . These quantities are directly related by the so-called circulation theorem of fluid dynamics; they allow us to quantify rotation, a challenging quantity to estimate, using two completely independent means. The dashed lines sloping up to the left in the panels consistently separate the four cruises with the strongest cyclonic components of rotation from all other cruises when rotation components were weaker. Two of the four cruises with strong rotation, one in fall and one in winter, also had high levels of localized phytoplankton productivity in cyclonic eddies (green symbols). None of the other 4 fall cruises had similar productivity levels eddies. We hypothesize that eddy-generated phytoplankton production is an important source of carbon for the pelagic foodweb of the Santa Barbara Channel.

A second focus of our analysis is to understand the transport processes that exchange materials between the near shore in kelp forests and the open ocean offshore. Prevailing coastal circulation patterns place regions of high productivity and chlorophyll biomass upstream from extensive kelp forests along the mainland coast because: (a) offshore currents are counter-clockwise and tend to transport materials from the high productivity area of the western Santa Barbara Channel toward the mainland shore in the central portion of the Channel, and (b) near shore currents along the mainland coast are predominantly westward. We are conducting a comprehensive analysis of circulation and water mass data from the moorings, HF radar, and shipboard surveys to quantify these transport processes. The effort will be augmented by a new NSF project (to Fewings and Washburn) to study coastal circulation processes related to coastal trapped waves. Results to date show a strong link between coastal winds measured by NOAA weather buoys and inner shelf circulation over the western parts of the SBC LTER study area. However, in the more sheltered eastern parts of the study area the flows are not strongly linked to regional winds. We speculate that circulation driven by remotely generated coastal trapped waves may be an important driver in these regions where wind effects are weak or absent. In all regions, the alongshore and cross-shore velocity structure over the inner shelf resembles that found elsewhere such as on the US east coast. Residence time estimates based on cross-shore flow structure are short, typically less than 3 days, indicating rapid exchange between the inner shelf and offshore waters.

Biogeochemical Observations: The spatial and temporal patterns of inorganic and organic nutrient distributions and heterotrophic bacterioplankton dynamics as well as the partitioning of organic matter and its bioavailability to microbial processes were assessed in a time-series study across the continental shelf of the Santa Barbara Channel from January 2008-April 2009. The goal of the study was to elucidate cross-shelf processes that affect supply and export of key resources to and from the near shore rocky reef environment. Results demonstrated significant variability in cross shelf distributions of inorganic and organic nutrients (Figure 2) resulting in the near shore being at times strongly influenced by offshore waters during periods of upwelling, to it being highly isolated from offshore supply when

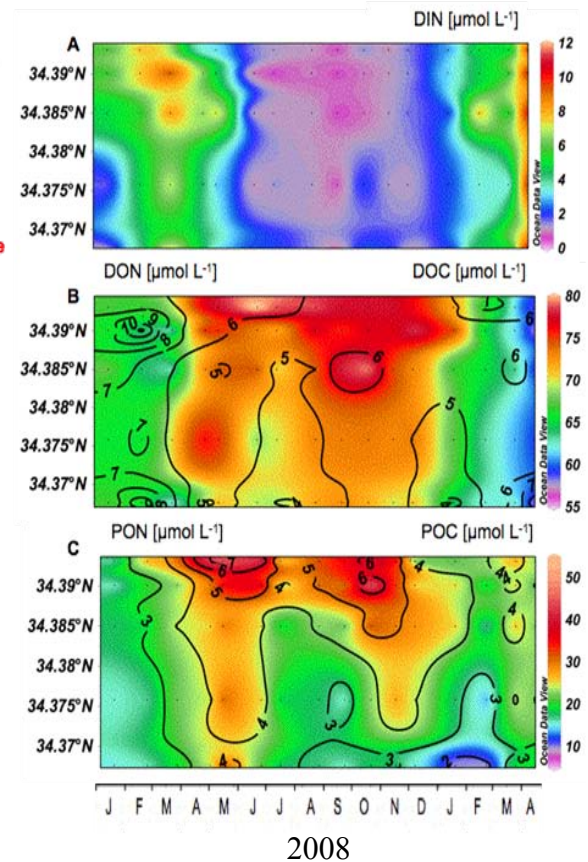


Figure 2. Integrated and depth normalized measures of dissolved inorganic nutrients (A), DOM (B), and POM (C).

upwelling relaxed.

During periods of mixing, dissolved inorganic nitrogen (DIN), particulate organic matter (POM) and dissolved organic carbon (DOC) were low while dissolved organic nitrogen (DON) concentrations were elevated across the shelf. During winter and spring upwelling, large pulses of DIN were introduced to surface waters, stimulating phytoplankton blooms.

Phytoplankton Distribution and Succession: A seasonal pattern in connectivity and isolation of the inner shelf with offshore waters is revealed by the pattern of phytoplankton biomass and productivity. Phytoplankton primary productivity was fairly uniform across the shelf with upwelling during both 2008 and 2009. With the onset of seasonal stratification the inner shelf becomes more isolated as evidenced by the stronger, but variable, cross-shelf gradients in both productivity and chlorophyll biomass.

Enumeration of phytoplankton taxa reveals considerable variability in the spatial distribution of major groups across the shelf and a clear temporal succession (Figure 3). The prymnesiophyte, *Phaeocystis*, dominated the upwelling-driven spring bloom associated with upwelling in 2009 whereas diatoms typically dominate during upwelling offshore. A diatom bloom, followed coincident with the onset of thermal stratification. Dinoflagellates were the dominant group during summer and fall. Upwelling stimulated a bloom again in 2009 which was dominated by diatoms. Both the diatom and dinoflagellate blooms were confined to the inner shelf near Mohawk Reef consistent with the temporal and spatial pattern of productivity. These patterns in productivity, biomass and taxa suggest that for much of the year much of the phytoplankton productivity supporting consumers on the reefs of the inner shelf is generated locally rather than being advected from offshore. The origin of the nutrients that support this nearshore productivity are currently unknown.

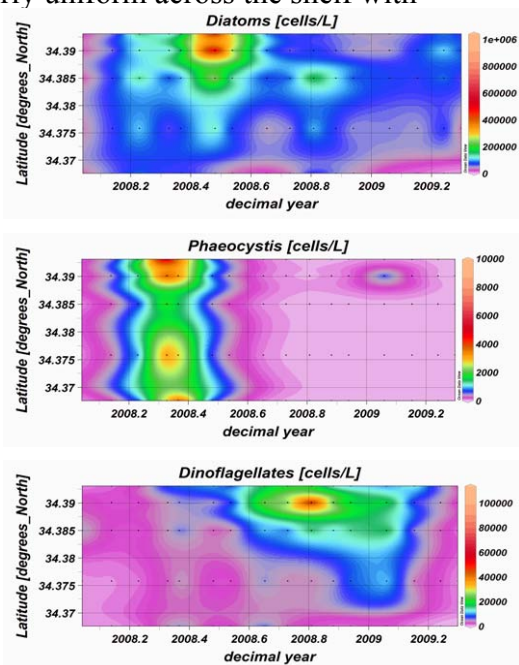


Figure 3. Abundance of diatoms, *Phaeocystis* and Dinoflagellates at 5 m depth across the continental shelf at Mohawk Reef. The mainland is to the north.

It is notable that both the diatom and dinoflagellate blooms contained significant number of potentially harmful species. *Pseudo-nitzschia* spp. were the most dominant diatoms during the spring 2008 and 2009 diatom blooms and the potentially harmful dinoflagellate, *Lingulodinium* sp., was prevalent during the summer. These and other HAB groups are monitored weekly at Stearns Wharf, Goleta Pier and Gaviota Pier along the mainland coast by Associate Investigator Brzezinski as part of the NOAA sponsored Southern California Coastal Ocean Observing System (SCCOOS). Interpretation of those taxonomic and toxin data relies on data on water column characteristics monitored by the SBC LTER.

Partitioning of Organic Matter and DOC availability: Approximately 61% of the organic carbon that accumulated during the bloom period was partitioned into the particulate phase, but as the bloom senesced and the system became stratified, a larger fraction (56%) of the seasonally produced organic matter was retained as DOC relative to POC. Throughout the time-series spatial gradients in POM and DOM became pronounced with maxima occurring closest to the near shore region where kelp forests occur.

The percent bioavailability of dissolved organic carbon (%BDOC), as well as bacterial growth efficiency (BGE) and biological carbon demand (BCD) were estimated from experiments conducted with cultures obtained from the farthest offshore and most near shore stations. Results show that DOC was most available during upwelling periods, with a maximum of 20% bioavailable DOC in May 2008 in the near shore (Figure 4).

BGE was highly variable, ranging from 0.05-0.5, with highest efficiencies observed during stratified periods. BCD as determined from field measurements of bacterial production and experimentally derived growth efficiencies ($BCD = BP/BGE$) ranged from 2-293 $\text{mg C m}^{-3} \text{d}^{-1}$, with highest demand in May 2008 in the near shore and exceeding 5m primary production estimates. This resulted in net heterotrophy during sampling of the spring upwelling period, while during the remainder of the study the system was net autotrophic.

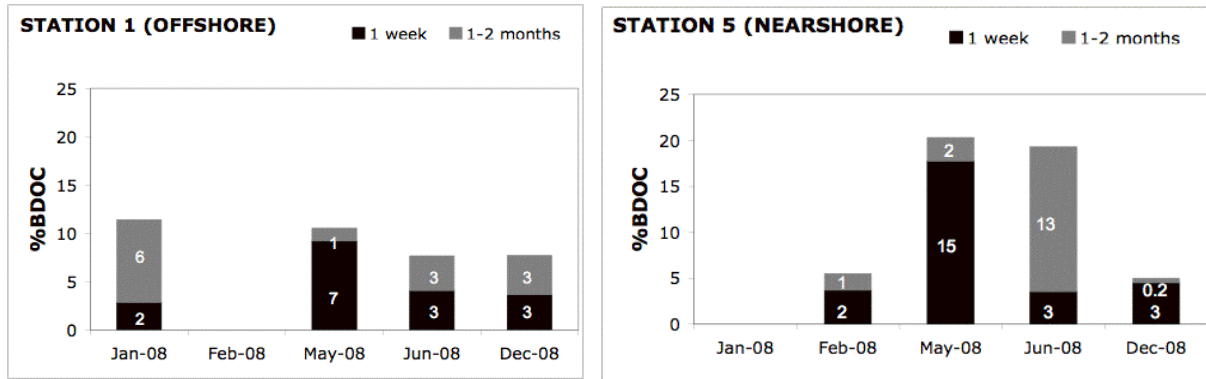


Figure 4. Short and long term percent bioavailability of dissolved organic carbon (%BDOC) in seawater cultures at the offshore (A) and near shore (B) stations of the cross shelf transect. Delta DOC concentrations ($\mu\text{mole C L}^{-1}$) are displayed on each bar.

Watershed processes & land subsidies to kelp forests

Hydrology and biogeochemistry: Seventy-four catchments, with a total area of 790 km^2 (ranging in area from 1 to 50 km^2), drain from the Santa Ynez Mountains along the northern coast of Santa Barbara Channel to coastal waters that support kelp forest ecosystems. These coastal catchments have mountainous headwaters, transitional foothills and coastal plains of varying widths. From west to east, headwater elevations increase from approximately 300 to 1400 m, and land uses on the coastal plain and foothills change from mostly rangeland to a combination of urban and agricultural land with chaparral in the mountains.

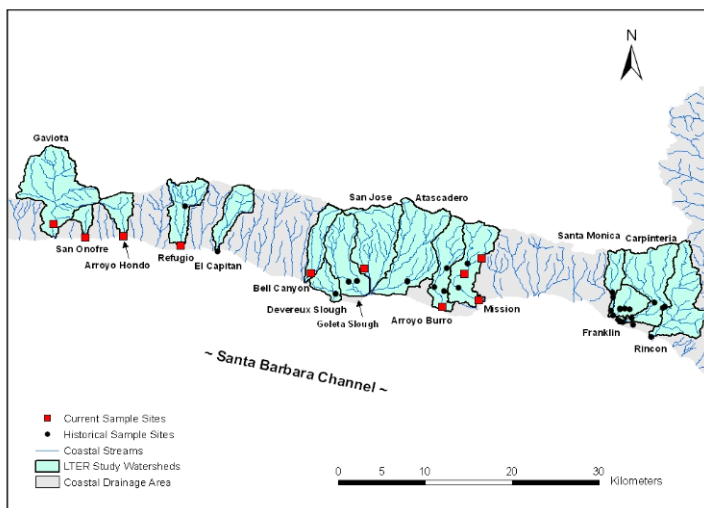


Figure 5. Location of Santa Barbara Coastal watersheds studied from 2002 to 2010 and of current and historical sites sampled for nutrients and gauged for discharge.

A network of rain gauges and water level recorders have been installed to permit calculation of rainfall and runoff for a representative set of coastal watersheds (Figure 5). Intensive sampling during rainfall events and weekly to bi-weekly collections during periods with baseflow are routinely performed in the instrumented watersheds. Water samples from streams are analyzed for (a) nitrate, ammonium, total dissolved nitrogen, and particulate nitrogen; (b) soluble reactive phosphorus, total dissolved phosphorus and particulate phosphorus; (c) particulate organic carbon; (d) total suspended sediments; and (e) conductivity. Subsets of

samples are analyzed for silica, major cations and anions, and the natural abundances of ^{15}N and ^{13}C .

Figure 6 shows the annual flux of nitrate, soluble reactive phosphorus and suspended sediments exported as a function of runoff for the period from 2002 to 2009. Except during years with large amounts of runoff, agricultural catchments exported more nitrate than urban catchments and both export more than the undeveloped catchments. An especially interesting feature is the steep slope of nitrate export from undeveloped catchments. As annual runoff increases, there is a disproportional increase in export, until in the largest runoff years flux from these areas about equals that contributed from urbanized or agricultural zones. The slopes of all three land use regressions are similar in the case of soluble reactive phosphorus, possibly a consequence of a common hydrologic mobilization mechanism such as the sorption of soluble reactive phosphorus to suspended sediment loads (e.g., clays, oxyhydroxides) during runoff

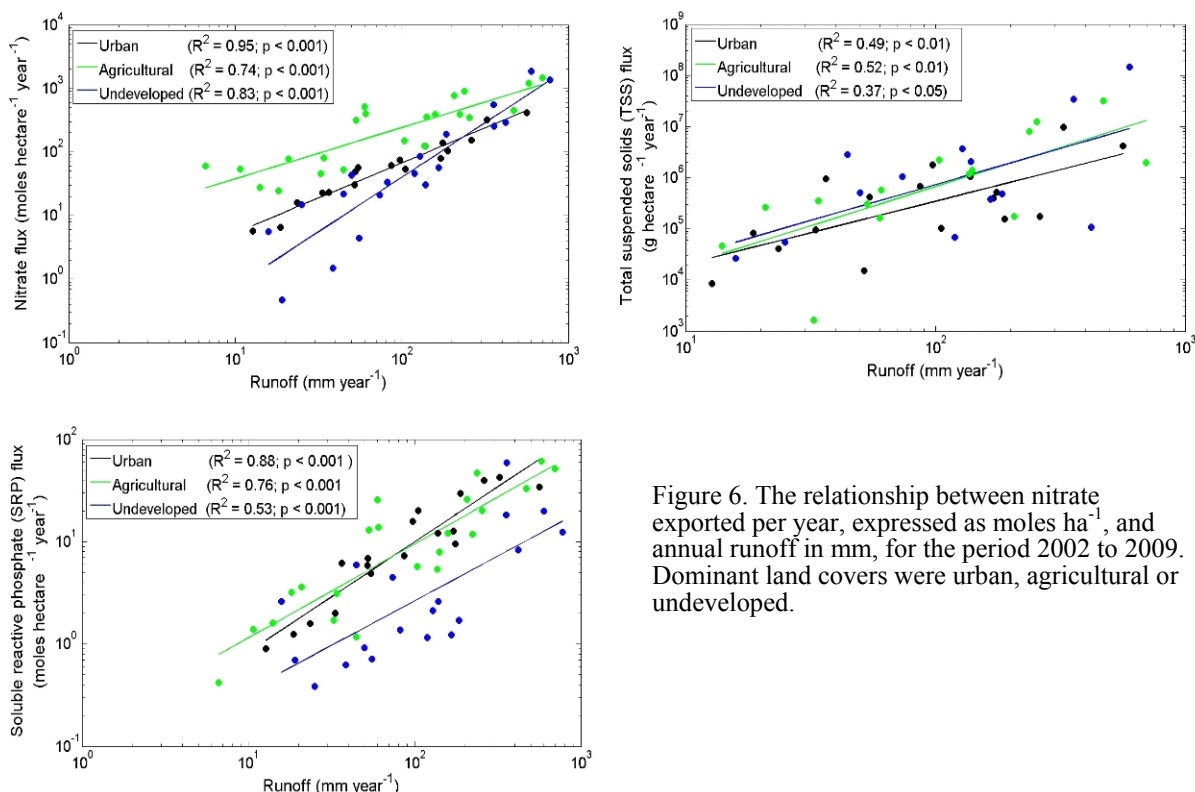


Figure 6. The relationship between nitrate exported per year, expressed as moles ha⁻¹, and annual runoff in mm, for the period 2002 to 2009. Dominant land covers were urban, agricultural or undeveloped.

events. As expected, urban and agricultural catchments export higher amounts of soluble reactive phosphorus than undeveloped catchments. Surprisingly, urban and agricultural catchments also appear to export similar amounts of soluble reactive phosphorus over the runoff range. Agricultural and undeveloped catchments demonstrate similar amounts of total suspended sediment export over the runoff range, with urban catchments exporting less over the runoff range. The urban catchments export progressively less total suspended sediment than the agricultural and undeveloped catchments per unit runoff increase, (i.e., urban catchment regression line has a lower slope than the agricultural and undeveloped catchment regression lines). This is explained by urban catchment land use, which is characterized by higher impervious surface areas (pavement, buildings, etc.) that lower the proportion of more erosion-susceptible bare soil/chaparral/coastal sage scrub land cover.

Land-derived dissolved nutrients and particulate organic matter (POM) transported to the coastal ocean in runoff may be incorporated into the near shore food web. We have found little evidence for the incorporation of land-derived carbon by reef suspension-feeders (Page et al. 2008). However, variation in N isotope values among reefs in the mucus feeding tube worm *Diopatra* suggests that it and other sediment dwelling organisms incorporate land-derived N

perhaps through a trophic intermediate. To explore the incorporation of land-derived N into the benthic food web, N isotopes are currently being measured in *Diopatra*, assorted infauna, macroalgae, and sediment POM along an inshore-offshore gradient in soft bottom areas near reefs at 5 sites that vary in exposure to freshwater runoff.

We have developed a hydrological model that predicts runoff from rainfall to extend our measurements of stream discharge and nutrients to all coastal watersheds entering the Santa Barbara Channel within our primary 790 km² study area (Beighley et al. 2003, 2005). Furthermore, we have used our rainfall-runoff model to explore the impacts of watershed characteristics, transient weather regimes and land conversion on the frequency distributions of runoff events and their influence on nearshore waters (Beighley et al. 2008). Based on historical evidence and projected urbanization, a 600% increase in runoff during storms from the coastal plain was calculated to occur from 1929 to 2050, which shifts the dominant source of runoff from the mountains to the coastal plain. By combining drainage areas, export relationships, runoff frequencies, nearshore water volume, ambient nitrate and phosphate concentrations in nearshore waters and an assumed mixing volume, we modeled the probability of a runoff event resulting in a particular nearshore nitrate or phosphate concentration. For example, the frequency of a storm event that produces runoff ≥ 2.5 cm and a nearshore nitrate concentration greater than 12 $\mu\text{mol L}^{-1}$ ranges from 3% in non-El Nino years to 20% in El Nino years.

Regression models have been developed to estimate the flux (mol ha^{-1}) for a given storm based on the percentage of catchment area used for agriculture or classified as impervious surface, the estimated discharge during the storm and the cumulative water year discharge at the end of the storm. Daily models were also developed to estimate the daily flux ($\text{mol ha}^{-1} \text{d}^{-1}$) using daily flow and the cumulative water year discharge at the end of the given day.

To extend our modeling to include mechanistic aspects of the water balance and N and C dynamics, we have begun to apply the Regional HydroEcological Simulation System (RHESSys) model to the Mission Creek catchment. Initial work has focused on the effect of uncertainty in water and climate inputs on model estimates of streamflow and evapotranspiration (ET). Current modeling work in the Mission Creek catchment is focused on quantifying the role of fine scale urban spatial complexity and impervious surface connectivity on water available to vegetation. Initial hillslope scale results of this modeling indicate that while the total amount of impervious surface is a key factor in determining the partitioning of water into streamflow and ET, the impact of increasing impervious surface can potentially be mitigated if direct hydrologic connections between impervious surfaces and the stream are minimized. Future research will be focused on expanding this work to consider the impact of different vegetation covers and watering regimes. A complementary goal of our modeling work is to modify the RHESSys model to incorporate estimates of fine scale impervious connectivity into simulations run at a coarser and less computationally intensive spatial scale. This modification will allow us to explore the potential catchment scale impacts of altering impervious connectivity as development in the catchment evolves.

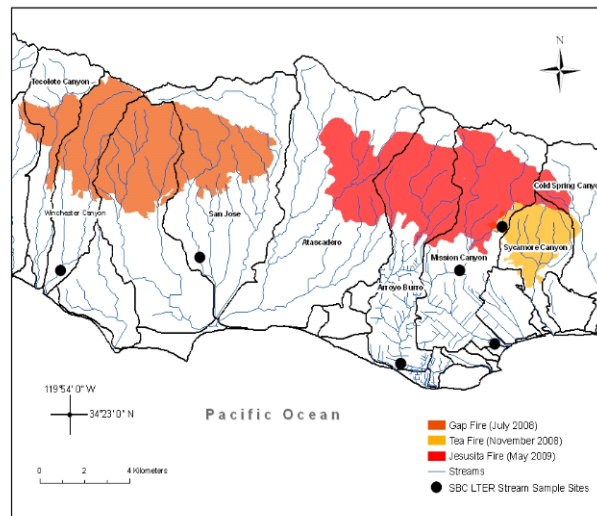


Figure 7. Location of Gap, Tea and Jesusita fires, and of SBC stream sampling sites in the same region.

Fires impact the hydrology and suspended sediment and nutrient export. From July 2008 to June 2009, three major fires occurred in the foothills and mountains above the greater Santa Barbara area, all within the area being studied by the Santa Barbara Coastal LTER program (Figure 7). One immediate result of the fires is large increases in nutrient export, as illustrated for nitrate in Rattlesnake Creek during 2010 (Figure 8). Because of differences in timing and extent of burning among these fires, we can compare the influence of fire timing (autumn versus spring versus no fire) and fire severity on a variety of ecological and environmental responses. The following sections present results from geomorphological surveys using LiDar, hyperspectral remote sensing of land cover, and investigations of stream ecology in the context of fire effects.

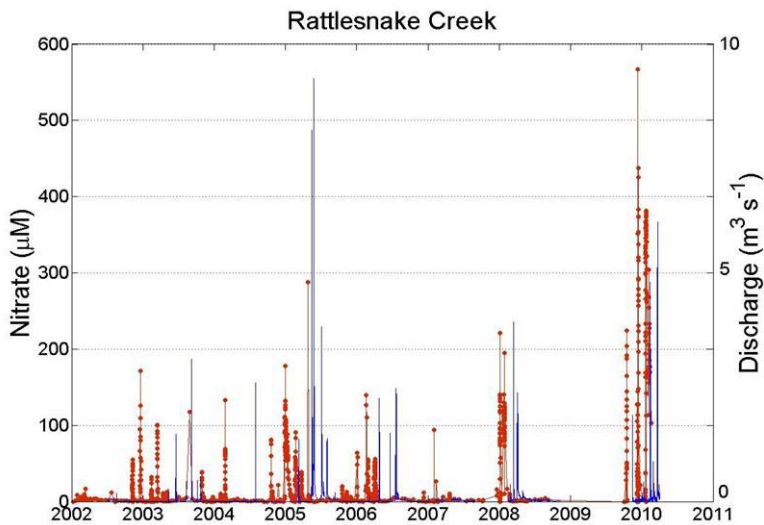


Figure 8. Nitrate concentrations in Rattlesnake Creek sampled intensively during storms and weekly or biweekly during other periods. Discharge was computed from continuously recorded stage.

Geomorphological studies: In order to identify and quantify geomorphologic characteristics of the wildfire regions in the Santa Ynez foothills in Santa Barbara, airborne and ground-based LiDAR (Light Detection And Ranging) datasets were acquired. The raw point clouds of the airborne LiDAR data were processed to identify geomorphic parameters such as topography, slopes, curvature (Figure 9A), and drainage density, and to measure canopy height at spatial scales of 1 m^2 (Figure 9B). The data were collected with high point densities ($8\text{-}12 \text{ pts/m}^2$) that generally result in reliable bare-earth topography and canopy characterization in steep, densely vegetated terrain. The airborne data

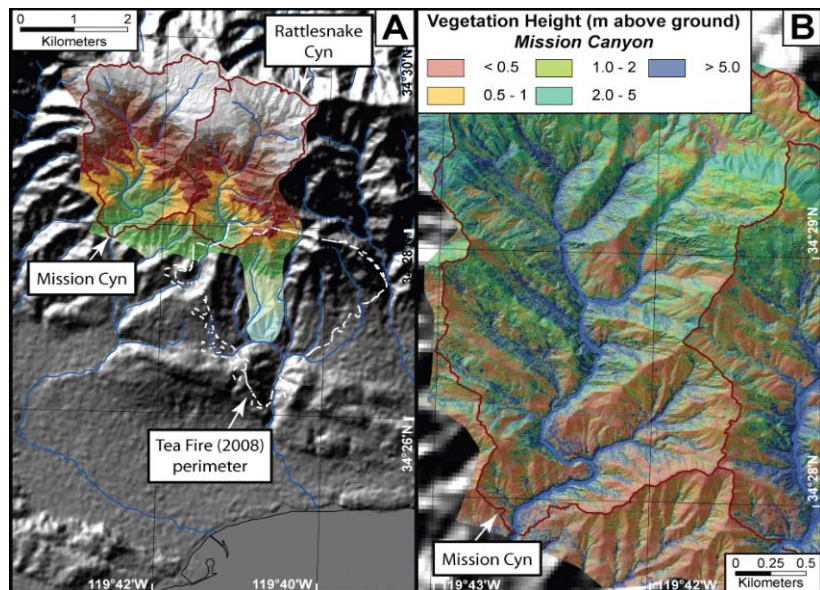


Figure 9. (A) Shaded relief of Santa Barbara and Santa Ynez foothills area using 10-m DEM data. The 1-m LiDAR bare-earth DEM includes the Mission and Rattlesnake Canyon areas and is shown in color. Blue lines are major streams, red lines delineate catchments, and white dashed line is the Tea Fire perimeter. (B) Canopy height in meters above ground as taken from the classified LiDAR pointclouds acquired on 27 December 2009. In the southern part of the Mission Canyon, catchments have generally low vegetation heights because these areas were affected by the Jesusita Fire (May 2009). Riparian vegetation was much less affected by this wildfire.

were collected in late December 2009 before intense rainstorms accelerated sediment transport and erosion during the 2009/2010 El Niño. A second flight will be collected during summer 2010 and surface changes will be identified. The ground-based LiDAR data were collected at several sites with a spatial resolution of 0.1 m² and point densities of several thousand points/m². Initial results indicate that sheet wash and erosion plays a major role in removing sediments. In a related project, the airborne LiDAR DEM (Digital Elevation Model) is used to orthorectify a 30-year airphoto time series and perform image-cross correlation techniques to identify earth-surface deformation such as slow moving landslides. Initial results indicate that landslide velocities and spatial distribution is tightly coupled to underlying lithologies, geologic structures, and topographic curvature.

Remote sensing of land cover: Airborne Visible Infrared Imaging Spectrometer (AVIRIS) data were analyzed to define pre-fire fuel conditions in advance of the Gap, Tea and Jesusita fires and post-fire response. Initial pre-fire analysis focused on the most extensive pre-fire data set, acquired on 6 August 2004. Fuel types were mapped using Multiple Endmember Spectral Mixture Analysis (MESMA: Roberts et al. 1998) to map 14 dominant cover types, including five native shrub species, three tree cover types (two species, one including several Riparian species), senesced grass, soil/rock, three anthropogenic classes (urban, lawn/grass, orchards) and water. These analyses will also be used to improve the land cover used in the hydrochemical flux calculations. Fuel properties mapped included pre-fire moisture content (also correlated with Leaf Area Index) and cover fractions of green

vegetation, non-photosynthetic vegetation (NPV: litter, stems), soil/rock and ash (Figure 10). Analysis of post-fire perimeters suggests that pre-fire fuel type, such as chamise vs big-pod *Ceanothus*, did not alter fire spread, but higher moisture content fuels did modify perimeters that did not extend far into urban lawns, orchards and many riparian areas. Post-fire analysis focused on canopy moisture content, changes in cover fractions and fire severity measures such as the Normalized Burn Ratio (NBR). This analysis, initially applied to 26 August 2009 imagery, showed that much of the Jesusita fire scar consisted of ash (blue). It also demonstrated considerable

damage to some riparian areas, characterized by a central core of undamaged green foliage and riparian margins showing extensive canopy mortality with a high NPV fraction (Figure 10). Current analysis is focusing on AVIRIS data acquired on 10 March 2009, 17 June 2009 and 30

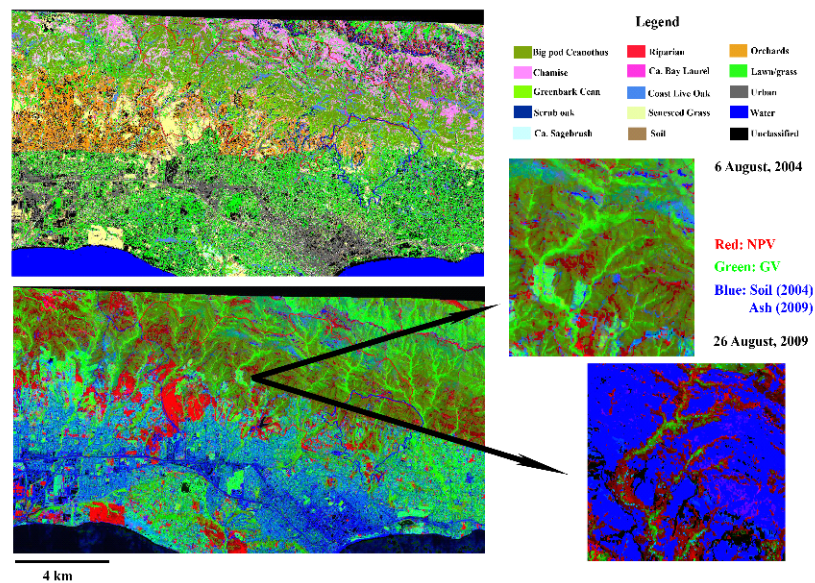


Figure 10. Upper frame showing species-level map of a subset of the August 2004 AVIRIS flights covering the entire Santa Barbara coastal plain and front range. Red and blue lines mark the extent of the Jesusita and tea fires, respectively. The lower frame shows a map generated using Spectral Mixture Analysis (SMA: Roberts et al., 1993) mapping the fraction of green vegetation (GV), non-photosynthetic vegetation (NPV) and soil (blue). Subsets to the right show a blow up of the San Roque watershed before and after the Jesusita fire, showing that virtually all of the shrub cover was burned and extensive canopy mortality in riparian areas.

April 2010. NASA has also authorized the acquisition of an additional AVIRIS flight in August, 2010.

Plant and soil nitrogen responses to watershed burning: As part of the larger scale study of watershed responses to high intensity landscape fire, we are conducting on-the-ground sampling of plant community composition and structure and soil nitrogen dynamics in two of the watersheds regularly monitored as part of the LTER network. These are the Mission Canyon and Rattlesnake Canyon watersheds, both of which burned in the 2009 'Jesusita Fire'. Results from these studies will be integrated with LiDAR and AVIRIS images to achieve a greater understanding of controls over sediment and nitrogen transport as well as ecosystem recovery in burned coastal watersheds. To select sampling locations, eight irregularly shaped polygons were selected from a pool of sites within the two watersheds where pre-burn vegetation data were available from AVIRIS imagery (collaborator D. Roberts). One to four 15 m by 15 m plots were then established at random points within each polygon (based on accessibility). Plots are arrayed throughout the two watersheds, but plot location was limited by slope steepness and access. Plot locations were recorded with a GPS for future comparison of sampled locales and pixels measured with AVIRIS and LiDAR.

Vegetation sampling was initially conducted in fall 2009 to determine the density and % survival of shrubs by species and to estimate fire intensity according to the minimum branch diameter method outlined by Moreno & Oechel (1989). Initial soil cores for nitrogen sampling were installed at that time. Plots are being revisited every other month to evaluate the effects of burn intensity on N mineralization and leaching while the vegetation was surveyed in detail at peak biomass in late spring 2010. This timing corresponded with flowering and fruiting of the post-fire ephemeral species prior to their senescence. At that time approximately 45 transects were sampled using point intercept sampling methods, recording all species encountered and canopy height at each point. Shrub densities and cover were then sampled in 12 1m² subplots within each 15 m x 15 m plot. These plots were destructively sampled to obtain total live and dead biomass, % moisture held in the vegetation and nitrogen and carbon sequestration into aboveground biomass. These data will be used as ground truthing for the AVIRIS images taken of the region in May 2010 to track vegetation recovery after wildfire.

Nitrogen dynamics were sampled in each plot by installing four in-situ field-incubation cores using a slightly modified version of the DiStefano & Gholz (1986) procedure. Incubations consist of intact soil cores taken with 5 cm diameter by 15 cm height polyvinyl chloride (PVC) tubes that are fitted at the base with nylon enclosed resin discs. Two cores are maintained adjacent to live shrubs, and two in initially open areas. Differences between pre- and post-incubation NH₄ and NO₃ concentrations will provide estimates of net mineralized and nitrified N at each site (DiStefano & Gholz 1986). Such measurements provide a useful index of overall N availability (Schimel & Bennett 2004). We are also measuring volumetric soil moisture adjacent to each core using time domain reflectometry (TDR; Topp et al 1980). Nitrogen values from these cores will be compared over time to N export from streams as measured by our long-term hydrological studies (see above) and values will be integrated into the Regional Hydro Ecological Simulation System model to evaluate how the changes caused by landscape fire influence N loss from these watersheds. Over time nitrogen transformation values will also be compared to vegetation recovery and ecosystem N storage values across landscape positions in the watersheds.

Responses of stream communities to fire: Sampling and analyses of ecological characteristics at a series of sites done before the fires has been repeated after the fires in burned and unburned basins (Tables 1 and 2). These studies are being complemented with experiments to examine the nutrient (phosphorous vs. nitrogen) limiting algal growth, with measurements of leaf decomposition rates, and with stable isotope analysis of food web structure, in both burned vs. unburned streams.

Table 1. Study sites for stream ecology.

Burned vs. Unburned Basin	Riparian zone intact or burned	Stream Sites
Burned	Intact	Cold Spring, Rattlesnake (upper and lower), Mission (Rocky Nook – downstream from burned areas)
Burned	Burned	Mission (Botanic Gardens), San Roque (added site), San Antonio
Unburned	Intact	Romero, San Ysidro, San Jose (Trout Club), El Capitan, Refugio, Arroyo Hondo, San Onofre

Table 2. Variables measured at each stream site.

Type of Variable	Specific Variables Measured
Physical-Chemical	Riparian canopy cover, current velocity, substrata sizes, temperature, conductivity, nutrient concentrations, pH, geomorphology
Bacteria	TRFLP fingerprints
Algae	Chlorophyll concentration, ash free dry mass, % cover by different algal types, algal species composition
Particulate organic matter	Measures of coarse (> 1 mm) and fine (< 1 mm) particulate organic matter
Invertebrates	Invertebrate densities, relative abundances, diversity, species composition

Although there are some data on stream responses to forest fires, data on chaparral stream responses to fire are nearly non-existent. We have observed immediate fire effects on stream ecosystems owing to reduced shading and lowered leaf inputs from bank vegetation, as well as associated increases in temperature and nutrient levels. However, the greatest short-term effects of fire on chaparral streams are mediated through run-off and flooding during the subsequent rainy season, which engender large changes in stream geomorphology (via erosion and

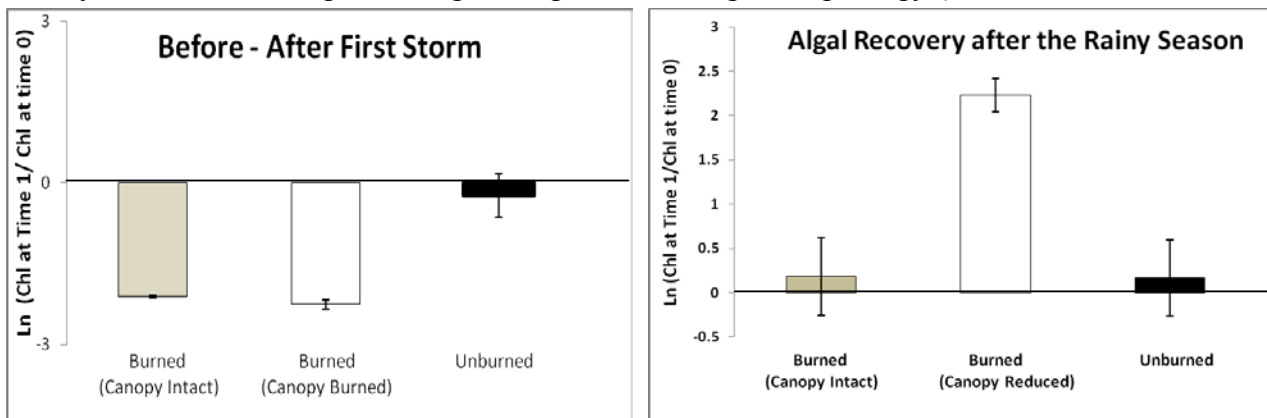


Figure 11. Per capita changes in chlorophyll concentrations [$\ln(\text{chlorophyll a concentration at time 1} / \text{chlorophyll a concentration at time 0})$] from before to after the first major storm of the 2009-10 rainy season (in mid-December) (top graph) and from after the first major storm to late March, after the rainy season has largely passed (bottom graph) in streams draining burned (riparian canopy intact), burned (riparian canopy reduced), and unburned basins. The left graph represents an assessment of the resistance of algal biomass to storm disturbance, whereas the right graph provides an index of algal biomass resilience (recovery after the rainy season). Heights of histograms are means and error bars are $\pm 1\text{SE}$.

sedimentation). Many of the pools in streams draining burned basins have been filled by fine sediment, whereas we have observed little change from 2009 to 2010 in unburned streams. In addition, nutrient (nitrogen and phosphorous) concentrations are much higher in burned versus unburned streams. Algal biomass was reduced during the first large storm of the rainy season at burned sites, but remained relatively unchanged at unburned sites; however, the recovery of algal biomass after the rainy season depended on both nutrient and light levels, with algal blooms being primarily observed in burned streams where the riparian canopy was reduced (Figure 11). Although there were few immediate effects of fires on stream invertebrates, invertebrate

communities at burned and unburned sites diverged after the rainy season, presumably owing to the interactive effects of fire and flooding on stream geomorphology, substratum characteristics, and food resources (leaf litter versus algal levels). Finally, substantial trout populations in Rattlesnake Creek and in Mission Creek at Rocky Nook Park have largely disappeared in the wake of the fires and subsequent rainy season floods, presumably owing to wash-out and scouring. Trout populations in unburned streams, such as Arroyo Hondo, however, have largely not changed from 2009 to 2010, and may be even increasing owing to higher stream flows in 2010.

C inputs to kelp forests identified by stable isotopes.

Understanding trophic connections and how resource variability affects consumers is necessary to predict how food webs might shift in the face of environmental change. Macroalgae and phytoplankton support highly productive marine ecosystems. Research based on stable isotope analyses has supported the idea that macroalgal detritus, especially that of the giant kelp *Macrocystis*, is a major source of dietary carbon to benthic suspension-feeders. However, our recent findings from a four-year stable isotope study (Page et al. 2008) suggest that phytoplankton, not kelp, are the main food resource for benthic suspension-feeders on reefs in the Santa Barbara Channel, and that variation in phytoplankton abundance, combined with feeding selectivity and the scale of consumer tissue turnover times, may drive variability in consumer isotope values.

A common assumption made in ‘snapshot’ isotope studies of coastal ecosystems over the past 20 years is that the isotopic signature of coastal phytoplankton is similar to that of offshore phytoplankton. Our results suggest that this important supposition may be incorrect. Typically this assumption is made because of the difficulty in separating phytoplankton from detritus to obtain an uncontaminated isotope signature, also a problem encountered in freshwater systems. We are developing methods to overcome these problems and address fundamental questions about the role of POM in coastal food webs. Our objectives are to: 1) determine the contribution of phytoplankton and giant kelp detritus to the pool of suspended reef POM and whether POM composition varies with distance from kelp forests, and 2) evaluate how different components of the POM are used as food by reef suspension feeders.

Associate Investigator Page and post-doc Miller are exploring the contribution of phytoplankton and kelp detritus to POM in coastal waters using two complementary approaches: (1) an advanced flow cytometry and cell-sorting system to separate phytoplankton from bulk POM, and (2) analyses of essential polyunsaturated fatty acids (PUFA) in POM and consumers. They have obtained preliminary data that demonstrate the feasibility of both of these methods (Figure 12), and have recently received NSF funding and developed collaborations to support

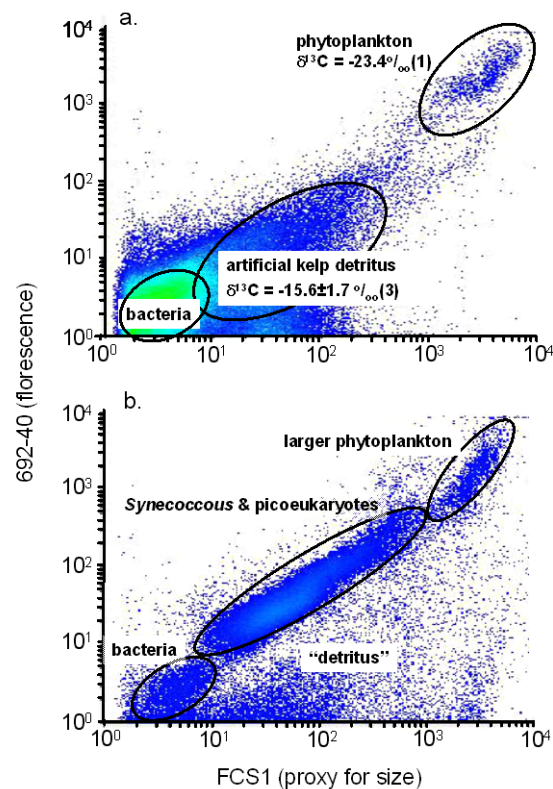


Figure 12. (a) Illustration of the separation of particle classes of natural suspended POM based on size and fluorescence using the Influx Mariner flow cytometer. Particle classes can be "gated" by optical properties and sorted for isotopic analysis. (b) Separation of laboratory cultured phytoplankton from kelp (*Macrocystis pyrifera*) detritus generated in the laboratory based on optical properties.

expanded work on these issues. Isotope values of isolated inshore phytoplankton and kelp, and compound-specific PUFA, will be used in mixing models to estimate relative contributions of these two major primary producers to suspension feeder diets. They will also test two hypothesized mechanisms influencing isotopic composition of consumers: (1) selective feeding on particular fractions of the POM, and (2) tissue turnover times. Results from this work should provide new insights into the trophic support of benthic suspension feeders, an ecologically and economically important guild in coastal ecosystems.

Timing and magnitude of nitrogen delivery to giant kelp forests from different sources

We examined sources of nutrients to the kelp forests of the Santa Barbara Channel using time series obtained from an *in situ* nitrate autoanalyzer moored at three of our long-term study sites (Carpinteria, Naples, Arroyo Quemado). The data obtained from this effort provided the first high-resolution (every 30 minutes) time series of nitrate + nitrite (dissolved inorganic nitrogen, DIN) concentrations for this environment. These measurements showed that the major mechanisms that supplied DIN to the inner shelf of the Santa Barbara Channel varied seasonally and consisted of upwelling, diurnal internal tides, and storm runoff (McPhee-Shaw et al. 2007). Upwelling dominated increases of inner-shelf DIN between March and May and accounted for more than half of the annual advective DIN transport to shallow reefs where kelp forests occur (Table 3). In summer, internal waves provided an important source of DIN because they

Mechanisms for nutrient delivery	Days	Contribution to annual DIN supply			
		With dilution estimates		With hydrologic estimates	
		Low end-member stream DIN (%)	High end-member stream DIN (%)	Greater ocean volume (%)	Smaller ocean volume (%)
Year 1: 01 Mar 2001–28 Feb 2002					
Spring upwelling	39	70	68	63	47
Summer internal waves	54	15	15	14	10
Winter upwelling	13	12	12	11	8
Terrestrial storm runoff	6/37*	2	4	12	35
Year 2: 01 Mar 2002–28 Feb 2003					
Spring upwelling	65	81	77	79	70
Summer internal waves	48	9	9	9	8
Winter upwelling	11	7	7	7	6
Terrestrial storm runoff	13/22*	2	7%	4	15

* Days are identified using the moored salinity time series and the hydrographic methods (see text for details).

Table 3. Annual contribution for two sequential years of DIN supplied by four primary mechanisms that advect nitrate into the inner shelf of the Santa Barbara Channel.

occurred when surface nutrient concentrations were depleted and the other supply mechanisms were inactive. Brief episodes of upwelling became important in late autumn and early winter. DIN inputs from storm runoff, detected as salinity dilution at the moorings and estimated from measurements of stream discharge and nutrient concentration were significant during winter runoff events.

Building on this work we sought to determine the relative importance of different sources of nitrate to the annual nitrogen needs of the giant kelp *Macrocystis pyrifera*. We did this by measuring ambient nitrate concentrations in the kelp forest at the Mohawk Reef kelp for 13 months (using the moored nitrate autoanalyzer described above) and characterizing nitrate delivery using water column thermal structure and flow data collected in the forest interior and at its offshore edge (Fram et al. 2008). Rates of net nitrogen uptake by kelp were calculated for the entire forest (using data collected from our long-term studies of kelp net primary production; Table 1 and Theme 2 below), and for a select subset of kelp fronds to isolate vertical and cross-shore differences in nitrogen acquisition. The forest's monthly nitrate supply varied by a factor of 50, while measured net nitrogen acquisition varied only fivefold regardless of the method used to measure it. Maximum net nitrogen acquisition rates for fronds in the forest interior were 0.18 mmol N g⁻¹ month⁻¹ during spring upwelling and declined fourfold during autumn until upwelling resumed the following year. Modeled gross nitrogen uptake with consideration of

Michaelis–Menten kinetics for nitrate and mass transfer limitation was higher than observed net acquisition except during the warm stratified summer and autumn months, when net acquisition exceeded modeled gross uptake (Figure 13). This shortfall indicates that the kelp forest received over half its nitrogen from sources other than nitrate (such as ammonium from epibionts) during this period. Most of the nitrate in the forest was delivered as a result of upwelling-favorable winds and convection. Internal waves and local streams contributed, 9% of the nitrate delivered to the forest on an annual basis and 20% during stratified periods. Kelp used less than 5% of the nitrate supplied to the forest. Nitrate delivery to this modest sized kelp forest was roughly equivalent between alongshore (45%) and cross-shore flows (55%), which distinguishes it from large kelp forests in which cross-shore flows dominate exchange.

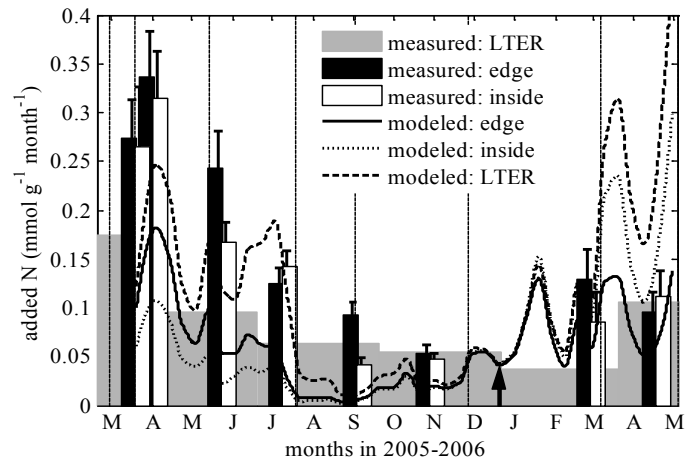


Figure 13. Time series of measured acquisition and modeled uptake of nitrogen in $\text{mmol (wet g)}^{-1} \text{ month}^{-1}$ by growing canopy fronds at the edge and inside the Mohawk kelp forest, and of all fronds in a 40 m x 40 m area of the interior of the forest (LTER) for the period 21 March 2005 through 30 April 2006.

Carbon and nitrogen linkages between giant kelp forests and sandy beaches

Wave-exposed sandy beaches represent a classic example of a subsidized sedimentary ecosystem where *in situ* primary production is very low and biotic communities are primarily supported by imported organic material from other ecosystems. Subsidies of drift macroalgae or wrack exported from kelp forests to beaches in the Santa Barbara Channel can exceed $500 \text{ kg m}^{-1} \text{ y}^{-1}$ for *Macrocystis pyrifera* alone (Dugan et al. *press*). These inputs from kelp forests to beaches exhibit strong temporal variation in response to pulse and press drivers, such as seasonal variation in wave climate, sediment supply and ENSO events, as well as kelp forest condition (Revell et al. *in press*, Figure 14). To describe these inputs over time, monthly surveys of wrack cover and volume are conducted on five beaches on the mainland coast of the Santa Barbara Channel along with counts of stranded *Macrocystis* plants and holdfasts (Figure 14).

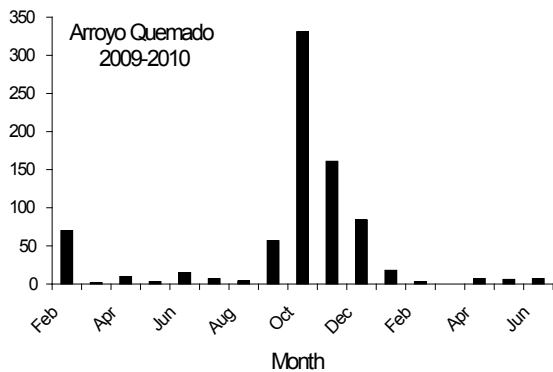


Figure 14. Number of stranded *Macrocystis* plants km^{-1} from monthly surveys of the beach inshore of the Arroyo Quemado kelp forest.

Our ongoing investigations of the role of kelp wrack subsidies in beach ecosystems indicate that they support a substantial component of the beach food web. Spatial variation in wrack abundance propagates up through invertebrate detritivores (Figure 15) to predatory shorebirds, including the Western snowy plover, a threatened shorebird that breeds on beaches (Dugan et al. 2003). Temporal variation in the supply of kelp wrack to beaches in response to press and pulse drivers is expected to have important consequences to the beach food web. For example, we found a doubling of invertebrate consumer richness in 8 weeks following weekly additions of fresh *Macrocystis* to one of our beach study sites. Consumption of kelp

wrack can be rapid as talitrid amphipods alone were estimated to consume kelp wrack at a rate of 18 kg m^{-1} of shoreline in one month, which constituted about ~40% of the measured input.

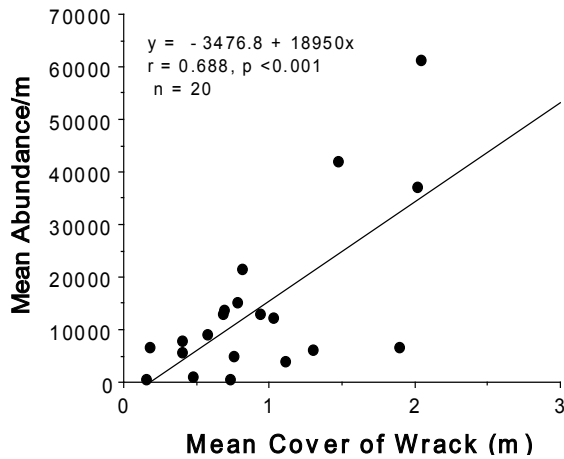


Figure 15. Relationship between the biomass of kelp wrack and the abundance of talitrid amphipods.

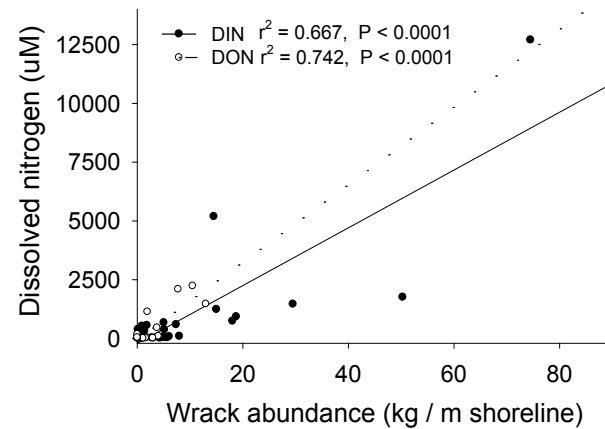


Figure 16. Relationships between the biomass of macroalgal wrack and dissolved inorganic nitrogen and dissolved organic nitrogen in beach pore water

The rapid processing of macroalgal wrack by invertebrate detritivores and its decomposition and subsequent nitrogen mineralization by bacteria can lead to high concentrations of dissolved nitrogen in intertidal pore water ($>1000 \text{ µM}$, Figure 16), particularly on beaches with heavy wrack accumulation (Dugan et al. *in press*). DIN concentrations were highest on the upper beach in the vicinity of the drift line where wrack accumulation and wrack consumer activity are greatest while lowest concentrations were found in the surf zone. However, surf zone DIN concentrations of dissolved nitrogen were also positively correlated with wrack biomass and intertidal DIN concentrations suggesting release of pore water nutrients to the nearshore ocean (Dugan et al. *in press*).

The interaction of press and pulse drivers such as tidal forcing, erosion events and sediment dynamics are expected to strongly affect release and transport of dissolved nutrients from beach aquifers, as will interactions with terrestrial groundwater sources when present. Our studies indicate that highest DIN concentrations ($>200 \text{ µM}$) in intertidal porewater were found in late summer and fall when sand accumulation on Santa Barbara beaches is greatest. Much lower DIN values ($<100 \text{ µM}$) occurred in winter and spring when sand levels are typically low. As indicated above, the beach ecosystem may also represent a nutrient source to coastal ocean primary production as wave and tidal activity circulates organic materials, such as wrack and phytoplankton, through beach sand where they are decomposed and mineralized. Studies of the decomposition and mineralization of kelp wrack, and the timing and magnitude of the release of intertidal pore water will be used to evaluate the significance of this potential nitrogen source to coastal waters and kelp forests.

The ability of beach ecosystems to accumulate and process wrack material can be significantly affected by abiotic press and pulse drivers that interact with human activities (Schlacher et al. 2007). Our finding of significant relationships between wrack abundance and dry beach width (Revell et al. *in press*), suggests that when dryer upper beach zones are narrow or absent, wrack accumulation and its availability to beach consumers and potential remineralization is decreased. Of particular concern in this regard is climate-induced sea level rise which is expected to increase coastal erosion and reduce beach width, thereby negatively affecting beach food webs and ecological functions, such as nutrient cycling. Coastal armoring, a common societal response to beach erosion is expected to expand with sea level rise. We found that beaches with coastal armoring were significantly narrower and wrack biomass was 1-3 orders of magnitude lower compared to adjacent unarmored beaches (Dugan et al. 2008). Shorebird use of armored sections was also significantly lower. Our studies of the effects of

coastal armoring on intertidal beach communities and ecosystem processes are ongoing and should provide important insights into interactions between humans and climate change and their ecological consequences to linkages between sandy beach and kelp forest ecosystems.

THEME 2: The direct and interactive effects of key press and pulse drivers on kelp forest community structure and function

Role of disturbance and N supply on giant kelp abundance and NPP

Net primary production (NPP) is fundamental to life on earth as it influences nearly all ecosystem processes. As such, NPP constitutes a critically important ecosystem function and determining its patterns and principal environmental drivers is justifiably one of the core research areas shared by all sites in the LTER network. NPP is influenced by disturbance-driven fluctuations in foliar standing crop (FSC) and resource-driven fluctuations in rates of recruitment and growth, yet most studies of NPP have focused primarily on factors influencing growth. We have been measuring NPP, FSC, recruitment, and growth rate of the giant kelp, *Macrocystis pyrifera* at three kelp forests in the Santa Barbara Channel since May 2002 to determine the relative roles of FSC, recruitment and growth rate in contributing to variation in annual NPP (Rassweiler et al. 2008). This involves non-destructively measurements of in situ changes in kelp biomass (via allometric relationship) coupled with independent measurements of frond and plant loss. These data are then used in a simple model of kelp dynamics, which assumes that, within a sampling period, biomass was produced and lost at rates proportional to existing FSC.

Our results to date show that the initial FSC present at the beginning of the growth year and the recruitment of new plants during the year explained 63% and 21% of the inter-annual variation observed in NPP, respectively (Reed et al. 2008). The previous year's NPP and disturbance from waves collectively accounted for 80% of the inter-annual variation in initial FSC. No correlation was found between annual growth rate (i.e., the amount of new kelp mass produced per unit of existing kelp mass) and annual NPP (i.e. the amount of new kelp mass produced per unit area of ocean bottom), largely because annual growth rate was relatively constant compared to initial FSC and recruitment, which fluctuated greatly among years and sites. Although growth rate was a poor predictor of variation in annual NPP, it was principally responsible for the high values observed for NPP by *Macrocystis* (up to 4.4 kg dry mass m⁻² y⁻¹). These high mean values reflected rapid growth (average of ~ 2% d⁻¹) of a relatively small standing

crop (maximum annual average = 444 g dry mass m⁻²) that replaced itself about seven times per year. Our observations of continuously high nitrogen content in kelp (generally above 1%) coupled with our finding that growth was unrelated to the concentration of DIN in seawater at two of our three sites (Figure 17) suggests that growth has rarely been nitrogen limited since our study began. These findings contrast with those of other investigators who studied kelp growth during prolonged conditions of nutrient stress associated with the 1982-83 El Niño, and they lend support to the contention that the importance of intra-annual variation in nitrogen supply in determining kelp growth and production depends on the state of longer-term climatic regimes.

Research over the last 40 years, indicate macro algae release a considerable portion of their photosynthetic products as dissolved organic matter and thus significantly influence the organic composition of seawater and ecology of the near shore. The exudation rates and chemical composition of dissolved organic carbon (DOC) released by macro algae has since become an

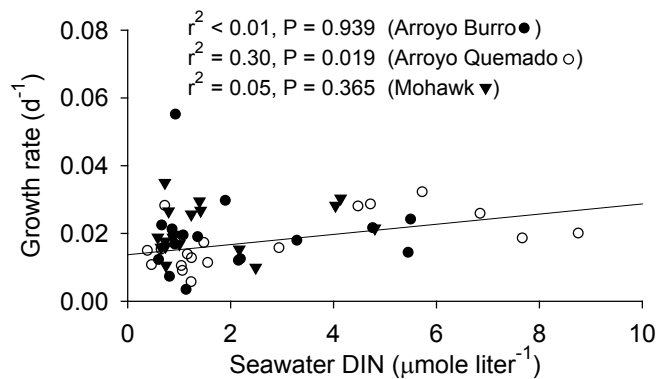


Figure 17. The relationship between specific growth rate and the ambient concentration of dissolved inorganic nitrogen (DIN).

important concern in constraining energy and nutrient budgets in coastal zones dominated by these primary producers. Unfortunately, production lost as dissolved exudates are not considered in our estimates of giant kelp NPP, simply because it is not logistically feasible for us to measure these losses on a reoccurring monthly time frame. Therefore to account for the fraction of NPP

lost as DOC we initiated a year-long study to (1) determine average rates of DOC release by *Macrocystis*, which could then be used to adjust our allometrically determined estimates of NPP, and (2) investigate the fate and bioavailability of macroalgal derived DOC. Results show that the contribution of DOC to giant kelp NPP varied considerably throughout the study, but on average accounted for 43% indicating that DOC is a significant component of NPP by *Macrocystis pyrifera* (Figure 18). DOC bioavailability experiments revealed that a large fraction of kelp derived DOC is labile and is immediately available to the heterotrophic microbial community in the kelp forest ecosystem, being remineralized on the order of days to weeks. However, a portion remains unused on timescales of a

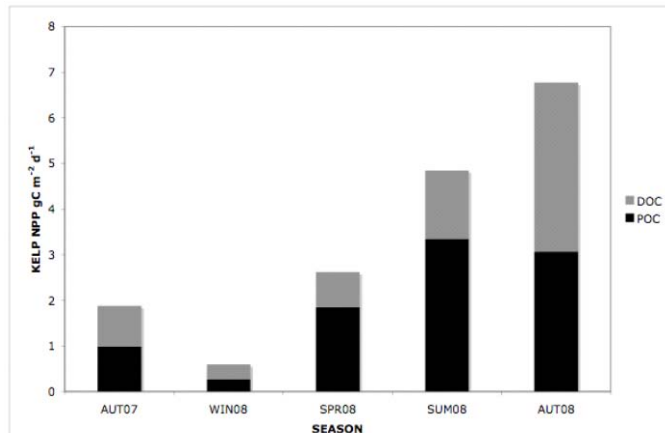


Figure 18. DOC release rates (grey bars) incorporated with seasonal NPP measurements from the long term SBC LTER data set (black bars), showing that carbon in the dissolved phase ranged from 28-54% of NPP over the course of a year, on average accounting for 43%

month and this accumulated DOM is potentially available for horizontal export away from the kelp reef via physical processes. This indicates that macroalgal derived organic matter can contribute to marine DOM pools in adjacent near shore and offshore waters, making understanding the production and fate of *Macrocystis* derived DOC important as it has implications for carbon cycling within the greater Santa Barbara coastal ecosystem

Our time series data on biomass and NPP by giant kelp (Rassweiler et al. 2008) are unique in that we know of no other data for macroalgae that match their temporal and spatial resolution (monthly measurements ongoing since 2002 at three sites). Such resolution is needed to detect directional changes in kelp biomass and NPP associated with long-term press drivers (e.g. global climate change) in the presence of more variable fluctuations associated with short-term pulse drivers (e.g., winter storms, grazing, conditions of nutrient limitation). Unfortunately, the large effort associated with collecting data on kelp biomass and NPP limit the number of sites that we can sample, which greatly restricts our ability to place our results into a larger regional context. Motivated by this limitation we analyzed our time series data to evaluate the validity of using a common and easily measured population variable (kelp frond density) to estimate the more difficult to measure variables of standing crop and NPP. We found that standing crop was strongly correlated to frond density ($r^2 = 0.79$) and that data on frond density collected in summer were particularly useful for estimating annual NPP, explaining nearly 80% of the variation in the NPP from year to year (Reed et al. 2009).

Currently we are applying these relationships to nine years of annual time series data on frond density collected at our long-term kelp forest sites as well as to similar data collected by colleagues at 8 kelp forests in central California. We have taken advantage of regional differences in environmental forcing and consumer abundance to examine the relative importance of nutrient availability (bottom-up), grazing pressure (top-down), and storm waves (disturbance) in controlling the standing biomass and net primary production of *Macrocystis pyrifera* in California, which is the dominant biomass producer of kelp forests in this region. Time series analyses show that there are consistent differences in nutrients, grazers and waves between central California and southern California. Proponents of bottom up control would expect the cold, nutrient rich waters of central California to support more kelp biomass and production than the more oligotrophic waters of southern California. Those who favor top down

control would also expect central California to have more kelp, although they would attribute this pattern to the near absence of sea urchin grazers in this region due to the presence of sea otters, a top kelp forest predator. Surprisingly, we found that patterns of kelp biomass and production do not match either of these predictions. Rather biomass and production of giant kelp was generally lower in central California, which is consistent with our prediction that the more intense wave disturbance on the central coast overwhelmed bottom-up and top-down forces.

Limits to the spatial extent of data that are routinely collected by divers have led us to search for additional means of investigating regional patterns in kelp biomass and NPP. With additional funding from NASA we have been exploring the use of high-resolution satellite imagery to investigate regional dynamics of giant kelp biomass and production (Figure 19). Our estimates of kelp canopy area using SPOT 5 imagery compared very favorably with near-coincident high-resolution aerial camera surveys ($r^2 = 0.90$; Cavanaugh et al 2010). Importantly, our monthly

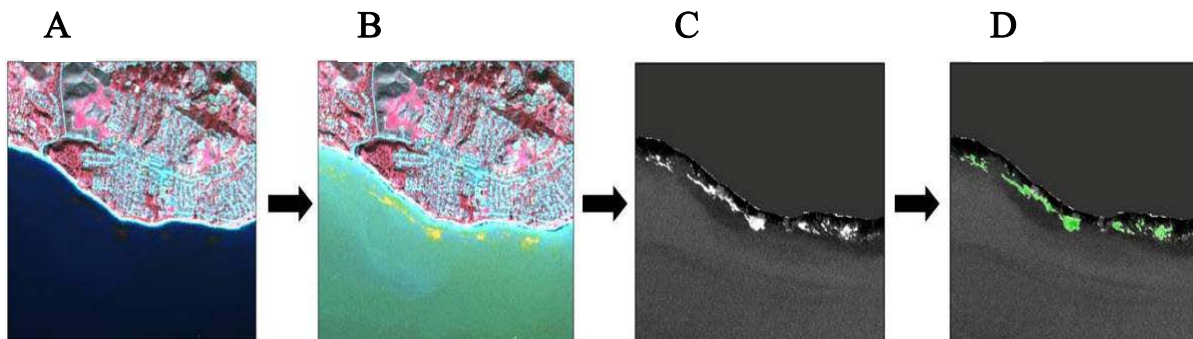


Figure 19. Four steps in the procedure for canopy cover delineation from SPOT 5 imagery. (A) False color SPOT image after geometric and atmospheric corrections have been performed (B) Resampled image after land and cloud areas have been masked out (C) PC band 2 (see Table 1 for band loadings), kelp is easily differentiated in this image because kelp's spectral signature closely matches the second mode of variability of the principal components rotation (D) PC band 2 after the threshold, manual edits, and winnowing filter have been applied. Pixels of kelp canopy are displayed in green.

measurements of kelp biomass and frond density in fixed plots collected by divers were strongly correlated with satellite determinations of Normalized Difference Vegetation Index (NDVI) signals of those plots ($r^2 = 0.77$). We used this relationship to examine variation in giant kelp biomass across multiple spatial scales (pixel, plot, site, and region). In doing so we found that the relationship between plot scale (40 m) changes in biomass and remote assessments of site scale (~1 km) changes varied among sites and depended on the relative location of the plot and the size of the kelp forest at each site. On a regional scale, changes in biomass among sites were well correlated with each other and with the aggregated regional (~60 km) total. We are currently working on calibrating imagery from Landsat 5 for use in examining regional patterns and drivers of kelp biomass and canopy area. Landsat data have a distinct advantage for assessing kelp dynamics because they recently were made available to the public at no cost, and have a much greater temporal (1984-present) and spatial (the Pacific coast of North America) extent. Once developed we plan to use this 25+ year Landsat data of high-resolution distributions of giant kelp biomass to develop a spatiotemporal model of the functional responses of giant kelp to climate variability and change. We will also be using these data in our ongoing studies of kelp population genetics and the role of inbreeding depression in regulating the metapopulation dynamics of giant kelp.

Interactions between the forest & its flow environment and their consequences on kelp and associated biota

Pulse and press drivers that alter the biomass of giant kelp change the physical structure of the kelp forest, which can have cascading effects on fluid flow, light attenuation and the delivery of waterborne subsidies. These interactions in turn can profoundly influence the biotic structure and ecological functioning of the kelp forest community. To examine the extent to which the

forest interacts with impinging currents we measured the flow characteristics inside and surrounding the kelp forest at Mohawk Reef using an array of 13 acoustic Doppler current profilers. We found that velocities were damped by as much as 60% in the interior of the forest and accelerated by as much as 200% along the forest's outer boundary as flow was shunted around the forest (Gaylord et al. 2007). We also found that the shading by the kelp canopy caused as much as a 90% reduction in fraction of surface light reaching the bottom in the interior of the forest relative to the edge of the forest (Figure 20).

These physical features bear on the performance of kelp and other forest organisms that rely on light for photosynthesis and/or currents to deliver nutrients and food. For example, we found that kelp fronds on the seaward edge of the forest were longer, bushier (i.e. had larger more numerous blades per unit length) and had higher overall growth rates than fronds growing in the interior of the forest (Stewart et al. 2009). Carbon and nitrogen accumulation by edge fronds was also higher, which fueled growth rates of edge fronds that were nearly twice as high as interior fronds when the kelp canopy was densest. Thus, the growth and tissue chemistry of *M. pyrifera* within the kelp forest depended on the extent to which the kelp forest modified the physical conditions within it.

We have evidence that giant kelp similarly affects the performance of kelp forest consumers. The colonial bryozoan *Membranipora serrilamella* is a ubiquitous filter feeding invertebrate that lives on the blades of giant kelp. We have found that abundance and frequency of occurrence of *Membranipora* were as much as two orders of magnitude higher on the outside edges of forests compared to their interiors (Figure 21), due to higher rates of recruitment and growth at the forest edge (Arkema 2008). Lower rates of recruitment and growth in interiors of forests were attributed to measured reductions in flow and particle flux caused by the presence of giant kelp.

Feeding success was highest at intermediate flow speeds and *Membranipora* abundance and growth rate were greatest at sites where water moved at intermediate flow speeds the majority of the time (Arkema 2009).

Collectively our results demonstrate how the physical structure of the kelp forests interacts with its surrounding environment to influence the biotic structure of the kelp forest community, and they highlight the importance of environmental drivers of giant kelp in influencing the entire kelp forest community.

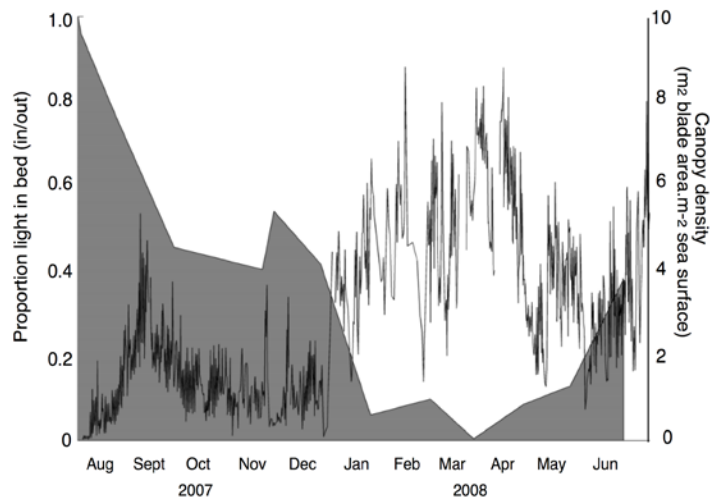


Figure 20. Ratio of bottom irradiance in the interior of the kelp forest to that outside the kelp forest. Shaded area denotes the density of the surface canopy of giant kelp

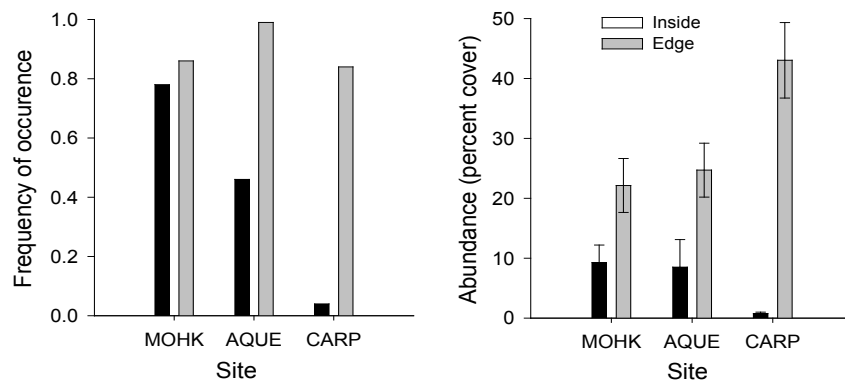


Figure 21. The frequency of occurrence and percent cover of *Membranipora* on kelp blades inside and at the outside edge of the kelp forests at Mohawk Reef (MOHK) Arroyo Quemado (AQUE) and Carpinteria Reef (CARP).

Effects of wave disturbance on food web structure -

While the last twenty years have witnessed an explosion in research detailing the general structure of ecosystem food webs in nature {Dunnet et al 2007}, we know much less about how abiotic and biotic forces shape the structure of food webs at the community level. This is a particularly pressing need, as in the next century climate change will influence the frequency and intensity of a variety of press and pulse disturbances in marine ecosystems. Indeed, in California the last fifty years have witnessed an increase in both the frequency and intensity of winter storms {Graham and Diaz 2001; Bormoski et al 2002}. Here at the SBC LTER, we are using our long-term data to address how these disturbances both directly and indirectly alter the structure of kelp forest food webs.

To understand how changes in wave disturbances from winter storms influence kelp forest food webs, we examined the direct and indirect mechanisms by which large storms influence kelp forest food web structure using Structural Equation Modeling (SEM). SEMs were used to describe how maximum winter wave disturbance, kelp abundance before storms, and kelp abundance both immediately and several months after winter storms (i.e., spring and summer) influence species richness and four metrics of food web complexity derived from network theory (Vermaat et al. 2009): the mean number of feeding links per species (i.e., linkage density), consumer diet breadth (i.e., the standard deviation in the number of prey per consumer), and the mean and variation (i.e. standard deviation) in food chain length from basal species to top predators. Additional SEMs considered the richness of species in different trophic or functional groups.

To fit models, we used data collected from our long-term kelp forest sites from 2002 through 2009. Food webs from these reefs comprised 217 species with ~1800 possible feeding links documented in the literature. We included data on kelp cover in spring using LANDSAT images. We also utilized the Coastal Data Information Project (CDIP) to determine maximum winter wave heights. We then used parameterized models to simulate changes in food web structure under three different storm scenarios: 1) minimal storm disturbance, 2) one year of strong storms, and 3) multiple consecutive years of strong storms that remove all kelp from a reef. We verified these predictions using our long-term field experiment mimicking kelp loss from large storms in 2000m² plots.

Our models show that single wave disturbances increase multiple metrics of food web complexity, but that repeated wave disturbances decrease both food web complexity and number of trophic levels (e.g. linkage density as seen Figure 22). This is due to an initial increase in algal and herbivore diversity due to additional light after one year of kelp removal. After multiple years of kelp removal, however, the food web collapses due to the lack of the habitat, food, and other resources provided by giant kelp. These results are matched by patterns seen in our long-term experiment.

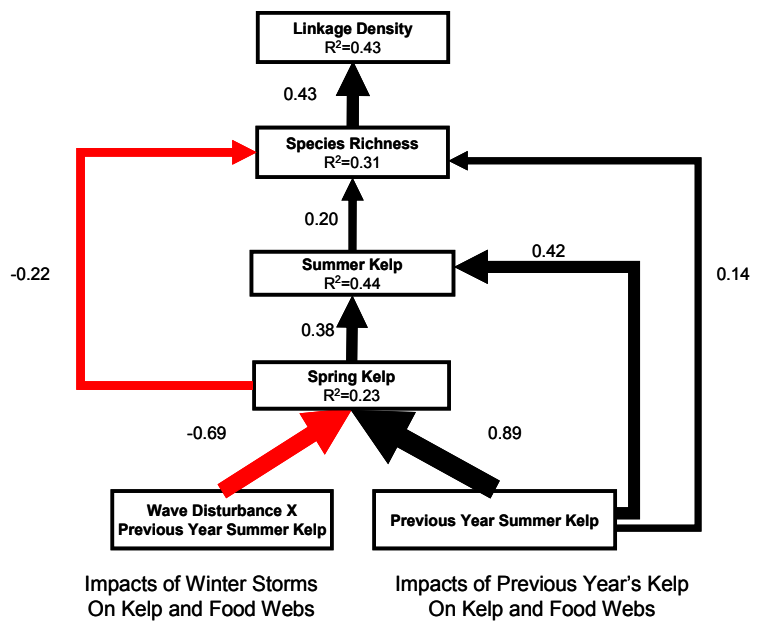


Figure 22: Results from a structural equation model linking different forms of disturbance with kelp density, species richness, and food web linkage density. Path width is proportional to effect size. Red paths are negative. Black paths are positive. Paths that are non-significant at $p=0.05$ are not shown.

Our work demonstrates that impacts to giant kelp may fundamentally alter food web structure if the frequency of severe weather events continues to increase due to climate change (Figure 23). Recovery of giant kelp under warming from climate change can also be stymied by climate change's effect on its species physiology, and in other kelp ecosystems the expansion of more tropical herbivores able to tolerate warmer waters has also proven problematic following storms.

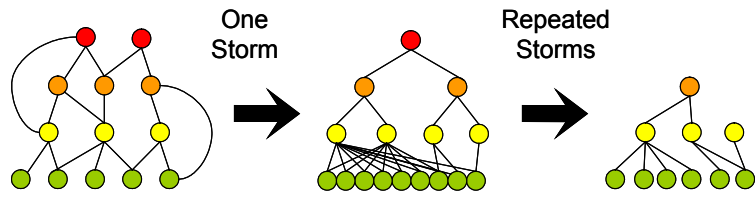


Figure 23: Conceptual model of how increases in storm frequency due to climate change will alter kelp forest food webs.

Phase shifts and resilience of kelp forest communities in response to pulse and press drivers

Kelp forest landscapes tend to consist of mosaics of patches in distinct community states, and switches between states within each patch are often sudden and dramatic. These patterns are commonly thought of within the framework of phase shifts and alternative stable states, but they also have important implications for understanding how the ecosystem responds to pulse and press drivers. If alternative stable states are present, then the response of the system to a change in one driver will be dependent not only on the condition of the other drivers, but also on the current state of the system. Long-term research in this case is crucial because each community state can persist for many years and because the full behavior of the system cannot be understood without studying how each state responds to changes in different environmental drivers.

The effect of sea urchins on kelp provides a well understood example of the interaction between community state and environmental drivers. When present at high densities, sea urchins actively graze and prevent the establishment of kelp and other organisms, whereas at low densities they remain

sedentary and feed passively by capturing drifting pieces of algal detritus. Because of this behavioral switch, an environmental driver that promotes kelp recruitment will have little effect on kelp abundance when sea urchin densities are high, but lead to large increases in kelp abundance when sea urchins are rare. We have used our long-term data on kelp forest community dynamics to show that this feedback is important in kelp forests off Santa Barbara (Arkema et al. 2009); giant kelp is only present when urchins are below a certain threshold density (28 urchins m^{-2}), regardless of other conditions (Figure 24). Although the effect of sea urchins on kelp is best known, we have shown that their presence has important effects on other taxa, maintaining low densities of sessile invertebrates and algae and clearing enough bare space that the space competition which typifies these sessile communities is minimized (Arkema et al. 2009).

We have also been studying another important community shift that appears to exhibit alternative stable states, in which a macroalgal dominated community is replaced by one dominated by the filter feeding sea cucumber *Pachythyone rubra*. Such shifts in community structure have obvious negative effects on primary production, as autotrophs are replaced by

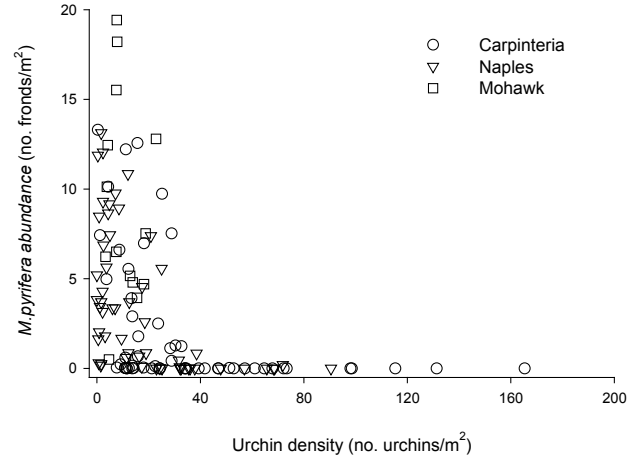


Figure 24. The relationship between kelp frond density and sea urchin density at three reefs in the Santa Barbara Channel. Data represent mean densities observed on a given transect during a given year.

heterotrophs, but they also have cascading effects on the entire food chain, with the loss of macroalgae leading to a reduction in micro-crustaceans and in their associated fish predators. We have been studying shifts between these states at a number of sites off Santa Cruz Island in the Santa Barbara Channel and we have documented very rapid shifts and also the persistence of a single state for many years.

We have experimentally explored the interactions between macroalgae and *P. rubra* to determine the mechanisms that explain the shifts between community states and the maintenance of each state (Rassweiler 2008). We found that the sea cucumbers and macroalgae compete strongly for space, which is consistent with results from analogous systems. More surprisingly, we found that the sea cucumbers consume algal spores at a sufficient rate to have a strong effect on algal settlement. This web of interactions, in which one species consumes its competitor (known as intraguild predation) is often associated with alternative stable states. We have used analytical models and spatially explicit simulations to show that in this system intraguild predation reinforces the *P. rubra* aggregations, and may even create alternate stable states (Rassweiler 2008).

We have also analyzed our time-series of *P. rubra* and macroalgal abundance alongside long term data on potential physical and biological drivers (Rassweiler et al. in press). We found that the switch into the high *P. rubra* phase was most likely triggered by a period of low waves (Figure 25).

Because macroalgae rely on waves and water motion to compete for space, their competitive ability was reduced during this period and *P. rubra* was able to establish. Although the low waves were only temporary, representing a pulse disturbance, other mechanisms such as intraguild predation were sufficient to maintain *P. rubra* dominance once it was established. We found that a different mechanism explained the end of the high *P. rubra* state, with the sea cucumbers' reduction coinciding with the appearance of its major predator, the sunflower sea star *Pycnopodia helianthoides*. This predator represents a press disturbance in the system, and its continued presence explains the continued low density of sea cucumbers. It appears that interactions between the key press and pulse drivers are important in structuring this system, as the initial switch to *P. rubra* dominance was only possible because of the absence of its main predator. A similar pulse disturbance of low waves would be unlikely to allow *P. rubra* to increase if it occurred today given the current levels of predation.

Our work on kelp-urchin state change and our study of shifts between macroalgal and filter feeder dominated communities both mesh well with a broader cross-site LTER interest in phase shifts and alternative stable states. To this end we have been collaborating with scientists from other LTER sites (Jornada, California Current Ecosystem, Moorea Coral Reef, Palmer Station and Harvard Forest) on general processes and mechanisms promoting phase shifts in ecological systems. At an Ecotrends working group in Spring 2009, we initiated two cross-site manuscripts. The first illustrates a new method for detecting of phase shifts in ecological communities, and applies it to datasets from several LTER sites, including two from SBC, one on kelp dynamics and the second on *Pachythyone rubra* populations. That first manuscript is well underway. The second manuscript deals with how the detection of phase shifts depends on

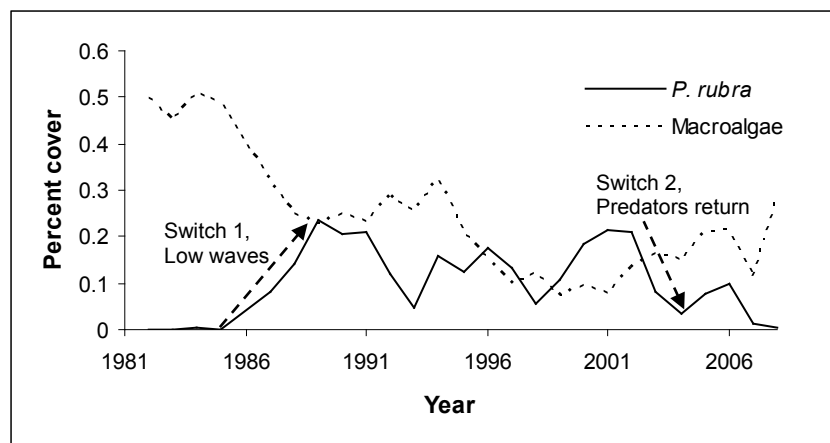


Figure 25. Mean cover of *Pachythyone rubra* and macroalgae at SBC-LTER sites at Santa Cruz Island. Switches in 1986 and 2003 are marked with dotted arrows.

the spatial scale being sampled and requires observational data on phase shifts that have been collected at multiple spatial scales. We are currently compiling data for this analysis both from within and outside the LTER network.

THEME 3: The indirect effects of pulse and press drivers on kelp forest community structure and function and the feedbacks between structure and function

Direct and indirect effects of disturbance-driven fluctuations in giant kelp abundance on benthic community structure

The giant kelp *Macrocystis pyrifera* is considered both a foundation species (*sensu* Dayton 1975) and an ecosystem engineer (*sensu* Jones et al. 1994) because not only does it provide food and shelter for a diverse array of species, but it also drastically alters the physical environment in which it lives. Hence press and pulse drivers that affect the abundance of giant kelp should have corresponding effects on species that associate with it. Kelp forest communities are characterized by a trophic structure that is unique to shallow reef ecosystems in that the primary space holders (i.e., macroalgae and sessile suspension feeding invertebrates) occupy different trophic levels and thus do not compete for resources other than space. However, competition *within* the two space holder groups for other resources may indirectly affect the strength of competition for space *between* them. For example, shade from the canopy of the giant kelp negatively affects understory algae, which raises the possibility that giant kelp indirectly facilitates sessile invertebrates, via suppression of understory algae. We took a two-fold approach to examine this phenomenon (Arkema et al. 2009). First, we experimentally removed giant kelp from 40 m x 40 m study plots and measured the responses of understory algae and sessile invertebrates. We found a negative effect of giant kelp on both light availability and understory algal abundance and a positive effect on the abundance of sessile invertebrates, which was consistent with an indirect effect mediated by shade from the kelp canopy. Secondly, because frequent disturbance causes kelp populations to fluctuate greatly in space and time, we used

observational data on kelp forest community structure from long-term monitoring sites to examine whether the interactions among kelp, understory algae and sessile invertebrates observed experimentally in space led to predictable patterns over time. We found that interannual variability in the abundances of understory algae and sessile invertebrates were significantly and positively related to interannual variability in the abundance of giant kelp ($r^2 = 0.74$, $P < 0.001$ for understory algae and $r^2 = 0.46$, $P = 0.03$ for sessile invertebrates). Results from structural equation modeling indicated that giant kelp negatively affects understory algae via canopy shading, understory algae negatively affects sessile invertebrates through space competition, and giant kelp indirectly facilitates sessile invertebrates (Figure 26). In fact, the magnitude of the indirect effect of giant kelp frond density on sessile invertebrates ($-0.39 \times -0.74 = 0.29$), was nearly six times greater than the magnitude of the direct effect ($= -0.05$). The coefficient for the path representing the direct effect of giant kelp frond density on sessile invertebrates was not significantly different from zero, nor were the paths between the percent cover of giant kelp holdfasts and the percent cover of understory algae and sessile invertebrates, suggesting that the significant effects of kelp resulted from shading by kelp fronds rather than competition for space by kelp holdfasts. Our results

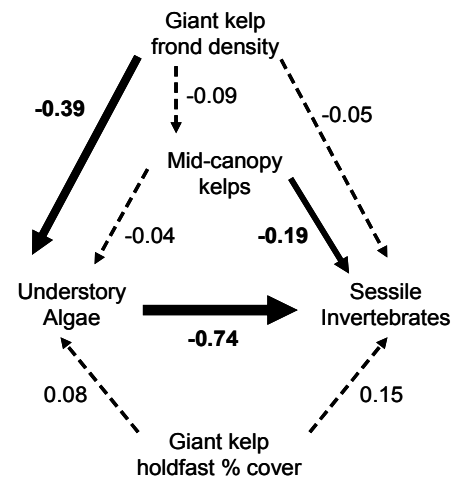


Figure 26. The fitted competition and facilitation model used to estimate the strength of direct and indirect effects. Values are standardized coefficient estimates. Solid lines indicate significant paths ($P < 0.05$). Dashed lines are non-significant.

suggest that the dynamic structure of the kelp forest community is driven in large part by variability in the abundance of a single structure forming species (giant kelp) that has indirect positive, as well as direct negative effects on associated plants and animals.

Disturbance, assemblage structure and the partitioning of primary production among giant kelp, understory macroalgae and phytoplankton

Giant kelp forests are highly productive ecosystems, rivaling those of tropical rain forests. This productivity and its associated standing biomass, however, vary greatly both within and among years in large part due to disturbance from waves (Reed et al. 2008). Such variation in turn affects the entire kelp forest assemblage of primary producers, which are negatively affected by kelp canopy shading (Arkema et al. 2009). To date, estimates of kelp forest production have focused mainly on *Macrocystis*, excluding the diverse community of phytoplankton and understory benthic algae from consideration. Strong competition for light with giant kelp in the forest may cause populations of these two groups of autotrophs to vary out of phase with *Macrocystis*, which may serve to dampen the variability in ecosystem production by kelp forests. To the extent that *Macrocystis* dominates total reef ecosystem NPP, variation in *Macrocystis* canopy will drive corresponding variation in total ecosystem NPP. Alternatively, if NPP of understory algae and/or phytoplankton increases in response to reduced *Macrocystis* canopy, then variability in ecosystem NPP will be reduced. The amount of such compensatory productivity will depend upon the magnitude and temporal lag in the production of understory algae and phytoplankton to the more favorable light conditions associated with kelp loss following disturbance. Phytoplankton are likely able to respond rapidly as the biomass of phytoplankton in the kelp forest is determined by larger scale processes that affect the regional production and transport of phytoplankton (see “Theme 1 Transport of offshore shelf C and N to the inner shelf”). In contrast, the recruitment and growth of understory algae is influence by conditions within the forest, and because of their slower growth rates and seasonal recruitment NPP by understory algae in the kelp forest may lag substantially behind that of phytoplankton following kelp loss.

To examine the role of disturbance in partitioning NPP among different groups kelp forest producers we developed methods for measuring NPP by understory algae *in situ* (Miller et al. 2009) and used these methods to compare rates of NPP by understory macroalgae with those by phytoplankton and giant kelp in an area where giant kelp was removed and in an area was it was left in place. The study was done at Mohawk Reef over a 17-month period in 2007-2008 during which time wave disturbance caused substantial variability *Macrocystis* standing crop and production. We hypothesized that the *Macrocystis* canopy would negatively affect the productivity of understory macroalgae and phytoplankton, and that these effects would vary with *Macrocystis* standing crop. We predicted that understory algae, unlike phytoplankton, would be unable to respond immediately to reductions in *Macrocystis* shading, and one of our goals was to estimate the magnitude of this time lag,. Finally, we compared NPP by *Macrocystis* with that by understory macroalgae and phytoplankton to determine whether natural fluctuations in *Macrocystis* biomass, led to similar fluctuations in the NPP of the entire kelp forest ecosystem.

We found strong evidence that the presence of the giant kelp canopy suppressed production by phytoplankton and understory algae (Miller et al *in review*). As predicted, increased NPP by phytoplankton occurred immediately following disturbance-induced reductions in the kelp canopy, while NPP by understory algae displayed a substantial time lag in response to kelp loss due to the time required to increase its biomass via recruitment and growth. Importantly, we found that in the absence of giant kelp NPP by phytoplankton and an established understory was comparable to that of an established kelp forest community (Figure 27a). Somewhat surprising was our finding that phytoplankton and understory algae contributed on average about one third of ecosystem NPP at the *Macrocystis* canopy control site (Figure 27b).

These results illustrate how indirect effects of pulse and press drivers can influence important aspects of kelp forest structure and function and how the structure of kelp forests as defined by the biomass and species composition of their autotrophs feeds back to influence net primary production, which is a critically important ecosystem function.

While the use of benthic incubation chambers has allowed us to investigate the contribution of understory algae to the productivity of the kelp forest ecosystem, logistical constraints render them less useful for longer-term comparative studies and experiments, which are needed to better understand the patterns and controls of primary production by macroalgae and their ecological consequences. To this end we developed a simple physiologically-based model of benthic macroalgal production using three components: (1) bottom irradiance obtained from PAR sensors mounted to the sea floor, (2) taxon-specific macroalgal photosynthesis versus irradiance (P vs. E) parameters measured in the laboratory, and (3) taxon-specific foliar standing crop measured non-destructively in the field using allometric relationships developed by SBC LTER. To test the model we compared its predicted estimates of production to measured estimates obtained with the benthic chambers deployed in situ and found a near 1-to-1 correspondence. This model is being applied to data collected in our long-term kelp removal experiments to investigate the extent to which increases in mortality rates of giant kelp (an expected consequence of climate change) lead to changes in ecosystem NPP and foodweb structure. We are also using data collected from these experiments to investigate the extent to which biomass alone predicts annual NPP of understory algae, much like we did for giant kelp (Reed et al 2009). Our hope is to uncover a strong relationship between the biomass of understory algae in summer and annual NPP of understory algae that we can apply to our ongoing 10-y time series of kelp forest community structure at our long-term study sites.

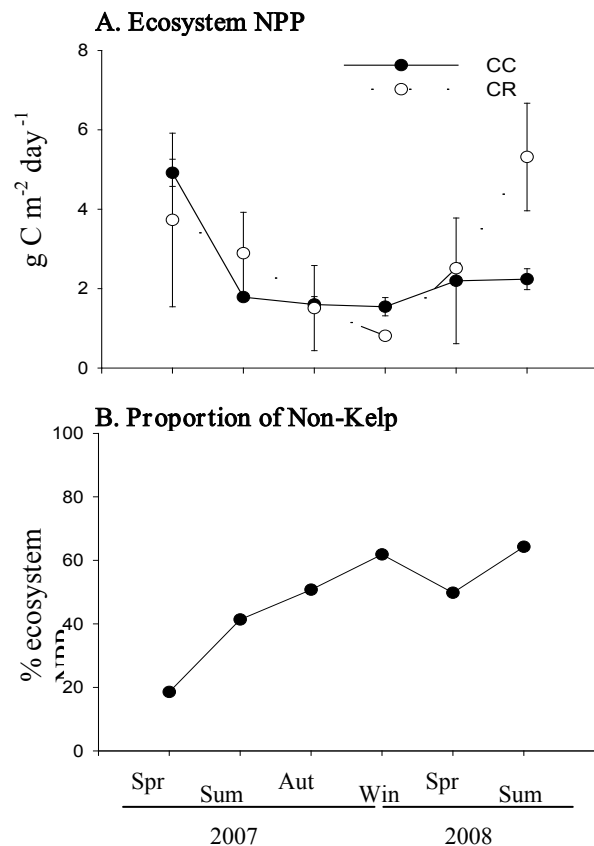


Figure 27. (A) mean ecosystem NPP, including *Macrocystis*, understory, and phytoplankton NPP at the kelp canopy removal (CR) and kelp canopy control (CC) sites at Mohawk Reef. Error bars are 1 standard error. (B) Percentage of non-kelp NPP (Understory + Phytoplankton NPP) inside the kelp forest (canopy control site).

Feedbacks between benthic diversity and grazing intensity in giant kelp forests

In seeking to understand the complex dynamics of communities, researchers have typically concentrated on factors that either regulate community structure or community function. Nowhere has this dichotomy been more evident than in biodiversity research, where separate research traditions have attempted to tease apart either the causes or the consequences of biodiversity. Both are inextricably linked. For example, theories such as the Intermediate Disturbance Hypothesis state the biodiversity is maximized at intermediate levels of disturbance {Connell 1978}. On the other hand, biodiversity ecosystem function research has shown repeatedly that high levels of biodiversity can actually reduce the intensity of disturbance

{Hillebrand and Cardinale 2004; Hughes and Stachowicz 2004}. We hypothesize that these two relationships form a feedback between species diversity and disturbance (Figure 28).

Within kelp forests, biological disturbance by sea urchins can drastically alter levels of primary productivity. Sea urchins prefer to feed on kelp detritus, but when starved for drift kelp they change their mode of feeding to one of active grazing. Dense aggregations of grazing sea urchins are common in kelp forests worldwide and their ability to denude the bottom substrate of most sessile species has been well documented. However, yet to be determined is the extent to which the diversity of the benthic assemblage that sea urchins attack influences their effect on the structure of that assemblage and the extent to which the realized amount of disturbance to an assemblage in turn feeds back to alter the diversity of the recovered community by altering recruitment, growth, and species interactions.

To investigate potential feedbacks between sessile species diversity and sea urchin disturbance, we

initiated an experiment in summer 2009 in which we manipulated densities of the purple sea urchin (*Strongylocentrotus purpuratus*) in caged 0.5 m² plots that varied in sessile species diversity. Densities of sea urchins were augmented within the caged plots in a response surface design such that plots at all levels of diversity were subjected to a complete range of grazing intensity. We showed that, while high densities of sea urchins inflict uniformly high grazing damage, at low densities sessile species richness actually enhances grazing disturbance. This finding, contrary to our expectations, is even more intriguing in that we only see the pattern at high levels of sessile species richness. These results are highly suggestive that urchins are attempting to maximize the types of nutrition they gain from different resources – the Balanced diet hypothesis. To confirm this result, we are currently running detailed laboratory experiments.

We found that these changes in disturbance feed back to alter diversity in the short-term. Grazing damage was negatively related to species richness immediately after grazing. However, to ascertain the long-term consequences of this feedback, we are currently following the recovery of grazed communities through the fall of 2010. In this manner, we are both examining how initial species diversity alters the impact of grazing, as well as how different levels of realized disturbance (e.g., amount of cover removed) alters future changes in species diversity.

Long-term experiment: Implications of climate change on kelp forest structure and function

Modeling and correlative analyses of our long-term data coupled with cause and effect relationships gleaned from an assortment of short-term mechanistic experiments are providing us with considerable insight into our overarching question of *How do abiotic drivers acting over different spatial and temporal scales interact to influence kelp forest structure and function?*

Longer-term manipulative experiments conducted at ecologically relevant temporal and spatial scales offer a powerful means of verifying predictions generated by our correlative analyses and short-term experiments. Because the giant kelp *Macrocystis* extends throughout the water column it is easily dislodged by large waves associated with winter storms. With this in mind we initiated a long-term experiment in January 2008 to test an assortment of predictions concerning the consequences of consistent annual kelp loss arising from increases in the frequency and intensity of winter storms, a trend that has been observed in California over the last 50 years {Graham and Diaz 2001; Bormoski et al 2002}.

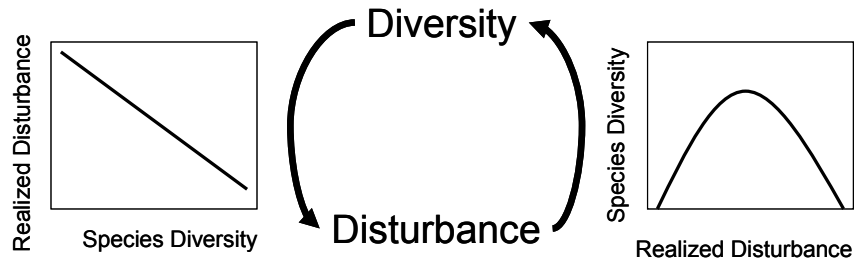


Figure 28: Hypothesized feedbacks between species diversity and disturbance. Diversity of an assemblage determines how much disturbance results from a particular event (e.g., highly diverse communities will potentially experience very little disturbance). The amount of disturbance realized by a community in turn feeds back to alter the diversity of the subsequent assemblage.

To simulate the consequences of increased storm activity we remove all giant kelp once per year in winter from permanent 40 m x 40 m plots at four of our long-term study sites (Arroyo Quemado, Naples Reef, Mohawk, and Carpinteria Reef). Adjacent 40 m x 40 m plots at each site where kelp is left undisturbed serve as controls (Figure 29). These sites vary in wave exposure and level of sea urchin grazing. As such we hope to gain valuable insight over the long-term with respect to how the effects of selectively removing giant kelp vary with different levels of physical and biological disturbance.

We are following changes in the biological structure (species abundance and richness of algae, invertebrates and fish), and various ecosystem processes (e.g., NPP by macroalgae, detrital accumulation) 2x per season in fixed transects and quadrats located in each plot. Because there are no off the shelf methods for estimating NPP by understory macroalgae we have been developing a non-destructive approach for examining patterns of understory NPP using species-specific allometric relationships (to estimate biomass) coupled with a bio-optical model. Our bio-optical model incorporates algal biomass, photosynthetic efficiency (derived from laboratory derived photosynthesis vs. irradiance curves for ~20 species that comprise over 95% of the biomass), and photosynthetically active radiation measured once per minute by sensors anchored to the bottom in each kelp control and removal plot.



Figure 29. Schematic of the long-term kelp removal experiment showing a giant kelp removal plot with abundant understory kelps and algae on the right and a kelp canopy control plot with giant kelp and a sparse understory on the left.

Our initial results show that giant kelp is among the first species to colonize in spring following its removal in the preceding winter. Dense thickets of young giant kelp have colonized sites with low grazing in each of the first two years. We hypothesize that colonization by giant kelp into the kelp cleared plots will decrease over time as other understory species become established and monopolize light and space. Such changes will undoubtedly influence a diverse assemblage of kelp forest consumers that depend directly and indirectly on giant kelp for food and/or shelter.

In addition to examining potential consequence of climate change, the long-term removal of giant kelp will also provide a wealth of information on how the kelp forest system responds in the absence of its foundation species. Moreover, the design of our experiment (in terms of plot size and replication among sites) allows it to serve as a template for both short and long-term investigations that explore a wide variety of ecological issues and questions pertaining to the presence (or absence) of giant kelp. Indeed our current studies of kelp forest food webs and feedbacks between ecosystem structure and function were designed to make use of the long term experiment

Social-ecological interactions and feedbacks involving reef-based fisheries

Spatial-based approaches to management of marine ecosystems are gaining momentum, a transformation that is due in large part to an upwelling of recent scientific research focused on marine reserves, landscape-level ecology and conservation planning, public-private partnerships, and collaborative fisheries research and co-management. A group of SBC LTER researchers led by Associate Investigator H. Lenihan have been working in these areas, specifically with former adversaries in the form of fishermen opposed to marine reserves, to assess the ecological impacts

of fishing, evaluate the effects of marine reserves on kelp forest communities and fishery yield, and create collaborative reserve-based fishery co-management in the Santa Barbara coastal marine ecosystem.

A network of twelve marine reserves was established in the Northern Channel Islands in 2003. SBC LTER researchers and local trap fishermen created a research partnership (www.calobster.org) in which they designed and executed a field sampling program to evaluate the response of spiny lobster and rockfish populations to reserve protection, the response of fishermen in terms of the redistribution of fishing effort around reserves, changes through time in fishery yield and fishing revenue, and using an intensive tag-and-recapture program the spillover of juvenile and adult lobsters from reserves into the fishery. Results indicate that lobster populations have increased four-fold in reserves and that mean lobster size has increased substantially. Spillover from reserves to surrounding areas has not yet influenced fishery yield, and at present there appears to be as many lobsters moving into reserves as there are moving out from reserves to areas being fished. The local lobster fishery significantly redistributed their effort in space, and during the first four years after reserves were established (2003-2007) fishing revenue was reduced, probably due to the fact that fishermen spent time and thus fuel finding new fishing locations. Revenue increased in 2008 and extensive interviews with fishermen indicated that increasing profits probably resulted from fishermen learning to fish in different areas in between the reserves. However, there was no indication that fishermen targeted the borders of reserves as hypothesized because these areas were generally not good lobster habitat. To test the ecological impact of lobster fishing, time-series data from our long-term kelp forest collected in the SBC LTER time series sampling of kelp forest communities were integrated with lobster fishing data to examine whether fishing caused the reduction of kelp through a trophic cascade associated with lobsters, urchins, and kelp. Analyses of these data indicated that lobster populations probably control urchin populations through predation, but that fishing effort did not reduce lobster populations enough to influence urchin abundance. Finally, variation in kelp abundance was not related to variation in urchin abundance, thereby reinforcing information generated from other SBC LTER studies that disturbance and nutrient availability have substantial influence on kelp abundance, especially for giant kelp.

We also designed and tested a new management process in which fishermen who target grass rockfish record their catch and fishing effort in fine spatial detail in areas open to fishing, and then compare those data with samples collected from within local reserves (Wilson et al. 2010). Data from collaborative sampling inside and outside of reserves were then used in Management Strategy Evaluation (MSE) models, which integrate population dynamic modeling with decision theory as a means of comparing the accuracy, cost, and long-term viability of grass rockfish populations in the Santa Barbara Channel. Output from MSE models using a traditional large-scale and spatially-inexplicit fishery stock assessment were compared to that using a collaborative and reserve-based (i.e., spatially-explicit) process based on a decision-tree framework borrowed from a South Pacific tuna fishery and restructured for use in the Santa Barbara Channel. Results indicate that co-management of grass rockfish using reserves as an ecological baseline and a decision-tree focused on releasing large, highly productive fish will not only be less expensive for the state of California to operate than conventional management, but will be sustainable even at increased catch rates. This study is being cited nationally and internationally as a seminal paper describing how marine reserves can be used in spatial-based fishery management.