Submitted on: 06/02/2008
Principal Investigator: Ohman, Mark D.
Organization: U of Cal SD Scripps Inst
Title: LTER: Nonlinear transitions in the California Current Coastal Pelagic Ecosystem

### Project Participants

<table>
<thead>
<tr>
<th>Name</th>
<th>Worked for more than 160 Hours:</th>
<th>Contribution to Project:</th>
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<tbody>
<tr>
<td>Ohman, Mark</td>
<td>Yes</td>
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<tr>
<td>Landry, Michael</td>
<td>Yes</td>
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<tr>
<td>Miller, Arthur</td>
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<td>Goericke, Ralf</td>
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<td>Barbeau, Katherine</td>
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<tr>
<td>Aluwihare, Lihini</td>
<td>Yes</td>
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<td>Checkley, David</td>
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<td>Franks, Peter</td>
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<td>Mitchell, Brian</td>
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<tr>
<td>Sugihara, George</td>
<td>Yes</td>
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<tr>
<td>Azam, Farooq</td>
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</tbody>
</table>
Worked for more than 160 Hours: No
Contribution to Project:
Name: Bograd, Steven

Worked for more than 160 Hours: No
Contribution to Project:
Name: Burton, Ron

Worked for more than 160 Hours: Yes
Contribution to Project:
Name: DiLorenzo, Emanuel

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

Worked for more than 160 Hours: No
Contribution to Project:
Name: Palenik, Brian

Worked for more than 160 Hours: No
Contribution to Project:
Name: Smith, Ken

Worked for more than 160 Hours: Yes
Contribution to Project:
Name: Sydeman, William

Worked for more than 160 Hours: No
Contribution to Project:
Name: Davis, Russ

Worked for more than 160 Hours: Yes
Contribution to Project:
Name: Chekalyuk, Alexander

Worked for more than 160 Hours: Yes
Contribution to Project:
Name: Koslow, Tony

Worked for more than 160 Hours: Yes
Contribution to Project:
Name: Baker, Karen

Worked for more than 160 Hours: Yes
Contribution to Project:
Name: Venrick, Elizabeth
Contribution to Project:

Post-doc

Name: Fuchs, Heidi
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Buck, Kristen
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Ward, Jessica Raye
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Wang, Haili
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Millerand, Florence
Worked for more than 160 Hours: Yes
Contribution to Project:
Comparative Science and Technology Interoperability study participant providing human computer interface expertise

Name: Chhak, Ketty
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Perruche, Coralie
Worked for more than 160 Hours: Yes
Contribution to Project:
Universite de Brest Occidentale (CCE modeling, process studies).

Name: Li, Qian
Worked for more than 160 Hours: Yes
Contribution to Project:

Graduate Student

Name: Powell, Jesse
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Taylor, Andrew
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Davison, Pete
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Decima, Moira  
Worked for more than 160 Hours: Yes

Contribution to Project:

Name: DeJesus, Roman  
Worked for more than 160 Hours: Yes

Contribution to Project:

Name: Dupont, Christopher  
Worked for more than 160 Hours: Yes

Contribution to Project:

Name: Hansman, Roberta  
Worked for more than 160 Hours: Yes

Contribution to Project:

Name: Hopkinson, Brian  
Worked for more than 160 Hours: Yes

Contribution to Project:

Name: Hsieh, Chih-hao  
Worked for more than 160 Hours: Yes

Contribution to Project:

Name: Hull, Pincelli  
Worked for more than 160 Hours: Yes

Contribution to Project:

Name: King, Andrew  
Worked for more than 160 Hours: Yes

Contribution to Project:

Name: Maurer, Ben  
Worked for more than 160 Hours: Yes

Contribution to Project:

Name: Ruhl, Henry  
Worked for more than 160 Hours: Yes

Contribution to Project:

Name: Rykaczewski, Ryan  
Worked for more than 160 Hours: Yes

Contribution to Project:

Name: Stukel, Michael  
Worked for more than 160 Hours: Yes
Name: Vardaro, Michael  
Worked for more than 160 Hours: Yes  
Contribution to Project:

Name: Soldevilla, Melissa  
Worked for more than 160 Hours: Yes  
Contribution to Project:

Name: Hanson, Kate  
Worked for more than 160 Hours: Yes  
Contribution to Project:

Name: Karakoylu, Erdem  
Worked for more than 160 Hours: Yes  
Contribution to Project:

Name: LeBlond, Julien  
Worked for more than 160 Hours: Yes  
Contribution to Project:

Name: Cawood, Alison  
Worked for more than 160 Hours: Yes  
Contribution to Project:

Name: Samo, Ty  
Worked for more than 160 Hours: Yes  
Contribution to Project:

Name: Linacre, Lorena  
Worked for more than 160 Hours: Yes  
Contribution to Project:

Name: Kim, Hey Jin  
Worked for more than 160 Hours: Yes  
Contribution to Project:

Name: Taniguchi, Darcy  
Worked for more than 160 Hours: Yes  
Contribution to Project:

Name: Sheffield, Lisa  
Worked for more than 160 Hours: Yes  
Contribution to Project: Seabird observations

Name: Raimonet, Melanie  
Worked for more than 160 Hours: Yes  
Contribution to Project: Universite de Brest Occidentale (CCE modeling, ROMS configuration)

Name: Song, Hajoon
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<tr>
<th>Name</th>
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<tr>
<td>Subramanian, Aneesh</td>
<td>Yes</td>
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<tr>
<td>Conners, James</td>
<td>Yes</td>
<td>Web and database expertise</td>
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<tr>
<td>Ward, Nick</td>
<td>Yes</td>
<td>Aluwihare's lab</td>
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<tr>
<td>Kahn, Amanda</td>
<td>Yes</td>
<td>MBARI Summer Intern</td>
</tr>
<tr>
<td>Daniels, Emy</td>
<td>Yes</td>
<td>EBE Undergraduate student</td>
</tr>
<tr>
<td>Wick, Daniel</td>
<td>Yes</td>
<td>ESYS Undergraduate student</td>
</tr>
<tr>
<td>Wanetick, Jerome</td>
<td>No</td>
<td>Computational Center Director providing computational infrastructure</td>
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<tr>
<td>Yarmey, Lynn</td>
<td>Yes</td>
<td>Metadata and data organizational skills</td>
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<tr>
<td>Haber, Shaun</td>
<td>No</td>
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<tr>
<td>Reynolds, Susan</td>
<td>Yes</td>
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Name: Dovel, Shonna  
Worked for more than 160 Hours: Yes  
Contribution to Project:  

Name: Seegers, Brian  
Worked for more than 160 Hours: Yes  
Contribution to Project:  

Name: Townsend, Annie  
Worked for more than 160 Hours: No  
Contribution to Project:  

Name: Chong, Laurie  
Worked for more than 160 Hours: Yes  
Contribution to Project:  

Name: Roadman, Megan  
Worked for more than 160 Hours: Yes  
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Name: Romagnan, Jean-Baptiste  
Worked for more than 160 Hours: Yes  
Contribution to Project:  
SIO Research Assistant, former graduate student  

Name: Kahru, Mati  
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Contribution to Project:  

Name: Kortz, Mason  
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Name: Ellena, Jacob  
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MBARI Research Technician  

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Contribution to Project:  

Other Participant  
Name: Lee, Daniel  
Worked for more than 160 Hours: Yes  
Contribution to Project:  

Name: Balch, Debbie  
Worked for more than 160 Hours: Yes
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Name: Erez, Oya  
Worked for more than 160 Hours: Yes

Contribution to Project:

Name: Spear, Natalie  
Worked for more than 160 Hours: Yes

Contribution to Project:

Name: Seegers, Bridget  
Worked for more than 160 Hours: Yes

Contribution to Project:

Name: Liddell, Kenneth  
Worked for more than 160 Hours: Yes

Contribution to Project:

Name: Cerullo, Mary  
Worked for more than 160 Hours: Yes

Contribution to Project:

Participated in K-12 reading experience.

Name: Aubery, Sara  
Worked for more than 160 Hours: Yes

Contribution to Project:

Name: Feakins, Jonathan  
Worked for more than 160 Hours: Yes

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Name: Hofheimer, Jean Lea  
Worked for more than 160 Hours: Yes

Contribution to Project:

Name: Jensen, Dave  
Worked for more than 160 Hours: Yes

Contribution to Project:

Name: Vollmer, Beth  
Worked for more than 160 Hours: Yes

Contribution to Project:

Name: Westlake Storey, Robin  
Worked for more than 160 Hours: Yes

Contribution to Project:

Name: Yoshinaga, Marcos  
Worked for more than 160 Hours: Yes
Name: Lee, Dong-Yoon  
Worked for more than 160 Hours: Yes  
Contribution to Project: 

Name: Kelly, Rachel  
Worked for more than 160 Hours: Yes  
Contribution to Project: 

Name: Feldman, Lindsey  
Worked for more than 160 Hours: Yes  
Contribution to Project: 

Name: Kansteiner, Matt  
Worked for more than 160 Hours: Yes  
Contribution to Project: 

Name: Fitzpatrick, Dylan  
Worked for more than 160 Hours: Yes  
Contribution to Project: 

Name: Lewis, Jeffrey  
Worked for more than 160 Hours: Yes  
Contribution to Project: 

Name: Davis, Edward  
Worked for more than 160 Hours: Yes  
Contribution to Project: 

Name: Stewart, Neil  
Worked for more than 160 Hours: Yes  
Contribution to Project: 

Name: Riviere, Pascal  
Worked for more than 160 Hours: Yes  
Contribution to Project: 
Universite de Brest Occidentale (CCE modeling, process studies).

Research Experience for Undergraduates  
Name: Tsyrklevich, Kate  
Worked for more than 160 Hours: Yes  
Contribution to Project:  

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 2007  
REU Funding: REU supplement
Name: Bundy, Randie

Worked for more than 160 Hours: Yes

Contribution to Project:

- 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: 2007
- REU Funding: REU supplement

Organizational Partners

- NOAA/Southwest Fisheries Science Center
  Collaborative efforts with scientists and seagoing personnel.

- NOAA Pacific Fisheries Environmental Lab
  Analysis and publication of hydrographic data.

- San Diego Supercomputer Center
  Staff are assisting with Information Management design.

- Georgia Institute of Technology
  Cooperative modeling project.

- Point Reyes Bird Observatory
  Studies of marine avifauna.

- Duke University
  Studies of marine avifauna.

- Cascadia Research
  Marine mammal studies.

- Ocean Institute, Dana Pt., CA
  Education and Outreach partner

- University of Bergen
  Collaborative research concerning long-term changes in ocean optical properties.

- Universite de Brest Occidentale
  Collaborations in physical-biological modeling.

- NASA Goddard Institute for Space Studies
  Collaborative research on phytoplankton optical properties using hyperspectral methods.

- Preuss School, San Diego
  Science curriculum development with UCSD's Preuss school teachers.

- Rancho Bernardo High School
  Science curriculum development for high school students.
Monterey Bay Aquarium Research Institute
Collaborative research concerning deep-sea benthic ecology

Woods Hole Oceanographic Institution
Logistical and technician support on research cruises

Cicese
Studies of carbon in Pacific coastal waters (Mexico)

Santa Clara University
Relations with the Science, Technology and Society Institute

University of Quebec
Human computer interface expertise provided (Montreal).

UC San Diego - COSMOS program
UC summer school (math and science) enrichment program, grades 8-12.

SERC
Satellite Educational Resources Consortium

DLESE
Digital Library for Earth System Education

NSDL
National Science Digital Library

TIEE
Teaching Issues and Experiments in Ecology

SLTER
Schoolyard Long-Term Ecological Research

Aquarium of the Pacific
Interactions with the aquarium in Long Beach, CA for education

Ocean Literacy Network
Ocean literacy on-line meeting place for educators and scientists

Exploratorium
Collaborative educational work, located at the San Francisco Museum.

National Marine Educators Association
NMEA annual meetings for Education and Outreach participation.

Rancho Santa Fe Middle School
Marine science educational visit from Middle school students

Aquatic Adventures
Project provides opportunities for staff to volunteer at sea.
University of Paris
Collaborations on mesozooplankton abundance and size (Zooscan).

University of Aix-Marseille
Collaborations with the Barbeau Lab on trace metal studies.

Lamont-Doherty Earth Observatory of Columbia University
Collaborations regarding bio-optical research (ALF).

TWISTED
Collaborative work with French research modelers, members of ToWard Integration of Subgrid Turbulence in Ecosystem Dynamics.

CSIC - Spain
Spanish National Research Council

Stanford University

University of Michigan
Information School

UCSD
Science Studies Program (IM)

National Science Teachers Association
NSTA promotes excellence and innovation in (E&O) science teaching

International Polar Books Club
Polar Books is a project formed to produce and promote quality books reflecting International Polar Year themes - http://www.grida.no/polarbooks/about.aspx

Moonlight Publishing
Children's book publisher

Other Collaborators or Contacts
- Carmen Castro, CSIC, Vigo, Spain
- Naomi Oreskes, Science Studies Program, UCSD
- Geoffrey Bowker, Science, Technology and Society Institute, Santa Clara University
- Cyndy Chandler, JGOFS Data Management
- Harry Helling and Rick Baker, Ocean Institute, Dana Point
- Palmer Station LTER site (Robin Ross and Langdon Quentin - 'Sea Secrets: Tiny Clues to a Big Mystery' children's book)
- Santa Barbara Coastal LTER site (Dan Reed and Mark Brzezinski)
- Linda Powell, Florida Coastal Everglades LTER site
- Wade Sheldon, Georgia Coastal Ecosystem LTER site
- Alec Barron, teacher, The Preuss School (a minority-serving charter school)
- Season Mussey, teacher, The Preuss School
- Jay Hendricks, teacher, Rancho Bernardo High School
- Dag Aksnes, Professor, University of Bergen, Norway
- David Ribes, Information School, UMichigan
- Geoffrey Bowker, Santa Clara University
- Jun Nishioka, Hokkaido University, Japan (Odate/Aline projects)
Activities and Findings

Research and Education Activities:

2008

Process cruises: This year has been largely devoted to analyses of samples from two CCE LTER Process cruises (P0605- May 2006 and P0704- April 2007) and presentations of results at scientific meetings.

Augmented CalCOFI Cruises: The CCE LTER group participated on four CalCOFI cruises as planned (R. Goericke). In the winter and spring of 2008, not all stations were sampled, due to bad weather. At the stations that were occupied the planned suite of samples was taken, i.e. samples for the characterization of biogeochemical properties (total organic carbon, total nitrogen, particulate organic carbon and nitrogen), phytoplankton biomass and community structure (chl a size fractionation, flow cytometry, analysis of taxon-specific pigments, epi-fluorescence microscopy, inverted microscopy), zooplankton biomass and community structure (LOPC profiles, ADCP acoustic backscatter, net tows for samples to be analyzed using the Zooscan or traditional identification). During transits, observers enumerated seabirds and marine mammals. Marine mammals were also monitored acoustically while underway via a towed hydrophone array and on station using sono-buoys.

Fe limitation studies: Graduate student A. King completed analysis of samples taken on the Nov 2006 augmented CalCOFI cruise and the April 2007 CCE LTER Process Cruise for total dissolved iron. Postdoc K. Buck completed Fe speciation analysis on samples taken during the April 2007 Process Cruise. In July 2007, K. Barbeau's group completed a research cruise on the R/V New Horizon, completing a transect along CalCOFI line 93. This cruise was funded by a separate NSF grant to Barbeau, but data from this cruise contribute to the overall data set on iron in the CCE LTER study area, and the data will be entered in the CCE LTER database. K. Buck and A. King have also completed analysis of total dissolved iron and iron speciation samples collected during this cruise.

Midwater trawling: The midwater 'Oozeki trawl' (MOHT) samples from the 2007 CCE-LTER Process Cruise (T. Koslow and P. Davison) were sorted. The invertebrate catch was split and stored in the SIO Pelagic Invertebrates Collection for future analysis. All fish were identified to species, measured, and weighed. Biomass of fish per square meter was calculated for the stations where trawling was performed. The size distribution of the vertically migratory fish species was used in conjunction with a physiological model to calculate the carbon exported from the epipelagic zone by the fish. Dissections of fish to measure stomach content variation over a diel cycle have begun in order to estimate ingestion and evacuation rates.
Deep-sea ecology: Over the past year the Pelagic-Benthic group, led by K. Smith (CCE LTER Associate), along with J. Ellena, M. Vardaro, and H. Ruhl at the Monterey Bay Aquarium Research Institute (MBARI) has worked on several research topics related to the CCE LTER program. These included: 1) linking surface ocean parameters, including climate and CalCOFI zooplankton abundances, to the arrival of visible aggregates of particulate organic matter on the seafloor; 2) researching the influence of food supplies on the abundance and community structure of sediment macrofauna; 3) determining the biogeochemical role of sediment macrofauna; 4) researching the influence of climate and food supply on the speed, body size distributions, and sediment bioturbation rates of a commonly occurring mobile megafauna; 5) evaluation of the carrion food supply of abyssal fishes including comparisons with CalCOFI fish egg abundance and spatial distribution data; and 6) evaluating the abundance and size distribution patterns of a benthic sponge, an animal thought to be slow growing.

LOPC/SOLOPC: The Laser Optical Plankton Counter (LOPC) was deployed on the augmented CalCOFI CCE-LTER quarterly cruises (D. Checkley), with data successfully acquired on each cruise. In addition, the SOLOPC data were analyzed from the spring 2007 Process cruise.

Analysis of curl vs. coastal boundary upwelling: Graduate student R. Rykaczewski, working with D. Checkley, identified an effect of upwelling velocity on the size spectrum of mesozooplankton. The higher vertical velocities associated with coastal boundary upwelling appear to favor larger-bodied zooplankton via larger-sized phytoplankton cells, while the region of wind stress curl-driven upwelling leads to lower vertical velocities that favor smaller phytoplankton cells and smaller-bodied mesozooplankton. Long-term changes in the curl-driven upwelling are associated with changes in the relative abundance of the two primary zooplanktivorous fish in the region, Pacific sardine and Northern anchovy (Rykaczewski and Checkley 2008).

Bio-optical measurements: B.G. Mitchell's group continued to provide SST and ocean color satellite imagery support for the CCE study site. We continued our collaboration with A. Chekalyuk's lab at LDEO, Columbia University, to develop the next generation Advanced Laser Fluorometer (ALF-2). Data collected from previous CCE process cruises were processed, and QC of data and database merging is in progress.

Spray ocean gliders: Two glider lines are now regularly occupied across the California Current along CalCOFI line 80 (off Pt. Conception) and line 90 (off Dana Pt), both extending 300-400 km out into the open ocean. Although supported by separate funds (the Moore Foundation), these glider lines are in direct support of the CCE LTER site (M. Ohman, R. Davis).

Ecosystem modeling: Part I û A group led by E. Di Lorenzo has identified a new mode of climate variation in the North Pacific, the NPGO (North Pacific Gyre Oscillation). This second mode of sea surface height and SST variability has a north-south spatial pattern similar to the Victoria mode, unlike the east-west spatial pattern of the PDO (Di Lorenzo et al. 2008). While the PDO correlates well with temperature variability in the N. Pacific, it is a poor explanation of more biologically relevant variables. Conversely, the NPGO is an excellent descriptor of decadal-scale variations in variations in salinity, nitrate, and chlorophyll, in both the CCE-CalCOFI region and much further north along the Sta. P line leading into the Subarctic Pacific.

Part II - P. Franks, H. Fuchs, P. Riviere and Q. Li continued the development of a continuum size-structured planktonic ecosystem model, and began the implementation of the NEMURO ecosystem model in the ROMS physical framework. We also coupled the continuum ecosystem model to ROMS, and have begun one-dimensional (vertical) experiments exploring the influence of mixing on the ecosystem size structure. Part III - Tests of the incremental strong constraints 4D-variational (IS4DVAR) assimilation procedure using ROMS in the CalCOFI domain (A. Miller) were executed by graduate student H.-J. Song, using real observations and wind forcing for a weeklong test period. The data assimilation window was July 1-7, 2002, for which Advanced Microwave Scanning Radiometer (AMSR-E) satellite SST data and CalCOFI cruise hydrographic temperature and salinity data were used to correct the model first guess. ROMS IS4DVAR successfully reduced the rms model-data misfit by approximately 75%. Several issues need to be addressed, i.e. strong nonlinearity of ROMS causes the fitting procedure to fail for longer fitting time intervals. We are exploring increased viscosity and changes to other model parameters to deal with this. Also, adjustment of the surface wind and heat-flux forcing have not yet been implemented or tested for real time-dependent forcing fields. A prototype of the forcing correction procedure is now available, so we plan to implement and test this. These issues will be examined using the CalCOFI cruise in April 2006 and the LTER Process cruise in May 2006.

Part IV - Research over the past year (S. Bograd) has involved the analysis of in situ hydrographic data obtained primarily from CalCOFI. This work has focused on three projects: (1) an analysis of long-term trends in dissolved oxygen in the southern California Current, and implications for ecosystem structure; (2) an analysis of trends in the transport and properties of the California Undercurrent; and (3) an analysis of variability in deep flushing of the Santa Barbara Basin. The goal of these projects is to describe and understand variability in the source waters to the CCE-LTER region, and to relate this variability to observed ecosystem fluctuations.

Seabird observations: As part of the CCE LTER and CalCOFI programs, we (W. Sydeman and K. Hyrenbach) have studied the distribution and abundance of marine birds and mammals in relation to climate change - ecosystem change for over two decades. Seabirds were observed during July 2007, and January and April 2008 on CalCOFI cruises for the CCE LTER program, representing the 21st and 22nd years of observations. Studies of marine birds and mammals in the study area began in May 1987. During the course of this research we have documented a major decline in one of the most abundant seabirds of the California Current Ecosystem, the Sooty Shearwater (Veit et al. 1996),
as well as a general shift in the avifauna from one comprised primarily of sub-arctic species to one of sub-tropical species affiliations (Hyrenbach and Veit 2003).

Information Management: Initial design of Datazoo, an information system that provides a single portal to multiple applications, was completed and the system launched as a production site at the end of 2007 (K. Baker's group). With developers and users having full functionality assembled in one data space, co-design of the system could be undertaken jointly such that the system was fully redesigned in 2008, to achieve a more robust internal architecture and a more transparent stakeholder interface. In this process a logging of user access was established. This module, along with several others (unit dictionary, participant module, term set lists) were recast as API modules, thus providing a more serviceable and extensible infrastructure from which to grow ('Databits'-Conners and Kortz, 2008). A core feature of the information system is data and metadata management through web interfaces with tiered permissions that enable data providers to participate in making their data accessible. The new system is built upon a relational database with object-oriented API layer that supports Web-based data query, integration, and exchange. Interdependent sets of dictionaries describe datasets to the column level. There are currently 19 cruise studies in the data system along with several dozen long-term datasets that extend over multiple cruises studies and/or time periods. We are actively populating the database with recent, as well as legacy datasets.

2007

Process cruises: We successfully conducted the second CCE LTER Process cruise in April 2007 (P0704), headed by Chief Scientist and Co-PI M. Landry. The science plan of our process cruises has involved a series of experimental/measurement cycles. Water masses of varying characteristics were marked with a drogued drift array and followed over the course of 4-5 days to assess the temporal evolution of the ambient physical and chemical environment and the biological community, while conducting experimental studies on the contributions of phytoplankton growth, micro- and meso-zooplankton grazing and particle export to community change. Microscopical and flow cytometric analyses of pico-, nano- and microplankton samples from last year's (P0605) cruise have been completed. Sample analyses for P0704 should be completed this summer, and we are working through a backlog of samples from quarterly CalCOFI cruises.

Fe limitation studies: K. Barbeau and grad. students (Barbeau Lab - http://barbeaulab.ucsd.edu) conducted Fe limitation research on 3 cruises: Nov. 2006 CalCOFI cruise, Nov. 2006 Santa Barbara Basin cruise, and April 2007 CCE LTER Process cruise #2. The role of Fe on phytoplankton communities within the CCE LTER site was investigated using shipboard Fe addition grow-out experiments, and additional samples of dissolved Fe concentrations were collected. Many presentations on preliminary work have been given at various meetings and conferences (i.e. ASM, AGU, NPMO, Yokohama workshop).

Dissolved/particulate organics (C&N): Samples were collected for isotope analysis and DOC/POC measurements (April 2007 Process Cruise #2) and will be compared to our baseline, non-El Nino sample set from the May 2006 Process cruise #1 (L. Aluwihare, L. Chong). These two CCE LTER sample sets will allow us to determine whether the remote physical forcing associated with El Nino events alters the isotope signatures of inorganic and organic pools in the central California Current region. Samples were also taken on the Nov. 2006 CalCOFI cruise during the early stages of the El Nino event, to specifically evaluate the isotopic composition of DIN in the California Undercurrent and California Current along the CalCOFI grid. The ultimate goal is to determine the source and isotopic composition of the upwelled nitrate, and how this source varies temporally in the region. Additionally, an mRNA-based assay for evaluating N use by phytoplankton (at low N concentrations) is currently being developed by an undergraduate student (N. Ward), with the goal of applying this assay to determine the availability of N in the CalCOFI region. Another LTER benefit has been the work of two high school students, who helped process and load cruise samples for analyses. Some preliminary results were reported on (Aluwihare) at the 2007 ASLO meeting.

Bio-optical measurements: Comprehensive bio-optical investigations were carried out (B.G. Mitchell's group) during April 2007 Process cruise #2. SST and ocean color satellite data imagery support were also provided. Optical variables acquired by underwater instruments included: multispectral radiometry, backscattering coefficients, beam attenuation coefficients, and variable fluorescence. Water samples were also collected for analysis of hyperspectral absorption coefficients of particulate and soluble fractions, HPLC pigments, phycobiliprotein (PBP) pigments, CHN element analysis, photosynthesis vs. irradiance (PvsE) experiments, variable fluorescence, and size distribution of particles. FRRF (Fast Repetition Rate Fluorescence) underway measurements were also conducted through the ship's uncontaminated seawater system. These observed measurements were coordinated with the cruise measurements of Dr. Alexander Chekalyuk (LDEO, Columbia University). Our joint goal is to develop the next generation Advanced Laser Fluorometer (ALF-2) instrument for oceanographic applications, seeking to improve quantitative assessments (i.e. chlorophyll-a (Chl), PBP pigments), and to provide basic characterization of the phytoplankton community structure. The system was used for the underway flow-through sample measurements and analyses of discrete water samples. In addition, diel variability in pigment fluorescence was studied during the cruise to improve the accuracy of fluorescence pigment assessments and retrieve more information about phytoplankton photophysiology.

Seabird observations: A seabird observer was placed on several CCE LTER (CalCOFI) cruises, obtaining data on the inter-annual variability of seabird distributions within the CCE study site.
Information Management: The data system (datazoo) provides a single portal to multiple projects and runs in parallel with our project-specific second generation systems. Site information management activities focused this year on moving design of a third generation data system to production status (80% of development complete). We have prototype deployments of both unit and attribute dictionaries, a participant and a platform dictionary, as well as a re-factoring of code toward more modular and object-oriented elements. Work on a local geographic dictionary has been initiated. The incorporation of data has begun with initial LTER time-series datasets, entailing extensive engagement with users for feed-back on the interfaces. Web forms for data and metadata entry and modification have been introduced, moving from a pipeline model to a federated model more open to interaction with community participants. By design, a flexible structuring reaches from the data center to the investigator's lab to provide an umbrella structure that prompts update of laboratory understandings of data management.

The project web now includes web pages for the two process cruises, and the education pages will be updated this summer. A second computational platform was installed as part of the Ocean Informatics information infrastructure, doubling our storage capacity to the terrabyte range and permitting dissociation of web services from development and user work. Security has been updated in addition to implementation of single sign-on directory services (Baker et al, 2007; Spring Databits Newsletter).

As an example of our articulation efforts, 8 individuals associated with Information Management contributed more than a dozen articles to Databits, the LTER Information Management Newsletter.

Ecosystem modeling: 1) H. Fuchs (P. Frank's post-doc) developed a continuous-size nutrient-phytoplankton-zooplankton model (1024 size classes, each) to study how size-selective feeding by zooplankton affects the structure and biomass of plankton communities. Phytoplankton have allometrically scaled maximal growth rates; this is the only size-dependent parameter in the model. Considerable work has gone into defining the grazing kernel - the distribution of size classes available to a grazer/predator. 2) French scientist P. Riviere continued analyses of archived CalCOFI data (1994-2004); A Matlab toolbox was developed for the extraction of different fields from the CalCOFI database, with statistical tools to analyze variability of tracers (nitrates, temperature, salinity and Chl-a) on isopycnal surfaces. The role of light in the control of nitracline depth in the CalCOFI area was investigated with D. Aksnes and M. Ohman. 3) Riviere also used the analyzed CalCOFI data in preparation for modeling experiments, exploring the influence of hydrographic variability on vertical nitrate fluxes in the study region. The results will inform the more complex biological models which will be used to explore how the ecosystem responds in terms of phytoplankton competition (coarse size structure) and phytoplankton-zooplankton interactions (trophic coupling). Comparisons with hydrological and biogeochemical measurements in the CalCOFI region will help on testing the validity of the model results. 4) In collaboration with E. Di Lorenzo, a modeling study is ongoing with the implementation of a ROMS model configuration on the CCS region, forcing boundaries (nested grid) by a North East Pacific simulation (50 years run). Different numerical resolutions will be used for the regional model, from medium resolution (10 km) to high resolution that will permit the production of submesoscale structures.

2006 Process Cruise: We just successfully completed the first CCE Process cruise in June 2006. This cruise had a Lagrangian design, where in situ incubation experiments were conducted while following a Globalstar-tracked drifter array and simultaneously measuring changes in the surrounding water column. Five experimental Cycles were conducted in this manner, with sites chosen to span the spatial variability in hydrographic and plankton community composition across the California Current. The cruise began with a forward run from a ROMS model, following assimilation of data from the just-completed CalCOFI cruise. The ROMS forecast, together with MODIS-Aqua imagery, were used to help guide the sequence of sites for experimental studies. Site surveys were conducted on a daily basis with a Moving Vessel Profiler (MVP) to analyze along-flow and cross-flow spatial gradients. The MVP sections were supplemented by sections with an autonomous Spray glider, permitting high resolution analysis of vertical current shear, as well as Chla fluorescence and CTD profiling. Mesozooplankton translocation experiments were carried out, as well as studies of diel periodicity of grazing from bongo-LOPC samples and analyses of vertical distributions with 27 Mocness tows. Additional experiments evaluated susceptibility to iron limitation, isotopic characterization of different fractions of dissolved organic matter, and flow-through analyses of phytoplankton variable fluorescence and pigment composition using hyperspectral techniques. Two tow-yo sections were carried out with a Video Plankton Recorder (VPR II). Eleven graduate students participated at sea in this process cruise. During the coming year, we will be analyzing cruise results.

LOPC: A Laser-Optical Plankton Plankton Counter (LOPC) and CTD were acquired with CCE LTER funds in mid 2004. The LOPC and CTD were mounted within one side of the standard CalCOFI bongo net frame, replacing the previously-used Optical Plankton Counter (OPC). The LTER LOPC is battery powered and stores data internally. Tests were performed prior to routine deployment to ensure that performance of the standard CalCOFI bongo collection of zooplankton was not affected. Since then, the bongo-LOPC (with CTD) has been used successfully on seven CalCOFI-LTER cruises, beginning with 0411 (November, 2004). Approximately 475 oblique profiles from surface to 210m or near the bottom, have been performed. Matlab software has been written for rapid initial processing of the LOPC and CTD and storage in a form amenable to further analysis. Initial inspection of the LOPC and CTD data indicate consistency with prior results from use of the OPC, with temporal (diel, seasonal, interannual) and spatial (horizontal, vertical) pattern evident. Of particular interest is using shape and transparency to infer types of particles and plankton.

The bongo-LOPC was also used on the CCE LTER Process Cruise of 8 May - 7 June 2006. Seventy-nine profiles were performed. These data
will be valuable for inferring not only about the time-space distribution of particles and plankton but also for comparison with the data from the LOPC deployed on the Moving Vessel Profiler. Initial impressions of data from the Process Cruise are consistent with those from the CalCOFI-LTER and other, NSF-funded cruises indicating the dominance of the particle field in situ by types of particles other than plankton, including marine snow and the houses of larvaceans. SIO graduate student Ryan Rykaczewski sampled zooplankton with the LOPC and nets on the Process Cruise to investigate variation in its size, abundance, and availability as food to larval anchovy and sardine. SIO graduate student Peter Davison participated in the Process Cruise to study myctophid fish by use of the MOCNESS.

The LOPC and CTD purchased with CCE LTER funds have also been used on three NSF-funded cruises of particles and plankton.

Augmented CalCOFI cruises: We have completed four more Augmented CalCOFI cruises since the last report, with a suite of measurements of microbial elements of the food web (by flow cytometry and automated epifluorescence microscopy), phytoplankton HPLC, dissolved and particulate organic matter, LOPC profiles, ADCP acoustic backscatter, and other properties.

Mesozooplankton/Zooscan analyses: After technical problems with our Zooscan, which required reshipment to Europe for repairs, we are working actively on the development of protocols for morphometric analyses of mesozooplankton, as well as automated pattern recognition.

Remote sensing: We now have MODIS-Aqua and/or SeaWifs satellite imagery posted regularly in the public domain (http://spg.ucsd.edu/Satellite_Projects/CCE-LTER/Satellite_support_for_CCE-LTER.htm), in the form of composite images of Chla and SST that correspond exactly to the time periods of our LTER Augmented CalCOFI cruises.

Ancillary activities: In research related to our LTER site, but funded separately from this NSF grant, we have initiated an ecosystem observation program using Spray ocean gliders and a Moving Vessel Profiler.

Information management: The CCE LTER computational infrastructure was augmented this year to include updated data sharing technology (webDAV file sharing and directory services). A digital event logger was prototyped on quarterly CalCOFI-LTER grid cruises and deployed on the May process cruise. Strategic design teams were organized to address cross-project design schema, dictionaries, and plotting alternatives. An intensive data modeling effort is developing sophisticated mappings and relations among the heterogeneous datasets as part of a fully functional relational database system. A personnel, unit registry and attribute dictionary as well as an administrative module providing a multi-user interface have been integrated into the new information system design. In addition, the project website (http://cce.lternet.edu) was redesigned into a two site architecture - development and public arenas - in order to facilitate prototyping of more complex web elements. A photo/media gallery, station converter, and dynamic mapping application were developed for the website.

Network information management: LTER CCE information management network activities include coleading a Dictionary Process Design Team (Baker et al, 2005) that culminated in demonstration of a community unit registry prototype at the Information Manager meeting. Members of the CCE information management team contributed a variety of articles to Databits, the LTER Community Newsletter (Baker et al, 2006a,b; Millerand et al, 2006; Yarmey, 2006; Haber, 2006; Kortz, 2006; see Databits Spring 2006 http://lternet.edu). The CCE Information Manager participated in the LTER Planning Process as a member of three committees (Governance, Human Dimensions, and Cyberinfrastructure). Work with the governance team culminated in a major LTER by-laws revision approved by the coordinating committee in May 2006. Three members of the CCE data management team attended the annual LTER Information Manager meeting.

Social informatics: Collaboration with social scientists (G.Bowker, director of SCU Science Technology and Society Institute; PostDoc Florence Millerand; graduate students David Ribes and Brian Lindseth) involved ethnographic field work and participation in site events. This work has been presented to the LTER community via talks and written communications. Papers were presented at the American Society of Information Science and Technology (ASIST 2005) as well as the International Digital Government Conference (DGO 2006) on social science engagement and infrastructure building.

Education: CCE research has been disseminated through a variety of outreach efforts in the public domain, in classrooms, and universities, national and international collaborations. These include:

- Establishment of a nearshore phytoplankton time series at the Ocean Institute in Dana Point, CA, a nonprofit educational facility that takes school children to sea.
- Participant in Ocean Literacy Conference @ the Long Beach Aquarium of the Pacific (June 7th, 8th 2006)
- Continuation of local networking with the UCSD Preuss School
- Framing the instructional module with Ocean Institute on nearshore phytoplankton
- Participant in the Online Ocean Literacy Network Workshop, College of Exploration (May, 2006)
2005

1. (All) A quarterly LTER observation program has been established in the California Current focusing on the following components of the pelagic food web: prokaryotic and eukaryotic picoplankton, using flow cytometry; nano- and microplankton assemblages, using epifluorescence microscopy and automated image analysis; primary production in both the dissolved and particulate phases, from 14C incubations; phytoplankton floristic composition, using HPLC, light microscopy, and some FlowCAM analyses; zooplankton size distributions and vertical distributions in situ, using an in situ Laser Optical Particle Counter; sentinel species of holozooplankton from selected cruises, using light microscopy; dissolved organic nitrogen and carbon, using high temperature platinum catalyst combustion; particulate organic nitrogen and carbon, using dry combustion. These measurements supplement the core CalCOFI measurements of temperature, salinity, ADCP currents, nutrients, irradiance, light transmission, dissolved oxygen, Chla, zooplankton biomass, and ichthyoplankton distributions taken on the same cruises.

Our inaugural LTER cruise was launched in November 2004 and two additional LTER cruises have now been completed.

2. (Graduate student King, and K. Barbeau) The potential for Fe limitation in the southern California Current System (CCS) has been investigated using shipboard Fe addition grow-out experiments.

3. (Graduate student Hsieh, and G. Sugihara) Retrospective analysis of existing time series of physical and biological variables sampled in the California Current has been conducted using numerical methods that differentiate between linear and nonlinear signatures.

4. (Graduate student Ruhl, and K. Smith) Analyses of organic C fluxes to the deep sea (4,000 m) have been related to long term variations in primary production from overlying surface waters.

5. (Miller and DiLorenzo, and graduate student Kim). Analyses of historical data initiated as a prelude to enhancement of coupled biophysical models of the CCS.

6. (Mitchell and Kahru) Priorities established for analysis of satellite remote sensing imagery, and a movie made of the El Nino-related changes in SeaWifs Chla pigments.

7. (Bograd) Analysis of historic CalCOFI data for indications of subduction of recently upwelled waters.

8. (Baker) A CCE LTER website has been created (http://ccelter.sio.ucsd.edu). A new server (iOcean) has been integrated into the local infrastructure during this first year, providing web and shared data storage services. An information and data management survey has been conducted to learn LTER and CalCOFI PI's current and intended practices regarding data storage. A new shipboard data organization scheme has been implemented, centered around event numbers. Work to establish dictionaries and controlled vocabularies is proceeding in parallel with development of metadata forms.

9. (Simmons) A science Artists and Writers program/ Storytelling workshop was held at UCSD/SIO in 2004/05. A lesson on phytoplankton/krill interactions was developed and presented to 6th graders at the University of California, San Diego's Preuss School. Education coordinator Simmons participated in the Ocean Literacy Workshop at the Long Beach Aquarium of the Pacific June 15th, 2005. She is currently compiling Education/Outreach portfolio materials and artifacts as resources for program participants and classroom teachers.

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

2008

Process cruises: By design, CCE Process cruise studies (M. Landry's grad. students and CCE colleagues) follow the temporal evolution of plankton communities in drifter-marked water parcels over the course of several days while experiments are conducted to elucidate process rates and interactions. During two springtime Process cruises (May 2006, April 2007) over a wide range of initial ecological conditions, these Lagrangian studies have shown coherent system trends in community composition, biomass and size structure, growth rate, production, production:biomass and grazing losses to micro- and mesozooplankton. The sums of experimentally measured process rates explain 86% of the variability of net rates of chlorophyll change observed in the ambient system. These results set the stage for detailed analyses of the dynamics of component populations and parameterization of ecosystem models to study broader scales of temporal and spatial responses to system variability (M. Landry, R. Goericke, M. Ohman).

Contrasting regions of the CCE were studied in May 2006 in the dynamic area off of Point Conception, CA. Picoplankton populations were analyzed by flow cytometry. Nano- and microplankton were enumerated and sized using automated epifluorescence microscopy with digital
image analysis and neural network cell identification. Mean euphotic zone values of total autotrophic biomass varied from 7.5 to 1.7 g carbon m\(^{-2}\) from coastal to offshore regions, respectively. Coastal upwelling and offshore oligotrophic stations also differed substantially in biomass depth distributions, size dominance and C:Chl a ratios. Contrasting regions in the CCE provide a significant opportunity to investigate how physical-chemical environmental conditions determine taxonomic composition, size structure and bio-optical properties of the plankton community (A. Taylor, M. Landry).

Continuous size spectra of nano- and microplankton were also determined (May 2006) based on analyses from digital image epifluorescence microscopy. Among different waters examined, auto- and heterotrophs showed similar size spectral patterns in the mixed layer, which may be a general system characteristic. The spectra however diverged at depth, with larger heterotrophs and smaller autotrophs becoming proportionally more abundant at the base of the euphotic zone. Predator-prey dynamics underlying these size relationships are being explored experimentally and in food web models (D. Taniguchi, M. Landry, A. Taylor).

Mesozooplankton grazing has been analyzed (M. Ohman and K. Tsyrlkevich) from both process cruises using size-fractionated gut fluorescence (> 0.2 mm, 0.5, 1.0, 2.0, and 5.0 mm). Mesozooplankton grazing is consistently dominated by the smallest size fractions in all locations. The smallest size fraction shows no evidence of diel periodicity in grazing, while the largest size fractions consistently show elevated grazing at night. This nocturnal increase is explained primarily by diel vertical migration (DVM) behavior rather than by periodic variations in feeding effort unassociated with DVM.

Grazer addition incubations conducted during the April 2007 Process cruise revealed contrasting grazing preference patterns for two system dominant mesozooplankton, with Euphausia pacifica showing plastic preference that varied with relative availabilities of prey sizes and types - while Calanus pacifica demonstrated more of a fixed size preference. Behavioral plasticity results in spatial differences in the potential grazing impacts on microplankton groups, which do not scale linearly with prey abundance (M. Decima, M. Landry, M. Ohman).

Over a broad range of ecological conditions from coastal upwelling to offshore oligotrophy studied during both CCE Process cruises, Th\(^{234}\) derived measurements of carbon export across the 100-m depth horizon averaged 10% of primary production. Contrary to expectations and the model of Laws et al. (2000), export ratio (ThE = export : production) was negatively correlated with primary productivity. Using a simple box model of the marine food web, ThE estimates were shown to be consistent with contemporaneous measurements of phytoplankton growth and micro- and mesozooplankton grazing processes (M. Stukel, M. Landry, C. Benitez-Nelson).

Augmented CalCOFI Cruises: Off Southern California, upwelling in the spring of 2007 began slightly early and was slightly stronger than usual. Over the last year mixed layer temperatures were significantly below long-term averages, consistent with the basin-wide La Nina conditions. After a 3-year period of anomalously low mixed layer salinities, these returned to values close to long-term averages in 2006 and rose to anomalously high values at the beginning of 2007, but decreased over the course of the year to values close to the long-term average. Since 2000 nitracline depths have been approximately 10 m below long-term averages. Early in 2007 nitracline depth anomalies for the whole CalCOFI region were similar to those observed since 2000; i.e. slightly below long-term averages. In the fall of 2007 and winter of 2008 nitracline depths declined to extremely low values, similar to the lowest observed values during the La Nina of 1989. Consistent with shallow nitracline depths, mixed layer concentrations of nitrate were elevated during 2007 and early 2008. In contrast, mixed layer concentrations of silicate and phosphate, when averaged over the seasons, were close to long-term averages, albeit variable. Whereas concentrations of silicate covaried with mixed layer salinity during the last 8 years, no such covariation was apparent during the last year. Concentrations of Chl a were similar to those observed over the last decades. No pronounced bloom was observed during the spring cruise â likely a function of timing rather than an absence of the spring bloom. Rates of primary production were similar to those observed during previous years.

Zooplankton demography: We completed one of the first analyses of spatial variations in zooplankton mortality rates (Ohman et al. 2008). This revealed that the copepod Calanus pacificus shows elevated rates of mortality in the nearshore zone influenced by coastal upwelling in the California Current, despite high primary production and elevated particulate food supply for copepod production in this region. This zone of elevated mortality is associated with a region of inferred predation by zooplanktivorous fish. This result implies that there are important spatial trade-offs between growth and mortality. Therefore studies that focus exclusively on feeding and growth, thus neglecting population mortality terms, will arrive at erroneous conclusions.

Fe limitation studies: Lagrangian studies during the April 2007 Process Cruise provided an opportunity to observe decoupling between nitrate and dissolved Fe in the mixed layer. Over the course of the 4-day experiment, dissolved Fe concentrations were drawn down significantly more than nitrate, increasing the nitrate:Fe ratio and resulting in iron stress in the phytoplankton community. Fe speciation measurements from on-deck incubation studies suggest that production of strong Fe(III) binding ligands occurs in situ and is correlated with the degree of iron stress on the planktonic community. In situ Fe speciation measurements made in conjunction with the Lagrangian study indicate a potential role for photolysis as a sink for excess Fe ligands.

Profile transects from inshore out completed in Nov 2006 and July 2007 reveal significant decoupling between Fe and nitrate in the vertical dimension. This represents an important area for future study.

Midwater trawling: Biomass of migratory midwater fish varied with distance from shore with a peak over the continental slope of 3.28 g m\(^{-2}\) at Cycle 4. The offshore oligotrophic station (Cycle 2) had the lowest mean wet weight biomass (0.63 gm-2). One trawl in the Santa Catalina
Part IV - One of the more intriguing findings from this year’s research was the substantial decline in dissolved oxygen observed at mid-depths have magnitudes that are roughly one to two orders greater than the offshore surface chlorophyll observed by CalCOFI. Pier and CalCOFI station 93.27 (12.5 km offshore) are on the continental shelf (water depth < 200m), but the Pier chlorophyll observations are coherent at low frequencies (3-7 years) with nearby offshore in situ surface chlorophyll observations at the CalCOFI station 93.27. Both the entire observing period, but a few strong El Niño and La Niña events have significant impacts on the Pier data. The Pier chlorophyll is highly variable over these two decades. The interannual variations of the Pier SST and chlorophyll is not correlated with tropical El Niño or La Niña conditions over the two decades. The annual mean Pier chlorophyll concentration exhibits a clear increasing trend with no concomitant trend evident in the Pier SST over these two decades. Consequently, classical coastal upwelling may not be the process that drives chlorophyll variations in the nearshore SCB.

Seasonal anomalies of the chlorophyll have no significant correlation with local winds, offshore winds, or upwelling index anomalies. The spring bloom occurs with irregular timing and intensity each year, unlike sea-surface temperature (SST), which is dominated by a regular seasonal cycle. In the 1990’s, the spring bloom occurred earlier in the year and with larger amplitudes compared to those of the 1980’s. Seasonal anomalies of the chlorophyll have no significant correlation with local winds, offshore winds, or upwelling index anomalies. Consequently, classical coastal upwelling may not be the process that drives chlorophyll variations in the nearshore SCB.

LOPC/SOLOPEC: D. Checkley’s findings to date are for the 2007 CCE LTER process cruise. These include estimates of the time-space distributions of particle size and abundance at the main stations sampled for a full cycle. In addition, his lab has estimated particle flux based on particle size distributions. A clear increase of particle abundance and flux was observed from offshore to inshore. Size spectra and EOF analyses of those spectra are consistent with three main classes of particles, i.e. aggregates and small zooplankton (100-1000 microns equivalent spherical diameter, esd), large copepods (1-2mm esd), and euphausiids (2-5 mm esd).

Bio-optical measurements: Coastal and offshore waters of the CCE study site had very different phytoplankton community structure and environmental forcing of photosynthetic physiology. We observed very low variable fluorescence (Fv/Fm) in the upper mixed layer of the offshore anti-cycloonic eddy area, indicating pronounced nutrient stress. The phytoplankton assemblage consisted mainly of small-sized Prochlorococcus, Synechococcus and Prymnesioflagellates, having low quantum yield of carbon fixation. In coastal eutrophic water, on the other hand, diatoms dominated the community with higher quantum yield. The data acquired during the LTER P0704 process cruise (April 2007) with a new instrument, the Advanced Laser Fluorometer (ALF, A. Chekalyuk), were thoroughly analyzed. The ALF is a portable instrument that provides underway flow-through measurements and discrete sample analysis for characterization of the key aquatic constituents, including chlorophyll-a (Chl-a), phycobiliproteins and chromophoric dissolved organic matter (CDOM). New valuable information about spatial and temporal variability in phytoplankton pigments, photophysiology, community structure and CDOM was retrieved from the ALF measurements.

Though high correlation was observed between the fluorescence and HPLC assessments of Chl-a, it was found to be non-linear in the offshore waters of the California Current. The ALF capacity for discriminating 3 spectral types of phycoerythrin was used for characterization of cryptophytes vs. ‘coastal’ vs. ‘oceanic’ cyanobacteria in the mixed algal populations. The pump-during-probe (PDP) measurements of variable fluorescence were spectrally corrected for the emission of CDOM and other constituents to improve assaying the phytoplankton photophysiological status. Overall, the ALF instrument and its analytical algorithms have been shown to be a useful integrated tool for research and observations within the LTER CCE Program. Our recent publication (Kahru and Mitchell, 2008) shows that during the last 11 years (the period of availability of modern satellite ocean color) many areas in the world, most notably the eastern boundary currents like the California Current, are experiencing significant increase in phytoplankton bloom magnitude. This is one of the first results showing global environmental change using satellite ocean color.

Spray ocean gliders: A study with autonomous Spray ocean gliders (Davis, Ohman, et al. 2008) has uncovered persistent mesoscale frontal features that extend from physical properties through phytoplankton chlorophyll and zooplankton acoustic backscatter. Calculations of a structure function from the glider data revealed that mesoscale spatial structure is considerably more developed in the spring-summer than in the fall-winter, which implies a more spatially heterogeneous prey field in spring-summer and likely benefits to motile predators of seasonally variable search patterns.

Ecosystem modeling: Part II - Our continuum size-structured model (P. Franks and CCE colleagues) shows that planktonic diversity is strongly controlled by the characteristics of the grazers and predators. Systems dominated by generalist grazers tend to be much less diverse than systems with specialist grazers. The model gives realistic size spectra of phytoplankton and zooplankton, allowing us to compare the theoretical spectra to those gathered during the CCE LTER field program. Coupling the continuum model to ROMS has shown that vertical mixing can change the vertical distribution of size structure, filling in gaps in the size spectra, and forming pronounced subsurface maxima in phytoplankton biomass and size.

Part III - The first analysis of the 18-year Scripps Pier chlorophyll dataset was completed by former graduate student H.-J. Kim (Ph.D. completed April 2008). Surface chlorophyll measured at the Pier in the Southern California Bight (SCB) from 1983 Ú 2000 reveals that the spring bloom occurs with irregular timing and intensity each year, unlike sea-surface temperature (SST), which is dominated by a regular seasonal cycle. In the 1990’s, the spring bloom occurred earlier in the year and with larger amplitudes compared to those of the 1980’s. Seasonal anomalies of the chlorophyll have no significant correlation with local winds, offshore winds, or upwelling index anomalies. Consequently, classical coastal upwelling may not be the process that drives chlorophyll variations in the nearshore SCB.

The annual mean Pier chlorophyll concentration exhibits a clear increasing trend with no concomitant trend evident in the Pier SST over these two decades. The interannual variations of the Pier SST and chlorophyll is not correlated with tropical El Niño or La Niña conditions over the entire observing period, but a few strong El Niño and La Niña events have significant impacts on the Pier data. The Pier chlorophyll is highly coherent at low frequencies (3-7 years) with nearby offshore in situ surface chlorophyll observations at the CalCOFI station 93.27. Both the Pier and CalCOFI station 93.27 (12.5 km offshore) are on the continental shelf (water depth < 200m), but the Pier chlorophyll observations have magnitudes that are roughly one to two orders greater than the offshore surface chlorophyll observed by CalCOFI.

Part IV - One of the more intriguing findings from this year’s research was the substantial decline in dissolved oxygen observed at mid-depths
Throughout the CCE-LTER region. We (S. Bograd and CCE colleagues) quantified significant declines in oxygen at most CalCOFI stations, which effectively resulted in a shoaling of the hypoxic boundary on the continental shelf by up to 90 m. Expansion of the oxygen minimum zone could lead to cascading effects on the local benthic and pelagic ecosystem, including habitat compression and community reorganization.

Seabird observations: Recently, the most significant finding from this research has been the substantial increase of planktivorous auklets in the CCE study area during July 2005 (Sydeman et al. 2006), 2006 (Peterson et al. 2006), and 2007 (Goericke et al. 2007). The increase in auklets in the study area has occurred at the same time as the largest population in California (that of the Farallon Islands) has shown unprecedented reproductive failures. These findings suggest that auklets from central California dispersed to southern California in search of food. The significance of these observations is that while the California Current may be considered one large marine ecosystem, there are apparent regional variations. The auklet is an obligate planktivorous species, feeding primarily on the euphausiids, E. pacifica and T. spinifera. The fact that the auklets migrated to southern California after abandoning their colony in central California suggests that euphausiids were more abundant to the south. We plan to continue these observations into the foreseeable future, and conduct new studies on auklet movements and euphausiids (analysis of acoustic data) to better understand the dynamics of this predator-prey relationship.

Information Management: Having established a local, long-term informatics environment supporting CCE research through articulation work (Baker and Millerand, 2007 HICSS), enactment mechanisms (Millerand and Bowker, in press), and recognition of distinct knowledge provinces (Baker and Millerand, 2007, ASIST), comparative studies were undertaken within the Ocean Informatics framework that led to articulation of a set of informatics strategies for marine science (Baker and Chandler, in press) and to definition of information infrastructure (Bowker et al, in press). We have also explored information issues associated with data curation and the digital library community (Karasti, Baker, and Schmidt, 2007; 'Databits'-Yarmey, 2008a, 2008b) and have proposed an augmented approach to the school of Participatory Design (Karasti and Baker, in press).

2007 Process cruises: Initial results of phytoplankton growth and grazing experiments from CCE Process cruise P0605 were presented as part of an analysis of trophic transfer efficiencies in different ocean systems (M. Landry, 4th Intl Symposium on Zooplankton Production, Hiroshima, Japan). This analysis revealed a trend between community size structure and transfer efficiency of primary production to higher trophic levels among systems where production was tightly coupled to grazing losses. However, trophic transfer efficiency in coastal systems with large phytoplankton and metazoan grazers can also be less efficient than in small-phytoplankton dominated systems when production and grazing processes become loosely coupled during phytoplankton blooms in the richer coastal ecosystems. Graduate student M. Decima reported on results of the first experimental studies on brood size in Euphausia pacifica from the P0605 cruise (LTER-All Scientists Meeting). A multiple regression analysis (stepwise regression technique) was run to choose the appropriate predictors of brood size. Among female length and various size classes of Chla, the only significant predictor was an unexpected negative correlation with large phytoplankton (>20-Ám Chla). Also, initial export flux results from the P0605 cruise (M. Stukel, ASM) showed high Thorium-disequilibrium deficiencies were found throughout the study region with a modest trend consistent with the onshore-offshore gradient of trophic richness. These measurements still need to be converted to carbon-based estimates of export flux with further analyses of the C:Th ratios in the large particle field. However, they were sufficiently promising to expand the export measurements to include direct sediment trap measurements of sinking material and its elemental and biological characteristics on subsequent Process cruises.

Theoretical ecology: We discovered that time series of natural populations of marine pelagic organisms sometimes show linear dynamics, in contrast to the more common circumstance of nonlinear population variability. We proposed the Linear Tracking Window hypothesis (Hsieh and Ohman 2006) to explain this phenomenon: populations are most likely to track linear stochastic environmental forcing when their generation time matches the characteristic time scale of the environmental signal. This concept provides a means to predict which types of populations will be most affected by variations in the physical environment. This result seems to have attracted the interest of a number of ecologists across the LTER network and elsewhere, in addition to our marine colleagues.

Zooscan: After a considerable investment of time and effort, we (Ohman's Lab) have now achieved reproducible results with digital scanning of preserved zooplankton samples together with automated image analysis. We have analyzed 142 vertically stratified MOCNESS samples from 4 experimental cycles from the first CCE LTER Process Cruise (P0605). A total of 235,000 objects was enumerated and measured using digital image processing methods. Of seven classifier algorithms evaluated, the Random Forest algorithm consistently provided the best results (i.e., highest true positives and lowest false positives). We also experimented with different levels of aggregation of categories of organisms, and compiled the following five categories identified with high fidelity from these samples: copepods other than eucalanids, eucalanid copepods, chaetognaths, euphausiids, and other zooplankton. Our analyses revealed a nonlinear dependence of the copepod size spectrum on the proportion of edible phytoplankton in the water column in our LTER site. We also uncovered a size-dependence of diet vertical migration behavior by copepods, reflecting three different types of copepod behavior that are strongly influenced by body size. These results have implications for forecasting long-term changes in California Current food webs.

Fe limitation studies: Dissolved Fe samples collected between 2002-2006 were analyzed. New samples were collected on cruises in Nov 2006
and April 2007. Our growing data set of dissolved Fe concentrations in the Southern California Bight region is providing us with an improved picture of how availability of this important micronutrient changes spatially, seasonally and inter-annually in our study area. On the April 2007 Process Cruise, in addition to collecting dissolved Fe samples, the Barbeau Lab continued to investigate the influence of Fe on phytoplankton growth and community structure under various regimes (forced by different processes) within the southern California Current System. Surface (~5-10 m) seawater was used for shipboard Fe addition grow-out bottle experiments to evaluate the influence of Fe on phytoplankton growth and community structure when nitrate was present. Fe limitation was evaluated based on changes in chlorophyll a (chl a) in control (unamended) and Fe-addition (+5 nM FeCl3) experiments. Preliminary results indicate that Fe was at times a limiting nutrient in two upwelling water masses (4-day cycles) located within the CCE study site. Additional data from these incubation studies is currently being analyzed.

Dissolved/particulate organics (C&N): The Aluwihare lab has developed a method for isolating sugars from our DOM samples, and the first radiocarbon measurements on purified fractions confirm that carbohydrates are representative of modern DOM (those dissolved compounds that are derived from recent biological production) accumulating in the surface ocean reservoir. We will compare data on the 14C content of sugars obtained during the 3 cruises (May 2006 cruise, November 2006 and April 2007). If the mild El Nino leads to observable changes in surface ocean 14C-DIC which is, in turn, transferred to the carbohydrate fraction, then we will have conclusive evidence in support of an annual flux through the carbohydrate reservoir. Regardless, these measurements will provide the first time series data on 14C of DOM fractions. Preliminary surface ocean 15N-POM data show values similar to deep ocean 15N-nitrate in near coastal and open ocean waters; more elevated values are observed in the California Current. At all sites sampled during the CCE Process cruise #1, water masses were followed for approximately 5 days to study the evolution of the biology and chemistry. During most of these experiments, an increase in POM corresponded to an increase in 15N-POM as expected (based on the Rayleigh Fractionation model), suggesting that during these 5 day experiments, additional inputs of ‘new’ N was not detectable.

Bio-optical measurements: Results from the various underway FRRF measurements (Mitchell, Process cruise #2) indicated highly variable photosynthetic physiology of phytoplankton in the dynamic CCE study site. Among the interesting observations of the ALF flow-through fluorescence assessment of seawater constituents was a consistently observed increase in the relative abundance of the accessory phycobiliprotein pigments (phycocyanin, and allophycocyanin) vs. chlorophyll-a towards and below the bottom of the euphotic layer. This may suggest respectively elevated relative abundance of cyanobacteria vs. eukaryotes in the phytoplankton community.

Moving Vessel Profiler (MVP, Ohman): Our MVP has proven invaluable for the LTER process cruises. It includes an LOPC (Laser Optical Particle Counter), Chla fluorometer, and rapid response CTD. It is operated in computer-controlled free fall mode with the ship underway at 11-12 kts. The MVP is our principal tool for identifying fronts and other spatial structures for our Lagrangian water-parcel tracking experiments. It is typically used to map the along-flow and across-flow gradients surrounding the satellite-tracked drifter and sediment trap. We have developed Matlab scripts to rapidly process MVP data at sea, permitting near real-time display of 3-dimensional sections of distributions of planktonic particles and the associated physical environment.

VPR (Video Plankton Recorder): We found sharp transitions in planktonic faunal and floral compositions associated with the major cross-shore frontal systems in the California Current. The locations of these biotic fronts were used to position the driftarrays for our experimental cycles.

Seabird observations: In 2006, the Cassin’s Auklet, a dominant planktivorous seabird in the system, abandoned breeding colonies in central (Farallones) and southern (Prince Island) California for the second year in a row. Observations on CCE LTER cruises indicated a large spike in abundance in July 2006 corresponding to this large-scale breeding failure, and suggesting a redistribution of the birds from the central-northern CCE to the southern CCE.

Information Management: We are finding the focus of a local, long-term informatics environment benefits from articulation work (Baker and Millerand, 2007 HICSS), enactment mechanisms (Millerand and Bowker, in press), and recognition of design strategies for differing knowledge provinces (Baker and Millerand, 2007, ASIST). Further, acting upon an understanding of information infrastructure as an intertwined set of social, technical and organizational arrangements is critical to providing new ways to support contemporary mandates for work with scientific data (Bowker et al, in press; Millerand and Baker, accepted; Baker and Bowker, 2007; Karasti et al, 2006).

Ecosystem modeling: 1) The size-structured model of Fuchs and Franks gives continuous size spectra when a grazing kernel in the shape of a Laplace distribution is used to define the size preferences of grazers and predators. Changing the width of this distribution suggests that ecosystems dominated by generalist predators should have more biomass, fewer size classes, fewer top predators, and steeper and gappier biomass spectra than ecosystems with specialist predators. These results have important implications for the California Current Ecosystem, where the relative abundances of some generalist predators have been correlated to climate oscillation indices. 2) An analytical model that predicts two optical effects of the euphotic zone on the nitracline has been developed (Aksnes, Ohman, and Riviere 2007). The nitracline depth should vary inversely with light attenuation for downwelling irradiance, and the nitracline steepness should be directly proportional to light...
attenuation. This model reproduces features observed in the CalCOFI dataset (nitrates and Secchi depths). The optical effect on the nitracline may involve positive feedback mechanisms with phytoplankton production that have implications for interpretation and modeling of primary production. 3&4) The analyses of Riviere showed that it was most appropriate to calculate the nitrate flux through the base of the euphotic zone, rather than across a density or pressure surface. The euphotic depth has remained relatively stable in the CalCOFI region over the past 50 years, while the relationship of nitrate to density has changed. Long-time-scale changes in the nitrate-salinity relationship drive changes in the potential for vertical mixing of nutrients, as the nitracline moves vertically across isopycnals. These long-term changes appear to be uncorrelated with the PDO, but are strongly correlated with the second mode of variability in the North Pacific (Di Lorenzo et al in prep). This mode controls the alongshore flux of source waters into the CCS, and drives changes in the salinity and nutrients. We are presently using basin-scale models to understand the mechanisms and implications of this finding.

2006
Modeling

1) Ecosystem modeling: We have formulated a novel continuum size-structured planktonic ecosystem model. As in previous NPZ models, we classify organisms as either autotrophs P or heterotrophs Z with biomass in units of nitrogen N. This model differs from previous size-structured models in that both P and Z have continuous size distributions. The phytoplankton maximum growth rates are scaled allometrically. Zooplankton graze on both zooplankton and phytoplankton, and grazing preferences depend only on the predator/prey size ratio and the abundance of prey. The system is closed, i.e. the total nutrient in the system is constant and there is no transfer of biomass to higher predators. The model produces stable solutions even with unsaturated grazing. Here we explore the use of different grazing kernel distributions. Only a Laplace distribution produces smooth biomass spectra under a wide range of grazing kernel parameters and total nutrient levels. We find that when grazers are able to consume prey with a broad size distribution, very few size-species can persist. When grazers are specialized to consume prey with a narrower size distribution, hundreds of P and Z size-species can co-exist and the biomass spectra appear continuous. We will use this model with California Current Ecosystem LTER cruise data to estimate important parameters and to test hypotheses about effects of climatic forcing on ecosystem structure and plankton biomass. This model is easily adapted to include greater trophic diversity, and we will also use it to assess the effects of complex trophic interactions such as mixotrophy on ecosystem structure.

2) Retrospective data analysis and physical modeling: A major question driving our research concerns the mechanisms and temporal and spatial scales of nutrient inputs to the euphotic zone in the LTER study region, and how those nutrient inputs structure the ecosystem. In preparation for performing process-oriented 3D physical models of nutrient dynamics, it was necessary to define the most appropriate methods for determining fluxes. Analyses of CalCOFI data showed the importance of the euphotic depth in determining the vertical and horizontal gradients of nitrate. The relationship of the euphotic depth to the hydrography has changed over the last 50 years, as has the vertical structure of the nutrient and hydrographic fields (depth of mixed layer, strength of the pycnocline, etc.). We have found a method for quantifying phytoplankton patchiness resulting from nutrient injection events, and have begun constructing physical models to test our hypotheses.

Seabird observations: We continued the long-term program of at-sea surveys of marine bird and mammal distributions during seasonal CalCOFI cruises, initiated in the spring of 1987. This time series of historical observations allowed us to characterize seabird distributions with respect to meso-scale oceanographic features over a 17-year period (Yen et al. 2006). These analyses highlighted the importance of dynamic hydrographic features as areas of seabird aggregation in this environment.

The more recent survey data collected during 2005 - 2006 allowed us to document inter-annual variability in seabird distributions during the anomalous oceanographic conditions in the spring and summer of 2005 (Sydeman et al. 2006). In conjunction with colony-based observations of seabird reproductive timing and productivity, the at-sea surveys demonstrated a major geographic re-distribution of a planktivorous seabird in response to an apparent decline in the abundance of their euphausiid prey.

Fe limitation studies: Over the past year we have focused on refining our iron analytical methods so that we can analyze a backlog of samples from previous cruises, as well as begin developing a seasonal and interannual data set of Fe concentrations in the Southern California Bight as part of our contributions to the CCE LTER biogeochemical data set. Graduate student Andrew King has successfully set up a flow-injection analytical method for total dissolved iron analysis, based on sulfite reduction of Fe(III) with luminol chemiluminescence detection. King verified this technique in April 2006 by completing analysis of the newly available SAFe (Sampling and Analysis of Fe) surface and deep seawater standards (our values 0.100 & 0.015 nM (surface standard) and 0.915 & 0.027 nM (deep standard); consensus values currently 0.099 & 0.04 nM and 0.91 & 0.18 nM). King has now completed analysis of a series of archived dissolved Fe samples from spring and summer 2004. The iron data, combined with our Fe addition incubation results, are improving our understanding of nutrient biogeochemistry and the factors controlling phytoplankton growth and biomass in the Southern California Bight (SCB). The attached figure (1) shows how variations in sea-surface Fe and NO3 concentrations with distance offshore correlate with Fe addition incubation results, allowing us to define different biogeochemical regimes within the SCB. The transition zone between coastal and offshore waters appears to be a region prone to iron limitation, particularly in summer when NO3:Fe ratios are relatively elevated.

In addition to examining the influence of iron limitation on phytoplankton communities in the mixed layer of the SCB, we are also studying the influence of iron-light colimitation on phytoplankton populations at the deep chlorophyll maximum in the SCB. These investigations are motivated by laboratory experiments showing that phytoplankton iron requirements are determined primarily by the need for iron-rich
photosynthetic proteins. Ship-board iron and light manipulation experiments that we have conducted in the Eastern Tropical North Pacific as well as the SCB indicate that phytoplankton, particularly large diatoms, can be co-limited by iron and light in the subsurface chlorophyll maximum where light levels are low. By selectively inhibiting the growth of large diatoms, this co-limitation modifies phytoplankton community structure potentially affecting the rate of carbon export and pelagic food web structure.

On the May 2006 CCE LTER process cruise, the Barbeau group investigated the influence of Fe on phytoplankton growth and community structure in conjunction with the in-situ array experiments carried out in various regimes within the southern California Current System. Barbeau group participants included Andrew King, Brian Hopkinson, and Christopher Dupont, all graduate students. Work conducted on the cruise included Fe-addition grow-out bottle experiments with both mixed-layer and deep chlorophyll maximum populations. We also took our flow-injection chemiluminescence analysis system to sea for the first time for near real-time measurements of total dissolved Fe.

Data from this cruise are still being processed. Preliminary analysis of dissolved Fe concentrations measured at in-situ array cycles 1 through 4 were relatively consistent with distance from shore, and thus depth of the seafloor, ranging from 1-2 nM at nearshore stations to about 0.2 nM for the furthest offshore stations. This is consistent with our previous data for the region (see Fig 1). Surface (~5-10 m) seawater was used for shipboard Fe addition grow-out bottle experiments to evaluate the influence of Fe on phytoplankton growth and community structure when nitrate was present. Fe limitation was evaluated based on changes in chlorophyll a (chl a) in control (unamended) and Fe-addition (+5 nM FeCl3) experiments. At a nearshore, upwelling regime (cycle 1), where macronutrients and dissolved Fe appeared to be high, Fe was a limiting nutrient only at the end of a 4-day period (an experiment on day 1 indicated that Fe was replete). At an offshore, deeply wind-mixed regime (cycle 4), Fe appeared to be a limiting factor on the 3rd day and more severely limiting on the 5th day of a 5-day period. Several incubations with water from the deep chlorophyll maximum conducted on this cruise also indicated effects of Fe-light co-limitation, as we have observed previously.

Ocean Informatics: We have found three distinct elements - participatory design methodology, cross-project comparative strategies, and interdisciplinary collaboration - contribute to building of a program information system and its associated infrastructure. The significance of these elements is three-fold: 1) facilitating data handling in support of site science; 2) creating an effective environment for informatics and data modeling; and 3) addressing long-term data stewardship.

2005
Iron limitation of phytoplankton growth in the CCS has been consistently observed during the spring and summer at a subset of stations in the transition zone between coastal upwelling and oligotrophic waters offshore (King and Barbeau, ASLO 2005 poster).

Time series of physical ocean and atmospheric variables were found to have linear, stochastic characteristics (red noise), while biological time series were found to have nonlinear signatures. This result, published in Nature (Hsieh et al. 2005), implies that biological characteristics of ecosystems have different dynamics and cannot be forecast from physical measurements alone.

Decadal variations in fluxes of organic matter to the deep sea in the CCS were found to be related to long-term variations of satellite-reconstructed primary production, using a modified Behrenfeld and Falkowski model applied to SeaWifs data (Ruhl et al. 2005)

Signatures of subduction of upwelled water were observed throughout the historic CalCOFI record. These results imply that the processes leading to the subduction, cross-shore transport, and downstream advection of upwelled water masses are common and persistent in the California Current System (Bograd and Mantyla 2005).

CCE has contributed to the conceptual as well as the physical development of infrastructure to provide a computational environment for the work of information management (Baker et al. 2005).

Training and Development:
2008
The CCE LTER program has provided excellent research opportunities and dissertation topics for numerous SIO graduate students (25), postdocs (6), and undergraduates this past year.

Graduate student H.-J. Kim completed her PhD in April (co-PI A. Miller's student), having analyzed the Scripps Pier chlorophyll dataset. Two of K. Barbeau's graduate students successfully defended their theses - B. Hopkinson (Nov. 2007) and A. King (May 2008), regarding Iron/light colimitation, and Iron distribution and phytoplankton iron limitation in the southern California Current System, respectively.

Six postdocs have been trained within various elements of the CCE LTER program, two of which were trained in the development and
implementation of physical-biological models during the past year.

The first 'UC-LTER Graduate student/postdoc symposium' (cooperative between CCE, SBC, and MCR sites) was held in May 2008, coordinated by Graduate student R. Rykaczewski. Oral talks and posters representative of the LTER research were shared amongst the participants and others attending.

CCE LTER REUs Randelle Bundy and Kate Tsyrklevich worked with the Barbeau lab and Ohman lab, respectively, during summer 2007 and continued to work in the labs during the 2007/2008 school year on their ESYS projects. Both K. Barbeau and M. Ohman supervised their senior theses at UCSD.

M. Landry has provided supervisory committee and image analysis support for Lorena Linacre, a PhD student at CICESE (Ensenada) who has done CCE-relevant research at an upwelling study site off Punta Banda, Mexico.

The CCE LTER Process cruise results were included as a significant part of a new UCSD undergraduate course, California Coastal Oceanography, instructed mostly by two co-PIs (L. Aluwihare and M. Landry). As part of that course, students were taught how to access DataZoo and do problem sets with CCE LTER/CalCOFI data. Also, two UCSD undergraduate students (D. Wick, E. Daniels) participated in CCE microscopical studies during the current year under M. Landry's supervision.

Education and Outreach: We have continued to select candidates to participate in the Research Experience for Teachers (RET) program through sLTER funds. C. Milsap will continue her work as an RET developing online teachers resource materials based on the Chlorophyll-Temperature Time Series data, as well as facilitate cooperative efforts with our partners at the Ocean Institute.

2007

Nineteen Ph.D. graduate students at SIO, and one from Oregon State Univ. have been involved with this project, most of whom have gained considerable experience and valuable research opportunities for dissertation topics from CCE cruises and related modeling studies.

In addition to U.S. students, on the April 2007 process cruise, two visiting students (J.-B. Romagnan and J. LeBlond) from French Universities benefited from CCE cruise experience and project data for their Masters degrees. A Mexican Ph.D. candidate (L. Linacre, CICESE) learned experimental skills in the seawater dilution method that are directly applicable to her research.

This research has led to the training of many postdocs: H. Fuchs has gained considerable skill in modeling, data mining, and computer programming (under P. Franks); K. Chhak (under E. Di Lorenzo); and in France, C. Perruche and M. Raimonet (grad. student) are working on CCE LTER-related modeling projects under P. Riviere. In the bio-optics arena at SIO, H. Wang has been trained as a postdoc under B.G. Mitchell, K. Buck in the Barbeau Lab, and J.R. Ward in F. Azam's bacterial lab.

Two REUs joined CCE investigators (Barbeau and Ohman) for educational research experiences for the summer.

Two high school students (A. Tang & L. Lopez) worked in the Aluwihare lab and learned a variety of simple lab concepts. Neither had received any significant exposure to the marine sciences, or had interacted with a female professor or graduate students. The students provided a valuable mentoring experience for two graduate students in Aluwihare's lab as well.

Two courses were taught in Spring 2007: a new undergraduate course, 'California Current Oceanography,' taught by Co-PIs M. Landry and L. Aluwihare, focused on physics, chemistry and biology of the California Current, including research being conducted by CCE LTER PIs. Lead PI, M. Ohman, taught an SIO graduate seminar class, which concerned 'California Current Ecosystem Dynamics.'

2006

This project is providing research opportunities and dissertation topics for a sizable cadre of graduate students. Two completed PhD's in the past year (Hsieh and Ruhl). Eleven other graduate students participated in the recent Process Cruise, most of whom are pursuing thesis topics relevant to the CCE site.

This work has resulted in the training of a postdoc (Fuchs) in interdisciplinary oceanographic research.

Information based on our research has been incorporated into several graduate courses at SIO and at least one undergraduate course at UCSD.

The Education Coordinator (Simmons) has initiated development of instructional modules for the K-12 environment.
Seventeen graduate students participated in a seminar analyzing the scientific approaches taken and research at selected sites in the U.S. LTER and International LTER network. This promoted greater understanding of the 'invisible present,' the importance of the time dimension in ecology, the merits and challenges of interdisciplinary research, and the advantages of different approaches (manipulative experiments, long-term observations, natural experiments, modeling) to enhanced scientific understanding.

Two CCE graduate students made presentations at the graduate student LTER symposium at the Andrews forest LTER site in spring, 2005.

Five graduate students (Brian Hopkinson, Chih-hao Hsieh, Hey-Jin Kim, Andrew King, Henry Ruhl) have participated directly in LTER research activities related to their thesis research.

An SIO-based LTER graduate student group has been formed and a chair selected.

**Outreach Activities:**

2008

M. Landry (co-PI) participated in examination of dissertation proposal and general knowledge examination of international PhD student L. Linacre; Two LTER students (M. Stukel and M. Decima) were active in summer 2007 outreach programs 'Beneath the Surface: Concepts in Biological Oceanography,' UCSD Academic Connections.

K. Barbeau (co-PI) coordinated the search for undergraduates for available CCE LTER REU positions in spring 2008. A. Miller (co-PI) served as an event coach for Oceanography in the Science Olympiad for University City High School (San Diego). The oceanography team placed 5th in the state (Southern California) competition.

Education and Outreach: CCE research has been disseminated through a variety of outreach efforts in the public domain, in classrooms, and universities, national and international collaborations (B. Simmons). Some activities included: 1) participation in the SIO pier walk - allowing people to get involved with outreach opportunities on the pier by attending informative sessions themselves; 2) hosting Rancho Santa Fe Middle School students (Day of Outreach); 3) attending the 2007 National Marine Educators Association meeting; 4) development of the CCE Outreach Webpage with high school student and volunteer on web page design/development; and 5) setting up an online liason RET position (C. Milsap, Rancho Bernardo High School) for curriculum development and interface with Ocean Institute, our CCE outreach partner.

The better part of this year has been spent coordinating and producing a collaborative children's book titled, 'Sea Secrets: Tiny Clues to a Big Mystery.' It received funding from the sLTER Children's Book Fund (proposal submitted Feb. 2008). The story is for children (ages 5–8), written by M. Cerullo and B. Simmons, and illustrated by K. Carlson. It is a story about three distinctly different animals (a whale, penguin and auklet). The oceans from the California Current down to the polar waters west of the Antarctic Peninsula are explored, involving readers to uncover the link between all three. The book will continue to be a focus for the CCE Education and Outreach program as we enter the second phase of its production and marketing in summer 2008. Participation at the 2008 National Marine Educators Association will lend itself to announcing the book and evaluating the level of interest as a mechanism for outreach.

2007

CCE LTER 'Picture of the Day' was initiated on the April Process Cruise #2 (Barbeau's Lab A. King and E&O coordinator B. Simmons) for viewers on land to get a first-hand digital look at researchers and equipment used at sea, along with technical information for educational purposes. http://barbeaulab.ucsd.edu/cepod.html

Also, K. Barbeau and A. King participated in the UC San Diego COSMOS program for Grade 8-11 students, 'The Living Oceans and the Impacts of Climate Change,' in late summer.

M. Landry continues service on the Advisory Board of the California COSEE Program; Two of his grad. students (Stukel and Decima) continue to teach in outreach programs with K-12 students, 'Beneath the Surface: Concepts in Biological Oceanography,' UCSD Academic Connections (summer 2007).

CCE cruises: Six individuals received at-sea training as volunteers on the Process cruise (P0704), as well as several others on quarterly CalCOFI cruises, gaining valuable skills in conducting research at sea and knowledge from investigators.

Including high school students in the lab research component has been the major outreach contribution to date for L. Aluwihare. In addition, helping teachers with developing their chemistry curriculum and involving them in lab research has proved very valuable. Also, providing
Aquatic Adventure's staff an opportunity to participate on cruises has benefited enormously in their own classrooms.

Education and Outreach: We have captured the essence of outreach, the concepts of ecological studies, federated network collaboration, and the use of authentic inquiry science through various involvements (B. Simmons). These included: 1) RET and collaborations - 'Tale of Two Krill' Curriculum writing/Children's Book Project (Palmer site scientists R. Ross and L. Quentin, CCE Lead PI, M. Ohman, local high school teachers, and the site education coordinator), all contributing to the development of specific instructional modules comparing two species of krill and their role in ocean food web dynamics; 2) Initiation of the 'Picture of the Day' on the 2nd Process cruise in April; 3) Meeting with Exploratorium leader for future collaborations for CCE Outreach; 4) Hosting a day of outreach for middle school students at SIO; and 5) Participating in the annual NMEA meeting.

Ongoing support for our outreach partner (Ocean Institute) has been taken to the next level of posting nearshore phytoplankton and temperature data on our Ocean Informatics website.

2006

With one of our E&O partners, the Ocean Institute (OI) in Dana Point, California, we have initiated a nearshore program of analysis of covariability of phytoplankton and physical properties of the water column. During student cruises at OI (ca. 150 days per year), the middle and high school students take water samples for the analysis of total Chlorophyll a, the picoplankton fraction of Chlorophyll a, and temperature, as a part of the OI curriculum discussing primary and secondary production in the ocean. The Dana Point time series will also permit comparison with a similar nearshore program at Scripps pier.

Other training: Five individuals participated in the LTER process cruise as volunteers and acquired valuable skills in modern methods of seagoing research.

In 2004, Landry initiated a large (150 students) undergraduate course on Biological Oceanography, the first of its kind at UCSD. Two undergraduate students from this course (Andrew Taylor, Emy Daniels) have learned analytical techniques in Landry's lab with paid summer research positions. An additional student volunteer (Daniel Lee) worked in Landry's lab through AY05-06 and participated on the 2006 CCE Process cruise. Mr. Lee recently began graduate studies in oceanography at the University of Maryland, Chesapeake Biological Lab. Landry is on the Advisory Board of the California COSEE Program. During the funding period, he also actively participated in an educational workshop for K-12 science teachers (Tiburon, October 2004) and interacted with teachers-at-sea on two major oceanographic cruises (December 2004, September 2005), including ship-based, live-feed interactions and discussions with middle school students.

Two LTER graduate students, M. Stukel and M. Decima, have been active in summer outreach programs with K-12 students in the San Diego area. They participated as instructors in Aquatic adventures: Labs for Youths (3 weeks, summer 2005). This summer they are co-teaching a course entitled: 'Beneath the Surface: Concepts in Biological Oceanography', UCSD Academic Connections (summer 2006).

The Barbeau lab's Education and Outreach activities include:

2006 Mar 7 to Mar 9: UC Santa Cruz Workshop on Inquiry Based Instruction (participant Andrew King, as representative of UCSD COSMOS program).

2005 July 11 to Aug 5: UC San Diego COSMOS program for Grade 8-11 students (18 students), 'Living Oceans and the Impacts of Climate Change.' (Primary instructors Kathy Barbeau, Andrew Dickson, and Jeff Graham. Graduate student Andrew King worked as TA.)

2005 May 14: TRIO Marine Science Day for Grade 6-10 students (~80 students), phytoplankton and zooplankton lab and field activities. (participants Andrew King and Brian Hopkinson)

The Education Coordinator (Simmons) is actively developing middle and high school curriculum elements based on research at the CCE site.

2005

We have hired a part-time education and outreach coordinator, Ms. Beth Simmons, who is a certified teacher knowledgeable about both grade-level standards in the public school system as well as effective pedagogic techniques. She and K. Baker have coordinated the visit of two authors of children's books about the ocean environment (Lucy Bledsoe of the NSF Artists and Writers Program, and Mary Cerullo of Friends at Cosco Bay) to the Preuss school, a San Diego charter school intended for first generation college bound students from traditionally underrepresented groups. The authors' visits were enthusiastically received by the students, stimulating considerable interest in the subject matter. Discussions have been held with the authors to develop a plan for a children's book focusing on the California Current ecosystem.

Contacts have been made with Harry Helling of the Ocean Institute, a seagoing elementary-to-high school educational institution in Dana Point, CA, to develop a nearshore chlorophyll a time series project in conjunction with our LTER observations. Students will be involved in the
collection, analysis, and interpretation of the data.

Barbeau and King are involved in the 2005 COSMOS program at UCSD (California State Summer School for Mathematics and Science, a program for high school students). They are participating in the development of the 'Life in the Oceans' course which will be part of the COSMOS cluster at SIO. This course will cover marine food webs and the influence of environmental factors on planktonic marine ecosystems.

Journal Publications


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Bibliography: LTER Network Office


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Collection: Theoretical Ecology
Bibliography: Oxford University Press

Web/Internet Site

URL(s):
cee.lternet.edu
Description: California Current Ecosystem LTER website
Others associated with CCE LTER:
- Barbeau Lab: http://barbeaulab.ucsd.edu
- "Picture of the Day" from CCE LTER Process Cruise (P0704): http://barbeaulab.ucsd.edu/ccepod.html
- Ken Smith's group at Monterey Bay Aquarium Research Institute http://www.mbari.org/pelagic-benthic/
- Ocean Informatics group(IM) for data, resources, and management http://oceaninformatics.ucsd.edu/datazoo
- CCE LTER Education and Outreach Website: http://cce.lternet.edu/outreach/
- Sea Secrets: Tiny Clues to a Big Mystery (Children's Book Webpage) http://cce.lternet.edu/outreach/seasecrets
and IPY Polar Books Website - http://www.grida.no/polarbooks/
- ZooDB (an interactive web-based search engine, to retrieve and display extensive, detailed zooplankton enumerations from the CalCOFI zooplankton samples) https://oceaninfo-dev.ucsd.edu/zoodb/

Other Specific Products

Product Type: Physical collection (samples, etc.)
Product Description: Zooplankton samples accessioned into the SIO Pelagic Invertebrates Collection.
(2008) Several hundred new plankton samples were accessioned into the SIO Pelagic Invertebrates Collection.

Product Type:
Data or databases

**Product Description:**
Hydrographic and plankton data from CalCOFI cruises, in support of the CCE LTER site.

**Sharing Information:**
Freely available at: http://www.calcofi.org/newhome/data/data_archives.htm

**Product Type:**
Data or databases

**Product Description:**
Measurements of dissolved FE concentrations from CalCOFI and CCE LTER Process cruises.

**Sharing Information:**
Available at: http://oceaninformatics.ucsd.edu/datazoo/ccelter/data

**Product Type:**
Data or databases

**Product Description:**
All population data from microscopy and flow cytometric analyses from the two CCE LTER Process cruises have been submitted to the CCE DataZoo website.

**Sharing Information:**
Available at: http://oceaninformatics.ucsd.edu/datazoo/data

**Product Type:**
Postcard for publicity

**Product Description:**
A postcard for the Children's Book (Sea Secrets: Tiny Clues to a Big Mystery) to promote publicity

**Sharing Information:**
Available through our CCE LTER Education and Outreach program

**Contributions within Discipline:**

#### 2008

(Zooplankton demography) We have contributed to the development and application of inverse methods for estimating mortality rates of copepods and other stage-structured zooplankton. Also, the use of innovative seagoing technologies (ocean gliders) has added to defining mesoscale spatial structure in the ocean environment, with implications for the interactions of predators and prey.

(Deep-sea ecology) Scientific contributions have been made to biological and chemical oceanography, ecology more broadly, as well as understanding of climate variation impacts.

(Ecosystem modeling) We have created a novel continuum size-structured model of planktonic ecosystems. We hope to make this a community model, available to all for their studies.

(IM) We have contributed uniquely to the work of informatics by partnering with community members close to the source of the data in order to ensure appropriate support for data collection, to inform continuing redesign of our information applications, and to improve information literacy. Our team members have also contributed to the community LTER IM Newsletter ('Databits') on a regular basis.

(E&O) The teacher activity guide to accompany the children's book - Sea Secrets: Tiny Clues to a Big Mystery - will provide students with a unique and fun way to explore further into the book's contents.

#### 2007

We have contributed to the broader understanding of ecosystem variability and climate-relevant issues in related NSF-funded studies of plankton community dynamics in the Pacific Ocean. These include: temporal trends and biogeochemical impacts of the zooplankton community of the Northeast Pacific; the dominant roles of picophytoplankton as producers and microzooplankton as primary consumers and
secondary producers in the oceans; community responses along trophic gradients; the effects of cyclonic eddies on plankton community structure, production and export; and comparative plankton community studies in subtropical, equatorial and coastal ecosystems.

(DOC/DON) The most basic goal of this project is to increase our understanding of the marine C and N cycles. DOM represents a large reservoir of both C and N but the processes that form this reservoir and the residence time of C and N within this reservoir are poorly understood. Support offered by the CCE LTER is based on the premise that time series measurements of the isotope composition of various C and N reservoirs (which capitalize on temporal changes in upper ocean physics), will provide a more comprehensive picture of DOM residence time, sources and sinks, than is currently available. Our initial sampling program which has capitalized on a mild El Nino event should allow us to test this premise. The isotope and chemical composition data set that we have generated, and continue to generate for the California Current system does not currently exist for any other location.

(IM) We have contributed uniquely to the work of informatics through grounding information systems work with close ties to data and scientific research.

(E&O) We have continued to ground CCE Outreach through current educational research, have participated in a federated community-of-practice of educators focused on ecological research, and also disseminated educational and scientific research through a variety of outreach efforts in the public domain, formal (classrooms and universities), national and international collaborations. An educational project webpage has also been developed.

(Modeling) The model developed by H. Fuchs generates new insights into attributes of real foodwebs, including the mechanisms that generate gaps in measured plankton biomass distributions and how predator community composition affects the fractions of top, intermediate, and basal species. The analyses of P. Riviere and E. DiLorenzo show that the long-term variability of salinity and nutrients is tightly coupled to the second mode of variability in the North Pacific, rather than the first mode (the PDO). This observation will allow us to begin to predict how changes in the fluxes caused by long-term climate change may affect the planktonic ecosystem.

2006
We have contributed to the broader understanding of ecosystem variability and climate-relevant issues in studies of plankton community dynamics in a major eastern boundary current ecosystem.

We have officially reported our analytical results for the SAFe seawater iron standards to Ken Johnson, who is organizing the development of the SAFe samples as new seawater analytical standards. In this way, we are contributing to the development of new and improved certified trace metal analytical standards for the oceanographic community.

Our investigations of iron limitation in the Southern California Bight and at the subsurface chlorophyll maximum in stratified oceanic regimes are contributing to an improved understanding of the marine biogeochemistry of iron in environments which have thus far been understudied with respect to the effects of iron limitation on the phytoplankton community.

We are continuing development of an Ocean Informatics conceptual framework for information management working in tight coordination with an ongoing project science team. This interdisciplinary effort is developing mechanisms that address informatics literacy, information system sustainability, data integration, and cross-project collaboration in close coordination with the Palmer Station LTER (PAL), the California Cooperative Ocean Fisheries Investigations (CalCOFI), and the Southern California Coastal Ocean Observing System (SCCOOS).

2005
Understanding of the processes of coastal upwelling and transport of waters in the California Current; the times and locations of Fe-limitation of phytoplankton growth; the differences between characteristic signatures of biological and physical time series in the NE Pacific; the relationship between long-term changes in ocean primary production and the flux of organic matter into the deep sea.

Contributions to Other Disciplines:

2008
Our (zooplankton demography) research has allowed recognition of the importance of spatial differences in life history trade-offs in different environments. Also, demonstration of the utility of new technologies (ocean gliders) to revealing previously unrecognized spatial patterns has contributed greatly to other disciplines.

(Deep-sea ecology) In concert with science activities, the Pelagic-Benthic group has continued the technological development of new
instrumentation for sampling the deep sea. Additionally, research has refined techniques and, in particular, provided an evaluation of seafloor observing technology that will influence ocean observing designs relative to regional cabled observatories.

(IM) We continue our contributions to the disciplines of social science (science and technology studies, communication studies, infrastructure studies, ethnographic studies), information science (data organization, information environments, informatics), and history of science by working with interdisciplinary science studies partners to consider how we do our science and how to blend theory and practice (http://interoperability.ucsd.edu).

2007

The results of this project will contribute to a better understanding of climate impacts on ocean and earth ecosystems and to developing better predictive models of climate influences.

(IM) We are contributing to the disciplines of social science, information science, and history of science by working with interdisciplinary science studies partners to consider how we do our science and how we tie theory and practice. The Ocean Informatics environment augments and creates alternatives to traditional data handling models. Our collaborative work is presented periodically to the LTER community via talks and written communications.

(E&O) The development of the education coordinator/liaison role has evolved and continues to bridge education/outreach opportunities with ongoing environmental science research programs. A concerted effort has been made to increase collaboration with CCE researchers to develop education components for their work. This has proven successful in the initiation of the 'Picture of the Day' where photographs were shared in an online forum from the 2nd Process cruise. The Tale of Two Krill project will ultimately become a cross-site case study focusing on the role krill play in ocean food web dynamics from both participating LTER sites (PAL/CCE).

2006

The continuum size-structured planktonic ecosystem model may become a central tool in our explorations of the physical-biological interactions driving plankton dynamics in the ocean.

The results of this project will contribute to a better understanding of climate impacts on ocean and earth ecosystems and to developing better predictive models of climate influences.

We are contributing to the disciplines of social science and information science. The Ocean Informatics environment augments and creates alternatives to traditional computer science, information system, and technology approaches to data and information management.

2005

All of the above also have implications for other disciplines of science and engineering.

Contributions to Human Resource Development:

2008

Human resource development over the past year has included the training of many undergraduates, graduate students, and postdocs within the CCE LTER program. This also includes the training of two REU students and subsequent sponsorship of their senior thesis projects.

Through CCE E&O programs, B. Simmons has maintained her level of commitment to local education and outreach activities. They remain to be of utmost importance, as reflected by collaboration with graduate students, continuation of school visits by Rancho Santa Fe Middle School students, and with online teacher resource material development (RET C. Milsap)- based on the Ocean Institute's Chlorophyll-Temperature time series data.

2007

This project has led to the training of many postdoctoral scholars, graduate and undergraduate students through CCE research, cruises, and classes taught by PIs. It has encompassed several international students as well, e.g. on the 2007 Process cruise L. Linacre learned experimental skills that she will apply in her PhD research at CICESE (Ensenada, Mexico). Many volunteers gained valuable experience at sea this past year as well, exposing them to CCE research.

(E&O) A RET will gain valuable experience developing instructional materials this summer, facilitating progress on the book project ‘Tale of Two Krill.’ Attendance at the National Marine Educators Association Annual meeting (B. Simmons) will facilitate the collaboration on the book project and solicitation of interest.
2006
Graduate student training: Two LTER PhD theses have been completed in the past year (Hsieh and Ruhl). In addition, eleven other graduate students participated in the LTER process cruise in May-June 2006. Many have initiated thesis research related to the CCE site.

With one of our E&O partners, the Ocean Institute (OI) in Dana Point, California, we have initiated a nearshore program of analysis of covariability of phytoplankton and physical properties of the water column. During student cruises at OI (ca. 150 days per year), the middle and high school students take water samples for the analysis of total Chlorophyll a, the picoplankton fraction of Chlorophyll a, and temperature, as a part of the OI curriculum discussing primary and secondary production in the ocean. The Dana Point time series will also permit comparison with a similar nearshore program at Scripps pier.

2005
Training of graduate students in interdisciplinary fields of research in the ocean environment. Building graduate students' awareness of and skills for collaborative research in the complex domain of physical-chemical-biological ecological interactions.

Contributions to Resources for Research and Education:
2008
The Ocean Informatics (IM team) environment continues to be designed as an inquiry-based informatics learning environment for participants including programmers, technicians, graduate students, and associated researchers. Development of 'ZooDb,' for web-based access to an extensive zooplankton data set, has become a tremendous resource as well.

The applications of glider technology in the ocean environment allow for many research and education resource opportunities.

2007
(DOC/DON) We have upgraded some equipment and purchased consumables that have been used by graduate students outside of the laboratory. The UCSD undergraduate class (California Coastal Oceanography) was identified by SIO faculty as the first upper-level class (spring 2007) specifically designed for the SIO minor (Aluwihare & Landry).

(Modeling) We intend the size-structured plankton model to be a community resource, and a new architecture for building models of the planktonic ecosystem.

The Ocean Informatics environment is developing to support collaborative research programs through synergy with an inquiry-based informatics learning environment for participants, including programmers, technicians, grad students, and associated researchers.

2005
Creation of an ocean informatics data management framework that will permit disparate types of data to be shared among investigators and across disciplines.

Contributions Beyond Science and Engineering:
2008
We have contributed to the better understanding of some key processes that affect the ocean's response to climate forcing through our various CCE LTER research projects.

This past year, results from all elements within the CCE LTER program were represented through various public speaking events, presented papers and posters at local, national and international meetings, as well as through public websites with information on lab activities and available databases.

2007
Numerous oral and poster presentations were given on the various elements of the CCE LTER project at local, state, national, and international levels.

2006
Presentations to community groups, state, and federal entities concerned with management of the coastal ocean.

2005
Participation as a member of the Science Advisory Team for the Marine Life Protection Act task force, advising the state of California on the design of Marine Protected Areas (Ohman).
Participation in the National Marine Fisheries Service California Current Krill Advisory Committee, June 2005, intended to establish the guidelines for the commercial harvest of krill in the California Current system (Ohman).

Testimony on variability of marine ecosystems to the House Subcommittee on Fisheries and Oceans in WA, D.C., June 2005 (Ohman).

### Special Requirements

**Special reporting requirements:** None  
**Change in Objectives or Scope:** None  
**Animal, Human Subjects, Biohazards:** None

### Categories for which nothing is reported:
Figure 1. Surface dissolved Fe (nM) and NO₃ (µM) versus distance offshore (km) for 23 Mar-9 Apr (spring) and 12 Jul-28 Jul (summer) 2004; note log-scale on y-axes of dissolved Fe plots. Open circles represent stations where Fe-limitation was observed using Fe-addition grow-out bottle incubations.

(K. Barbeau et al.)