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

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<th>Name</th>
<th>Worked for more than 160 Hours:</th>
<th>Contribution to Project:</th>
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<tr>
<td>Ohman, Mark</td>
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<td>Landry, Michael</td>
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<td>Miller, Arthur</td>
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<td>Goericke, Ralf</td>
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<td>Barbeau, Katherine</td>
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<td>Aluwihare, Lihini</td>
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<td>Barbeau, Katherine</td>
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<td>Sugihara, George</td>
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Submitted on: 07/20/2006
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<td>Azam, Farooq</td>
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<td>Bograd, Steven</td>
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<td>Burton, Ron</td>
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<td>DiLorenzo, Emanuel</td>
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<td>Fuchs, Hedi</td>
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<td>Post-doc</td>
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Graduate Student

Name: Davison, Pete
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Worked for more than 160 Hours: Yes
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Name: DeJesus, Roman
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Worked for more than 160 Hours: Yes
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Name: Hopkinson, Brian
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Worked for more than 160 Hours: Yes
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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
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Contribution to Project:

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

Name: Rykaczewski, Ryan
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Name: Stukel, Michael
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Name: Vardaro, Michael

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Contribution to Project:
Name: Wanetick, Jerome

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Name: Yarmey, Lynn

Worked for more than 160 Hours: Yes
Contribution to Project:
Name: Haber, Shaun

Worked for more than 160 Hours: Yes
Contribution to Project:
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: Reynolds, Susan

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Contribution to Project:
Name: Dovel, Shonna

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

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Contribution to Project:
Name: Townsend, Annie

Undergraduate Student

Technician, Programmer

Other Participant
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Worked for more than 160 Hours: Yes  
Contribution to Project:  

Name: Balch, Debbie  
Worked for more than 160 Hours: Yes  
Contribution to Project:  

Name: Erez, Oya  
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Contribution to Project:  

Name: Spear, Natalie  
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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.

Research Experience for Undergraduates

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 Preuss school teachers.

Rancho Bernardo High School
Science curriculum development for high school students.

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, Ocean Institute, Dana Point
- Several co-PI's, Palmer Station LTER site
- Several co-PI's and Information Manager, Santa Barbara Coastal LTER site
- Linda Powell, Florida Coastal Everglades LTER site
- Wade Sheldon, Georgia Coastal Ecosystem LTER site
- Alexander Chekalyuk, NASA Goddard
- Alec Barron, teacher, The Preuss School (a minority-serving charter school)
- Season Mussey, teacher, The Preuss School
- Jay Hendricks, teacher, Rancho Bernardo High School
- Pascal Riviere, Visiting researcher, Universite de Brest Occidentale
- Dag Aksnes, Professor, University of Bergen, Norway

Activities and Findings

Research and Education Activities:
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 rapid 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: procaryotic 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)

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 & 0.1617; 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:
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.
2005

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:**

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


Books or Other One-time Publications

Collection: Food Webs and Marine Conservation
Bibliography: pp. 170-183

Collection: Schoolyard LTER Education Handbook
Bibliography: LTER Network Office


Web/Internet Site

URL(s):
cce.lternet.edu
Description:
California Current Ecosystem LTER website

Other Specific Products
**Product Type:**
**Physical collection (samples, etc.)**

**Product Description:**
Zooplankton samples accessioned into the SIO Pelagic Invertebrates Collection.

**Sharing Information:**
Web-based search engine posted (http://collections.ucsd.edu/pi/index.cfm). Samples available for use by qualified researchers.

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**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

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**Contributions within Discipline:**

**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.

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**Contributions to Other Disciplines:**

**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.

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**Contributions to Human Resource Development:**
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:
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:
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
Unobligated funds: less than 20 percent of current funds
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.)