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# Research Experience for Undergraduates at the Darling Marine Center, University of Maine, 2002-2005

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**Principal Investigator:** Eckelbarger, Kevin J. **Award ID:** 0139114
**Organization:** University of Maine
**Title:**
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## Project Participants

**Senior Personnel**

**Name:** Eckelbarger, Kevin
**Worked for more than 160 Hours:** Yes
**Contribution to Project:**

**Post-doc**

**Graduate Student**

**Undergraduate Student**

**Technician, Programmer**

**Other Participant**

**Research Experience for Undergraduates**

## Organizational Partners

## Other Collaborators or Contacts

One faculty associate, Dr. Gary King, taught a week-long introductory REU session at the beginning of the summer 2005 season.

## Activities and Findings

**Research and Education Activities:**

During the summer of 2005, seven REU students were employed. We received 75 applications from students at 61 universities in 29 states. The students selected for the program conducted the following research projects:

1) The Predictive Possibilities of a Marine GIS: Developing the architecture for a predictive habitat suitability model for Alcyonaceans in the US Eastern EEZ
Dan Agro, University of Southern Maine
REU, Advisor: Dr. Watling

The recent rediscovery of deep water corals along the continental shelves and slopes of the United States has sparked strong public interest in their conservation. Because of the many logistical issues that come from studying first hand characteristics of the ocean bottom, a proposal has been submitted to have a habitat suitability model built for eight coral species all within the family Alcyonaceans in the US Eastern EEZ. This model takes advantage of the most up to date GIS technologies to predicatively map the probability of the existence of the eight coral species within a geographic region.
My work and my research have focused on acquiring, organizing, developing methods for manipulating, and producing procedures for analysis of the habitat suitability data. All of this work was done in order to allow the data to be analyzed within the GIS software. Due to the

complexities of a habitat suitability model and the large amounts of different data that must be taken into account, I developed a relational database to help organize the data sets. This constitutes the bulk of the work for developing the habitat suitability model and with continued work the model will be at a functional stage in a matter of months.

2) Seamounts and Deep-water Corals of the North Atlantic Ocean: A GIS map and database
Tess Geers, Hampshire College
REU, Advisor: Dr. Watling

A biogeographic database has been assembled using ArcGIS 9.0. This database consists of a conglomerate of coral records for the North Atlantic Ocean, primarily octocorals and black corals. These records have been assembled from records dating back to the 1800&Mac226;s, recent journals, and the Geographic Database of Deepwater Alcyonaceans assembled by Watling, Auster, Babb, Skinder, and Hecker. Coral records plotted on the map are at a depth of at least 100 meters. Coral data represents 25 families and over 80 genera. The GIS map also contains data for the more than 14,000 seamounts documented by Kitchingman and Lai. These seamounts have a height of at least a thousand meters and are grouped according to their depth below the surface, from less than 500 meters to the greatest depth of 7500 meters. The coral and seamount data is plotted over a raster image of the bathymetry of the northern Atlantic area provided by NOAA. The object of this map is to help better understand the biogeography of the North Atlantic Ocean as well as the distribution of deep-water octocorals throughout the North Atlantic.

3) Reproductive Biology of the Deep-Sea Octocoral, Thouarella superba
Sara Matthews, Wittenberg College
REU, Advisor: Dr. Eckelbarger

Octocorals are soft corals that are found around the world, most widely known in tropical coral reefs. Recently, large populations were found in cold waters, such as those around the Aleutian Islands in Alaska. Little to nothing is known about the octocorals of the deep sea, but many colonies have been destroyed in Alaska through bycatch of fisheries and bottom trawls. This proves to be a problem because of the habitat it provides for many invertebrates and juvenile vertebrates. By doing histology of these organisms, we can learn more about their reproductive systems in order to predict the damage done to the colonies and their ability to recover. Thouarella superba (Alcyonacea: Primnoidae) is one of the most abundant octocorals of the Aleutian Islands. It has small polyps, and therefore faces many problems in reproduction. The female colonies can only produce two to three oocytes per polyp, which develop along the mesenteries, or foldings, near the base of the polyp. These can occupy most of the volume of the polyp, leaving little room for digestion. Through fixing and embedding these animals in paraffin for light microscope, I was able to count and measure the eggs in many polyps. This preliminary study has provided basic reproductive information on this species. Further ultrastructural studies will be required.

4) Analyses of BMS and OMP forms of coxL show genetic variation in Bradyrhizobium japonicum strains associated with lupine nodules
Kristy Podelnyk, University of Maine
REU, Advisor: Dr. King

The enzyme carbon monoxide dehydrogenase (CODH) facilitates the bacterial oxidation of carbon monoxide for growth and energy. Bradyrhizobium japonicum, a common nitrogen-fixing legume symbiont, possesses genes for BMS and OMP forms of the aerobic CODH enzyme. The coxL gene codes for the large subunit of the CODH enzyme, and is a reliable indicator of molecular variation within naturally-occurring B. japonicum strains and clone libraries. Species of Lupinus perennis, (from the plant family Fabaceae) house B. japonicum within specialized root nodules in exchange for nitrogen fixation. Different aspects of the coxL gene were examined at a molecular level by extracting root nodule DNA, amplifying signature coxL gene and cloning genes from microbial populations found in sterile and nonsterile lupine root nodules. DNA sequencing of clone inserts and post-sequencing amino acid analyses reveal variation in the coxL gene within environmental B. japonicum strains. Further molecular examination addresses microbial diversity between populations inside and external to lupine root nodules.

5) The Reproductive Biology of Skeleton Shrimp, Aeginina longicornis
Sarah Rathbone, Bryn Mawr College
REU, Advisor: Dr. Eckelbarger

Although crustaceans are a well documented subclass of marine invertebrates, little is known about the reproductive biology of skeleton shrimp (Amphipoda: Caprellidea). During the summer of 2005, an observational study of oogenesis and embryonic development of female Aeginina longicornis was conducted using specimens from the Damariscotta River of costal Maine. In the first part of the study, individual females were isolated from the males in PVC pipe compartments in flowing sea water. Every day for a month, development of the ovary and eggs, and embryos within the brood pouch were observed and recorded. Although general developmental stages in both the ovaries and brood pouch were

observed, the rate of egg and embryonic development varied greatly among individuals. Isolated females produced up to two broods during the month in captivity. Only a few of the second broods developed normally while others degenerated. This finding has potential importance in the study of crustacean reproductive biology, specifically the manner of copulation, and the possible sperm storage by females. After emerging from the brood pouch, the young were removed and isolated from the female. The age of each brood was recorded throughout the month. In the second part of the study, offspring at different developmental stages and females at different egg and embryo stages were fixed for electron microscopy. Thick sections of offspring at varying stages were taken to determine the age of sexual maturity. It was determined that eggs appear in the ovaries around day twenty-seven and that yolk filled eggs are present around day thirty-one, along with the development of the brood pouch. In the thick sections of mature females, it was also found that eggs in the ovaries do not develop simultaneously. More extensive research should be done over a longer period of time and with more specimens to gain a comprehensive understanding of the intriguing reproductive biology of skeleton shrimp.

6) The Effects of Iron and Copper on the Growth of Marine Phytoplankton
Amanda Satterfield, Lyon College
REU, Advisor:Dr. Wells

High-Nitrate, Low-Chlorophyll (HNLC) areas contain high amounts of major nutrients, however growth of phytoplankton is lower than expected. Large-scale iron fertilization experiments have shown these regions are limited by iron. The addition of iron to HNLC areas typically produces a large diatom population that quickly subsists to smaller cells once the iron chemistry changes. However, some fertilization experiments have shown that certain populations of pennate diatoms can persist, even when free-iron concentrations are very low. It is hypothesized that these cells can induce a high affinity iron uptake system that involves the presence of copper and the assistance of a copper chelator.
Four phytoplankton species, representative of various ocean regimes, were studied using trace metal clean techniques. The phytoplankton were grown separately in a range of iron and copper concentrations, 10-22.5M to 10-18.5M and 10-21.8 M to 10-17.8M, respectively. The coastal phytoplankton species tested were not able to grow under low iron conditions however, the oceanic species did appear to be able to utilize a high affinity uptake system in order to acquire iron. The oceanic species, T. oceanica, appears to have a requirement for copper in order to trigger iron uptake.

7) An Analysis of Emerging Benthic Organisms Using Various Orientations of TAPS
Laura Truxal, Texas A&M University
REU, Advisor: Dr. Jumars

TAPS (Tracor Acoustic Profiling System), an active sonar system, measures acoustic backscatter over a range of six frequencies in the water column. This acoustic backscatter reveals major emergence events in the Damariscotta River estuary. Emergence traps, checked daily, revealed that the mysid shrimp, Neomysis americana, was the dominant migrator. TAPS is regularly deployed in a metal frame in a vertical position. Due to TAPS being one meter long and the acoustic ringing of the metal frame, data within 2 to 3 m of the seafloor are contaminated. In order to alleviate this problem, TAPS was deployed nearly horizontally. The 8&Mac251; sound-beam spreading meant that the correct angle needed to be found to see close to the seafloor without this gradually spreading beam or more intense sound lobes hitting the bottom. An angle of 20&Mac251; was found to give data with good resolution. Programs and algorithms used to analyze data were modified to work with TAPS being nearly horizontal as opposed to vertical. Data reveal that the beam spreading and side lobes still show contamination by the seafloor as well as the surface of the water. Data above the region contaminated by backscatter from the air-sea interface were deemed unusable because of the complication of added acoustic forward scatter. Comparison of horizontal TAPS data with vertical data will indicate whether it useful to continue to deploy TAPS in a horizontal position. In principle, the shallow angle provides higher vertical resolution as well as horizontal information not contained in data collected in the normal vertical orientation.

Students participated in an 11-week internship program. An introductory workshop provided training in aspects of scientific methodology and related skills that are common to all scientific disciplines (hypothesis formulation and testing, elementary statistics, experimental and sampling design, scientific writing, and data presentation). Workshops were also provided in selecting a career in science, how to get into graduate school, and a series of seminars by resident faculty discussing their own research and science careers. Students were also required to attend weekly science seminars presented by visiting faculty as part of the Center's summer seminar series. At the end of the summer students were required to participate in a mini-symposium in which they presented their research results to faculty and graduate students.
Although it is often difficult to stay in contact with previous REU students, we can confirm that five of the seven students above have now entered graduate programs. Several faculty have submitted manuscripts for publications with REU students as co-authors.

**Findings:**

Students completed evaluation forms at the end of the program that were used to determine if changes or modifications of the program were

necessary in the future. It was apparent from these evaluations that students viewed the REU as extremely helpful as they determine the next steps in their career selection. Workshops on science careers and graduate school were most popular while faculty seminars received varying responses. Students were also enthusiastic about having research projects involving both laboratory and field components. We encourage all faculty to require some field work so students become familiar with research vessels and sampling techniques as well as the opportunity to work with living marine organisms.

**Training and Development:**

Each REU student was monitored throughout the summer by two faculty members (Kevin Eckelbarger and Gary King) to determine if there were any individual problems. All of the students reported that their research projects were stimulating and those involving extensive field experience received the highest marks. It was clear that students with exceptional academic records still harbor significant doubts about their ability to handle graduate school - primarily independent research expectations. There was also significant concern about selecting a career path that would be satisfying to them - students feel they are swamped with so many choices it is overwhelming. Our workshop on career selection appeared to be especially helpful and stimulated numerous follow-up questions to Eckelbarger and King throughout the remainder of the summer. Students focused on getting faculty help in writing a curriculum vita and in preparing essays for graduate school. As a result Eckelbarger and King spent considerable time reviewing and editing practice essays. Students all reported that they greatly benefited from the mini-symposium despite their general lack of experience speaking before a professional audience. Several faculty also involved students in preparing first drafts of their research for future publications even though the project would often need to be continued by the faculty member.

**Outreach Activities:**

The Darling Center sponsors nine evening lectures for the public each summer and several REU students were asked to attend these events and to spend 5-min. each describing their research projects to the general audience. We also introduced the REU students to members of the Center's fund-raising group, the Gulf of Maine Foundation (GMF) who raise funds for other summer scholarships. Members of the GMF Board of Directors are largely retired professionals who have a keen interest in science education. The GMF also funds a summer K-12 program in marine science so we informally involved several REU students in field trips with elementary students so they could share their science expertise with the children. The GMF Board members were very impressed by the REU students and they have since decided to model their own internship program after the NSF REU program. We view this development as very significant because it has increased the level of vigor into the GMF internships. In summer 2004 and 2005, we involved the GMF interns in our REU activities so the two groups of students could interact. Virtually all of our REU students were articulate and enthusiastic and this youthful energy encouraged the fund raisers to continue their efforts to look for support in the local community for K-12 marine science programs.

## Journal Publications

## Books or Other One-time Publications

## Web/Internet Site

## Other Specific Products

## Contributions

**Contributions within Discipline:**

Although some publications are being prepared that resulted from the 2005 REU student projects, a number of peer-reviewed publications have been produced with REU students as co-authors since the REU program began in the summer of 2002 (see below). The Darling Marine Center REU program has placed a strong emphasis on faculty-REU student joint publications so an effort is made to design projects that can produce published results. Due to this emphasis, REU students were strongly encouraged to submit written progress reports to their faculty sponsor and to actively participate in manuscript preparation as their research project results become available.

Mayer, L.M., L. Schick, K. SKORKO, and E. Boss, 2006. Photodissolution of particulate organic matter from sediments, Limnology and Oceanography, 51:1064-1071.

Eckelbarger, K.J., L. Watling, and H. FOURNIER. 2005. Reproductive biology of the deep-sea polychaete Gorgoniapolynoe caeciliae, a

commensal species associated with octocorals. J. Marine Biological Association of the United Kingdom, 85: 1425-1433.

Boudreau, B.P., C. Algar, B.D. Johnson, K.M. DORGAN, P.A. Jumars. 2005. Bubble growth and rise in sediments. Geol. 33: 517-520.

DORGAN, K.M. and P.A. Jumars., B. Johnson. 2005. Burrowing by crack propagation through muddy sediment. Nature 433: 475.

JOHNSON, S.L. and P.O. Yund. 2004. Remarkable longevity of dilute sperm in a free-spawning colonial ascidian. Biological Bulletin 206: 144-151.

DORGAN, K.M., P. Jumars, B.P. Boudreau. 2006. Macrofaunal burrowing: the medium is the message. Oceanography and Marine Biology: An Annual Review 44: 85-121.

Jumars, P., K.M. DORGAN, L.M. Mayer, B. Johnson. 2006. Infaunal lifestyles: may gravity and the strong forces be with you. IN: Trace Fossils: Concepts, problems, Prospects.

**Contributions to Other Disciplines:**

As an unexpected result of the REU experience, we noted that, as in previous summers, some students expressed an interest in changing their career plans from university-level research to possibly teaching high school or elementary school science. The Center operates a K-12 summer marine science program that also employs college intern students (non-NSF funding) who are intending to teach K-12. The exposure of REU students to the K-12 interns appears to result in a change of thinking with respect to careers. In addition, during our workshop on careers, we try to have at least one K-12 teacher speak to the group about careers in non-university teaching. In addition, we have had one or two graduate students speak to the REU students who are part of the NSF GK-12 program. This allows REU's to learn more about K-12 opportunities from graduate students in the marine sciences who are actually in a classroom setting.

**Contributions to Human Resource Development:**

The great majority of REU students have gone on to graduate school in the sciences. At least two have entered medical school and three entered the Ph.D. program at the University of Maine's School of Marine Sciendes. One of the REU students - Kelly Dorgan - was selected by Popular Science Magazine as one of the 'Brilliant 10' for 2006. She was featured in the magazine and in many New England newspapers and magazines. She was interviewed on Maine Public Radio and will be introduced to the Governor and full house of the Maine Legislature on February 15, 2007 by the new Chancellor of the University of Maine System. Ms. Dorgan also recently received a 3-year NSF postdoctoral fellowship to work with Mimi Khoel at UC Berkeley. In our view, the REU program at the Darling Marine Center has been incredibly successful and satisfying.

The Center did not seek a renewal of the REU site grant due to the loss of two faculty - Les Watling who is on long-term leave at the Univ. of Hawaii, and Gary King who has moved to LSU. However, the Center is recruiting new faculty and expects to have four new ones by the spring of 2008 (two will be moved in by August 2007) - including three biological oceanographers and one marine biologist. We expect to submit another REU proposal in 2008.

**Contributions to Resources for Research and Education:**

Each summer the Darling Center receives extensive coverage from the print, radio and television media because numerous research projects are being conducted by resident and visiting investigators. We have discovered that the press is particularly interested in speaking to REU students because they often conduct research projects that are of special interest to New Englanders. The University has also included REU students in video footage of University research activities that are eventually used for marketing. We have also invited local elementary and high school science teachers to tour the Darling Center and to meet REU students. A number of high school science clubs have visited and spoken with the REU students because the high school students are curious about college and research opportunities. Every summer, the REU students have also meet with the winning team from the National Ocean Science Bowl so the two groups can share their experiences. In our experience, REU students are generally articulate and excited about their projects and more than willing to speak to younger students. With REU student, Kelly Dorgan. being selected as one of the 'Brilliant 10' by Popular Science magazine has brought additional attention to the REU program because the local press is interested in her background.

**Contributions Beyond Science and Engineering:**

We have noted an upsurge in private financial contributions to our GMF support group by local citizens who want to help students obtain summer research fellowships. While GMF raises funds for a variety of causes at the Darling Center, undergraduate internships have become a major focus. We believe that exposure of the general public to REU students has helped stimulate these contributions because the students are such great role models. The Center conducts tours for the general public throughout the summer and they often encounter REU students in the laboratory who briefly summarize their research projects. Judging from the questions and comments, the REU students make a significant,

positive impression. As part of our workshop format each summer, we emphasize to REU students the need to articulate their research to the general public so we encourage them to speak with the press when they tour the Center.

**Categories for which nothing is reported:**

Organizational Partners

Any Journal

Any Book

Any Web/Internet Site

Any Product