tides, the filling of dams, and even the injection of electric current into the ground. Current injections in Russia by a magnetohydrodynamic power generator actually have activated seismicity [*Avagimov et al.,* 2004]. It has also been proposed that some external phenomena, such as geomagnetic storms and cloud-to-ground lightning, may affect seismicity [e.g. *Sobolev and Zakrzhevskaya*, 2003]. Since these events also disturb the atmosphere-ionosphere, it might be possible that some of the reported preseismic atmospheric-ionospheric anomalies simply were observed as a trigger of the earthquakes.

As discussed in this article, the cause and effect relationships may still be unestablished, but atmospheric-ionospheric anomalies before the earthquakes do exist and their further investigation, involving the lithospheric connection, remains an important research endeavor. Determining these connections possibly will aid with understanding and predicting seismic activity.

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What Do College Students Know About the Ocean?

PAGES 418, 421

By C. Cudaback

A recent survey of students entering a college-level course in introductory oceanography reveals that they feel a strong connection with, and curiosity about, the ocean. To guide this inherent curiosity into understanding and stewardship, educators need to know the 'hooks,' the topics and concepts that catch students' interests. According to a survey of 119 students at North Carolina State University-Raleigh, some useful hooks are students' personal, emotional connection with the ocean, human impacts (especially pollution), exotic biology, and cool technology.

Survey results further indicate that students already are gaining ocean knowledge from a wide variety of sources, and that the topics of interest to them can be organized using the Essential Principles of Ocean Literacy [*Centers for Ocean Sciences Education Excellence (COSEE),* 2005]. The students' general awareness of ocean science is a good basis upon which to build.

Given the declining quality of the marine environment, ocean educators have the responsibility to teach not only the science of the ocean, but also the interdependence between humans and the ocean. This interdependence is at the heart of ocean literacy, as recently defined by a national consensus of marine scientists and educators [*COSEE,* 2005]. An ocean-literate person understands ocean science, can communicate about the ocean, and is able to make informed decisions about ocean policy [*COSEE,* 2005].

The scientific understanding that every citizen should have is defined in the seven Essential Principles:

1. The Earth has one big ocean with many features.
2. The ocean and life in the ocean shape the features of Earth.
3. The ocean is a major influence on weather and climate.
4. The ocean makes the Earth habitable.
5. The ocean supports a great diversity of life and ecosystems.
6. The ocean and humans are inextricably interconnected.
7. The ocean is largely unexplored.

Most Americans attain voting age around the same time they complete their formal education in science—at the end of high school or after a few introductory college science courses. A college-level introductory oceanography class is the last chance to promote ocean literacy through formal education, and also provides an opportunity to measure the level of ocean literacy among high school graduates. As these students are self-selected, preclass survey results may indicate an upper bound for ocean literacy in the general population. Postclass surveys should indicate how well college educators are doing their job.

Prior studies of undergraduate classrooms have measured student beliefs and preconceptions about physics [*DeLaughter et al.,* 1998; *Adams et al.,* 2006], as well as their understanding of solid Earth geosciences [*Libarkin and Anderson,* 2005]. High school ocean science classes have been shown to have a significant effect on general scientific literacy [*Lambert,* 2005]. Public concern about the ocean has been shown to exceed public understanding of the ocean [*American Association for the Advancement of Science,* 2004; *Belden et al.,* 1999; *Steel et al.,* 2005], but no prior study has measured ocean literacy in the context of formal education.

A preliminary ocean literacy survey was developed based on the Essential Principles and consisted of open-format questions that allowed students to express their understandings or misunderstandings freely. Students filled out the survey on the first day of an introductory oceanography course at the North Carolina State University at Raleigh (in January 2006), and results from four of the most general questions are discussed here. Only the topics of interest to students are discussed here; their level of understanding will be addressed in a future paper.

Student Interest in Oceanography

The demographics of this class were roughly consistent with the university population as a whole. Students were nearly equally divided between the freshman, sophomore, junior, and senior classes, and half were majoring in science, mathematics, or engineering. One third of the students were in the College of

Humanities and Social Sciences, and 10% had not yet chosen a major.

During the school year, these students live in Raleigh, N.C., about a three-hour drive from the ocean, and all claimed to have been to the beach within the past year. Their personal experience of the ocean has affected them significantly.

Students were asked where they had learned about the ocean prior to taking the oceanography class, and they listed a wide variety of sources (Figure 1). Although 56% of students mentioned formal education, some comments suggested that ocean science was mentioned only briefly in their kindergarten through twelfth grade classes. Much of students' prior knowledge of the ocean came from personal experience (45%). Although a similar result might not hold in central and midwestern states, it can be inferred that most students living in coastal states have some direct experience of the ocean.

A quarter of the students mentioned media influences, especially television channels devoted to science and exploration. The students' interest in technology and biology may reflect the programming on these stations. In a separate survey question on marine ecosystems, over 40% of the students mentioned coral reefs, and informal questioning revealed that the students had been influenced by media depictions of coral. Informal questioning also revealed the significance of *Captain Planet*, a cartoon that promotes environmental preservation.

The survey revealed the importance of friends and family in teaching about the ocean (mentioned by 23% of students). Learning through casual interpersonal communication is a topic rarely mentioned in the discussion of ocean literacy, but it could be quite important. As one student wrote in an end-of-class essay, "It seems like now anytime I hear someone…speak about the ocean, I just want to jump in and explain everything I know." What is taught in class may be shared widely, including information on ocean stewardship.

Although there are three aquaria, an 'estuarium,' and a zoo within four hours of Raleigh, and a superb natural science museum downtown, very few students mentioned informal education. Only four students mentioned aquaria, and about the same number mentioned camps. They have learned more from their own acquaintances than from informal educators. In future surveys, students will be asked specifically whether they visit aquaria and what they learn there.

Students were also asked to write an essay in which they explained what interested them about the ocean and what they would like to learn in the oceanography class. The essays initially were examined without reference to the essential principles (EPs) of ocean literacy, but the key words and phrases in the essays suggested categories that turned out to fit within the EPs. Each EP includes two to nine Fundamental Concepts [*COSEE*, 2005] that helped sort student comments.

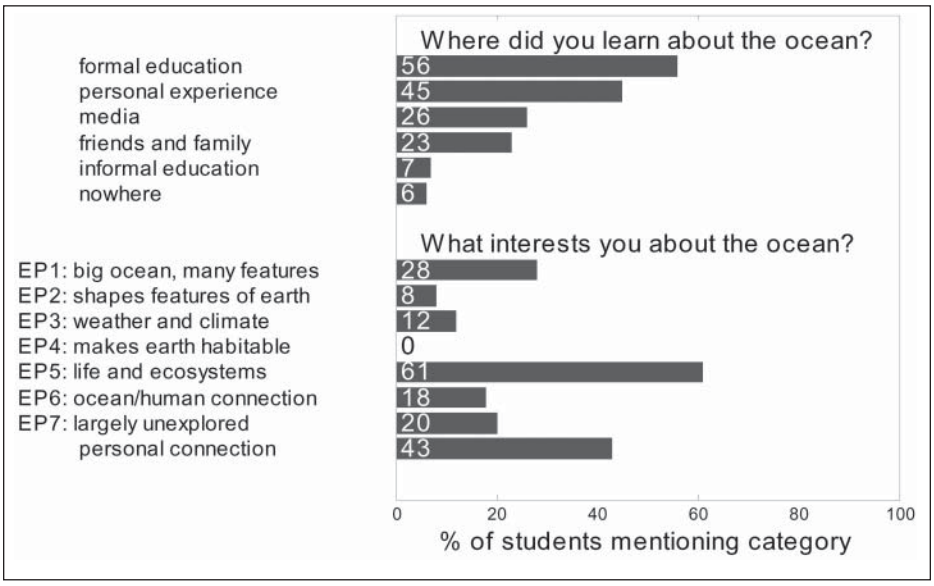

Figure 1: Student responses to the questions 'Where did you learn about the ocean?' and 'What interests you about the ocean?' Responses to the first question are grouped by source, and responses to second question are grouped using the seven Essential Principles of Ocean Literacy.

Student comments about the physics of the ocean, including its size, regional variations, and circulation, were gathered under EP1 (large ocean), mentioned by 28% of students. Interest in coastal and submarine features indicated EP2 (shaping the features of Earth), mentioned by 8% of the students. Climate, weather, and hurricanes (EP3) were mentioned by 12% of the students. EP4 (making the Earth habitable) includes only two Fundamental Concepts: the oceans as the birthplace of life and the source of atmospheric oxygen. In the pre-class survey, none of the student comments seemed applicable to EP4.

Marine life in general (EP5) was the most popular topic, mentioned by 61% of the students. Many students simply wanted to learn about marine animals, but others mentioned specific interests in scuba diving, fishing, maintaining saltwater aquaria, or studying marine biology. Their interest seemed to be on the scale of organisms, not ecosystems; fewer than 10% of students explicitly mentioned ecosystems, adaptations, or diversity.

Students were aware that the ocean is largely unexplored (EP7, mentioned by 20%) and were inspired by the ocean's mystery. Comments included: "There is so much that we don't know, and that's very intriguing. We probably know more about outer space than we do about deep-sea ecosystems," and "It makes my imagination go wild."

Some students were interested in connections between humans and oceans on the societal scale (EP6, mentioned by 18%), but many more students mentioned a direct personal connection with the ocean (43%). This connection could be an interest in water sports (14%), a career plan (8%), an emotional response (33%), or some combination.

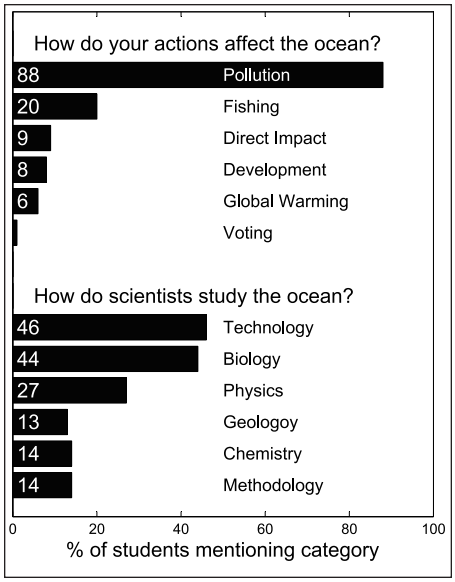

Figure 2: Student responses to the questions 'How do your actions affect the ocean?' and 'How do scientists study the ocean?' grouped by category.

This direct personal connection is an important hook for teaching oceanography. Student comments about the ocean revealed a passionate emotional response, sometimes expressed in romantic or religious terms. Comments included:

- "Every moment brings something new."
- "I feel a type of completeness I don't feel anywhere else."
- "I like the power, energy, motion, and sounds of the waves."
- "Mysterious and scary…beautiful and intriguing."
- "I'd say the ocean is the last semi-sacred place on Earth, where humans haven't colonized and totally demolished the place."

• "One of the most beautiful things in life is…a sunrise or a sunset at the ocean.… How do we, as a society, protect those moments and experiences?"

Students recognized the role of science in "connecting pieces of the large puzzle of how the world works and how we work on the world" (a fine definition of scientific literacy). Finally, they acknowledged the personal benefits of education, such as an ability to "impress girls at the beach with my knowledge of why the ocean does what it does." This comment is not only about pickup lines; as noted above, students attribute a great deal of their knowledge of the ocean to conversations with acquaintances.

When students were asked to discuss some ways their actions affect the ocean, it became clear that formal and informal efforts to educate the public about the dangers of pollution have paid off. About 88% of students mentioned pollution (Figure 2), and half of those gave a detailed explanation of pollution's effects. For example, "Almost everything we do affects the ocean, from littering on the beach to driving to school in the morning…They say that all water leads to the ocean, so in effect, any harm done to any water would affect the ocean."

Other human impacts were noted far less frequently, with 20% of students mentioning fishing and fewer than 10% mentioning coastal development or global warming. Direct individual impacts, such as driving on the beach or damaging coral while diving, were mentioned as frequently as coastal development. Only one student mentioned the political process as an influence on coastal health.

Finally, students were asked to describe a few ways scientists study the ocean. Answers to this question revealed the importance of the 'cool factor'—46% of students mentioned technology, including ships, submarines, and scuba, and 44% mentioned marine biology (Figure 2). Physics was mentioned by 27% of students, while the other subdisciplines of oceanography received only a few mentions (13–14%). Methodology, including references to observation, modeling, or the scientific method, was mentioned by 14% of the students.

New Directions

Undergraduates entering introductory oceanography courses have learned about the ocean from a variety of sources, feel a personal connection with the ocean, and are concerned about its well-being. College courses taught for the sake of promoting ocean literacy could find a receptive audience. Unlike a traditional oceanography course, an ocean literacy course might have objectives such as increasing student awareness of human impacts aside from pollution, or preparing students to become advocates about ocean protection and other coastal issues in their states.

The survey and results presented here are preliminary. New questions, as well as scoring rubrics for the existing questions, are under development. The survey discussed here, and a more recent version, are posted at http://www4.ncsu.edu/~cncudaba/Education/ocean_literacy.html

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NEWS

Hearings Highlight International Polar Year

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The upcoming International Polar Year will incorporate education and outreach activities into its major scientific themes, scientists told members of Congress at a 20 September hearing before the U.S. House of Representatives Science Subcommittee on Research. A second hearing was held on 26 September before the U.S. Senate Committee on Commerce, Science, and Transportation.

The upcoming International Polar Year (IPY; http://www.ipy.org) actually will run for two years, from March 2007 through March 2009. It is intended to be an international, multi-disciplinary, coordinated effort that will include observations and analyses of, and research in, the polar regions. Scientists around the world have proposed 225 projects that would involve 6000 scientists in 63 countries. The breadth of projects would extend across both polar regions and across multiple scientific disciplines, although most of the projects have not yet been finalized, and funding for many of them is not certain.

Arden Bement, Jr., director of the U.S. National Science Foundation (NSF), the lead U.S. agency for IPY, told Congress, "Fifty years ago, the third [IPY] and International Geophysical Year [1957–1958] entranced America's youth and galvanized America's innovative powers in ways that created a legacy that lives on today… We intend for the [upcoming IPY] to be a time to explore new frontiers in polar sciences, improve our understanding of the critical role of the polar regions in global processes, create a legacy of infrastructure and data for future generations of scientists, expand international cooperation, engage the public in polar discovery, and help attract and educate the next generation of scientists and engineers."

NSF, with support from NASA and the U.S. National Oceanic and Atmospheric Administration (NOAA), will focus U.S. IPY efforts on three scientific themes coupled to education and outreach: how organisms adapt to climate extremes, the creation of a circum-Arctic observation network, and a multi-national effort to understand changes in ice sheets and their global effects, Bement said.

NSF already has funded nine education and outreach projects for IPY in order to jumpstart these efforts, and the agency plans to announce funded projects in each of the three science areas by the end of October.

House Subcommittee Chair Bob Inglis (R-S.C.) said that he was pleased to see that education and outreach would be major components of the IPY. "It is so important that we take this opportunity to instill excitement about science in our children and motivate future generations of scientists," he said.

Donal Manahan, a biologist at the University of Southern California, Los Angeles, said that the new IPY expands on previous ones (which focused mainly on the geosciences) by introducing the concept of cross-disciplinary research—including the biological, chemical, physical, and social sciences—all in the context of complex systems, from biosystems to ecosystems to geosystems.

Robin Bell, who chairs the U.S. National Academies' Polar Research Board, the national coordinating committee for the IPY, told the subcommittee that "one of the distinct differences in this polar year is the inclusion of the human face," including how humans and especially communities in the Arctic region are part of the global system.