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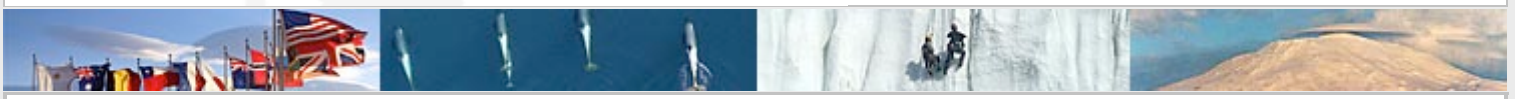

BIOLOGY AND MEDICINE

Four killer whales swim in McMurdo Sound. Researchers from NOAA Fisheries, Southwest Fisheries Science Center are studying the whales to determine if there are three separate species of Antarctic killer whales. They took aerial photos of the whales, such as this one taken in January 2005, as part of their work. (*NSF photo by Donald LeRoi, NOAA Southwest Fisheries Science Center*)

In this section:

- What limits denitrification and bacterial growth in Lake Bonney, Taylor Valley, Antarctica?
- Improving acoustic estimates of antarctic krill populations.
- Establishing a Polar Remote Interactive Marine Observatory (PRIMO) near Palmer Station on the western Antarctic Peninsula.
- Temporal variability in natural and anthropogenic disturbances at McMurdo Station, Antarctica.

Overview

Antarctica is a place like no other; as an intriguing habitat, it is a scientist's dream. It is a land where water is scarce—truly a desert—despite having more than two-thirds of the world's freshwater supply trapped in ice. Though it borders the world's major oceans, the Southern Ocean system is unique; it is a sea where average temperatures do not reach 2°C in summer, where even the water is so unusual that it can be identified thousands of kilometers away in currents that originated here. As the Earth, tilted on its rotational axis, makes its elliptical journey around the Sun each year, the Sun "sets" in April, not to be seen again until September. And the ice—an unimaginable, incomparable vastness of ice—appears in a dozen different varieties, at times and in places several thousand meters thick. There are two major ice sheets that change all the time. (One of them, the East Antarctic Ice Sheet, is larger than most countries.)

Adaptations and behavior developed in response to these extreme conditions provide insight into the intricacies, as well as the fundamental processes, of evolution. These extremes have also driven the development of ecosystems simple enough to reveal wonderfully clear pieces of the web of life on Earth.

The Antarctic Biology and Medicine Program funds research to improve understanding of antarctic ecosystems and life forms—their physiology, genetics, behavior, adaptations, and relationships. Projects range across all organizational levels, from the molecule, gene, cell, and organism to relationships within communities and ecosystems, to the level of global processes and the biosphere. This is another area of inquiry where scientific goals and benefits extend far beyond learning (in this field, about flora and fauna) in the high latitudes. Support is focused on the following areas:

- **Marine ecosystem dynamics:** Among the research topics are understanding the natural variability of marine ecosystems, correlating the structure and function of the marginal ice-zone ecosystem with oceanic and atmospheric processes, exploring the sources of nutrition and their influence on prey and on primary production, and examining the role of marine phytoplankton in carbon-dioxide cycling.
- **Terrestrial and limnetic ecosystems:** Organisms in ice-free areas and in perennially ice-covered lakes show remarkable adaptations to extreme environments. The fact that relatively few species thrive here facilitates the study of ecosystem dynamics and the interpretation of experiments, although much more remains to be learned about adaptive mechanisms and evolutionary processes.
- **Population biology and physiological ecology:** At the next level, looking at relationships among organisms, studies have focused on the variability and dynamics of populations of krill and other zooplankton. Ecological relationships among and between fish species, marine mammals, and birds have also been the object of much research, with many issues still to be further explored. Advances in genetic testing now permit scientists to establish relationships that were previously unverifiable between individuals and species in the wild. As organized programs of antarctic science enter their fifth decade (some have been in existence even longer), data sets and ongoing observations are elucidating manmade as well as natural changes.
- **Adaptation:** The extremes of light, temperature, and moisture have resulted in unusual adaptations. Research includes low-temperature photosynthesis and respiration, enzymatic adaptations, and adaptive physiology, such as the development of antifreeze compounds in fish and modifications to the circulatory system in seals. There is also continuing interest in the response of organisms to increased ultraviolet-B radiation from the ozone hole (as well as its impact on them). Here, too, new molecular DNA advances have had a profound impact on the types of studies that can be mounted.
- Genomics. "Genome-enabled" biology provides opportunities to examine polar questions related to structure and function in the environment and to do so with extraordinary depth and precision.
- **Human behavior and medical research:** Antarctica's extreme climate and terrain impose a spartan and unconventional existence on scientists and others who live and work there. As people are subjected to social, psychological, and physiological stresses (exacerbated during the winter isolation), opportunities for research arise. Studies focus on epidemiology, thermal regulation, immune system function, individual behavior, and group dynamics.

Impact of solar radiation and nutrients on biogeochemical cycling of dimethylsulfoniopropionate (DMSP) and dimethylsulfide (DMS) in the Ross Sea, Antarctica.

Ronald P. Kiene, University of South Alabama, and David J. Kieber, State University of New York–Syracuse.

Areas of the Southern Ocean have spectacular blooms of phytoplankton during the austral spring and early summer. One of the dominant species, the haptophyte Phaeocystis antarctica, is a prolific producer of the organic sulfur compound dimethylsulfoniopropionate (DMSP), and Phaeocystis blooms are associated with some of the world's highest concentrations of DMSP and its volatile degradation product, dimethylsulfide (DMS). Sulfur, in the form of DMS, is transferred from the oceans to the atmosphere, where it oxidizes and can affect precipitation chemistry and influence cloud properties and, possibly, climate. DMSP and DMS are also significant components of the carbon, sulfur, and energy flows in many marine food webs, although very little information is available on these processes in high-latitude systems.

We will therefore study how solar radiation and iron cycling affect DMSP and DMS production by phytoplankton and the subsequent use of these labile forms of organic matter by the microbial food web. Four interrelated hypotheses will be tested in field-based experiments and *in situ* observations:

- that solar radiation, including enhanced ultraviolet-B due to seasonal ozone depletion, plays an important role in determining the net ecosystem production of DMS in the Ross Sea;
- that development of shallow mixed layers promotes the accumulation of DMS in surface waters because of enhanced exposure of plankton communities to high doses of solar radiation;

- that DMSP production and turnover represent a significant part of the carbon and sulfur flux through the food webs of polar waters such as the Ross Sea; and
- that bloom development and resulting nutrient depletion (e.g., iron) will result in a high production of DMSP and high DMS concentrations and atmospheric fluxes.

The results of this study will greatly improve our understanding of the mechanisms controlling DMSP and DMS concentrations in polar waters, thereby enhancing our ability to predict DMS fluxes to the atmosphere from this important climatic region.

We actively engage high school, undergraduate, and graduate students in our research and are involved in formal programs that target underrepresented groups. The information gained from this research will also be used in teaching undergraduate and graduate courses. (B–002–N and B–266–N; NSF/OPP 02–30497 and NSF/OPP 02–30499)

Response of terrestrial ecosystems along the Antarctic Peninsula to a changing climate.

Thomas A. Day and Jeffrey M. Klopatek, Arizona State University–Tempe.

The striking increases in air temperatures and ultraviolet-B (UV–B) radiation documented along the west coast of the Antarctic Peninsula over the past 50 years represent a profound climatic change, arguably greater than has been experienced by any other region on Earth during this time. Along with these well-documented changes, annual precipitation and the depth of the winter snow pack along the Peninsula also appear to be increasing. These rapid changes provide a unique opportunity to examine the effects of climate change on terrestrial ecosystems.

Building on past work that focused on the impact of warming and UV–B radiation on terrestrial vascular plants on the Peninsula, we will examine how climate change alters nutrient (carbon and nitrogen) pools and cycling among plants, litter, and soils in vascular-plant-dominated communities, with the overall goal of predicting long-term effects on plant productivity. We will use two complementary approaches.

In the first approach, we will study shorter term responses to climate change by manipulating temperature, water availability, and UV–B exposure of vascular-plant microcosms over three growing seasons. We will assess how these manipulations influence plant growth and primary productivity, carbon dioxide fluxes, litter quality and decomposition, pools and turnover rates of carbon and nitrogen, and the structure of soil microbial and arthropod communities. These realistic manipulations will allow us to accurately assess the effects of different future warming scenarios, as well as the effects of solar UV–B radiation.

In the second approach, we will examine longer term responses to warming by measuring pools of carbon and nitrogen in plants, litter, and soils in plant communities along transects that represent gradients of long-term temperature regimes. Analyzing the results from short-term warming manipulations in the context of patterns found along these gradients will make it possible to develop a conceptual model of warming impacts over time.

The broader impacts of this project include

- recruiting and training undergraduate students from underrepresented minorities;
- disseminating findings to the general public; and
- contributing to society at large by improving our understanding of how climate change affects plant productivity and ecosystem carbon storage, as well as whether ecosystem responses to climate change will mitigate or promote continued buildups of greenhouse gases. (B–003–P; NSF/OPP 02–30579)

Patterns and processes: Dynamics of the Erebus Bay Weddell seal population.

Robert A. Garrott and Jay J. Rotella, Montana State University–Bozeman, and Donald Siniff, University of Minnesota–Twin Cities.

The Erebus Bay Weddell seal (Leptonychotes weddellii) population study in eastern McMurdo Sound was initiated in 1968 and represents one of the longest intensive field investigations of a long-lived mammal in existence. Over more than 35 years, a total of 16,809 animals have been tagged, with 161,994 resighting records logged in the database. This study is a valuable resource for understanding the population dynamics not only of Weddell seals, but also of other species of terrestrial and marine mammals. We are pursuing two lines of investigation that combine the long-term database with new field initiatives.

The continuity of the demographic data will be maintained by annually marking all pups born, replacing lost or broken tags, and performing censuses. We will combine these new data with the existing database and perform a complex series of demographic analyses that will allow us to test specific hypotheses about population regulation and evaluate previously determined temporal and spatial patterns of variation in vital rates among colonies.

The primary new field initiative is an intensive study of the mass dynamics of both pups and adult females to assess annual variation in marine resources and its potential role in limiting or regulating the population. In addition to collecting data on body mass dynamics, we will use satellite imagery to develop an extended time-series of sea ice in McMurdo Sound. (The extent of sea ice affects both regional primary productivity and availability of haul-out areas.) Increased primary productivity may increase marine resources, which would be expected to have a positive effect on foraging efficiency, leading to increased body mass. Understanding the mechanisms that limit or regulate Weddell seal populations and the specific linkages between climate, oceans, ice, and antarctic food webs can make important contributions to the knowledge of pinniped population dynamics, as well as the theoretical understanding of populations, communities, and ecosystems.

Such knowledge can enhance the ability of natural resource managers to effectively maintain assemblages of other large mammal species and the ecological processes they facilitate. Continuation of this long-term study may also contribute to understanding the potential impact of human activities such as global warming and the commercial exploitation of antarctic marine resources. (B–009–M; NSF/OPP 02–25110)

Drinking and sodium/potassium–ATPase alpha-subunit isoform expression and antarctic fish.

David Petzel, Frank Dowd, Margaret Scofield, and Philip Brauer, Creighton University.

Notothenioid fishes inhabiting the near-freezing (–2°C) waters of McMurdo Sound have some of the highest serum and cellular sodium concentrations and the lowest gill sodium/potassium-ATPase (Na/K-ATPase, the sodium/potassium pump) activities of any marine teleost. The enzyme Na/K-ATPase regulates the sodium concentration in the cells of many organisms. Maintaining a high salt content in the cells of these fish lowers the freezing point to allow them to inhabit cold antarctic waters and reduces the salt gradient between them and sea water.

On the basis of previous studies of temperature effects, we hypothesize that compared with New Zealand notothenioids that inhabit warmer waters, antarctic notothenioids have lower drinking rates, lower salt excretion rates, and a higher proportion of the low intracellular sodium affinity for a specific subunit of the Na/K-ATPase (a3-isoform). These unique osmoregulatory properties explain the high serum and cellular sodium concentrations found in notothenioids south of the antarctic Polar Front.

We will compare and contrast the unique osmoregulatory mechanisms of antarctic and New Zealand notothenioids with respect to

- sea water drinking rates and the serum and cellular chemical composition of the fish,
- enzymatic properties and the expression pattern of mRNA and protein, and
- temporal and spatial localization of the Na/K-ATPase a3-isoform subunit in the gills.

To accomplish these objectives, we will study four species of notothenioids, representing ecologically diverse habits above and below the Polar Front.

The information we gain will increase our knowledge about the role of Na/K-ATPase in the cellular function in many organisms, strengthen our understanding of the biochemical and physiological adaptations that allow antarctic notothenioids to survive and thrive in the icy waters south of the antarctic Polar Front, provide field and laboratory research experience for graduate and undergraduate students, and contribute to significant outreach activities in science education for elementary and high school students and teachers. (B–012–M; NSF/OPP 02–29462)

Remotely operable microenvironmental observatory for antarctic marine biology research.

Samuel S. Bowser, New York State Department of Health, and Anthony D. Hansen, Magee Scientific Company.

Research diving over the past two decades has yielded important insights into the ecological importance of giant (larger than 1 millimeter) foraminifera in McMurdo Sound. Unfortunately, the *in situ* behavior of these single-celled organisms and their interactions within the food web can be observed only in "snapshots" during summer dives, when algal production is at a maximum under 24-hour light. Much would be learned by observing foraminifera over extended periods, to study mobility, response to food availability, and other directed behaviors. It would be valuable to be able to extend observations to the winter months to study these organisms in the dark, with no algal production, and to experimentally manipulate *in situ* conditions and observe the behavioral response.

Research diving requires costly support and cannot provide extended observation of individual organisms. Moreover, the logistical requirements, costs, complexities, and risks of winter diving at remote locations in Antarctica are prohibitive. However, human diving is not required to make long-term *in situ* observations. Technology and communications have advanced to the point where it is feasible and practical to install video macro- and microview cameras in a submersible enclosure; they can transmit both live and sequential time-lapse images over the Internet to a remote user throughout the year. Such an instrumentation platform could then be used for experimental manipulation of the environment.

We will develop a submersible, remotely operable underwater observatory for the study of foraminifera and associated benthic fauna. This observatory will be connected to a shoreline unit by fiberoptic cable and linked by radio to the Internet for year-round access. The design and operation of this observatory will function as a technology template to meet other year-round antarctic research requirements by means of telescience rather than personnel deployment. (B–015–M; NSF/OPP 02–16043)

The molecular signals that regulate the ontogeny of aerobic capacity, lipid metabolism, and elevated myoglobin concentrations in the skeletal muscles of Weddell seals.

Shane B. Kanatous, University of Texas.

What are the molecular signals that regulate the changes in skeletal muscle physiology as young Weddell seals *(Leptonychotes weddellii)* develop into elite divers? We will address this broad question during a 3-year study that builds on our previous work, which characterized the enzymatic and structural adaptations for diving that occur in the skeletal muscles of newly weaned, juvenile, and adult Weddell seals and began to define the molecular signals that regulate these ontogenetic changes in skeletal muscles. We will proceed as follows:

- First, we will use enzymatic, immunohistochemical, and myoglobin assays to further characterize the ontogenetic changes in muscle aerobic capacity, lipid metabolism, and myoglobin concentration and distribution in newly weaned, subadult, and adult seals.
- Second, we will determine the molecular controls that regulate these changes in aerobic capacity, fiber type distribution, and myoglobin in skeletal muscles during maturation.

Through subtractive hybridization and subsequent analysis, we will determine the differences in mRNA in the swimming muscles of the different age classes of seals. These techniques will allow us to identify the proteins and transcription factors that influence the ontogenetic changes in myoglobin concentration, fiber type distribution, and aerobic capacity. The results will increase our

understanding of the ontogeny and molecular mechanisms by which young seals acquire the physiological ability to make deep (up to 700 meters) and long (about 20 minutes) aerobic dives.

This study will advance our knowledge of the molecular regulation of adaptations that enable active skeletal muscle to function under hypoxic conditions; this has broader applications for cardiac and pulmonary disease in humans. The project will involve a postdoctoral fellow and two graduate students and also has a significant outreach component. In addition to interviews, e-mail exchanges with high school and middle school students, public seminars, and presentations at meetings, we will continue to support our Web site in collaboration with the Science Teachers Access to Resources at Southwestern (STARS) Program (www.swmed.edu/stars/02antarcticexpedition), where we supply weekly updates about our research during the field season, answer questions from students and teachers, and supply periodic off-season updates on our results. (B–018–M; NSF/OPP 04–40713)

Genomic networks for cold-adaptation in the embryos of polar marine invertebrates.

Adam G. Marsh, University of Delaware.

Although the cold ocean ecosystems comprise 72 percent of Earth's biosphere by volume, they remain sparsely inhabited and relatively unexploited, particularly the metazoan phyla. Consequently, the few animals that can exist at this border of intracellular freezing are ideal for exploring genomic-level processes of environmental adaptation. Understanding life at the margin will convey significant insights into the processes essential for survival under intense selection pressures.

Our study of adaptive mechanisms in genomic networks focuses on a system that faces a formidable challenge at cold temperatures: embryonic development of two antarctic echinoderms, the seastar *Odontaster validus* and the sea urchin *Sterechinus neumayeri,* at sea water temperatures of –1.8°C. We will quantify temperature effects on gene expression and protein turnover networks during early development by using a Bayesian network analysis (a method of statistical analysis) to identify clusters of genes and proteins whose levels of expression are associated in fixed, synergistic interactions. Ultimately, the question to be addressed is whether it is more or less difficult (complex) for an embryo to develop in an extreme environment. To answer this question, we will decipher network topologies and subnet structuring to uncover gene connectivity patterns associated with embryonic development in this polar environment. We also intend to interest students in the developing field of environmental genomics by increasing the awareness of career opportunities within the field and increasing the racial diversity of those attracted to it.

Working in a remote, extreme environment such as Antarctica is always a challenge, but the adventurous nature of the work can be used to establish educational and outreach components of high interest to both undergraduate students and the public. We will bring the experience of working in Antarctica to a larger audience by

- incorporating environmental genomics into a new bioinformatics curriculum being developed at the University of Delaware,
- implementing an intern program to involve minority undergraduates in summer research in the United States and then to bring them to Antarctica to participate in research, and
- creating a K–12 education program that will bring the excitement of working in Antarctica to the classrooms of thousands of children (in the United States and around the world) through a program produced in conjunction with the Marine Science Public Education Office at the University of Delaware. (B–029–M; NSF/OPP 02–38281)

Geographic structure of Adélie penguin populations: Demography of population expansion.

David G. Ainley, H.T. Harvey and Associates, and R. Glenn Ford, RGFord Consulting.

In collaboration with scientists from New Zealand, Italy, and France, we are investigating the mechanisms responsible for the geographic structuring, the founding of new colonies, and the recent population expansion of the Adélie penguins *(Pygoscelis adeliae)* of Ross and Beaufort Islands. Similar expansion has been occurring throughout the Ross Sea, where 38 percent of the world's population of this species resides, and is in some way related to ameliorating climate. We continue to examine

- the relative importance of resources that constrain colony growth;
- aspects of natural history that might be affected by exploitative or interference competition among neighboring colonies;
- climatic factors that influence the latter;
- behavioral mechanisms that influence colony growth; and
- foraging effort, as a function of diving and swimming capabilities and food availability.

We have shown how sea ice affects diet, foraging, and winter survival. In addition, the large colony at Cape Crozier, in concert with minke and killer whales, affects the foraging patterns of penguins at the smaller colonies and, perhaps, their size. Emigration also appears to be constrained by sea ice, with reasonable concentrations of ice favoring the growth of smaller colonies where foraging competition is minimal.

We will use 10 cohorts of marked penguins from each colony to assess juvenile survival, recruitment age, and age-specific fecundity and subsequent survival. These data will be compared with another demographic study, the only one for this species, conducted at Cape Crozier during the 1960s and 1970s, when populations were declining. Satellite tags are providing information on local, foraging movements, and geolocation tags are providing information on the winter journeys of southern Ross Sea penguins.

Information will be related to sea ice as quantified by satellite images. Global climate is changing the fastest in the polar regions. The Adélie penguin is tied to sea ice, a primary factor in rapid polar climate change. Our study will contribute greatly to understanding the effects of climate change on antarctic marine organisms. (Additional information can be found on our Web site: www.penguinscience.com.) (B–031–M; NSF/OPP 0440643)

Investigations on deterioration in the historic huts of Antarctica.

Robert A. Blanchette, University of Minnesota.

During the first two decades of the 20th century, Europeans mounted a handful of expeditions in hopes of reaching (and claiming) the geographic South Pole. Base camps established in the McMurdo Sound region by Scott at Hut Point and Cape Evans and by Shackleton at Cape Royds were abandoned once the expeditions were over, leaving behind thousands of artifacts, as well as the huts the explorers built for shelter and storage. Over the intervening 90 years, the extremes of the polar environment have actually protected some of the artifacts from rapid decay, but conservators have become concerned about the serious degradation of what is an important historical, archaeological site.

Some of the gravest threats are as follows:

- Wood in contact with the ground is being destroyed by a fungus. Also, various molds and cellulose-degrading fungi are attacking artifacts made of leather, textiles, and other organic materials.
- Exterior wood is being degraded by nonbiological processes as well, including salt, ultraviolet radiation, and wind erosion.
- Chemical damage within the huts is apparent, and the soils on the site are contaminated with aromatic hydrocarbons from petroleum products.

We plan to identify the biological and nonbiological agents responsible for the deterioration, study the mechanisms and progressive sequence of the events taking place, test methods to be used to control future deterioration, determine the extent of environmental pollutants in soils at the historic sites, and evaluate chemical spills within the huts. The goal is to provide the scientific data conservators need to help protect these important sites for future generations. But the project should also shed light on these unique deterioration processes, as well as augment scientific understanding of the biology of antarctic microorganisms and the biodiversity of microbes present in this unusual environment. (B–038–M; NSF/OPP 02–29570)

Foraging behavior and demography of *Pygoscelis* penguins.

Wayne Z. Trivelpiece, National Oceanic and Atmospheric Administration.

Seabird research conducted at Admiralty Bay, King George Island, in the Antarctic Peninsula region has documented annual variability in the life history parameters of the population biology of three related penguin species: the Adélie, the gentoo, and the chinstrap (*Pygoscelis adeliae, P. papua,* and *P. antarctica,* respectively). This long-term study has collected more than 25 years of data on these three related species, including survival and recruitment, population size and breeding success, and diets and foraging ecology.

We will extend the research linking penguin demography and foraging ecology to variability in the antarctic marine ecosystem. A major focus will be on the population biology data for the Adélie and gentoo penguins and the distribution and trophic interactions among the three species during the breeding season and the nonbreeding, winter period. Recent studies using satellite tags and time-depth recorders to examine postfledging foraging have provided the first detailed data on the wintering distributions of Adélie and chinstrap penguins in the Antarctic Peninsula.

Specific topics include an examination of the size and sex of krill captured by penguins feeding chicks and krill collected concurrently by net hauls in the adjacent marine environment and the length-frequency distribution of krill collected from penguin diet samples. The winter survival of breeding adults and the recruitment of young (2- to 4-year-old) prebreeding penguins to their natal colony will be compared with the extent of sea ice in the winter before the breeding season. These variables are expected to be positively correlated for the Adélie but negatively correlated for the chinstrap penguin. Detailed studies of adult gentoo penguins, which do not disperse widely from their natal colony, will be conducted using satellite tags.

The data we gather on the impact of environmental variation on the structure of upper-trophic-level predators such as the *Pygoscelis* penguins will improve our understanding of the structure and function of the Antarctic. (B–040–E; NSF/OPP 01–25985)

Evolution of morphology and trophic strategies in antarctic agglutinated foraminifera.

Samuel S. Bowser, New York State Department of Health.

We will study, in an interdisciplinary fashion, the evolution and ecological significance of foraminiferan protists, a major but neglected group of marine organisms. For over a decade, we have studied the cell biology, ecophysiology, and evolution of single-chambered foraminifera (allogromiids), focusing on giant (larger than 1 millimeter) high-latitude species.

Our studies have revealed a high degree of diversity in this group. The molecular phylogenetic framework is based on studies of a single gene (ribosomal small subunit or SSU) that, unfortunately, does not clearly indicate the relationship between major groups. Adding to the confusion is the fact that morphological characters traditionally used for species identification are not distributed in any meaningful way on the SSU tree. Therefore, there is no well-determined phylogeny to evaluate ecological and evolutionary hypotheses. Also, morphological identifications in the field do not always reflect the underlying biological reality. Without a better understanding of morphology, genetic identity, and ecologically relevant behavior, studies of this group are less likely to yield meaningful data.

We will study a taxonomically definitive group of allogromiids to generate a more robust, detailed phylogeny and use this new evolutionary framework as a springboard to test hypotheses in polar marine science. Specifically, we will investigate the biogeography of morphospecies that appear to be distributed in both arctic and antarctic waters. We will also use newly established underwater macroscopy equipment, lipid biomarker analyses, and predator/prey assays to determine the extent of carnivory within the early-evolving lineages. Ultimately, we intend to further develop rapid molecular screening methods for ecological studies and to understand the forces that led to the early diversification of foraminifera, whose origin dates from the Neoproterozoic and spans the dawn of skeletonization in multicellular organisms.

Our interactions with other scientists and international collaborations help transfer state-of-the-art advances in biomedical research to the ocean sciences. We will continue to promote the training of women and underrepresented groups through grass-roots efforts and participation in formal regional and national programs. Moreover, we interface original research with K–12 education and public outreach and will continue to partner with science teacher organizations and educational foundations that emphasize hands-on learning. (B–043–M; NSF/OPP 04–40769)

Interannual variability in the Antarctic–Ross Sea (IVARS): Nutrients and seasonal production.

Walker O. Smith, College of William and Mary, Virginia Institute of Marine Sciences.

During the past few decades, oceanographers and other scientists have found significant variations in Southern Ocean biogeochemical processes from year to year. Some of the more significant of these interannual variations are the extent and concentration of the ice, the composition of herbivore communities, and the distribution and reproductive success of birds and marine mammals.

Even though phytoplankton production is central to the food web, surprisingly little is known about how it varies from year to year or what role these variations may play. The production system in the Ross Sea consists predominantly of two major functional groups: diatoms and *Phaeocystis antarctica,* a colonial haptophyte. We will collect time-series data and assess the interannual variations of phytoplankton in the southern Ross Sea.

The Ross Sea provides a unique setting for such an investigation. We can build on a de facto, already ongoing time-series because so many studies have been conducted there in the past decade. Also, it has been established that there are fewer species there (relative to some other sites) and that seasonal production is as great as anywhere in the Antarctic. Most important, seasonal production of the total phytoplankton community (as well as its two functional groups) can be estimated from late summer nutrient profiles.

Interannual variations in seasonal production (and of the two major taxa of producers) may be an important factor in the growth and survival of higher trophic levels within the Ross Sea food web. They also shed light on the natural variability of the suite of biogeochemical processes in the region. Having a scientific handle on that baseline of change is important because of efforts to model how climate may change in the future. As climate changes, so certainly will biology be profoundly affected, and to model and evaluate such change we need to place it in the context of natural interannual variability. (B–047–M/N; NSF/OPP 00–87401)

Complex molecular-to-global interactions and feedbacks in the marine dimethylsulfide (DMS) cycle.

Patricia Matrai, Bigelow Marine Laboratory.

Ocean ecosystems are part of a complex web that transforms matter and energy and sets the conditions for life on Earth. Communication and feedback among different parts of this web are mediated by the exchange of biogenic trace gases. One feedback involves marine plankton, the volatile sulfur compound dimethylsulfide (DMS), and global climate. DMS produced by marine phytoplankton and the food web enters the troposphere and is oxidized to sulfate particles, which influence cloud albedo and, consequently, climate. Large-scale climate change, in turn, affects the abundance of phytoplankton and food web processes in the oceans and thereby closes the loop.

The strength of this loop is still unknown because of the complex processes that affect DMS emission. No field studies have measured all of the relevant rates and concentrations in the marine DMS cycle simultaneously, nor have complex interactions or measurements been included for important geophysical and chemical parameters, thus hampering the ability of models to accurately map variations in surface DMS concentrations. To address this problem, we will

- measure and model all relevant fluxes of concentrations of DMS and related species in a subtropical gyre and the Southern Ocean,
- develop a global marine DMS model from the field measurements and other existing measurements and models, and
- use this model to evaluate the potential for feedbacks between climate and the DMS cycle.

The DMS system helps explain the complexities in biosphere-geosphere regulation and serves as an excellent model for food-web-dependent biogeochemical processes. Because dimethylsulfoniopropionate (DMSP), the precursor of DMS, is intimately connected to virtually all levels of the food web and because DMSP itself contributes significantly to the carbon flow in the ocean, our investigation will shed light on the critical factors influencing the distribution of organisms in the sea and the cycles of major nutrient elements.

We will include undergraduate and graduate students, as well as a postdoctoral modeler and two K–12 teachers, and create an interactive page on the Bigelow Web site. In addition, each of the investigators will formalize ongoing interactions with regional K–12 schools by creating and using a shared presentation. (B–048–P; NSF/OPP 02–21748)

Free-drifting icebergs: Influence of floating islands on pelagic ecosystems in the Weddell Sea.

Kenneth L. Smith, University of California–San Diego, Scripps Institution of Oceanography.

Over the past decade, atmospheric warming has been associated with retreating glaciers and the increasing prevalence of icebergs in the Southern Ocean. The highest concentration of icebergs occurs in the northwest Weddell Sea, where they drift in a clockwise pattern to the northeast, following the contours of the Antarctic Peninsula through an area called "Iceberg Alley." But little is known about the impact of free-drifting icebergs on the pelagic ecosystem of the Weddell Sea or the Southern Ocean as a whole.

We believe that small to intermediate-size icebergs (less than 10 kilometers) impart unique physical, chemical, and biological characteristics to the surrounding water. Our research will address three questions:

- What are the dynamics of free-drifting icebergs on temporal scales of days to months, based on the correlation of field measurements with imagery from satellite sensors?
- What is the relationship between the size of free-drifting icebergs and the structure of the associated pelagic communities?
- What is the estimated combined impact of free-drifting icebergs in the northwest Weddell Sea on the biological characteristics of the pelagic zone?

We will use oceanographic sampling to determine the sphere of influence for a set of biological factors as a function of iceberg size. Our program is divided into four components:

- remote sensing of icebergs,
- phytoplankton communities,
- zooplankton and micronekton assemblages, and
- iceberg ecosystem synthesis/modeling.

Our research will provide critical data on the effects of atmospheric warming on the Antarctic Peninsula. The recent prevalence of free-drifting icebergs should have a pronounced enrichment effect on the pelagic ecosystem in the Southern Ocean. Enhanced primary production associated with them could influence the global carbon cycle, since the Southern Ocean is considered a major sink for excess carbon dioxide from the atmosphere.

Our results will be incorporated into a collaborative effort called the Ocean Exploration Center, whose focus is to provide researchers and the public with a comprehensive view of the oceans and direct access to databases and Web sites. These data will then be extrapolated to evaluate the impact of icebergs on the ecosystem and archived in a digital library. (B–050–L; NSF/OPP 05–29815)

Former elephant seal colonies in the Antarctic: Implications for Holocene climate change and genetic diversity in the Southern Ocean.

Brenda L. Hall, University of Maine, and Paul Kock, University of California–Santa Cruz.

What drives climate change? Long-term fluctuations may be paced by astronomical cycles, but how these factors and shorter-term variations control climate is poorly understood. The Southern Ocean and Antarctica are crucial for testing hypotheses of global change because their climate may be out of phase with that of the rest of the world. If this is true, it would favor the hypothesis that abrupt climate changes are caused by variations in ocean circulation. We will therefore develop data to address the pattern, timing, and cause of Holocene climate change.

During previous research, we discovered that colonies of southern elephant seals *(Mirounga leonina)* once existed along the Victoria Land coast. Molted sealskin and hair are found along 300 kilometers (km) of coastline, more than 1,000 km from any extant colony. The colony was apparently abandoned about 1600 A.D., possibly because of cooling and the encroachment of land-fast, perennial sea ice that made access to haul-out sites difficult. The record of seal habitation along the Victoria Land coast may therefore be a proxy for climate change.

We will address several questions:

- Why did elephant seals colonize and then abandon the coast?
- What does the record reveal about Holocene climate change and sea-ice conditions?
- What were the seals' foraging strategies and did they change with the climate?
- What is the genetic structure of the Victoria Land seals versus extant populations?
- How did genetic diversity change?
- What can we learn about population dynamics?
- What was the relationship between elephant seals and the Adélie penguins that occupied the sites at different times?

Carbon and nitrogen isotope analyses will provide information on changes in feeding strategies. We will document past sea-ice conditions by beach morphology and sedimentology and determine genetic structure from skin sample analyses. These data will allow us to develop an integrated history of the Victoria Land colonies.

Data from this study will be compared with existing records and used to develop a proxy for Holocene climate. Our research will allow us to test hypotheses of global climate change, modify graduate and undergraduate courses, and train new researchers. (B–068–M; NSF/OPP 04–39979 and NSF/OPP 04–39906)

Long-term data collection at select Antarctic Peninsula visitor sites.

Ron Naveen, Oceanites, Inc.

The Antarctic Site Inventory Project has collected biological data and site-descriptive information in the Antarctic Peninsula since 1994. This research has provided data on sites visited by tourists on shipboard expeditions in the region. Our aim is to obtain data on the population of several key species of antarctic seabirds that might be affected by the cumulative impact of visits to the sites. We will focus on two heavily visited Antarctic Peninsula sites: Paulet Island, in the northwestern Weddell Sea, and Petermann Island, in the Lemaire Channel near Anvers Island. We selected these sites because both rank among the 10 most visited sites in Antarctica each year in terms of numbers of visitors and zodiac landings, both are diverse in species composition, and both are sensitive to potential environmental disruptions from visitors.

We will collect data over 5 years on two important biological parameters for penguins and blue-eyed shags:

- breeding population size (number of occupied nests) and
- breeding success (number of chicks per occupied nest).

Our main focus will be Petermann Island, which we selected for intensive study because of its visitor status and location near Palmer Station. This will allow us to compare data with the Palmer Long-Term Ecological Research Program.

We will collect demographic data in accordance with the standard methods established by the Convention for the Conservation of Antarctic Marine Living Resources Ecosystem Monitoring Program, and the information we gather will thus be comparable to similar data sets being compiled by the research programs of other Antarctic Treaty nations. While separating human-induced change from change resulting from a combination of environmental factors will be difficult, this work will provide a first step toward identifying potential impacts. The long-term data sets we compile will contribute to a better understanding of biological processes in the entire

region and will also contribute valuable information to be used by Antarctic Treaty nations as they address environmental stewardship issues in Antarctica. (B–086–E; NSF/OPP 02–30069)

Distribution and ecology of ammonia-oxidizing bacteria in the Palmer Long-Term Ecological Research study area.

James T. Hollibaugh, University of Georgia.

We propose to investigate the distribution, phylogenetic affinities, and aspects of the ecology of ammonium-oxidizing bacteria in the Palmer Long-Term Ecological Research (LTER) study area. Ammonia oxidation is the first step in the conversion of regenerated nitrogen to dinitrogen gas via denitrification, a three-step pathway mediated by three distinct guilds of bacteria. Although important to the global nitrogen cycle, ammonia oxidation and the overall process of nitrification-denitrification have received little attention in polar oceans where they are significant and where the effects of climate change on biogeochemical rates are likely to be pronounced.

Our goals are to

- obtain more conclusive information on the composition of antarctic ammonia oxidizers,
- begin characterizing their ecophysiology and ecology, and
- obtain cultures of the organism for more detailed studies.

We will characterize water column and sea-ice assemblages of ammonia-oxidizing bacteria phylogenetically and quantify different kinds in various samples. We will also measure nitrification rates across the LTER study area in water column, sea-ice, and sediment samples, determining grazing rates and evaluating the sensitivity of these bacteria to ultraviolet light. In addition, we will assess the significance of urea nitrogen as a source of reduced nitrogen to these bacteria. Finally, we will evaluate the response of nitrification over temperature ranges appropriate to the polar regions.

Our work will provide insights into the ecology of ammonia-oxidizing bacteria and the knowledge needed to model how water-column nitrification will respond to changes in the polar ecosystems accompanying global climate change. (B–114–L; NSF/OPP 02–34249)

Toward an understanding of protein homeostasis in cold-adapted antarctic fish.

Gretchen E. Hofmann, University of California–Santa Barbara.

We will examine protein homeostasis in the cells of antarctic notothenioid fishes. Since previous research has suggested that these proteins may be subject to a great deal of misfolding at the subzero temperatures typical of antarctic coastal waters, we will continue to use a comparative approach highlighting the physiological differences between temperate New Zealand notothenioid fishes and antarctic fishes. Specifically, we will

- use ubiquitin conjugate analysis to measure the levels of damaged proteins tagged and targeted for degradation by the proteasome in the cells of antarctic fishes;
- estimate the efficiency of protein synthesis in cold-adapted antarctic fish cells by using isolated hepatocytes, pulse-chase experiments, and proteasome inhibitors to measure the levels of defective ribosomal products and determine the efficiency of protein biogenesis;
- measure relative 26S proteasome activity in the cells of antarctic fishes by using an established *in vitro* fluorometric assay to provide insight into whether cells are processing high levels of misfolded or otherwise damaged proteins; and
- assess the nature of cold-adapted gene expression in antarctic fishes compared with their temperate New Zealand relatives by examining the patterns of specific genes by means of real-time polymerase chain reactions.

Further, in collaboration with other researchers, we will use DNA microarray analysis to examine genomic-scale gene expression patterns in antarctic fishes compared with the New Zealand species to provide a more global view and to highlight whether deficient expression or alteration in gene expression is found after evolution at subzero temperatures.

In addition to providing undergraduate and graduate students with research experience, we will have an extensive program that includes both K–12 curriculum development and informal outreach. Our team includes an award-winning middle-school science teacher and a writer/journalist who focuses on environmental issues and has written children's books. These efforts will be coordinated through a program called *Oceans Alive!* Sponsored by the Marine Science Institute at the University of California–Santa Barbara, this program has as its primary goal to increase public understanding of earth and ocean science. This collaboration and participants' significant educational expertise will ensure that our efforts will be communicated to a wider audience. (B–134–M; NSF/OPP 04–40799)

Microbial diversity and function in the permanently ice-covered lakes of the McMurdo Dry Valleys, Antarctica.

John C. Priscu, Montana State University–Bozeman; Brian D. Lanoil, University of California–Riverside; Michael T. Madigan, Southern Illinois University–Carbondale; and Steven J. Giovannoni, Oregon State University.

We plan to study prokaryotic organisms in the permanently ice-covered lakes of the McMurdo Dry Valleys in order to identify and characterize novel organisms and elucidate those aspects of their genome and metabolism that are critical to understanding their role in biogeochemical cycles. We will use molecular tools in concert with conventional and high-throughput culturing techniques to define representative prokaryotic groups responsible for the contemporary geochemical gradients existing in these lakes.

The McMurdo Dry Valleys form the driest and coldest ecosystem on Earth and, until relatively recently, have been thought to harbor little life. A primary reason for establishing a microbial observatory for these lakes is to understand not only how the environment controls the diversity of organisms, but also how diversity itself controls the way ecosystems function. The McMurdo Dry Valley lake systems lend themselves to answering this question in a unique way. Given their isolation, the lack of higher life forms, and their

evolutionary history, these lakes offer a unique experimental arena to search for novel microorganisms and to study the interplay of microbial diversity and ecosystem function.

The results we derive will be significant to the growing body of literature in biodiversity, biotechnology, geobiology, polar ecology, and astrobiology. We will work with existing and new programs to archive the phylogenetic and physiological data we collect so that anyone who is interested can access it easily over the Internet. Strong linkages will be made with the highly visible education, outreach, and human diversity programs supported by the National Science Foundation's Office of Polar Programs and the McMurdo Long-Term Ecological Research Program to yield a project that will have a broad impact on society. (B–195–M; NSF/OPP 02–37335, NSF/MCB 02–37576, NSF/MCB 02–37434, and NSF/MCB 02–37689)

Diving physiology and behavior of emperor penguins.

Paul J. Ponganis, University of California–San Diego, Scripps Institution of Oceanography.

The emperor penguin, *Aptenodytes forsteri,* is the premier avian diver and a top predator in the antarctic ecosystem. The routine occurrence of 500-meter dives during foraging trips is a physiological and behavioral enigma. We will attempt to determine how and why emperor penguins dive as deeply and long as they do by examining four major topics: pressure tolerance, management of oxygen stores, end-organ tolerance of diving hypoxemia/ischemia, and deep-dive foraging behavior. These subjects are relevant to the role of the emperor as a top predator and to critical concepts in diving physiology, including decompression sickness, nitrogen narcosis, shallow water blackout, hypoxemic tolerance, and extension of aerobic dive time.

We will test the following hypotheses:

- Prevention of nitrogen narcosis and decompression sickness in emperor penguins is due to inhibition of pulmonary gas exchange at depth.
- Shallow water blackout does not occur because of greater cerebral hypoxemic tolerance and, in deep dives, because of resumption of pulmonary gas exchange during the final ascent.
- The rate of depletion of blood oxygen stores is a function of the depth of the dive and the heart rate.
- The aerobic dive limit reflects the onset of lactate accumulation in locomotory muscle, not total depletion of all oxygen stores.
- Elevation of tissue antioxidant capacity and free-radical scavenging enzyme activities protect against the ischemia and reperfusion that routinely occur during diving.
- During deep dives, the antarctic silverfish, *Pleuoragramma antarcticum,* is the primary prey.

In addition to evaluating these hypotheses, we will cooperate with U.S. and foreign organizations such as the National Institute of Polar Research in Japan, Centro de Investigaciones del Noroeste in Mexico, National Geographic, University of Texas Southwestern Medical Center, and Sea World. Our work will be featured in National Geographic television documentaries that will provide unique educational opportunities for the general public.

Development of state-of-the-art technology (e.g., blood oxygen electrode recorders, blood samplers, and miniaturized digital cameras) will lay the groundwork for future research. Moreover, during our fieldwork at several Ross Sea colonies, we will continue to evaluate the effects of the B–15 iceberg on the breeding success of emperor penguins. (B–197–M; NSF/OPP 02–29638)

Monitoring the effects of tourism and environmental variability on Adélie penguins at Palmer Station, Antarctica.

William R. Fraser, Polar Oceans Research Group.

The potential consequences of antarctic tourism on Adélie penguins *(Pygoscelis adeliae)* have been debated for more than 20 years. However, the rapid proliferation of these activities since 1970, particularly on the Antarctic Peninsula, has not only forced an extension of these questions to wildlife populations in general, but also colored them with a sense of urgency and controversy that has polarized opinions. The key concern is that continued increases in these activities will eventually overcome the ability of research to address critical issues in a timely and biologically meaningful manner. This is a valid concern, since studies to examine human impacts have either not been implemented at critical sites or are limited in scope because of logistic and experimental constraints.

Understanding how tourism might affect Adélie penguins rests on the need to quantify and understand the natural variability manifested by breeding populations over space and time. However, although it is generally recognized that without these data it will be difficult to critically assess any localized changes from tourism, this ecosystem approach is expensive and complex and is not likely to be justified by the need to understand tourist impacts.

We will continue a tourist monitoring program underway at Palmer Station as part of a large ecosystem-scale study. Palmer Station mirrors current patterns in tourism and tourist-wildlife interactions in the western Antarctic Peninsula. It also provides unique opportunities for research on human impacts, including the presence of long-term databases that document environmental variability in both marine and terrestrial habitats, as well as the ability to examine potential tourist impacts as part of controlled experiments.

Our research will expand on two key findings. One is the discovery of a previously unrecognized source of variability in the Adélie penguin population resulting from interactions between landscape geomorphology and changing patterns of snow deposition due to climate warming. The other is the observation that penguins breeding in less desirable landscapes may be more susceptible to cumulative impacts induced by the presence of human activity.

These findings have important implications for understanding interactions between climate change and ecosystem response, and for detecting, mitigating, and managing the consequences of human activities such as tourism. (B–198–P; NSF/OPP 01–30525)

Interactive effects of ultraviolet radiation and vertical mixing on phytoplankton and bacterial productivity of Ross Sea *Phaeocystis* bloom.

Wade H. Jeffrey, University of West Florida; Patrick J. Neale, Smithsonian Institution; and Ann E. Gargett, Old Dominion University.

Ultraviolet (UV) radiation influences plankton in the near-surface waters of most ecosystems. In particular, the Southern Ocean is affected in the austral spring, when UV radiation is enhanced by ozone depletion. While progress has been made in estimating the impact of UV radiation on bacteria and phytoplankton in the Southern Ocean, important issues remain to be resolved. Little is known, for example, about responses by the colonial haptophyte *Phaeocystis antarctica,* which dominates spring blooms in the southern Ross Sea. The presence of open water at a far southerly location, well within the ozone hole in the spring, and of continuous daylight, with implications for DNA repair, make the Ross Sea of intense interest.

A number of studies suggest that vertical mixing can significantly modify the impact of UV radiation. However, the limited measurements that have been done of turbulence intensity in the surface layer have not been integrated with studies of the effects of UV radiation on phytoplankton and bacterioplankton. To address these issues, we will focus on vertical mixing and UV radiation in the Ross Sea and characterize phytoplankton and bacterioplankton responses in laboratory and solar incubations. These studies will lead to biological weighting functions and response models capable of predicting the impact of UV radiation on photosynthesis, bacterial incorporation, and DNA damage in the surface layer.

We will measure depth-dependent profiles of DNA damage, bacterial incorporation, photosynthesis, and fluorescence parameters over a 24-hour cycle. We have optimized measurements for typical springtime conditions in the Ross Sea, where stabilizing influences like solar heating and/or surface freshwater from melting ice mean that there is not enough turbulence to thoroughly mix the upper layer.

We will develop fine-scale vertical density profiles to directly estimate large eddy scales. Estimated turbulent diffusivities and eddy scales will be directly related to surface layer effects and used to generate models of UV radiation responses in the surface mixed layer.

This first in-depth study of UV radiation in the Ross Sea will enhance understanding of vertical mixing processes, trophic interactions, and biogeochemical cycling and will provide a valuable comparison with previous work in the Weddell–Scotia Confluence and Palmer Station regions. (B–200–N, B–203–N, and B–208–N; NSF/OPP 01–27022, NSF/OPP 01–27037, and NSF/OPP 01–25818)

Ultraviolet-radiation-induced changes in the patterns of production and biochemical composition of antarctic marine phytoplankton.

Joaquim I. Goes, Bigelow Marine Laboratory.

There is enough evidence to show that present levels of incident ultraviolet (UV) radiation—280 to 400 nanometers (nm)—are impairing phytoplankton productivity in the Southern Ocean. Yet efforts aimed at extrapolating these findings to allow accurate and unambiguous predictions of the consequences of UV radiation on the antarctic marine food web and biogeochemical cycles in the sea have been confounded by uncertainty. Estimates of the effects of UV radiation on the antarctic marine ecosystem range from insignificant to catastrophic. This disparity has been attributed to lack of information in key areas of photobiology and photochemistry.

Generally, studies have been based on broadband UV radiation and do not take into account competing responses of phytoplankton at different wavelengths across the waveband. Such information is critical if we are to understand the consequences of UV radiation enhancement on carbon assimilation by marine phytoplankton and its consequences for the food web and biogeochemical cycles. This is especially true in regions like the Antarctic, where stratospheric ozone concentrations can decrease by about 50 percent each spring, thereby altering the proportion of UV–B (280 to 320 nm) and UV–A (320 to 400 nm) radiation that phytoplankton receive during their growth season.

We will systematically investigate changes in the production rates and composition of biochemical compounds within antarctic phytoplankton cells under spectrally defined conditions. We will examine both laboratory cultures and natural populations in order to understand

- how the cellular biochemical processes of phytoplankton are affected by the interplay between the different UV wavelengths and visible light,
- how sensitivity to UV radiation varies across taxonomic groups of phytoplankton, and
- whether this difference in sensitivity is responsible for the dominance of one species over the other.

We will also study the effect of UV radiation on nutrient uptake by phytoplankton cells. The information we gain will help ascertain the role of UV radiation in the phytoplankton dynamics of the Southern Ocean. (Additional information can be found on our Web site: http://www.bigelow.org/arctic/goes.html.) (B–206–N; NSF/OPP 01–26150)

Comparative and quantitative studies of protistan molecular ecology and physiology in coastal antarctic waters.

Rebecca J. Gast and Mark R. Dennett, Woods Hole Oceanographic Institution, and David A. Caron, University of Southern California.

Phototrophic and heterotrophic protists (single-cell organisms—e.g., protozoa) are ubiquitous in extreme cold-water environments, where they are central to the production and use of energy and the cycling of elements. The dominance of protists in antarctic food webs indicates major ecological and biogeochemical roles for these unicellular eukaryotes. Understanding the structure and diversity of these communities and the adaptations that allow them to flourish near the lower limit of temperature in the ocean is of fundamental importance to a knowledge of biological oceanography, as well as the activities and evolution of life on our planet.

The diversity of protistan assemblages has traditionally been studied using microscopy and morphological characterization. Such an approach is inadequate for ecological studies of these communities due to its tedious nature and the inherent lack of taxonomic characters associated with most small protists. Molecular methods that use gene sequences to identify and quantify naturally occurring protists offer a better solution to this problem.

We will perform molecular and physiological studies on protistan assemblages in the sea water and ice habitats of the Ross Sea to address community structure, population abundance, and adaptation to life in extreme cold. We will focus primarily on species of

phagotrophic protists (protozoa) that are ecologically important but for which no information exists. Our work is designed to contribute to the understanding of the biodiversity of the protistan assemblages of coastal Antarctica, to provide tools for ecological studies, and to produce benchmark data on the basic physiological processes of protistan species in this extreme cold-water environment. (B–207–N; NSF/OPP 01–25833 and NSF/OPP 01–25437)

National Aeronautics and Space Administration–Astrobiology for Science and Technology for the Exploration of Planets: Subsurface ice and brine sampling—using an ultrasonic gopher for life detection and characterization in the McMurdo Dry Valleys.

Peter T. Doran, University of Illinois–Chicago.

Evidence for ice and fluids near the surface of Mars in both the distant and the recent past is growing with each new mission to the planet. One explanation for fluids forming spring-like features on Mars is the discharge of subsurface brines. These offer potential refugia for extant Martian life, and near-surface ice could preserve a record of past life as well. Proven techniques to get underground to sample these environments and get below the disruptive influence of the surface oxidant and radiation regime will be critical for future astrobiology missions to Mars. We will therefore develop and test a novel lightweight, low-power, ultrasonic corer in the McMurdo Dry Valleys, a Mars analogue environment.

Previous data from Lake Vida, one of the largest lakes in the Dry Valleys, reveal that brine with a salinity seven times greater than that of sea water and a temperature constantly below –10°C lies beneath roughly 20 meters (m) of ice that is at least 2,800 radiocarbon years old. Microbial mats occur throughout the ice column and are viable when thawed. Sediment layers in the ice effectively block incoming solar radiation. Ice below 16 m in depth and the brine body have never been sampled directly.

We will test two general hypotheses:

- Microbial communities within the brine and benthic sediments are viable and active and affect the geochemistry of the lake.
- The ice, brine, and benthos contain geochemical signatures of past microbiological activity.

The combined cold, hypersaline, aphotic, and atmospherically isolated conditions in Lake Vida make it one of the most extreme aquatic environments on Earth. The conditions that exist there were likely to have been present during the last stages of the purported lakes on Mars. The technology we develop and the experience we gain will be directly applicable to future Mars missions. It should also be possible to apply our results to shallow coring on Europa. (B–211–M; NASA/ASTEP 02–000–0036)

Plankton community structure and iron distribution in the Southern Drake Passage and Scotia Sea.

B. Greg Mitchell, University of California–San Diego, Scripps Institution of Oceanography; Christopher Measures, University of Hawaii–Manoa; Meng Zhou, University of Massachusetts–Boston; and Matthew Charette, Woods Hole Oceanographic Institution.

The Shackleton Fracture Zone (SFZ) in the Drake Passage defines a boundary between low- and high-phytoplankton waters. Low-chlorophyll water flowing through the southern Drake Passage emerges as high-chlorophyll water to the east. Previous results indicate that the southern front of the Antarctic Circumpolar Current goes south of the SFZ onto the Antarctic Peninsula shelf, where mixing occurs. The mixed water advects off-shelf with elevated iron and chlorophyll-a. Studying the SFZ can improve understanding of plankton responses to natural iron fertilization and their influence on the export of carbon to the ocean's interior.

We theorize that bathymetry influences mesoscale circulation and iron transport and that the position of the Antarctic Circumpolar Current influences the magnitude of the flow onto the Peninsula shelf, mediating the amount of iron transported into the Scotia Sea.

We will address these issues on a winter cruise in 2006 and a summer cruise in 2007, complementing surface surveys of chemical, plankton, and hydrographic properties with a mesoscale station grid for vertical profiles, water sampling, and bottle experiments. We will determine the distributions of manganese, aluminum, and radium isotopes to trace iron sources and estimate mixing rates. We will study the structure of plankton communities, as well as the relationship between iron concentrations and phytoplankton characteristics, to elucidate the connection between phytoplankton biomass and iron supply and to determine the most important sources of iron for the waters east of the Drake Passage.

Further, we will interpret estimates of organic carbon export from the upper ocean in relation to natural iron fertilization and use satellite photos to relate the current's southern front to seasonal and interannual variations in phytoplankton productivity east of the SFZ. Given indications that the Southern Ocean is warming, understanding the conditions regulating that ecosystem is important to predicting the effects of climate change.

Our project will involve postdoctoral fellows, graduate students, and undergraduates. Further, through a partnership with Literacyworks, we will contribute to the Polar Science Station Web site (http://literacynet.org/polar/), a resource for instructors and students in adult education, home schooling, tribal schools, and family literacy programs, as well as the general public. (B–225–N, B–228–E/N, B–248-N, and B–276–N; NSF/OPP 04–44134, NSF/OPP 04–43403, NSF/OPP 04–44040, and NSF/OPP 04–43869)

Environmental and ecological regulation of differences and interactions between solitary and colonial forms of *Phaeocystis antarctica.*

Kam Wing Tang, College of William and Mary, Virginia Institute of Marine Science.

Phaeocystis antarctica is widely distributed in the Southern Ocean and plays an important role in polar ecology and biogeochemistry. It is a dominant primary producer, a main component of organic matter vertical fluxes, and the principal producer of volatile organic sulfur in the region. Yet *P. antarctica* is also one of the lesser known species, and, moreover, information collected on other *Phaeocystis* species or from different locations may not be applicable to *P. antarctica* in the Ross Sea.

P. antarctica occurs mainly as two morphotypes—solitary cells and mucilaginous colonies; these differ significantly in size, architecture, and chemical composition. Relative dominance between solitary cells and colonies determines not only the size of the population, but also its carbon dynamics, nutrient uptake, and use, and colony formation could effectively alter predator-prey interactions and interspecific competition. However, what regulates the differences between solitary and colonial forms of *P. antarctica* is not certain. We will therefore address the following questions:

- Do solitary cells and colonies differ in growth, composition, and rates of photosynthesis?
- How do nutrients and grazers affect colony development and size distribution?
- How do nutrients and grazers act synergistically to affect long-term population dynamics?

We will conduct laboratory experiments at McMurdo Station to study size-specific growth and rates of photosynthesis in *P. antarctica*, size-specific grazing mortality from microzooplankton and mesozooplankton, the effects of macronutrients on the relative dominance of solitary cells and colonies, and the effects of iron and grazing-related chemical signals on colony development. We will use mesocosm experiments to study the synergistic effects of nutrients and grazing on the long-term dynamics of solitary cells and colonies.

P. antarctica is of critical importance in the Ross Sea and in the entire Southern Ocean, and our research will provide information on factors that regulate its role in food webs and biogeochemical cycles, as well as advance our understanding of many ecological and biogeochemical processes in the waters it dominates. Results will also allow us to compare *P. antarctica* with the better known *P. globosa* and *P. pouchetii* and begin to unveil their ecological and evolutionary similarities and differences. (B–230–M; NSF/OPP 04–40478)

Habitat utilization by Southern Ocean seals: Using novel methods of oceanographic data collection to determine the foraging behavior of crabeater and elephant seals.

Daniel P. Costa, University of California–Santa Cruz.

Marine mammals must be capable of accommodating broad variations in food resources over large spatial and temporal scales. Variation in the physical and biological environment is particularly profound in the Southern Ocean. Our current understanding of this spatial and temporal variation and of how animals respond is limited to population studies that cannot provide insight into the strategies individual animals use or their spatial or temporal course.

The key to understanding the processes that lead to high predator abundance is identifying the specific foraging behaviors associated with different features of the water column. We will examine the southern elephant seal *(Mirounga leonina)* and the crabeater seal *(Lobodon carcinophagus)* in the western Antarctic Peninsula. Although these two species are phylogenetically related, they use different but adjacent habitat types. Southern elephant seals are predominantly pelagic, moving throughout the Southern Ocean and venturing occasionally into the seasonal pack-ice, while crabeater seals range throughout the pack-ice and venture occasionally into open water. We will determine how specific foraging behaviors and animal movement patterns are related to oceanographic and bathymetric features, develop and test models of the importance of these features in defining habitat use, and compare how individual animals respond to environmental variability.

In addition to supporting some of the planet's most abundant marine resources, the Southern Ocean plays an important role in climate. Significant efforts are being directed at developing mathematical models of oceanographic processes with the goal of better understanding the role that the Southern Ocean plays, predicting the responses of ocean and global processes to climate change, and understanding the links between physical and biological processes. These efforts have been limited by the scarcity of oceanographic data, especially at high latitudes during the winter months. This lack impedes understanding of several key features of the Southern Ocean.

In addition to providing new data on temperature and salinity profiles, our efforts are geared toward understanding the dynamics of the upper water column of the continental shelf off the western Antarctic Peninsula, with an eye toward developing a mechanistic understanding of the column's annual and seasonal heat and salt budgets. (B–232–E; NSF/OPP 04–40687)

Physiological and molecular mechanisms of stress tolerance in a polar insect.

Richard Lee, Miami University of Ohio, and David L. Denlinger, Ohio State University.

Polar terrestrial environments are often described as deserts. In addition, prolonged low winter temperatures threaten survival, and summer temperatures produce potentially rapid and difficult transitions from freezing to desiccation. Global warming has had a further impact, especially as a result of glacial retreat along the Antarctic Peninsula.

We will focus on thermal and hydric adaptations in the terrestrial midge, *Belgica antarctica,* the largest and most southerly holometabolous insect living in this challenging environment. Since free water is unavailable, overwintering midge larvae encased in the frozen substrate must endure desert-like conditions for more than 300 days. During the summer, larvae may be immersed in melt water or the outwash from penguin rookeries and seal wallows, in addition to saltwater splash. Alternatively, larvae may be subjected to extended periods of desiccation as their microhabitats dry out.

Our research will focus on three areas:

- **Microclimatic variability:** Our primary objective is to obtain a detailed characterization of microclimatic conditions experienced by *B. antarctica,* especially related to thermal and hydric diversity, both seasonally and among microhabitats near Palmer Station. These data will be critical for establishing the relevant ecological conditions to be used in laboratory experiments.
- **Physiological and molecular responses to extreme fluctuations in water availability:** We will assess the hypothesis that midge larvae use cryoprotective dehydration for winter survival. It is also anticipated that genes encoding heat shock proteins and other genes are up-regulated in larval responses to dehydration and rehydration.
- **Dietary transmission of cryoprotectants:** Our experiments are designed to test the hypothesis that midge larvae acquire

increased resistance to desiccation and temperature stress by getting cryoprotectants from their host plants.

We will also provide outreach to elementary and secondary educators and their students. The field team will include a teacher and will use e-mail and digital pictures to communicate daily progress to elementary school teachers and students. These efforts will be supplemented by presentations at local schools and national teacher meetings and the publication of articles related to cryobiology and polar biology in education journals. Furthermore, our laboratories will continue to train undergraduate, graduate, and postdoctoral students. (B–256–P; NSF/OPP 03–37656)

Controls on Ross Sea Algal Community Structure (CORSACS): Interaction of iron, light, and carbon dioxide on phytoplankton community dynamics in the Ross Sea.

Giacomo R. DiTullio, University of Charleston; Robert Dunbar, Stanford University; Peter Sedwick, Bermuda Biological Station for Research; David Hutchins, University of Delaware; Philippe Tortell, University of British Columbia; and Walker O. Smith, College of William and Mary, Virginia Institute of Marine Science.

The Southern Ocean will play a central role in modulating future climatic changes and will in turn be greatly affected by them. The ability to predict these changes and to assess their impact on marine systems is hindered by a poor understanding of oceanographic processes and their links to global climate. A critical question concerns controls on the large-scale distribution and production of the two major bloom-forming phytoplankton in the Southern Ocean—diatoms and *Phaeocystis antarctica.* Through their involvement in the biogeochemical cycles for carbon, sulfur, and nutrient elements, these two groups may have played important roles in the climate variations of the late Quaternary and are likely to be key players in future environmental change.

One paradigm posits that irradiance (vertical mixing) and iron availability drive phytoplankton dynamics in the Southern Ocean. Recent work, however, suggests that carbon dioxide may also be important in structuring algal assemblages. The Ross Sea is ideal for investigating the factors that regulate the distribution and production of these two algal groups, since it has seasonal blooms that are typically separated by space and time. We will examine the interactive effects of dissolved iron concentration, irradiance, and partial pressure of carbon dioxide on diatom and *Phaeocystis* bloom dynamics in the Ross Sea through

- a field survey and analysis of algal assemblage composition, iron, mixed layer depth, and carbon dioxide levels on two transects in the southern Ross Sea during the spring *Phaeocystis* bloom and the summer postbloom period; and
- shipboard semicontinuous and natural community chemostat culture experiments to examine the response of diatom and *P. antarctica* assemblages to high and low levels of iron, light, and carbon dioxide.

Our project will provide information on the major factors controlling the production and distribution of these phytoplankton and the related biogeochemical cycling of carbon, sulfur, and nutrients. Our results will ultimately enhance the ability to predict how the Southern Ocean will be affected by and could modulate future climatic change. Moreover, we will involve graduate and undergraduate students, postdoctoral fellows, and a student teacher and engage in community outreach and educational activities. (B–258–N, B–267–N, B–272–N, B–279–N, B–282–N, and B–386–N; NSF/OPP 03–38097, NSF/OPP 03–38350, NSF/OPP 03–38164, NSF/OPP 03–38111, and NSF/OPP 03–38157)

Hydrologic controls over biogeochemistry and microbial community structure and function across terrestrial/aquatic interfaces in a polar desert.

Michael N. Gooseff, Colorado School of Mines; Cristina D. Takaes-Vesbach, University of New Mexico; and John E. Barrett, Dartmouth College.

Aquatic-terrestrial transition zones are crucial to understanding the biogeochemistry of landscapes. In temperate watersheds, these areas are generally dominated by riparian zones, which have been identified as biogeochemical hot-spots because of the increased microbial activity and because of their importance in facilitating and buffering hydrologic and biogeochemical exchanges between terrestrial and aquatic ecosystems.

In the antarctic Dry Valleys, terrestrial-aquatic transition zones are intriguing because of the vast importance of water in this polar desert and because the material and energy budgets of Dry Valley ecosystems are linked by hydrology. We will study hydrological margins in Dry Valley aquatic-terrestrial transition zones to answer two questions:

- What are the major controls over hydrologic and biogeochemical exchange across aquatic-terrestrial transition zones?
- To what extent do trends in nutrient cycling across these zones reflect differences in microbial communities or function versus differences in the physical and chemical environment?

The hydrologic gradients that define these interfaces provide the opportunity to assess the relative influence of physical conditions and microbial biodiversity and functioning on biogeochemical cycling. Our coordinated hydrologic, biogeochemical, and molecular microbial studies have the following objectives:

- to determine the role of sediment characteristics, permafrost and active layer dynamics, and topography on subsurface water content and distribution in hydrologic margins;
- to determine the extent to which transformations of nitrogen in hydrologic margins are influenced by physical conditions or by the presence of specific microbial communities; and
- to characterize the microbial community structure and function of saturated zones.

Our research will improve understanding of the interaction of liquid water, soils, microbial communities, and biogeochemistry within the Dry Valleys, whose streams and lakes are unique because higher vegetation does not influence the movement of water. They may therefore provide a model for understanding physical and hydrological influences on microbial ecology and biogeochemistry.

Our findings will contribute to antarctic science, as well as the broader study of riparian zones and hydrologic margins. We will involve

graduate and undergraduate students in our research and will disseminate information through a project Web site. Outreach will include science education in local elementary, middle, and high schools. (B–268–M; NSF/OPP 03–38267, NSF/OPP 03–36970, and NSF/OPP 03–38174)

Genetic sampling and satellite tracking of a fish-eating ecotype of killer whale in the southern Ross Sea.

Robert L. Pitman, National Oceanic and Atmospheric Administration, and Richard LeDuc and Wayne L. Perryman, National Oceanic and Atmospheric Administration, National Marine Fisheries.

We will continue to study the three distinct ecotypes of killer whales (*Orcinus* sp.: Types A, B and C) found in the Ross Sea during the austral summer. These forms have different prey and habitat preferences, different school sizes and geographic distributions, and distinct morphologies, suggesting that they may represent separate species. If true, this hypothesis will reshape our understanding of killer whales in Antarctica. Given their numbers (current estimates, 25,000 to 94,000) and status as top predators, killer whales are undoubtedly a major force in the antarctic ecosystem, but understanding their role and conservation status will depend on identifying their taxonomic relationships, specifying their dietary needs, assessing the impact of commercial fisheries on their feeding, and understanding their seasonal and annual movements.

This season we will focus again on the fish-eating ecotype (Type C) found in the ice leads near McMurdo Station:

- We will use a crossbow to collect projectile biopsy samples. These will be sequenced and analyzed to determine whether there is more than one species. To date, we have collected 59 samples from antarctic killer whales; as a target, we would like 50 of each form.
- We will implant satellite tags into the base of the dorsal fin of up to 20 killer whales. We will be working from the edges of the leads and poking the killer whales that swim by with fiberglass poles equipped with detachable tags. These should allow us to determine short-term movements within the Ross Sea and understand foraging range and habitat during the summer; tags set for longer periods will allow us to look at seasonal movements and migration patterns.

The killer whale is one of the most recognizable and best-studied large animals on Earth. Yet basic questions about how many species there are and what their role in the marine ecosystem remain unanswered. Some 300 to 400 minke whales are killed each year in the Southern Ocean Sanctuary for research purposes: our study will demonstrate the feasibility of using nonlethal techniques to conduct similar research. The possibility that there is a new species of killer whale in Antarctica serves to emphasize that our knowledge of marine biodiversity may be more limited than we realize. (B–289–M; NSF/OPP 03–38428)

Biogeochemistry of dissolved organic material in Pony Lake, Ross Island.

Yu-Ping Chin, Ohio State University; Penney Miller, Rose-Hulman Institute of Technology; Diane M. McKnight, University of Colorado–Boulder; and Christine M. Forman, Montana State University.

Dissolved organic matter is a significant component in aquatic systems because it acts as an important carbon source for microorganisms, absorbs harmful radiation, complexes metals, and participates in important biogeochemical redox reactions. We are studying the biogeochemical cycling of dissolved organic matter in Pony Lake, a small coastal pond on Cape Royds, Ross Island. Because there are no higher plants, all of the organic matter in this lake is microbially derived from photoautotrophic (having the ability to use light to synthesize food from inorganic materials), heterotrophic (dependent on complex organic compounds for nutrition), and mixotrophic organisms, making it an ideal study site.

We will

- examine how natural photolytic processes in the lake and laboratory irradiations of water samples and reconstituted samples of dissolved organic matter alter its composition,
- determine changes in the redox state of this material in the water column and in sediment interstitial water with increased oxygen input,
- examine how the chemical properties of dissolved organic material change with microbial utilization,
- monitor the changes in microbial abundance that result from shifts in dissolved organic material during the transition from ice to open water,
- track the changes in the microbial community as the energy source changes,
- determine whether the extracellular enzyme profiles of the water column vary in relation to the altered material, and
- examine the relationship between microbial diversity and the biogeochemistry of the material.

Last season, we studied the changes as the lake evolved from ice-covered to ice-free conditions. We fractionated samples into classes, as well as monitored composition and reactivity. Finally, we studied the microbial community and monitored changes that occurred during the transition from ice to open water and generated extracellular enzyme profiles, since enzymatic hydrolysis is believed to be the rate-limiting step in carbon remineralization.

This year, we will collect fulvic acid samples. The amount of water needed is significantly smaller than the amount lost to ablation, and all isolates will be thoroughly characterized. In year 3, we plan to perform solar-simulated photolysis and control experiments in the United States.

This project will greatly increase our understanding of carbon cycling and the relationship between microbial diversity and the biogeochemistry of dissolved organic matter. (B–300–M; NSF/OPP 03–38260, NSF/OPP 03–38121, NSF/OPP 03–38299, and NSF/OPP 03–38342)

A graduate training program in Antarctica: Integrative biology and

adaptation of antarctic marine organisms.

Donal T. Manahan, University of Southern California.

Biological impacts of the ozone hole, debates about global warming and temperature adaptations, and the evolution of biological diversity in the cold biosphere are some of the important themes that are central to scientific investigations in Antarctica. Yet because of its remoteness, few students ever have the opportunity to study there. We will therefore offer a series of three graduate training courses for doctoral students and postdoctoral scientists interested in the study of biological adaptations of antarctic marine organisms. The three (austral) summer courses will be offered at McMurdo Station in January 2006, 2008, and 2010, and each will accommodate 20 students. McMurdo Station, the major base for the U.S. Antarctic Program, has well-equipped laboratories suitable for instruction.

The major goal of these courses is to introduce students and new postdoctoral investigators to antarctic science through studies of the diversity of life forms and the mechanisms of biological adaptation in marine organisms. The courses will introduce students to a wide range of vertebrates (fish) and microbes and will be taught by instructors with considerable experience in teaching in Antarctica. A further aim is to train all of the participants in approaches to integrative biology by having them study unique processes that span several different levels of biological organization in the cold biosphere. For instance, long-standing questions on the evolution (cold adaptation) and ecology of antarctic organisms will be examined with physiological experiments on whole organisms, studies of isolated cells and tissues, experiments on protein structure and function, and molecular analysis of genetic systems.

These courses will provide students with hands-on science under realistic conditions. The general format will consist of field collections and laboratory experiments, together with lectures on polar science from course faculty and guest speakers. Some of the specific themes to be covered include biological diversity, biochemical and cold adaptation, energy metabolism, molecular phylogeny, and ultraviolet photobiology. These themes will be interwoven with independent, student-initiated research projects. (B–301–M; NSF/OPP 05–04072)

Salpa thompsoni in the Southern Ocean: Bioenergetics, population dynamics, and biogeochemical impact.

Patricia Kremer, University of Connecticut, and Laurence P. Madin, Woods Hole Oceanographic Institution.

Salps are holoplanktonic grazers that are strikingly different from krill, copepods, or other crustacean zooplankton. Salps sometimes occur in very dense populations that cover large areas and have been shown to have a significant impact from both grazing and the production of fast-sinking fecal pellets. Although salps are commonly acknowledged as a major component of the Southern Ocean zooplankton community, often comparable to krill, they have received relatively little attention. Extensive sampling has documented the seasonal abundance of *S. thompsoni* in the Southern Ocean, but there still is a paucity of data.

In addition to various rate measurements, we will make quantitative surveys of the horizontal and vertical distribution of salps. Results will be used to construct a model of population dynamics. Both experimental and modeling results will be interpreted within the context of the physical and nutritional conditions to which salps are exposed. This integrated approach will provide a good basis for understanding their growth dynamics.

Our tasks are as follows:

- survey the extent of *S. thompsoni* blooms to determine biomass and spatial distribution and to allow a regional assessment of their effects;
- measure the physical characteristics of the water column and the quantity and quality of particulate food;
- measure respiration and excretion rates for solitary and aggregate salps of all sizes;
- measure ingestion rates;
- determine somatic growth rates, fecundity (of solitaries), and fertilization success (for aggregates);
- synthesize rate measurements on salps into complete budgets for both carbon and nitrogen;
- formulate an individually based model of salp population dynamics that includes realistic behavior patterns as well as experimentally determined vital rates;
- identify salp hot-spots and interpret distributions in an appropriate hydrographic context;
- use satellite imagery and information on sea-ice cover to test hypotheses about conditions that result in high densities of salps; and
- evaluate the relationship between specified hydrographic conditions, ice cover, and blooms.

Our work will also involve training graduate and undergraduate students, participating in teacher-researcher workshops, and collaborating with the New England Aquarium on an IMAX movie about research in Antarctica. (B–307–L; NSF/OPP 03–38290)

What limits denitrification and bacterial growth in Lake Bonney, Taylor Valley, Antarctica?

Bess B. Ward, Princeton University.

Denitrification refers to the loss of fixed nitrogen from ecosystems, and its rate and regulation may directly affect primary production and carbon cycling. Previous investigation of the role of metals in regulating denitrification in cultured bacteria and in permanently ice-covered Lake Bonney produced three important findings:

- Cultured denitrifying bacteria could be limited by copper or iron, and nitrogen oxides accumulated because of limitation at the nitrite and nitrous oxide reduction steps, respectively.

- Manipulations of metal availability using chelators, additions of substrates, and cultured bacteria failed to elicit a response from the lake's natural microbial communities. No denitrification or thymidine incorporation was detected in the east lobe, while analogous experiments detected a denitrifying community in the west lobe.
- Silver and iron were the only metals that showed dramatic distribution differences between lobes. Silver concentrations were 150-fold higher in the east than in the west. Cadmium, lead, chromium, nickel, and zinc concentrations were 2- to 5-fold higher in the east than in the west, and iron concentrations were 200 times lower in the east. Low iron concentrations may exacerbate the toxicity of the other metals, so general metal toxicity could inhibit denitrification. Silver can specifically inhibit denitrification because it can interfere with copper binding in nitrite reductase and nitrous oxide reductase. High silver concentrations might prevent the functioning of nitrous oxide reductase in the same way that copper limitation does, causing a buildup of nitrous oxide and a nonfunctional nitrogen cycle.

It is not known whether the east lobe has oxygen concentrations low enough to trigger denitrification. We will use sentinel strains of denitrifying bacteria isolated from the lake, incubated in lake water, and subjected to various treatments to measure these concentrations and will study the effect of silver toxicity and general metal toxicity as well. We will quantify the responses of these strains to changes in metal and oxygen concentrations with single-cell probes.

The relationships between metals and denitrification are expected to shed light not only on Lake Bonney's unusual nitrogen cycle, but also on the role of metals in regulating microbial nitrogen transformations. (B–310–M; NSF/OPP 02–30276)

Improving acoustic estimates of antarctic krill populations.

Joseph Warren, Southampton College.

Antarctic krill are a vital link in the food web of the Southern Ocean. In addition to serving as prey for birds, pinnipeds, and whales, they are also harvested by several nations. To manage this fishery, acoustic surveys are conducted annually. While acoustic methods have several advantages, converting backscatter information to numerical abundance is difficult. In this 3-year program, we seek to improve the accuracy of acoustic surveys by examining three questions:

- Are acoustic surveys underestimating krill by avoiding shallow-water, near-shore areas?
- Is upwelled deep water the cause of the high productivity of the waters around Cape Shirreff, Livingston Island, and, if so, how does this vary?
- Can a new technique improve the conversion of acoustic backscatter data to numerical abundance?

Using a research vessel chartered by the National Oceanographic and Atmospheric Administration's Antarctic Marine Living Resources Program, we will conduct a small-boat survey to collect acoustic, meteorological, hydrographic, and video data. We will sample off- and on-shelf regions, focusing on two submarine canyons flanking Cape Shirreff. We will construct and deploy five spar buoys to collect acoustic backscatter and Acoustic Doppler Current Profiler data. We will use these data, along with the hydrographic information from the small-boat survey, to determine whether Upper Circumpolar Deep Water is traveling up the submarine canyons and increasing productivity. We will determine how this influx varies in order to understand the functions that control the abundance of krill.

We will measure the total target strength of different sizes, ages, and species of live krill during years 1 and 3 and develop algorithms to determine whether broad-bandwidth scattering data can be used to identify types. The results will improve the ability of scientists and fishery managers to use acoustic data to estimate krill abundance and will lead to a better understanding of the importance of near-shore populations and the factors controlling their distribution and abundance.

The instrumentation used in this project will be deployed off Long Island to provide students who will participate in data analysis with access to modern sampling methods. The buoy data and the course materials we develop will be placed on the Internet. (B–320–E: NSF/OPP 03–38196)

Establishing a Polar Remote Interactive Marine Observatory (PRIMO) near Palmer Station on the western Antarctic Peninsula.

Vernon Asper, University of Southern Mississippi, and Scott Gallager, Robert Beardsley, and Keith von der Heydt, Woods Hole Oceanographic Institution.

We will develop a remote underwater observatory that will allow scientists to make Internet-based virtual visits to the sub-ice ocean off Palmer Station. The observatory will consist of an instrument package on the seafloor in 130 meters (m) of water about 3.5 kilometers from Palmer Station. The package will be connected to shore by electro-optical cable, thus providing the capability for Internet-based teleoperation. The observatory will consist of a vertical profiler with conductivity-temperature-depth; a video plankton recorder; a hydrophone; a current meter; sensors for chlorophyll and dissolved organic matter fluorescence, oxygen, and nitrate; a bio-optical package; and an under-ice video observation surveillance system. The profiler will rise to the surface several times a day from a seafloor-mounted platform consisting of a winch, an acoustic Doppler current profiler, and a remote video camera. We will use this near-shore observatory as a proof of concept and test bed for the implementation of a similar observatory to be located on the shelf at a depth of 300 to 400 m. Both observatories will provide infrastructure for projects conducted by many scientists.

Our project will acquire data of interest and immediate application to several ongoing and planned projects. Specifically, the Long-Term Ecological Research project will benefit from year-round observations on the optical and physical properties of the water column, as well as the distribution of organisms living throughout the column. New projects proposed for this area will be invited to plug specific sensors or systems into the node.

In addition to the basic research applications of this project, it will be available for educators and the public to experience the sub-ice environment in Antarctica from anywhere in the world. Through educational programs and collaborations with schools and via mirror sites, virtual visitors will be able to both see and hear the environment around the node. The Web site will include information on the relevance of these and other long-term observations on global change, with specific emphasis on the amplification of this signal observed in the Southern Ocean. (B-390-P/L; NSF/OPP04-21431 and NSF/OPP 04-20757)

Temporal variability in natural and anthropogenic disturbances at

McMurdo Station, Antarctica.

Mahlon Kennicutt, Texas A&M University.

Antarctica represents one of the most carefully tended, strictly monitored habitats on Earth. Protecting the flora, fauna, and atmosphere of this pristine environment is important, but in addition, the extreme southern latitudes provide a virtual barometer of global pollution. A basic precept in understanding human-induced changes in natural systems is that they take place against a backdrop of natural variability that would occur with or without anthropogenic perturbation. The causes of change cannot be unambiguously determined unless natural variability is defined. This requires long-term observations. In this project, we will continue our previous studies at McMurdo Station to establish the extent of temporal variability in terrestrial and marine habitats.

We are collecting observations that should enable scientists to be more aware of any anthropogenic impacts, locating them precisely and tracking them over time. Drawing on our 3-year pilot program, we will create an initial environmental monitoring program that will include point-data sampling grids measuring a series of attributes indicative of change at various spatial scales. Our objectives are to determine

- the spatial and temporal scales of change, as well as its origin;
- how efficiently this system documents relevant changes in important habitat characteristics; and
- the usefulness of various approaches to reference or control locations.

We will collect a series of 163 terrestrial samples of hydrocarbons, trace metals, and carbon analyses at fixed-point and random-sample locations. We will also sample three transects of three offshore points for chemical contaminants, sediment properties, and benthic infaunal assemblages and assay them for toxicity. We will then use geographic information system techniques and geostatistical methods to organize these diverse data sets into a coherent, coordinated framework and multivariate statistics to analyze them.

Continuous observations are a critical component of U.S. environmental stewardship in Antarctica. Our monitoring will provide the objective information needed to make timely and informed management decisions on support and science operations. By providing fundamental knowledge of how antarctic systems operate and how human activities alter them, our study will also help fulfill environmental protection regulations under both domestic law and the Antarctic Treaty. (B–518–M; NSF/OPP 03–54573)