National Science Foundation
WHERE DISCOVERIES BEGIN

ORGANISMS AND ECOSYSTEMS

These gentoo penguin chicks are taking a nap after eating a big meal. (*NSF/USAP photo by Zee Evans*)

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 Organisms and Ecosystems 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 ecosystems.** Polar marine environments are characterized by complex interactions among biotic, chemical and physical processes, in areas that include the marginal ice-zone, continental shelves, polynyas, and open-ocean systems. Topics include interactions among trophic levels, factors influencing primary and secondary production, and the ecological role of organisms in biogeochemical cycling. Remote sensing techniques, long-term observations, and modeling are appropriate tools to enhance this area of research.
- **Terrestrial and freshwater ecosystems.** Organisms in ice-free areas, in ephemeral streams, and in perennially ice-covered lakes show remarkable persistence in the face of harsh conditions. Research on adaptive mechanisms, in the context of the present day hydrologic and biogeochemical environment, is encouraged. The McMurdo Dry Valleys of southern Victoria Land are of particular interest due to the large body of data available through ongoing research programs, including the McMurdo Dry Valleys LTER, but other locations can be proposed. Research in support of future field exploration of subglacial lakes is also considered.
- **Population dynamics, physiological ecology, and adaptation.** The extremes of light, temperature, and moisture have resulted in unusual adaptations within organisms at all levels of organization. Research concerning metabolic, physiological, and behavioral adaptations of marine and terrestrial organisms, their population dynamics, and their diversity, is encouraged. Of special interest are processes occurring during the austral winter. Long-term observations are also supported, with the goal of understanding the impact of environmental change on organismic and ecological processes.
- **Genomics.** "Genome-enabled" biology provides a foundation for understanding the genetic basis of organism-environment interactions. The unusual antarctic environment presents a compelling natural laboratory for the study of environmental genomics. A National Research Council report, *Frontiers in Polar Biology in the Genomics Era,* addresses some of these opportunities.

Effects of oxygen and temperature on egg mass function of Southern Ocean marine invertebrates.

Amy Ladd Moran, Clemson University, and H. Arthur Woods, University of Texas at Austin.

This project explores the evolutionary physiology and temperature biology of reproductive structures in antarctic marine organisms, specifically variation in egg mass function as it relates to low temperature, high oxygen conditions found at high latitudes in the Southern Ocean.

Research will include the following:

- using first principles to model the diffusion of oxygen into egg and embryo masses at environmentally relevant temperatures;
- testing model assumptions by measuring the temperature-dependence of embryonic metabolism and oxygen diffusivity through natural and artificial gels;
- testing model predictions by measuring oxygen gradients in both artificial and natural egg masses, as well as measuring developmental rates of embryos at different positions in masses; and
- comparing the structure and function of egg masses from the Southern Ocean those from temperate waters.

This study will provide insight into organismal solutions to the fundamental physiological problem of balancing oxygen supply and demand across different temperatures, which broadly relates to the impact of global climate change. In addition, this study will support further teaching, learning, and research in polar biology and polar ecological physiology via photographs, web-linked video, and experiments for high school and undergraduate students. (B-004; NSF/OPP 05-51969 and NSF/OPP 04-40577)

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. For over 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 boost 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)

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:

- 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.
- 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 World Wide Web site, this year in collaboration with the "Yes I Can Science Program" (http://www.polar06.yesican-projects.ca/), 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. Our earlier web site, developed in collaboration with the Science Teachers Access to Resources at Southwestern (STARS) Program, is available online at http://www.swmed.edu/stars/02antarcticexpedition/index.htm. (B-018-M; NSF/OPP 04-40713)

The chemical ecology of shallow-water marine macroalgae and invertebrates on the Antarctic Peninsula.

Charles D. Amsler and James B. McClintock, University of Alabama–Birmingham, and Bill J. Baker, University of South Florida

Much of our recent work has focused on defenses against predators in a variety of sluggish or non-free-moving marine invertebrates, including sponges, echinoderms, and nudibranchs and on defenses against herbivores in macroalgae. Mesoherbivores, specifically amphipods, are a dominant component of the macroalgal community in Antarctica. Despite their high abundance, the functional ecology, particularly the trophic relationships of antarctic amphipods, are poorly understood. Our project will evaluate the importance of mesograzers (small invertebrate predators approximately 1 to 25 mm in body length) in western Antarctic Peninsula marine communities by examining the role of mesoherbivores in structuring macroalgal communities and by explaining the ecological interactions of mesograzers with the marine sponges. Chemical studies also will be conducted to gain a more thorough understanding of the chemical defenses that Antarctic Peninsula sponges direct towards crustacean mesograzers.

We will address three sets of questions concerning the importance of mesograzers, particularly amphipods, in nearshore habitats of the western Antarctic Peninsula. First is the hypothesis that the high abundance of mesoherbivores in western Antarctic Peninsula marine communities has an important influence on algal community structure. Initially, we will document which species of amphipods feed in whole or part on microalgae and macroalgae, the incidence and distribution of filamentous endophytes (plants that grow within another plant) in dominant macroalgae, comparative night time patterns of amphipod abundances on macrophytes, and the role of chemical mediation in these relationships.

Second, we will test the broad hypothesis that mesograzers in general, and amphipods in particular, interact with and prey on sponges to a greater extent than has previously been recognized in antarctic communities. Considering the functional basis of these associations, we will examine whether the sponges are used as prey, and if they are, whether some sponges produce secondary metabolites that are effective against mesograzers like amphipods.

Third, we will test the following two hypotheses:

1. Antarctic algae and invertebrates biosynthesize secondary metabolites that deter feeding by amphipod predators.
2. Pigments found in three antarctic sponges are tryptophan catabolites produced as defenses against crustacean predators that impact molting.

We will evaluate these hypotheses based on isolation and characterization of the specific anti-feeding metabolites, on biosynthetic studies to establish the metabolic origin of the pigments, and on bioassays to establish the chemical defense roles of both groups of compounds.

Various educational activities will be a major component of this project. Opportunities will be made to support graduate and undergraduate research, both through NSF programs as well as home university-based programs, including a number of funded programs that enhance the representation of minorities in the sciences. We will continue to involve a large numbers of teachers, K–12 students, and other members of the community at large in their scientific endeavors in Antarctica and will actively participate in outreach efforts by presenting numerous talks on our research to school and community groups. (B-022-O; NSF/OPP 04-42769 and NSF/OPP 04-42857)

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 the only demographic study for this species that was 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 World Wide Web site: www.penguinscience.com.) (B-031-M; NSF/OPP 04-40643)

Differential expression of oxygen-binding proteins in Antarctic fishes affects nitric oxide—mediated pathways of angiogenesis and mitochondrial biogenesis.

Bruce D. Sidell, University of Maine, and Kristin O'Brien, University of Alaska, Fairbanks.

Antarctic fish, specifically the channichthyidae icefishes and the red-blooded notothenioid species, are the focus of this study on the physiology and biochemistry of fishes thriving at body temperatures around zero degrees Celsius.

Researchers will study the species' hemoglobin and myoglobin levels (or lack thereof), and the function of nitric oxide in these oxygen-binding proteins. For example, both proteins are normally considered essential for adequate delivery of oxygen to aerobically poised tissues of animals. To compensate for the absence of hemoglobin, icefishes have developed large hearts that rapidly circulate a large volume of blood. Overall characteristics between the two species will be compared physiologically, anatomically, and molecularly.

This study aims to test the hypothesis that loss of hemoprotein expression in icefishes has resulted in an increase in levels of nitric oxide that mediate modification of vascular systems and expansion of mitochondrial populations in oxidative tissues. In addition, the study may aid in understanding tumorogenesis and metabolic pathologies in humans. (B-036; NSF/OPP 04-37887 and NSF/OPP 04-38778)

Studies of Antarctic Fungi: Adaptive strategies for survival and protecting Antarctica's historic structures.

Robert Blanchette, University of Minnesota.

Microorganisms are fundamental to the functioning of antarctic ecosystems, but we know very little about their biology and ecology. Knowledge about their survival mechanisms in polar environments is also very meager. Fungi in antarctic ecosystems, major contributors of biodiversity, have great influence on processes such as biodegradation and nutrient cycling. It is essential for biological surveys as well as genomic and proteomic studies to be completed so a better understanding of these organisms is obtained.

During earlier projects our research team has identified unique fungi associated with historic wooden structures brought to Antarctica by Robert F. Scott and Ernest Shackleton during the Heroic Era of exploration. Many of the species had never been described and belong to a little known genus Cadophora. Investigations have shown that these fungi are some of the most prominent organisms found in wood and soils at the historic hut sites, as well as at diverse sites throughout Antarctica. The objective of our current research is to obtain important new information on the fungi present in the Ross Sea and Antarctic Peninsula regions, to determine their role in decomposition and nutrient recycling, and to elucidate their survival mechanisms and strategies. To assess microbial diversity in antarctic substrates, we will use new tools and methods of investigating fungi in the environment, including denaturing gradient gel electrophoresis (DGGE), real-time PCR, and proteomic profiling to obtain key details of the physiological adaptations these fungi have evolved.

The impacts of the proposed results are broad and far reaching. These studies provide important baseline data on fungal diversity and their function in not only the antarctic environment but for other polar ecosystems as well. Only with this basic understanding can we have greater insight into ecosystem functioning and its response to environmental change. This work, coupled with the training and learning opportunities it provides, will be of value to many fields of study including microbial ecology, polar biology, wood microbiology, environmental science, soil science, geobiochemistry, and mycology as well as fungal phylogenetics, proteomics and genomics.

Besides these fundamental studies of microbial biology, the results of this research will be immediately useful to help preserve and protect Antarctica's historic monuments. In cooperation with the Antarctic Heritage Trust and the University of Waikato in New Zealand, our team has carried out investigations of deterioration at three historic huts in the Ross Sea Region (Discovery hut, Cape Evans hut, and Cape Royds hut) and have shown that unique fungi are decaying wood in contact with the ground and various cellulose degrading fungi are attacking artifacts made of leather, textiles, paper and other organic materials inside the huts. This investigation will continue our work identifying the microbes attacking these historic structures and artifacts and describing their biology and ecology in the polar environment. This austral summer we will work in the Antarctic Peninsula region at East Base, an American historic site on Stonington Island from the Admiral Byrd and Ronne Expeditions of 1939–1948. In March, we will travel to Palmer Station, stopping on the way at Deception Island to study microbial diversity and decomposition processes in wood remain from whaling stations and abandoned bases. Samples of soil and organic material will be collected to provide information about microorganisms and possible ecosystem changes related to the effect of volcanic disturbances on the deterioration processes affecting the historic artifacts. At Palmer Station the team will study sites on Humble Island and near the old Palmer Station and retrieve samples from different sterile substrates previously placed into the ground to act as baits for microflora. (B-038-E/L; NSF/OPP award 05-37143)

Penguins as monitors of the krill-centric Southern Ocean marine ecosystem.

Wayne Z. Trivelpiece, National Oceanic and Atmospheric Administration.

Adélie, gentoo and chinstrap penguins (*Pygoscelis adeliae, P. papua* and *P. antarctica,* respectively), the major predators of krill (*Euphausia superba*) in the Antarctic Peninsula, are key species used to monitor the potential impacts of fishery activities in this area. This project continues our long-term work in testing hypotheses relating penguin breeding biology, foraging ecology, and demography to environmental variability during the breeding season. Additionally, this work will expand recent investigations to address questions on the distribution and trophic interactions among the three species during the winter.

Recent warming in the Antarctic Peninsula region is now well documented, but little is known about the real or potential future impacts of this warming on the antarctic marine ecosystem, particularly the impacts on animals in the higher trophic levels of the Southern Ocean community. A 2002 study highlighted several apparent impacts of warming on Antarctic seabird populations and discussed potential causes for changes in population trajectories in penguin species at some locations. However, the authors concluded that few studies had data with both the continuity and decadal time series needed to test hypotheses of the mechanisms and linkages associated with these changes.

We have been working with Adélie, gentoo and chinstrap penguins at our study site in Admiralty Bay since 1977. Consequently, we have data on all aspects of the breeding biology and foraging ecology of the *Pygoscelis* species at this site and the only long-term demographic data (e.g., adult annual survival, chick cohort survival, age at first breeding, life time reproductive success) for any penguin species at any site in the Antarctic Peninsula region. This region is the site of most krill fishery activity and is where the recent changes in climate (warming) are most dramatic and best documented. Our objective is to describe the functional relationships between penguin predators, their primary prey, antarctic krill and key environmental variables. To thoroughly understand the structure and function of the antarctic marine ecosystem, we must determine the impact of environmental variation on the structure and regulation of upper trophic level

predators such as the *Pygoscelis* penguins. (B-040-E; NSF/OPP 04-43751)

Aging in Weddell seals: Proximate mechanisms of age-related changes in adaptations to breath-hold hunting in an extreme environment.

Markus Horning, Oregon State University, and Jo-Ann E. Mellish, Alaska SeaLife Center.

Our primary objective is to establish diving seals as a model for the study of cardiovascular and muscular physiology in mammal aging. Research on Weddell seals could validate this model and thus develop a foundation for similar research on other species. Evolutionary aging theories predict that elderly diving seals should exhibit senescence. Aging humans, by contrast, exhibit marked reduction in aerobic and physical exercise capacities, as well as circulatory system changes.

The ability of pinnipeds to avoid apparent senescence is remarkable, giving rise to two questions:

- What specific physiological and morphological changes occur with advancing age in pinnipeds?
- What subtle adjustments are made by these animals to cope with such changes?

This investigation will be the first to describe specific, small-scale physiological and behavioral changes relating to dive capability with advancing age in a model pinniped. To answer these questions, data collected from Weddell seals at the peak and near the end of their reproductive age range will be compared. Blood and muscle samples will be collected, and assessments will be made of the seals' ability to do external work (i.e., diving and foraging) as well as internal work (i.e., muscle functionality).

Basic mammalian aging is an area of study that still requires considerable effort. With people living longer than ever, any research into the development of new models for the study of aging has tremendous potential benefits to society at large. If seals prove a viable model system as we anticipate, unusual mechanisms to cope with aging may be revealed. (B-041; NSF/OPP 04-40780 and NSF/OPP 04-40715)

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.

In addition, 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 grassroots efforts and participation in formal regional and national programs. Moreover, we interface original research with K– 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)

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 of coastline, more than 1,000 kilometers 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)

Impacts of elevated pCO_2 on a dominant aragonitic pteropod (Thecosomata) and its specialist predator (Gymnosomata) in the Ross Sea.

Victoria Fabry, California State University–San Marcos.

Rising carbon dioxide levels are affecting both oceans and marine organisms via decreased carbonate saturation that affects calcification rates and acid-based metabolic physiology disturbances. We propose to quantify the impact of elevated carbon dioxide on a dominant aragonitic pteropod, *Limacina helicina*, and its specialist predator, the gymnosome *Clione antarctica*, in the Ross Sea. The unusual, co-evolved relationship between the cosomes (a marine calcifying organism that forms shells made of calcium carbonate-based aragonite) and their gymnosome predators provides a unique backdrop against which to assess the physiological and ecological importance of elevated carbon dioxide. Pteropods are functionally important components of the antarctic ecosystem with potential to influence phytoplankton stocks, carbon export, and dimethyl sulfide levels that, in turn, influence global climate through ocean-atmosphere feedback loops.

New evidence suggests that because of rising atmospheric carbon dioxide concentrations and acidity in the ocean, surface waters of the Southern Ocean will become undersaturated with respect to aragonite within the next 50 to 100 years. We will expose animals to a range of pCO_2 values and directly measure pteropod calcification rates and sublethal effects on organismal energetics. These data can be used to evaluate critical processes and determine the carbon dioxide thresholds beyond which these effects may become detrimental.

Data collected in McMurdo Station fieldwork will be disseminated to high school students with the goal of infusing them with the excitement of Antarctica, the thrill of scientific discovery, and an awareness of the rapid environmental change underway in polar regions. (B-069; NSF/OPP 05-38710)

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 will 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 have an extensive program that includes both K– 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's primary goal is 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)

Altitude symptoms at the South Pole.

Bruce Johnson, Mayo Clinic.

The goal of this project is to develop algorithms to better understand the mechanisms of altitude-related illness; to develop demographic, biochemical (serum and plasma), and genetic predictors (or combinations of predictors) of who may be most susceptible to altitude sickness; and to develop protocols to help optimize acclimatization practice. This research is important to the antarctic program because each year a large number of individuals develop mild to moderate altitude-related symptoms as a result of the relatively sudden transition from sea level to the reduced atmospheric pressures associated with the South Pole. It could also benefit the increasing number of people worldwide who visit altitudes similar to that at the South Pole.

Symptoms will be assessed at sea level (McMurdo Station) and six times at altitude to follow the progression to symptom resolution. This project will emphasize the mild to moderate symptoms often experienced with acute exposure to moderate altitude. Researchers anticipate that results from this study will improve current altitude-illness preventive procedures at South Pole as well as help identify personnel who may be at increased risk for developing more severe altitude symptoms (and therefore require more effective preventive measures). Findings will also be applicable to commercial air travel and the space program (long-term space flight at reduced atmospheric pressures) and may provide insight into clinical pathologies that result in low oxygen tensions in the blood or tissues (e. g., lung disease, obstructive sleep apnea, and heart failure).

Researchers will develop a web site with links to local secondary school programs as well as mountaineering and clinical web sites that inform students, climbers, and the general population about altitude-related illness. In addition, with the help of secondary school teachers, a curriculum on altitude adaptation, symptoms, and prevention will be developed. (B-179; NSF/OPP 05-40710)

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 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 Valleys 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.

This austral summer the research team will focus on Lakes Bonney, Hoare, and Fryxell but will also visit Don Juan Pond, Bratina Island salt ponds, and Lake Vanda to collect sediment and water samples. One member of the team will study the microbial ecology of Blood Falls at the terminus of the Taylor Glacier.

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)

The aerobic dive limit: Oxygen transport and depletion in emperor penguins.

Paul John Poganis, Scripps Institution of Oceanograpy.

This project studies the diving of emperor penguins at an isolated dive hole on the sea ice of McMurdo Sound to investigate blood and muscle oxygen store depletion in relation to the documented aerobic dive limit (ADL), which is the onset of post-dive blood lactate accumulation.

The ADL is probably the most commonly used, but most rarely measured factor to interpret and model the behavior and foraging ecology of diving animals. This study of the diving of emperor penguins at the isolated dive hole is one of the few in which physiological responses and the ADL have actually been measured.

The project also continues its long-term monitoring of the Ross Sea emperor colonies, which is especially important in light of both fisheries activity and the movement of large icebergs.

Broad impactsof the project include

- technological development of a microprocessor-based near-infrared spectrophotometer backpack, which will be applicable not only to other species, but also other fields such as exercise physiology;
- collaboration with the U.S. Naval Hospital in San Diego to train anesthesia residents in research techniques and the application of those techniques to Antarctic field research; and
- an improved understanding of the ADL concept and its use in the fields of diving behavior and physiology.

In addition, the annual censuses of emperor penguin colonies in the Ross Sea, along with the continued evaluation of previously developed remote monitoring cameras, will form the basis of a new educational web site and an educational outreach program to school children through SeaWorld of San Diego. (B-197; NSF/OPP 05-38594)

Capital expenditure, lactation energetics, and the importance of foraging to Weddell seals and their pups.

Olav Tonnes Oftedal, Smithsonian Institution.

The Weddell seal of Antarctica had been thought to fast during its relatively long lactation period (68 weeks), but evidence from feeding biomarkers, diving behavior, and maternal mass loss suggests that most females feed, at least in late lactation. We will investigate the relationship of capital expenditure, lactation energetics, and food intake in the Weddell seal using a novel multimarker approach to determine the following:

- changes in maternal capital stores (body energy, fat, protein) over the course of lactation;
- maternal energy expenditure (heat production);
- milk production including transfer of energy, fat, water, and protein to pups;
- timing of the onset of feeding in lactating females and pups;
- contribution of food intake to the maternal energy and substrate budget; and
- duration of the lactation period and nature of the weaning process.

From the data collected, we expect to be able to evaluate the relative importance of capital expenditure and food intake, and of energy vs. protein, in the evolution of a mixed capital and income breeding strategy.

A multilevel outreach package for the Smithsonian National Zoological Park program will include development of a dedicated web page about the project; multimedia and interactive presentations and exhibits, demonstrations, and one-on-one interpretive interactions between scientists and zoo visitors; and participation with minority youths from the Columbia Science Workshop, an NSF-funded science program. (B-224; NSF/OPP 05-38592)

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 *Phaeocystis globosa* and *Phaeocystis 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.

Besides 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 as well as engage in community outreach and educational activities. (B-272-N; NSF/OPP 03-38097, NSF/OPP 03-38350, NSF/OPP 03-38164, NSF/OPP 03-38111, and NSF/OPP 03-38157)

Improving acoustic estimates of antarctic krill populations.

Joseph Warren, State University of New York at Stony Brook.

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 06-33939)

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)