U.S. Antarctic Program, 2004 – 2005

I. Aeronomy and Astrophysics

II. Biology and Medicine

III. Long-Term Ecological Research

IV. Ocean and Climate Systems

V. Geology and Geophysics

VI. Glaciology

VII. Artists and Writers Program

PDF Version

OPP home page

Antarctic Sciences Section

Polar Research Support Section

U.S. Annual Antarctic Treaty Exchange of Information

BIOLOGY AND MEDICINE

Palmer Station supports U.S. and cooperative research in the Antarctic Peninsula region. Scientists work at the station laboratory and on nearby islands. (*NSF/USAP photo by Jeffrey Kietzmann, Raytheon Polar Service Corp.*)

On this page:

- Ultraviolet-radiation-induced changes in the patterns of production and composition of biochemical compounds in antarctic marine phytoplankton.
- Comparative and quantitative studies of protistan molecular ecology and physiology in coastal antarctic waters.
- Southern Ocean GLOBEC (Global Ocean Ecosystem Dynamics) Mysticete whale acoustic census in the GLOBEC west antarctic project area.
- Physiological and molecular mechanisms of stress tolerance in a polar insect.
- Soil biodiversity and response to climate change: A regional comparison of Cape Hallett and Taylor Valley, Antarctica.
- Hydrologic controls over biogeochemistry and microbial community structure and function across terrestrial/aquatic interfaces in a polar desert.
- Relevance of planktonic larval dispersal to endemism and biogeography of antarctic benthic invertebrates.
- Genetic and photogrammetric investigations of three ecotypes of killer whales in the southern Ross Sea.
- Origin and evolution of antarctic and deep-sea macroinfauna: Systematics and reproductive patterns of polychaetes.
- Biogeochemistry of dissolved organic material in Pony Lake, Ross Island.
- *Salpa thompsoni* in the Southern Ocean: Bioenergetics, population dynamics, and biogeochemical impact.
- What limits denitrification and bacterial growth in Lake Bonney, Taylor Valley, Antarctica?
- Prevention of environment-induced decrements in mood and cognitive performance.
- SPISE3 (Science Package for the Exploration of Extreme Environments 3): A noncontact instrument suite for rapid detection of chemical biosignatures.
- Temporal variability in natural and anthropogenic disturbance of 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 in the world, 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. (The eastern sheet is larger than most countries.)

RPSC science technician Zan Stine works in the laboratory at Palmer Station. The majority of the science conducted at Palmer Station is biology, oceanography or aeronomy. The labs at all three U.S. stations are fully equipped to facilitate scientific research. (*NSF/USAP photo by Kristan Hutchinson, Raytheon Polar Services Corp.*)

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 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 subject 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 anthropogenic as well as natural changes.

- **Adaptation:** Antarctic extremes present a fundamental research opportunity; topics include 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.

- **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.

^ top

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

Ronald P. Kiene, University of South Alabama, and David J. Kieber, College of Environmental Science and Forestry (Syracuse), State University of New York.

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 and can affect the chemistry of precipitation and influence cloud properties and, possibly, climate. DMSP and DMS are also quantitatively 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 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 polar food webs, and
- that bloom development and resulting nutrient depletion (e.g., iron) will result in high production of DMSP and high DMS concentrations and atmospheric fluxes.

Results from this study will greatly improve understanding of the underlying mechanisms controlling DMSP and DMS concentrations in polar waters, thereby improving 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 to teach undergraduate and graduate courses. (B–002–N and B–266–N; NSF/OPP 02–30497 and NSF/OPP 02–30499)

^ top

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 larger than that 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 also appear to be increasing along the Peninsula. These rapid changes in climate 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 environmental 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)

^ top

Antifreeze proteins in antarctic fishes: Integrated

studies of freezing environments and organismal freezing avoidance, protein structure-function and mechanism, genes, and evolution.

Arthur L. DeVries and Chi-Hing Cheng, University of Illinois–Urbana-Champaign.

This project includes ongoing and new studies on the role of antifreeze glycoproteins (AFGPs) and a new antifreeze-potentiating protein (AFPP) in the freezing avoidance of antarctic fishes and their eggs and larvae. The specific areas of research to be investigated are:

- the rate of uptake of endogenous ice by ice-free specimens;
- the structure of AFPP and the mechanism whereby it potentiates the antifreeze activity of the large AFGPs, but not the small ones;
- the structure-function elucidation of eel pout AFPP through directed-evolution methodologies;
- the mechanism of freezing avoidance in embryos and young larval fish, and the temporal aspects of AFGP and AFPP expression during embryogenesis;
- comprehensive analyses of the antifreeze capacity at both the protein and gene levels across the suborder Notothenioidei;
- the evolution of the AFGP gene family and gene locus;
- the evolution of AFPP; and
- the origin of the Patagonotothen lineage (nonantarctic notothenioids and close relatives of the endemic antarctic notothenioid species).

The extreme cold and icy conditions of the McMurdo Sound arise from its association with the massive Ross Ice Shelf and the influence of cold shelf water. To elucidate the relationship between the McMurdo environment and ice exposure in the local fish population, we will conduct parallel physical measurements of the depth and extent of ice formation in various microenvironments in the sound and will complete biological experiments to determine ice load in fish at these locations by measuring the number of ice crystals in their spleens, as well as the rate of ice entry. These studies will ascertain the relationship between the degree of environmental extremes and the ice load in fish.

This project is associated with extensive international collaboration, and our findings may have broad implications for agriculture, food science, and cryomedicine. Public outreach and training of graduate and undergraduate students are integral components of the work. (B–005–M; NSF/OPP 02–31006)

^ top

Energetics of protein metabolism during development of antarctic echinoderms.

Donal T. Manahan and Robert E. Maxson, University of Southern California.

Larval forms are dominant in the life history of marine invertebrates. In Antarctica, energy budget calculations have shown that larval stages of echinoderms can survive without food for several months to years. This has led to speculation that energy metabolism is more efficient in these forms and that this enhanced efficiency might be unique to life in extreme cold.

Our recent work on the biochemical bases of developmental physiology in antarctic marine invertebrates has indicated that contrary to expectations of low metabolism and low rates of macromolecular synthesis in the cold, embryos and larvae of an antarctic sea urchin have high rates of protein synthesis and low rates of metabolism. This apparent paradox was resolved with our recent finding that the cost of protein synthesis in this sea urchin is 1/25th that reported for other animals. This is the highest efficiency for protein synthesis reported for an animal and has important implications for the physiology of growth and development in cold environments. We now propose to investigate this unique biochemical efficiency of protein synthesis in detail.

We have three major objectives:

- We will test the generality of our recent findings by measuring metabolism and protein synthesis during the development of other antarctic echinoderm species.
- We will directly test the hypothesis that growth efficiencies will be high in such organisms by measuring the physiology of protein growth efficiencies in larvae.
- We will seek to explain the unique high efficiency of protein synthesis in antarctic sea urchin embryos in specific molecular terms by studying each of the component processes. We will supplement these measurements of whole population protein synthesis with measurements based on selected individual proteins (histones).

Understanding metabolic efficiency in polar organisms will help resolve long-standing questions about temperature compensation and adaptations to food limitation in polar regions. Our approach will emphasize the cellular and subcellular levels of biological analysis in order to test the hypothesis that there is a new biochemistry for protein synthesis in these organisms. (B–006–M; NSF/OPP 01–30398)

^ top

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 nearly 36 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 both 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 progressively 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 the 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 be readily applied to 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)

^ top

Community dynamics in a polar ecosystem: Benthic recovery from organic enrichment in the

Antarctic.

Stacy L. Kim, Moss Landing Marine Laboratories/San Jose State University.

The Antarctic is considered one of the most pristine habitats on the planet. Humans occupy only a tiny portion of the continent. Though the human footprint in Antarctica is small and generally highly localized, there are areas where anthropogenic contamination is severe. For example, past practices at McMurdo Station have resulted in a few highly contaminated marine areas, such as the one near the sewage outfall. High levels of organic enrichment have radically altered the local benthic community. The altered community and surrounding undisturbed communities have been well described over a 10-year period.

In February 2003, a sewage treatment plant was completed at McMurdo Station, and the organic input to the seafloor dropped markedly. On the basis of existing information on community recovery dynamics in polar ecosystems from ice-mediated disturbances (icebergs and anchor ice) and in temperate ecosystems from organic-loading, we predict that recovery will begin immediately. However, growth and reproduction are often slow in antarctic species. Thus, complete recovery may extend over a much longer period than in temperate areas. In addition, slow microbial processes at low polar temperatures have allowed a large pile of organic material to build up at the outfall site, and some changes may be the result of burial rather than organic enrichment. Finally, the size of the disturbance is unusual; small organic inputs such as seal feces and dead fish are common, but large sewage outfalls are not. Thus, the outfall and new treatment plant provide a unique opportunity for a large-scale experiment on recovery.

Our experiments will elucidate the roles of organic enrichment, burial, and disturbance size in benthic community recovery dynamics. We will compare the rates observed with those predicted from a meta-analysis of recovery from organic disturbance in a variety of habitats, and contrast the role of organic loading with burial and patch size. Our integrated approach will further the understanding of anthropogenic impacts in polar environments. We continue to communicate the excitement of scientific research to students of all ages, not only by involving graduate and undergraduate students directly in our field and lab research, but also to K-12 students via classroom and community presentations and web interactions from the field (B–010–M; NSF/OPP 01–26319)

^ top

Biogeochemistry of Victoria Land coastal ponds: Role in terrestrial ecosystem organic carbon dynamics and structure.

Maria Uhle, University of Tennessee, and Peter T. Doran, University of Illinois–Chicago.

Since 1993, structure, processes, and functional linkages in the antarctic terrestrial ecosystem have been the focus of the Long-Term Ecological Research site in the McMurdo Dry Valleys. This ecosystem has a modern component linking organic carbon dynamics between the soils, glaciers, streams, and ice-covered lakes, plus a legacy to ancient glacial events that deposited paleo-organic carbon. The soil reservoir contains 72 percent of the seasonally unfrozen and biologically available organic carbon within Taylor Valley, and a substantial fraction may be recalcitrant carbon derived from ancient climatic events.

One potentially large source of labile, and hence bioavailable, organic carbon that has not been investigated is the many small ponds found in most areas of the McMurdo Dry Valleys, especially near the coast. These ponds have a relatively large surface area, and they seem to generate a significant amount of stranded microbial mat as they shift position. Their transient nature renders the organic matter vulnerable to transport and possibly represents a significant source of modern, labile carbon in the ecosystem. A preliminary estimate suggests that the coastal pond reservoir may constitute at least 11 percent of the carbon in the McMurdo Dry Valleys soil reservoir. Therefore, these ponds may significantly affect the carbon cycle and must be considered in developing a carbon budget for this polar desert.

We will determine the extent of the coastal pond reservoir, assess how productive it is, and determine whether it is a source or sink within organic carbon dynamics and the overall structure of the terrestrial ecosystem. We will focus on understanding the biogeochemistry of these ponds in terms of the factors affecting organic carbon

production and nutrient cycling.

We should derive a more detailed understanding of the linkages between modern ecosystem components, develop insights into the biogeochemical cycling within polar desert ecosystems, and, possibly, identify mechanisms that help sustain life in extreme environments. We will also involve predominantly African-American K–5 students from Knoxville, Tennessee, city schools. These students will be involved in question-and-answer sessions over the Internet, and older students will design experiments and be introduced to the scientific method. Science and math classes will use data analysis to develop analytical skills and place them in a relevant context. (B–011–M; NSF/OPP 02–30237)

^ top

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 in order 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 intend to develop a submersible, remotely operable underwater observatory for the study of foraminifera and associated benthic fauna. This observatory would 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)

^ top

Cultural emergence and health in Antarctica.

Timothy D. Dye and Nancy Chin, University of Rochester.

The emergence of a long-term population in space will, in many ways, parallel the emergence of a sustained population in Antarctica, where development has expanded beyond the initial population of scientific and military personnel and now includes support staff and construction personnel. Experts speculate that a similar mix of residents may emerge as space populations develop. Such organizational and cultural merging in restricted environments undoubtedly creates new cultural landscapes (ethnoscapes) that could influence health and health behavior. Because of the extreme environment, health risks and health care are particularly important. The study of cultural emergence in Antarctica as an analog to space could prove useful in the development of models of health and health behavior in an isolated confined environment (ICE) and could help planners better structure these environments to reduce health risks and identify factors that predispose people to those risks.

We aim to:

- model the emergence of cultural stages in ICE ethnoscapes as experienced by both short- and long-term populations;
- identify those elements of ICE ethnoscapes that are specific to an individual season and those that are repeated;
- relate how the temporal and content stages of ICE ethnoscapes interact with risk, behavior, and injury; and
- demonstrate the utility of electronic and distance-based assisted ethnography in the conduct of social research in ICE environments of Antarctica and, possibly, in space.

We will begin with key informant interviews and focus groups conducted throughout the United States with people who have spent at least one season on the ice in the past 3 years. The purpose is to elucidate the behaviors, risks, and health events that residents face, particularly in the emergence of ethnoscapes. The next phase has us residing in Antarctica for an extended period and conducting participant observation and interviews at two different sites. This phase will include the Self-Disclosure Technique (SDT), an anthropological method for identifying the conceptual structure of a cultural event. SDT will be used to describe cultural dynamics in occupational, recreational, spiritual, and other group activities. Fieldwork will involve both short- and long-term residence. The data will be processed, and models will be tested for validity with informants on the ice.

This research could contribute to the development of screening procedures for long-term residence in ICEs and context-sensitive explanatory models of culture and injury risk, as well as illustrate the utility of distance-based ethnography. (B–027–M; NSF/OPP 01–25893)

^ top

Genomic networks for cold-adaptation in 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)

^ top

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

David G. Ainley, H.T. Harvey and Associates; Nadav Nur and Grant Ballard, Point Reyes Bird Observatory; and Katie Dugger, Oregon State University.

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 30 percent of the world's population of this species resides, and is in some way related to ameliorating climate. Thus far we have been examining:

- the relative importance of resources that constrain colony growth (the amount of nesting habitat versus access to food);
- aspects of natural history that might be affected by exploitative or interference competition among neighboring colonies (breeding success and foraging effort);
- climatic factors that influence the latter, especially extent and concentration of sea ice; and
- behavioral mechanisms that influence colony growth as a function of initial size and location, emigration, and immigration.

Only the Beaufort Island colony is nesting space limited, and we have shown how the extent and concentration of sea ice affect diet, foraging effort, and winter survival. In addition, the large colony at Cape Crozier affects the foraging patterns of penguins at the smaller ones, all within range, and, perhaps, ultimately their size. The rate and direction of emigration also appear to be constrained by sea-ice conditions, with reasonable concentrations of ice favoring the growth of smaller colonies where foraging competition is minimal. The arrival of the large icebergs, B–15A and C–16, following the 2000 season has provided an unusual opportunity, a natural experiment, to investigate the factors encouraging emigration and/or its absence (philopatry).

We will use eight 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.

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 (less sea ice, less reflection of solar energy). The extreme sensitivity of these penguins to climate change has often been noted. Understanding the demographic mechanisms behind this sensitivity will contribute greatly to knowledge of 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 01–25608)

^ top

Occupation history and diet of Adélie penguins in the Ross Sea region, Antarctica.

Steven D. Emslie, University of North Carolina–Wilmington.

We will build on previous studies to investigate the occupation history and diet of Adélie penguins (*Pygoscelis adeliae*) with excavations of the many abandoned and active penguin colonies in the Ross Sea region: specifically, the Victoria Land coast from Cape Adare to Marble Point. Some of these sites have been radiocarbon-dated and indicate that Adélie penguins have occupied them for 13,000 years. The material we will recover, as demonstrated from previous investigations, will include penguin bones, tissue, and eggshell fragments, as well as abundant remains of prey (fish bones, otoliths, squid beaks) preserved in ornithogenic soils (formed from bird guano). These organic remains will be quantified and subjected to radiocarbon analyses to obtain a colonization history of the penguins in this region. Identification of prey remains in the sediment will allow us to assess penguin diet.

We will collaborate with New Zealand scientists to analyze other data from these sites (ancient DNA) and will interpret past climatic conditions from published ice-core and marine-sediment records. These data will be used to test the hypothesis that Adélie penguins respond predictably to climate change, past and present. In addition, we will test the hypothesis that these penguins alter their diet in accordance with climate, sea-ice conditions, and other marine environmental variables along a latitudinal gradient. Graduate and undergraduate students will be involved, and a Web site will be developed to report results and maintain educational interaction between project personnel and students at local middle and high schools in Wilmington, North Carolina. (B–034–M; NSF/OPP 01–25098)

^ top

Cold body temperature as an evolutionary shaping force in the physiology of antarctic fishes.

Bruce D. Sidell, University of Maine.

Notothenioid fishes that dominate the fish fauna surrounding Antarctica have been evolving for 10 to 14 million years at a nearly constant body temperature of roughly 0°C. Many unusual physiological characteristics of these fishes are adaptations to life at cold body temperatures or physiological or biochemical features that are permitted by life at cold body temperatures but that would be deleterious in other environments.

We have three main objectives:

- to identify in antarctic fishes the amino acid substitutions in the fatty acid–binding pocket of fatty acyl coenzyme A synthetase (FACS) that explain its substrate specificity. Fatty acids are a major source of energy metabolism in antarctic fishes, and FACS catalyzes this metabolism.
- to produce a rigorous biochemical and biophysical characterization of the intracellular calcium-binding protein, parvalbumin, from the white axial musculature of antarctic fishes. Parvalbumin plays a pivotal role in facilitating the relaxation phase of fast-contracting muscles and is a likely site of strong selective pressure. Preliminary data indicate strongly that the protein from antarctic fishes has been modified to function at cold temperatures.
- to conduct a broad survey of the pattern of cardiac myoglobin expression in the suborder Notothenioidei. Previous work has indicated a variable pattern of presence or absence of myoglobin (Mb), an intracellular oxygen-binding protein, in the hearts of *Channichthyidae* (icefish). Because Mb has physiological value in species that express it, this part of the project will survey for the presence of cardiac Mb in as many notothenioid species as possible.

We will perform a combination of shipboard collection and laboratory experimentation (cloning and site-directed mutagenesis of FACS). Full-length cDNA clones for antarctic fish parvalbumin(s) will be obtained, permitting the deduction of primary amino acid sequence. These data will yield insight into structural elements that permit the protein from notothenioid fishes to function at very cold body temperatures.

Both modified and wild-type FACS will be produced using a cultured expression system, and the protein products will be isolated and subject to enzyme kinetic analyses. These experiments may permit us to determine the specific amino acid substitutions that explain both substrate specificity and the preservation of catalytic rate of notothenioid FACS at cold temperatures. (B–036–L; NSF/OPP 01–25890)

^ top

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 recently 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–E; NSF/OPP 02–29570)

^ top

Foraging behavior and demography of *Pygoscelis* penguins.

Wayne Z. Trivelpiece, National Oceanic and Atmospheric Administration, Southwest Fisheries Science Center.

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)

^ top

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

Walker O. Smith, 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. In this project, 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; NSF/OPP 00–87401)

^ top

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–P; NSF/OPP 02–30069)

^ top

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)

^ top

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)

^ top

Diving physiology and behavior of emperor penguins.

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

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 in the antarctic ecosystem 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 planned 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 by taking population censuses. (B–197–M; NSF/OPP 02–29638)

^ top

Monitoring the human impact 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 fundamentally on the need to quantify and understand the natural variability manifested by breeding populations over spatial and temporal scales. 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 over time and space in both marine and terrestrial habitats, as well as the ability to examine potential tourist impacts as part of controlled experiments.

Our research is expected to capitalize and expand on two key findings to date. 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)

^ top

Effects of foraging on the lipid biochemistry of freely diving Weddell seals.

Michael A. Castellini, University of Alaska–Fairbanks, and Lorrie D. Rea, University of Central Florida.

Our primary goal is to quantify the dynamics of lipid uptake and use in a naturally foraging mammalian carnivore by examining freely diving Weddell seals (*Leptonychotes weddellii*) in Antarctica. This species, in this environment, offers a unique opportunity—one that may not be possible in any other system—to follow the biochemistry and physiology of nutrient use in a large carnivore.

To our knowledge, the *in vivo* nutritional biochemistry of foraging in a free-ranging, large mammalian carnivore has never been attempted. While such studies can be conducted in laboratories or zoos, they are necessarily limited to captive animals whose feeding times and diets are determined and constrained.

For several decades, the Weddell seal has been the focus of studies using isolated holes through the sea ice near McMurdo Station to study natural diving physiology. In that system, the seal has access to a single ice hole where it routinely returns to breathe, sleep, and digest. Using blood-sampling catheters, we have been able to collect serial samples whenever the seal returns to the surface between diving bouts. During such experiments on diving physiology, these seals actively caught and digested their prey, but any observations on nutritional chemistry were incidental and not part of the study design.

Like all seals, Weddell seals rely primarily on lipid metabolism for their daily energy demands. Therefore, we will examine the kinetics of lipid uptake and use during active foraging bouts. We will obtain blood samples from freely diving animals during these bouts; use labeled, traced experiments to quantify lipid turnover rates; and separate the lipid pool into its various components.

In addition, we will compare adults with pups, which are biochemically adapted for massive and rapid lipid use while nursing. This project is unique to Antarctica and will provide an insight into mammalian biochemistry never before possible. These data will be important not only to antarctic ecosystem studies, but also to the entire field of lipid metabolism in mammals and to the study of carnivore biology. (B–199–M; NSF/OPP 01–30417)

^ top

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, and Patrick J. Neale, Smithsonian Institution.

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 in systems dominated 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 of turbulence intensity in the surface layer that have been done have not been integrated with parallel 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 both 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 not enough turbulence is present 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 scientific understanding of vertical mixing processes, trophic interactions, and biogeochemical

cycling in the Ross Sea and will provide a valuable comparison with previous work in the Weddell–Scotia Confluence and Palmer Station regions. (B–200–N and B–203–N; NSF/OPP 01–27022 and NSF/OPP 01–27037)

^ top

Ultraviolet-radiation-induced changes in the patterns of production and composition of biochemical compounds in 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: www.bigelow.org/arctic/goes/index.html.) (B–206–N; NSF/OPP 01–26150)

^ top

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)

^ top

Southern Ocean GLOBEC (Global Ocean Ecosystem Dynamics) Mysticete whale acoustic census in the GLOBEC west antarctic project area.

John A. Hildebrand, Scripps Institution of Oceanography, University of California–San Diego, and Deborah Thiele, Deakin University.

Before large-scale commercial whaling during the early 20th century, the Southern Ocean held the world's most extensive population of baleen whales, as well as large numbers of blue, fin, sei, and humpback whales. Despite a nearly complete ban on whaling since the 1970s, antarctic populations of baleen whales remain low. Passive acoustic surveys, coupled with shipboard visual surveys, provide an efficient means of assessing the population, distribution, and seasonality of whales.

Our main interest is the blue whale (*Balaenoptera musculus*), followed by the fin (*B. physalus*), humpback (*Megaptera novaeangliae*), minke (*B. acutorostrata*), and sperm whale (*Physeter macrocephalus*, an odontocete). Because the vocalizations of these whales are unique and easily recognizable, it is possible to use passive acoustic techniques to distinguish particular species so we can understand why they return or do not return to the Southern Ocean.

We will examine the variability of whales in the Antarctic and how their presence relates to krill, ice, and other Southern Ocean Global Ocean Ecosystem Dynamics (SOGLOBEC) studies. Determining the patterns of whale abundance and distribution is central to understanding ecological interactions involving these top predators.

We are using continuous-recording sea floor packages and collecting data during biannual survey cruises. Instruments were deployed in 2001, and each records continuously at 500 samples per second for 15 months. During this season's cruises, we will refurbish and redeploy these seafloor recording packages and perform more passive acoustic studies. We will also conduct visual surveys and deploy sonobuoys, expendable underwater listening devices that can transmit acoustic data for up to 8 hours. Deployed around observed groups of whales, these recordings provide a means for correlating calls with numbers of whales present, and they can also be compared with the seafloor data.

The deployment of a large-aperture autonomous hydrophone array will promote incorporation of passive acoustics as a tool for whale detection and census and provide new insight into the role of these top predators in polar ecosystems. The recovery or potential loss of the antarctic blue whale population, which once numbered more than 200,000, is not only a question of species extinction, but it is also relevant to all Southern Ocean ecosystem studies. (B–239–N and B–280–N; NSF/OPP 01–36493)

^ top

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)

^ top

Soil biodiversity and response to climate change: A regional comparison of Cape Hallett and Taylor Valley, Antarctica.

W. Berry Lyons, Ohio State University; Diana H. Wall, Colorado State University; Ross A. Virginia and John E. Barrett, Dartmouth College; and Stephen C. Cary, University of Delaware.

Soil ecosystems along the Victoria Land coast from the McMurdo Dry Valleys in the south to Cape Hallett in the north occur across broad gradients of biodiversity, climate, and soil resource legacies from previous climates (organic matter, nutrients, and salts). The range of conditions can be used to test specific hypotheses derived from a soil biodiversity and habitat model developed from the McMurdo Dry Valleys Long-Term Ecological Research Program (LTER). This habitat suitability model describes the distribution, abundance, and diversity of soil biota based on a combination of legacy and contemporary soil and climate properties.

We will extend this model to the greater Victoria Land region at Cape Hallett. Insights into the relationship between biodiversity (microbes and invertebrates) and ecosystem functioning (soil respiration and nutrient cycling) may be especially important in Victoria Land since it encompasses a range of ecosystems, from those with near-minimum organic matter and no invertebrates to those with very high organic matter deposits and complex food webs. Our 2-year program of field and laboratory research will address

how soil food webs and ecosystem processes are affected by climate, legacy, and contemporary soil processes.

We will begin the regionalization of results and insights from the McMurdo LTER study and determine whether the changes in biodiversity along the range of soil habitats and landscape gradients in Taylor Valley occur similarly across gradients in a richer, more complex habitat (Cape Hallett). There is an immediate need to understand how soil biodiversity and ecosystem functioning are related and to determine the factors influencing the distribution of soil biodiversity across Antarctica.

The taxonomic complexity of soil food webs elsewhere limits our ability to draw inferences about the functional significance of biodiversity and the responses of soil communities to varying conditions and climate. The extension and testing of a conceptual model of soil biodiversity based on the simplest soil communities on Earth will contribute to the knowledge of complex temperate ecosystems. These linked studies of microbial and invertebrate diversity in relation to soil organic matter, moisture, and temperature change at Taylor Valley and Cape Hallett will provide one of the most complete quantitative assessments of soil diversity to date. (B–259–M; NSF/OPP 02–29836)

^ top

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

Michael N. Gooseff, Utah State University; 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 research 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 hydrological 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)

^ top

Relevance of planktonic larval dispersal to endemism and biogeography of antarctic benthic invertebrates.

Kenneth M. Halanych, Auburn University, and Rudolf S. Scheltema, Woods Hole Oceanographic Institution.

Because of the extreme isolation of the antarctic continent since the Early Oligocene, a unique invertebrate benthic fauna with a high degree of endemism would be expected. Yet some invertebrate taxa that constitute important ecological components of sedimentary benthic communities include more than 40 percent nonendemic species (e.g., benthic polychaetes). To account for nonendemic species, intermittent genetic exchange between antarctic and other (South American) populations must occur. The most likely mechanism for such gene flow, at least for infaunal and mobile macrobenthos, is dispersal of planktonic larvae across the subantarctic and antarctic polar fronts.

To test for larval dispersal as a mechanism for maintaining genetic continuity across polar fronts, we will take plankton samples along transects across the Drake Passage during both the austral summer and winter seasons while concurrently collecting the appropriate hydrographic data (vertical and horizontal temperatures and horizontal current data). Such data will help elucidate the hydrographic mechanisms that allow dispersal across the Drake Passage.

Using a molecular phylogenetic approach, we will also compare seemingly identical adult forms from Antarctica and South America to identify genetic breaks and historical gene flow and control for the presence of cryptic species, and employ similar molecular tools to relate planktonic larvae to their adult forms. Through this procedure, we will link the larval forms to their respective antarctic or South American origins.

Our research is intended to build a synthetic understanding of historical gene flow and present-day dispersal mechanisms in the South America/Drake Passage/Antarctic Peninsula region. This work represents one of the first attempts to examine recent gene flow in antarctic benthic invertebrates. We will train graduate students and a postdoctoral fellow, and if possible, one of our team members will be a high school teacher in order to promote K–12 education. (B–281–L; NSF/OPP 03–38218 and NSF/OPP 03–38087)

^ top

Genetic and photogrammetric investigations of three ecotypes of killer whales 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 evaluate the hypothesis that three distinct ecotypes of killer whales (*Orcinus sp.*) are found in the Ross Sea during the austral summer. These forms have different prey and habitats, different school sizes and geographic distributions, and distinct morphologies. If true, this hypothesis will largely 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 their role and conservation status depend on properly identifying their taxonomy, specifying their dietary needs, and assessing the impact of fisheries.

We will focus on two main activities:

- using a launch to collect projectile biopsy samples that will be sequenced and

analyzed to compare genetic divergence among the three forms. To date, we have collected 47 samples from antarctic killer whales; as a target sample size, we would like 50 of each form.

- using a helicopter-mounted camera system to obtain aerial photographs of individual whales. These photographs will be used to accurately determine length and body proportions for morphological comparisons.

Previously published data indicate that the form that is most common in the southern Ross Sea may be significantly smaller than the typical killer whale. The scarcity of exposed beaches on which whales might strand and the poor odds that they would be found if they did mean that collecting a holotype specimen seems unlikely. However, we have perfected a technique for accurately determining the body length and proportions of cetaceans photographed from the air to provide morphological evidence of phenotypic divergence.

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 place is in the ecosystem remain unanswered. Our study will demonstrate the feasibility of using nonlethal techniques to conduct research on whales in the Southern Ocean Sanctuary: some 300 to 400 minke whales are killed each year in Antarctica to conduct similar research. Confirming new species would also highlight the fact that our knowledge of marine biodiversity is more rudimentary than is currently thought. (B–289–M; NSF/OPP 03–38428)

^ top

Origin and evolution of antarctic and deep-sea macroinfauna: Systematics and reproductive patterns of polychaetes.

James A. Blake, University of Massachusetts.

We will address the origin of deep-sea benthic fauna in relation to the antarctic shelf and linkages to the deep-sea fauna of the Atlantic and Pacific Oceans, hypotheses to explain high biodiversity in the deep sea, benthic community structure in the Southern Ocean, and biological processes including reproduction and larval development of benthic invertebrates. We will focus on seven polychaete families: *Orbiniidae*, *Oweniidae*, *Paraonidae*, *Spionidae*, *Cirratulidae*, *Scalibregmatidae*, and *Opheliidae*. Other families will be included as appropriate.

Our research is divided into the following tasks:

- participate in the ANDEEP (antarctic benthic DEEP-sea biodiversity: colonisation history and recent community patterns) III survey, which will collect infauna samples from the deep basin between southern Africa and the Scotia Sea, the eastern Weddell Sea, and the deep Weddell Sea Basin; collect box core or multicore sediment samples (all fauna will be removed from the sediment, sorted, and preserved on the ship);
- study the systematics of the seven families;
- collect larval and postlarval polychaetes from surficial multicore sample sediments to develop data on transient postlarval stages;
- collect larvae from the near-bottom environment and from near the surface to understand the mode of larval dispersal of antarctic and deep-sea polychaetes;
- synthesize the results to develop a benthic community analysis comparable to that being developed from samples taken during ANDEEP II;
- synthesize the results of individual research and contribute to a larger interdisciplinary effort with other members of the ANDEEP team; and
- use surface photographs and sediment profile images to provide detailed supporting documentation of the physical and biological properties of the sediments.

There are very few studies that address the origins of polychaetes in the Southern Ocean and even fewer for the families we will study. We will use modern cladistic methods to

address the phylogenetic relationships and biogeographic origins of these polychaetes, as well as their systematics. Data on reproduction, development, and distribution will contribute to a benthic community database that will also permit comparisons with deep-sea fauna in other parts of the world. (B–292–E; NSF/OPP 00–86665)

^ top

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 chemical 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 will study 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 (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.

During the first season, we will study the changes as the lake evolves from ice-covered to ice-free conditions. We will also fractionate samples into chemically unique classes, as well as monitor the composition and reactivity of the material. Finally, we plan to study the microbial community and monitor changes in abundance, diversity, and productivity that may occur during the transition from ice to open water and generate extracellular enzyme profiles, since enzymatic hydrolysis is believed to be the rate-limiting step in carbon remineralization.

In year 2, 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 the cycling of carbon 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)

^ top

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 salp population dynamics. Both experimental and modeling results will be interpreted within the context of the physical and nutritional conditions to which the 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 in an IMAX movie about research in Antarctica. (B–307–L; NSF/OPP 03–38290)

^ top

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

Bess B. Ward, Princeton University; Mark L. Wells, University of Maine; and Charles G. Trick, University of Western Ontario, Canada.

Denitrification refers to the loss of fixed nitrogen from ecosystems, and thus its rate and regulation may directly affect primary short- and long-term production and carbon cycling. Our previous investigation of the role of bioactive metals in regulating denitrification in cultured bacteria and permanently ice-covered Lake Bonney in the Taylor Valley of East Antarctica produced three important findings:

- Growth experiments demonstrated that cultured denitrifying bacteria could be limited by copper or iron and that nitrogen oxides accumulated in the medium due to limitation at the nitrite and nitrous oxide reduction steps, respectively.

- Manipulations of metal availability using chelators, additions of substrates, and cultured bacteria all failed to elicit a response from the natural microbial communities in the lake. No denitrification or thymidine incorporation was detected in the subchemocline waters of the east lobe of Lake Bonney, while analogous experiments detected an active denitrifying community in the west lobe.

- Silver and iron were the only metals that showed dramatic distribution differences between the two lobes. Silver concentrations were up to 150-fold higher and iron concentrations were 200 times lower in the east lobe than in the west. Low iron concentrations may exacerbate the potential toxicity of other metals, so general metal toxicity could possibly inhibit denitrification. Since silver can specifically inhibit denitrification, high silver concentrations might prevent the functioning of nitrous oxide reductase in the same way that copper limitation does by causing a buildup of nitrous oxide and a nonfunctional nitrogen cycle.

Other factors are likely also at work. We will determine whether oxygen concentrations are low enough to trigger denitrification in the east lobe. We will also investigate silver toxicity, general metal toxicity, and oxygen concentration by using a suite of sentinel strains of denitrifying bacteria isolated from the lake, incubated in lake water, and subjected to various treatments to quantify their responses.

The relationships between metals and denitrification that we discover here are expected to shed light not only on Lake Bonney's unusual nitrogen cycle, but also, more generally, on the potential role of metals in regulating microbial nitrogen transformations. (B–310–M; NSF/OPP 02–30276 and NSF/OPP 02–30151)

^ top

Prevention of environment-induced decrements in mood and cognitive performance.

Lawrence A. Palinkas, University of California–San Diego.

Cognitive performance degrades with residence in Antarctica, and mood alteration fits a seasonal pattern during extended residence. Although these changes suggest psychological responses to physiological adaptations to cold and dim light, the exact mechanisms are poorly understood.

Our first objective is to determine whether long-term exposure to cold temperatures and/or to dim light is associated with significant changes in cognitive performance and emotional well-being:

- Is physiological adaptation to cold or adaptation to dim light independently or synergistically associated with decrements in cognitive performance and emotional well-being?

- Do personnel at South Pole Station experience greater physiological adaptation and decrements than personnel at McMurdo Station do?

We also wish to determine whether these decrements can be prevented or minimized by pharmacologic interventions and/or phototherapy:

- What are the effects of combining liothyronine sodium with levothyroxine sodium versus supplementation with tyrosine (a precursor to both thyroid hormone and catecholamines) and daily phototherapy?

- Is phototherapy used in combination with a pharmacologic agent more effective than either intervention used alone?

In phase I, we established computer-testing protocols, developed an effective placebo capsule, packaged the necessary drugs, and tested the validity and reliability of computer-administered cognition and mood protocols with 30 hypothyroid outpatients on constant thyroid hormone replacement and 30 healthy, age- and sex-matched controls in New Zealand.

In phase II, 50 members of the 2002 winter crews, 35 at McMurdo Station and 15 at South Pole Station, were randomized in a double-blind crossover design into 1 of 2 treatment groups (20 subjects in each group) and 1 control group (10 subjects). Baseline measurements were conducted, and treatment groups were switched after a 1-month washout period. Mood and memory testing comprised 5 assessments over 12 months. Treatments consisted of 50 micrograms (mcg) of levothyroxine sodium plus 12.5 mcg of liothyronine per day, 150 milligrams per kilogram of tyrosine per day, and a placebo.

In phase III, a similar design will be used to evaluate the effectiveness of phototherapy, alone and in combination with the more effective of the two pharmacologic interventions.

Our research will lead to an improved understanding of the specific environmental conditions and physiological mechanisms that affect behavior and performance in the Antarctic, help develop countermeasures for circannual oscillations of mood and cognitive performance, and contribute to a reduction in accidental injuries at high latitudes. (B–321–M/S; NSF/OPP 00–90343)

^ top

SPISE3 (Science Package for the Exploration of Extreme Environments 3): A noncontact instrument suite for rapid detection of chemical biosignatures.

Pamela G. Conrad, National Aeronautics and Space Administration.

Endolithic microbial communities inhabit harsh environments that may represent the closest analog to the Martian environment. As part of a study of the chemical signatures of endolithic microbes in hot and cold deserts, we will go to the McMurdo Dry Valleys with a unique set of portable nondestructive instruments that do not touch the rocks that host the organisms in order to detect subtle chemical biosignatures associated with life. The instrument suite, called SPISE3 (Science Package for the Exploration of Extreme Environments 3), is composed of a spectroradiometer, portable gas chromatograph, and an ultraviolet visible light wavelengths fluorescence spectrometer and imager. Our goal is to develop tools and strategies in preparation for life-detection missions to Mars and other planets. Our tasks are as follows:

- We will determine whether we can reliably and reproducibly detect chemical biosignatures that can be differentiated from chemical signatures associated with minerals.
- We will verify that biosignatures are observable over various spatial scales that in part define how far away one can be from a sample or how much sample is needed for chemical biosignatures to be observable.
- We will see whether the chemical fluxes associated with metabolism are distinct from abiological, geochemical ones.

Microbial endolithic communities living in cold deserts exhibit different chemical signatures than those adapted to life in hot deserts, and we will see whether these differences will be observable in terms of spatial and temporal scales and chemical concentrations.

Although the chemistry of the sandstone hosting endolithic communities in the antarctic Dry Valleys is relatively simple (mostly silicon and oxygen), there are a variety of endolithic communities in the Mojave Desert that inhabit more mineralogically and chemically complex rocks and sediment. What does the addition of more complex chemistry do to our instruments´ ability to differentiate between geological and biological contributions to the chemical environment?

Over a 10- to 14-day period during the austral summer, therefore, we will take measurements four times a day from the rocks at Battleship Promontory in the Dry Valleys. We will compare those measurements with the data we gathered from the endolithic communities in hot deserts, analyzing the data both in Antarctica and in our home laboratories. (B–330–M; NSF/NASA agreement, NASA award NASA ASTEP–02–0040–0014)

^ top

Temporal variability in natural and anthropogenic disturbance of McMurdo Station, Antarctica.

Mahlon C. Kennicutt, Texas A&M University.

Antarctica represents one of the most carefully tended and strictly monitored habitats on Earth. Not only is it important to protect the flora, fauna, and atmosphere of a relatively pristine environment, but the extreme southern latitudes provide a virtual baseline barometer of global pollution. The Antarctic Treaty's Protocol on Environmental Protection, supplemented by the policies and practices of the nations that work there, have combined to focus scrutiny on any anthropogenic impacts that can be foreseen or detected.

We will therefore collect a series of observations that should enable scientists to be more aware of any such impacts on both marine and terrestrial habitats in and around McMurdo Station, locating them precisely and tracking them over time. An environmental monitoring program based on a 3-year pilot program of sampling and data analysis is continuing to collect samples. We will further evaluate the feasibility of this design and establish point-data sampling grids at various spatial scales measuring a series of attributes indicative of change.

Our objectives are to determine:

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

We will organize these diverse data sets into a coherent, coordinated framework. The results should provide additional fundamental scientific information for developing a long-term strategy to document and minimize the impact of future science (and support operations) on antarctic resources and values. (B–518–M; NSF/OPP 03–54573)

^ top

Print this page

Top

Website Policies and Links | Privacy | FOIA | Help | Contact NSF | Contact Web Master | SiteMap

The National Science Foundation, 4201 Wilson Boulevard, Arlington, Virginia 22230, USA
Tel: (703) 292-5111, FIRS: (800) 877-8339 | TDD: (800) 281-8749

Last Updated:
Jan 27, 2005
Text Only