BIOLOGY AND MEDICINE

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.)

Brett Pickering, a member of Dr. Bill Fraser's research team, counts Adélie penguins on Torgersen Island, near Palmer Station. Dr. Fraser, from the Polar Oceans Research Group, has been traveling to Palmer Station since 1975. His research is examining the impact of tourism on Adélie penguins.

NSF photo by Laura Hamilton

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

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

- **Marine ecosystem dynamics:** Among the research topics are understanding the natural variability of marine ecosystems, correlating the structure and function of the marginal ice-zone ecosystem with oceanic and atmospheric processes, exploring the sources of nutrition and their influence on prey and on primary production, and examining the role of marine phytoplankton in carbon-dioxide cycling.

- **Terrestrial and limnetic ecosystems:** Organisms in ice-free areas and in perennially ice-covered lakes show remarkable adaptations to extreme environments. The fact that relatively few species thrive here facilitates the study of ecosystem dynamics and the interpretation of experiments, although much more remains to be learned about adaptive mechanisms and evolutionary processes.

- **Population biology and physiological ecology:** At the next level, looking at relationships among organisms, studies have focused on the variability and dynamics of populations of krill and other zooplankton. Ecological relationships among and between fish species, marine mammals, and birds have also been the object of much research, with many issues still to be further explored. Advances in genetic testing now permit scientists to establish relationships that were previously unverifiable between individuals and species in the wild. As organized programs of antarctic science enter their fifth decade (some have been in existence even longer), data sets and ongoing observations are elucidating manmade as well as natural changes.

- **Adaptation:** 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.

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

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

Areas of the Southern Ocean have spectacular blooms of phytoplankton during the austral spring and early summer. One of the dominant species, the haptophyte *Phaeocystis antarctica,* is a prolific producer of the organic sulfur compound dimethylsulfoniopropionate (DMSP), and *Phaeocystis* blooms are associated with some of the world's highest concentrations of DMSP and its volatile degradation product, dimethylsulfide (DMS). Sulfur, in the form of DMS, is transferred from the oceans to the atmosphere 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 in teaching undergraduate and graduate courses and will enrich students' experience. (B–002–N and B–266N; NSF/OPP 02–30497 and NSP/OPP 02–30499)

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

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

The striking increases in air temperatures and ultraviolet-B radiation (UV-B) 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 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.

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)

Antifreeze proteins in antarctic fishes: Integrated studies of freezing environments and organismal freezing avoidance, protein structure-function and mechanism, genes, and evolution.

Arthur 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 AFP 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)

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

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

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 35 years, a total of 15,636 animals have been tagged, with 144,927 resighting records logged in the database. This study is a valuable resource for understanding population dynamics not

only of Weddell seals, but also of other species of both terrestrial and marine mammals. We intend to proceed with 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 the 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 will involve an intensive study of mass dynamics of both pups and adult females to assess annual variation in marine resources and their 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. (Regional 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 knowledge of pinniped population dynamics, as well as 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 impacts of human activities such as global warming and the commercial exploitation of antarctic marine resources. (B–009–M; NSF/OPP 02–25110)

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

Stacy 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.

In October and November 2002, we collected data to describe the habitat and community while the outfall was still in operation. This will be added to the data we collected from 1988 to 1998 to provide a baseline. We initiated experiments with organic content, burial, and disturbance size as variables. During the next two seasons, we will track the recovery of the benthic community, compare the rates 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. (B–010–M; NSF/OPP 01–26319)

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

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

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 since 1993. 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. The transient nature of these ponds 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 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)

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

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

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

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

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

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

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

Remotely operable microenvironmental observatory for antarctic marine biology research.

Samuel 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 mm) 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, transmitting 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)

Yeasts in the antarctic dry valleys: Biological role, distribution, and evolution.

Laurie B. Connell, University of Maine.

The soil community of the antarctic polar desert comprises few endemic species of bacteria, fungi, and invertebrates. Both filamentous and single-cell fungi have been isolated from a diversity of antarctic soil types, but only yeasts appear to be endemic to the polar desert soils. Although their ecological role in antarctic soils is undefined, yeasts may be the principal taxa synthesizing the sterols required by soil invertebrates. In addition, yeasts may be involved in accumulating and mobilizing growth-limiting nutrients such as phosphorus into the polar desert food web. Although yeasts have been well described in agricultural and industrial systems, little is known about their ecological role.

This multidisciplinary, collaborative research will characterize the role soil yeasts have in the McMurdo Dry Valley ecosystem in order to better understand polar deserts and other extreme environments, as well as provide a foundation for incorporating yeasts into biogeochemical models of temperate environments. Soil microbiota mediate most processes such as decomposition, soil respiration, uptake and fixation of micro- and macronutrients, and detoxification of heavy metals and serve as major global carbon sinks. The complexity of soil communities in temperate regions poses difficulties in studying the relationships between biotic and abiotic parameters, and the factors controlling populations of soil microbiota remain poorly understood. The extreme climate and relatively simple community structure of the continental antarctic desert lend themselves to such studies.

We will first correlate the abundance and distribution of yeasts in polar desert soils with physical and chemical soil properties. Several physiological parameters will be explored in vitro to develop a basis for understanding the functional role these organisms might have. Sterols synthesized by McMurdo Dry Valley soil yeasts, as well as their ability to survive multiple freeze-thaw cycles, will be characterized. The capacity of indigenous antarctic yeasts to use, compete for, and store phosphorus will be ascertained. The evolution of Dry Valley yeasts will be addressed by determining intra- and intervalley relatedness patterns based on DNA sequence.

Both soil samples and extracted DNA will be shared with other interested laboratories. Moreover, students from middle school (Biolab Inc.) through college (University of Maine) will be given the opportunity to collaborate on this project, as well as to develop their own projects. (B–019–M; NSF/OPP 01–25611)

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

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

Many organisms are not mobile and so cannot escape from predators. One way they can keep from being eaten is to make themselves unappetizing by producing defensive chemicals known as secondary metabolites. However, the energy and other resources that go into making these compounds could instead have gone into growth or reproduction. We are studying the evolution of these tradeoffs and hope to understand ways that organisms maximize the usefulness of their investments in defensive chemistry.

For marine plants, the physical environment of Antarctica is very different from most other places in the world's oceans because nutrients are plentiful but light is often limited. So the currency that is used to pay for defense, growth, and reproduction is different than it is for plants in most other marine communities. This allows us to test theories about the costs and benefits of defense in ways not possible elsewhere in the world.

For marine animals, Antarctica is unique in that predation by sea stars is much more important than in other marine communities. Sea stars feed by extending their stomachs through their mouths and digesting prey outside their bodies. We predict that this should lead to a much higher investment in defensive metabolites in the outer layers of the prey. We intend to test the hypothesis that sponges (an important component of these communities) will maximize their investment in chemical defense by having the highest levels of defensive secondary metabolites in their outermost layers.

This research should also advance our general understanding of the evolution of chemical defenses. We hope to elucidate the nature and role of bioactive agents in the specific ecology of the antarctic marine

benthos (that is, organisms living at the bottom of marine environments). (B–022-L/P; NSF/OPP 01–25181 and NSF/OPP 01–25152)

Dynamics of predator-prey behavior in the Southern Ocean.

Richard Veit, City University of New York–College of Staten Island.

We plan to bring two groups of undergraduate students to the Antarctic, where they will learn a broad range of skills in physical and biological oceanography by participating in collecting data on seabird abundance and behavior. We will combine research on the dynamics of seabirds that feed on antarctic krill with the teaching of mathematical modeling of foraging behavior and spatial statistics. Our goal is to learn how foraging antarctic seabirds respond to changes in the abundance and distribution of their prey, primarily antarctic krill.

Our approach will be to study bird behavior near krill swarms and to contrast this behavior with that observed in areas lacking krill. From these comparisons, we will build foraging models that will make predictions about the dispersion of birds under differing levels of krill abundance. Our long-term goal is to be able to make predictions about the impact of future changes in krill stocks on seabirds. We will conduct our work in the vicinity of Elephant Island over two seasons. Each season, we will survey the insular shelf north of Elephant Island and record the abundance, distribution, and behavior of seabirds.

We will attempt to quantify the linkage between prey abundance and bird behavior in order to use this behavioral information to index long-term changes in the prey base. Our teaching goal is twofold: first, we will introduce inner-city college students to a spectacular and economically important ecosystem. Through their work on an oceanographic research vessel, students will be exposed to a broad range of research topics and methods, from behavioral ecology to physical oceanography. Second, once back at home, students will participate in the development of a mathematical biology initiative at the College of Staten Island. Here, they will be encouraged to apply basic mathematical reasoning and computer modeling to a real problem—determining how foraging choices made by seabirds can ultimately impact their reproductive success. (B–023–L; NSF/OPP 99–83751)

Culture and health in Antarctica.

Timothy 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 face residents, 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)

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

Adam 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 –1.8ºC. We will quantify temperature effects on gene expression and protein turnover networks during early development by using a Bayesian network analysis to identify clusters of genes and proteins whose levels of expression are associated in fixed, synergistic interactions. Ultimately, the question to be addressed is whether it is more or less difficult (complex) for an embryo to develop in an extreme environment. To answer this question, we will decipher network topologies and subnet structuring to uncover gene connectivity patterns associated with embryonic development in this polar environment. We also intend to interest students in the developing field of environmental genomics by increasing the awareness of career opportunities within the field and increasing the racial diversity of those attracted to it.

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

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

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

David G. Ainley, H.T. Harvey and Associates; Nadav Nur and Grant Ballard, Point Reyes Bird Observatory; and Katie Dugger, Southern Illinois University–Carbondale.

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 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.

None of the colonies 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, large colonies affect the foraging patterns of smaller ones 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. Yet to be determined is the demographic mechanism of colony growth (or decline). Reproductive success does not appear to be important, however.

We will use seven 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 been often noted. Understanding the demographic mechanisms behind this sensitivity will contribute greatly to knowledge of the effects of climate change on antarctic marine organisms. (B–031–M; NSF/OPP 01–25608)

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

Steven 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: more 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 these sites 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)

The development of olfactory foraging strategies in antarctic procellariiform seabirds.

Gabrielle Nevitt, University of California–Davis.

Procellariiform seabirds (petrels, albatrosses, and shearwaters) are distinguished by their acute sense of smell. These birds have pelagic lifestyles and forage over thousands of miles of ocean to find patchily distributed resources. We will study the development of olfactory sensitivity in burrow-nesting procellariiform seabirds within the Kerguelen Archipelago and will explore the hypothesis that during development, chicks become tuned to odors associated with feeding in a manner analogous to olfactory imprinting.

We have three primary objectives:

- First, we will use videotape documentation to characterize the behavioral responses of chicks to two prey-related odors (dimethylsulfide and cod-liver oil), one novel odor (phenyl ethyl alcohol or rose scent), and burrow-related odors (burrow and colony dirt).

- Second, we will determine whether chicks can learn odor cues by exposing them to a non-prey-related odor during the egg stage and then testing for increased sensitivity to that odor after they hatch.

- Third, we will quantify key behavioral responses induced when a chick is exposed to an odor plume within a portable wind flume.

Only a handful of studies have addressed the olfactory abilities of procellariiform seabirds or indeed any bird. Results from our research will be among the first to address the development of olfaction in an ecologically important context. Overall, these results will greatly extend our knowledge of the foraging ecology of these fascinating birds. Such knowledge is not only useful to basic science, but it may also help bolster efforts to ensure the conservation of procellariiforms, given the threatened or endangered status of many species.

Our work will include research experience for a graduate student and an active international collaboration with the French Institute for Polar Research and Technology. Furthermore, our results may be transferable to other potentially important organisms, such as salmon and insects, where understanding the developmental stages of olfaction has commercial importance. (B–035–E; NSF/OPP 02–29775)

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 specific wood-destroying fungus. Various molds and cellulose-degrading fungi are attacking artifacts made of leather, textiles, and other organic materials.

- Exterior wood is being degraded by nonbiological processes as well, including salt, ultraviolet radiation, and wind erosion.

- Chemical damage within the huts is apparent, and the soils on the site are contaminated with aromatic hydrocarbons from petroleum products.

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

International collaborative expedition to collect and study fish indigenous to subantarctic habitats.

H. William Detrich, Northeastern University.

Notothenioids are a major group of fish in the Southern Ocean. The ancestral notothenioid fish stock of Antarctica probably arose as a sluggish, bottom-dwelling perciform species that evolved some 40 to 60 million years ago in the then temperate shelf waters of the antarctic continent. The grounding of the ice sheet on the continental shelf and changing trophic conditions may have eliminated taxonomically diverse late Eocene fauna and initiated the original diversification of notothenioids. On the high antarctic shelf today, notothenioids dominate the ichthyofauna in terms of species diversity, abundance, and biomass, the latter two at levels of 90 percent to 95 percent. Since the International Geophysical Year of 1957–1958, fish biologists from the Antarctic Treaty nations have made impressive progress in understanding the notothenioid ichthyofauna of the cold antarctic marine ecosystem. However, integration of this work into the broader marine context has been limited, largely because of lack of access to, and analysis of, specimens of subantarctic notothenioid fish.

The fish of this suborder are critical for a complete understanding of the evolution, population dynamics, ecophysiology, and ecobiochemistry of their antarctic relatives. Our project will support an international, collaborative research cruise to collect and study fish indigenous to subantarctic habitats. Research topics include systematics and evolutionary studies; life history strategies and population dynamics; physiological, biochemical, and molecular biological investigations of major organ and tissue systems; genomic resources for the subantarctic notothenioids; and ecological studies of transitional benthic invertebrates.

In a world that is experiencing changes in global climate, the loss of biological diversity, and the depletion of marine fisheries, the antarctic and subantarctic regions and their biota offer compelling natural laboratories for understanding the evolutionary impact of these processes. Our work will contribute to developing a baseline understanding of these sensitive ecosystems, one against which future changes in species distribution and survival can be evaluated judiciously. (B–039–N; NSF/OPP 01–32032)

Foraging behavior and demography of *Pygoscelis* penguins.

Wayne 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 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 to 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)

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

Walker 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 distributions and reproductive success of birds and marine mammals.

Even though it is so central to the food web, surprisingly little is known about how phytoplankton production 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)

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 with similar data sets being compiled by the research programs of other Antarctic Treaty nations. While separating human-induced change from change resulting from a combination of environmental factors will be difficult, this work will provide a first step toward identifying potential impacts. The long-term data sets we compile will contribute to a better understanding of biological processes in the entire region and will also contribute valuable information to be used by Antarctic Treaty nations as they address environmental stewardship issues in Antarctica. (B–086–E; NSF/OPP 02–30069)

Microbial diversity and function in the permanently ice-covered lakes of the McMurdo Dry Valleys, Antarctica.1

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

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

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

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

Diving physiology and behavior of emperor penguins.

Paul 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)

Monitoring the human impact and environmental variability on 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 scales 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)

Interactive effects of ultraviolet radiation and vertical mixing on phytoplankton and bacterioplankton in the Ross Sea.

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

Ultraviolet (UV) radiation influences plankton in the near-surface waters of most ecosystems. In particular, the Southern Ocean is affected in the austral spring, when UV radiation is enhanced by ozone depletion. While progress has been made in estimating the impact of UV radiation on bacteria and phytoplankton in the Southern Ocean, important issues remain to be resolved. Little is known, for example, about responses 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 in the spring, well within the ozone hole, and 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 use 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, B–203–N, and B–208–N; NSF/OPP 01–27022, NSF/OPP 01–27037, and NSF/OPP 01–25818)

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

Joaquim 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. (B–206–N; NSF/OPP 01–26150)

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

Rebecca Gast and Mark Dennett, Woods Hole Oceanographic Institution, and David 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 biological oceanography and to understanding 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 in order 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)

Plankton community structure and iron distribution in the southern Drake Passage.
B. Greg Mitchell, University of California–San Diego; Christopher Measures, University of Hawaii–Manoa; Meng Zhou, University of Massachusetts; and Osmund Holm-Hansen, Farooq Azam, Sarah T. Gille, and Katherine Barbeau, Scripps Institution of Oceanography, University of California–San Diego.

The Shackleton Fracture Zone (SFZ) in the Drake Passage marks a boundary between low- and high-phytoplankton waters. West of the passage, waters have very low concentrations of surface chlorophyll, and east of the SFZ, mesoscale eddy kinetic energy and chlorophyll are higher than they are west of it. Data from a 10-year survey confirm the existence of a strong hydrographic and chlorophyll gradient in the region. We hypothesize that bathymetry, including the 2,000-meter-deep SFZ, influences mesoscale circulation and transport of iron, leading to the differences in phytoplankton patterns.

To test this hypothesis, we will examine phytoplankton and bacterial physiological states (including responses to iron enrichment) and the structure of plankton communities from virus to zooplankton; the concentration and distribution of iron, manganese, and aluminum; and mesoscale flow patterns near the SFZ. We will examine relationships between iron concentrations and phytoplankton in the context of the mesoscale transport of trace nutrients to determine how much of the variability in biomass can be attributed to iron supply, as well as the most important sources of iron east of the Drake Passage. Our goal is to better understand how plankton productivity and community structure in the Southern Ocean are affected by bathymetry, mesoscale circulation, and nutrient distributions.

We will perform rapid surface surveys of chemical, plankton, and hydrographic properties, complemented by a mesoscale station grid for vertical profiles, water sampling, and bottle incubation enrichment experiments. Manganese and aluminum distributions will help distinguish aeolian, continental shelf, and upwelling sources of iron. We will monitor the physiological state of the phytoplankton by active fluorescence methods sensitive to iron limitation. Concentrations of pigment, carbon, and nitrogen will be obtained by analysis of filtered samples, cell size distributions by flow cytometry, and species identification by microscopy. We will measure primary production and photosynthesis parameters (absorption, quantum yields, variable fluorescence) with depth profiles, surface surveys, and bulk samples from enrichment experiments. We will also determine the abundance of viruses and bacteria and ascertain whether bacterial production is limited by iron or organic carbon sources.

We aim to improve scientific understanding of processes controlling iron distribution and the response of plankton communities in the Southern Ocean. Moreover, we will have an undergraduate and teacher outreach component and plan to create a Web site and K–12 curricular modules. (B–228–L and B–248–L; NSF/OPP 02–30443, NSF/OPP 02–30445, and NSF/OPP 02–29966)

Southern Ocean Global Ocean Ecosystems Dynamics (GLOBEC): Mysticete whale acoustic census in the GLOBEC west antarctic project area.
John Hildebrand, Mark McDonald, and Sue Moore, Scripps Institution of Oceanography, University of California–San Diego.

The U.S. Southern Ocean Global Ocean Ecosystems Dynamics (GLOBEC) program focused on the distribution of antarctic krill (Euphausia superba) in the Marguerite Bay/West Antarctic Peninsula region, as well as on environmental and ecosystem factors that are important for krill distribution. Our primary goal was to study the distribution and abundance of mysticete whales by using both visual and acoustic techniques. These data allowed us to model the rates of krill predation by whales in the study area.

In continuing our research, we hope to better understand the relationship between the physical and biological factors that affect the behavior of whales and their krill predation. To estimate the population of mysticete whales, we used passive acoustic recording of vocalizing marine mammals and assessed their abundance and distribution by a combination of bottom-mounted acoustic recorders and sonobuoys. During the 2001–2002 austral summer, eight bottom-mounted acoustic recorders were recovered and redeployed at sites in the west Antarctic Peninsula. This austral summer, we intend to recover these acoustic recorders and begin analyzing our findings. (B–239–L; NSF/OPP 99–10007)

Soil biodiversity and response to climate change: A regional comparison of Cape Hallett and Taylor Valley, Antarctica.
W. Berry Lyons, Ohio State University; Diana Wall, Colorado State University; Ross A. Virginia and John Barrett, Dartmouth College; and S. Craig 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 a 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)

Iron and light effects on Phaeocystis antarctica isolates from the Ross Sea.

Giacomo DiTullio, University of Charleston, and Peter Sedwick, Bermuda Biological Station Research.

The colonial prymnesiophyte *Phaeocystis antarctica* is a major bloom-forming alga in antarctic shelf waters, where, together with diatoms, it is considered a key species in regional biogeochemical cycling and ecosystem structure. Iron levels in these waters fall sharply during the mid- to late summer to concentrations that are likely to limit the growth of phytoplankton, including *P. antarctica.* However, in contrast to diatoms, very little work has been done to examine the effects of iron, or the combined effects of iron and irradiance, on the growth, physiology, and biochemical composition of *P. antarctica.* We will collect samples of *P. antarctica* from the southern Ross Sea and samples grown in semicontinuous batch cultures to investigate the effects of iron availability and irradiance on growth rate, cellular iron quota, buoyancy, biogenic sulfur production, pigment content, redox-protein expression, and photosynthetic efficiency.

Over time scales ranging from seasonal to interannual, *P. antarctica* is known to have a significant effect on regional biogeochemical cycles of carbon, nutrient elements, and sulfur in the Ross Sea. This species may also have played a central role in the inferred basin-scale changes in biogeochemical cycles linked to glacial-interglacial climatic change. Thus, it is important to develop a mechanistic understanding of the factors that control the growth, physiology, and biochemical composition of *P. antarctica* in order to better understand the biogeochemical ecology of the Ross Sea and the wider Southern Ocean and possible linkages with regional and global climate. The data we gather from these laboratory experiments, together with the results of recent and ongoing field and modeling studies, will substantially improve our ability to predict how the antarctic region will be affected by and modulate future climate change. (B–272–M; NSF/OPP 02–30513 and NSF/OPP 02–30559)

Dynamic similarity or size proportionality? Adaptations of a polar copepod.

Jeannette Yen, Marc Weissberg, and Donald Webster, Georgia Institute of Technology.

We will explore the feasibility of using fluid physical analyses to evaluate the importance of viscous forces over compensatory temperature adaptations in a polar copepod. The water of the Southern Ocean is 20ºC colder and nearly twice as viscous as subtropical seas, and the increased viscosity has significant implications for swimming zooplankton. In each of these warm and cold aquatic environments have evolved abundant carnivorous copepods in the family Euchaetidae.

In this exploratory study, we will compare two species from the extremes of the natural temperature range (0º and 23ºC) to test two alternate hypotheses on how plankton adapt to the low temperature–high viscosity realm of the Antarctic and to evaluate the importance of viscous forces in the evolution of plankton. How do stronger viscous forces and lower temperature affect the behavior of the antarctic species? If the antarctic congener is dynamically similar to its tropical relative, it will operate at the same Reynolds number (Re). Alternatively, if the adaptations of the antarctic congener are proportional to size, they should occupy a higher Re regime, which suggests that the allometry of various processes is not constrained by having to occupy a transitional fluid regime.

We designed our experiments with clearly defined outcomes on a number of copepod characteristics, such as swimming speed, propulsive force, and size of the sensory field. These characteristics determine not only how copepods relate to the physical world, but also how their biological interactions are structured. The

results we derive will provide insights into major evolutionary forces affecting plankton and provide a means of evaluating the importance of fluid physical conditions relative to compensatory measures for temperature.

Fluid physical, biomechanical, and neurophysiological techniques have not been previously applied to these polar plankton. However, if productive and feasible, these approaches will provide ways to explore the sensory ecology of polar plankton and the role of small-scale biological-physical-chemical interactions in a polar environment. Experimental evidence validating the importance of viscous effects will also justify further research using latitudinal comparisons of other congeners along a temperature gradient in the world's oceans. (B–285–L; NSF/OPP 03–24539)

Victoria Land latitudinal gradient project: Benthic marine habitat characterization.

Rikk Kvitek, California State University–Monterey Bay.

Our work is part of a multinational, multidisciplinary program called the Victoria Land Latitudinal Gradient Project (VLLGP), which includes scientists from both the Italian Antarctic Research Program (PNRA) and the Antarctica New Zealand Research Program. The overall goal of the VLLGP is to take a latitudinal gradient approach to ecosystem studies in Victoria Land.

Personnel from the Seafloor Mapping Lab (SFML) at California State University–Monterey Bay will participate in a 20-day PNRA cruise on the research ship *Italica* during January 2004. The specific goals of this Italian/U.S. collaboration are to

- identify the environmental gradients linked to latitude and to relate community transitions along the Victoria Land coast to climatic, geomorphologic, and oceanographic features;
- identify biochemical, physiological, and other adaptive responses of representative organisms;
- quantify biodiversity patterns and test the hypothesis of progressive emergence of marine assemblages with latitude; and
- use biotic changes associated with steep environmental gradients to predict possible effects of climate change.

We will use high-resolution acoustic remote-sensing (multibeam and sidescan sonar) and spatial data-modeling tools to identify and characterize benthic habitats and species/habitat associations along the gradient from a depth of 0 to 200 meters. Accurate mapping and classification of habitat types within each study area will be critical to selecting comparable sampling sites so valid community comparisons can be made along the latitudinal gradient. Since the Ross Sea coast extends across one of the longest latitudinal gradients in the Antarctic (15 degrees), this study offers a unique opportunity for predicting and establishing a baseline to detect environmental and community responses to global change and anthropogenic disturbance.

This work will not only foster research, logistical, and data management collaboration among scientists from different disciplines and national programs, but it will also provide undergraduate students with the opportunity to participate in the research. (B–320–E; NSF/OPP 02–29991)

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 and/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 will comprise 5 assessments over 12 months. Treatments consist 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)

Complex pelagic interactions in the Southern Ocean: Deciphering the antarctic paradox.

Thomas Frazer, University of Florida.

Our primary goal is to quantify, examine, model, and validate the complex interactions involving the direct, indirect, and feedback effects that regulate the planktonic food web in the coastal waters of the Southern Ocean in order to find the causes of low phytoplankton biomass and production there despite the plentiful availability of nutrients. In particular, we will evaluate the feedback mechanisms induced through the role of ammonium, which is largely released by aggregations of herbivorous zooplankton (krill specifically) present in the Southern Ocean, on the resistance to ultraviolet stress by the phytoplanktonic community and, in particular, the effects on nitrogen incorporation rates, both ammonium and nitrate, and the subsequent development of phytoplankton blooms.

We will not only address the problem experimentally, but will also consider the context of the heterogeneous landscape, dominated by small parcels of water, where these complex interactions occur. This project will be conducted through a shore-based (at the Spanish station Juan Carlos I) operation in 2004 and a subsequent cruise (on the R/V *Hesperides*) in 2005. (NSF/OPP 03–36469)

Food web structure across a large-scale ocean productivity gradient: Top predator assemblages in the southern Indian Ocean

George Hunt, University of California–Irvine.

A pervasive goal of biological oceanography is to understand the processes that structure pelagic communities. Research suggests that the distribution of oceanic species is influenced by physical and biological variability on a number of spatial-temporal scales. Our objective is to test the hypothesis that the dispersion and community of top predators vary in accordance with large-scale variability in physical structure and ocean productivity in pelagic ecosystems. We will therefore conduct a survey of bird and mammal use of distinct oceanographic domains in the southern Indian Ocean.

Two U.S. scientists will join French scientists on board a French research vessel near Reunion Island. The French scientists will sample the physical environment and estimate oceanic productivity, while the U.S. scientists will survey top predator distributions in physical and biological properties across a 35-degree latitudinal gradient from subtropical to subantarctic waters.

We hypothesize that top predator assemblages are structured by spatial gradients in hydrographic properties and ocean productivity patterns known to influence the distribution and patchiness of their prey (zooplankton, fish, and squid) and that the overall abundance of marine top predators within a specific oceanic domain is largely determined by ocean productivity. Also, we hypothesize that the energetic costs of foraging determine which types of top predators inhabit specific domains. Species with high foraging costs must exploit dense prey aggregations within highly productive areas. Conversely, taxa with low foraging costs can inhabit low-productivity areas with more dispersed prey.

We will quantify the association of specific water masses with top predator assemblages, as well as their aggregative response at hydrographic and bathymetric domains. Because top predators respond to oceanographic variability at multiple scales of time and space, we will use a variety of analytical methods to assess their responses in the context of large- and coarse-scale (thousands and tens of kilometers, respectively) hydrographic and ocean productivity patterns in the subtropical and subantarctic Indian Ocean. This interdisciplinary perspective will enhance our understanding of the way physical and biological

processes structure pelagic communities in the southern Indian Ocean and will provide a model that has broader implications for the oceans as a whole. (NSF/OPP 02–34570)