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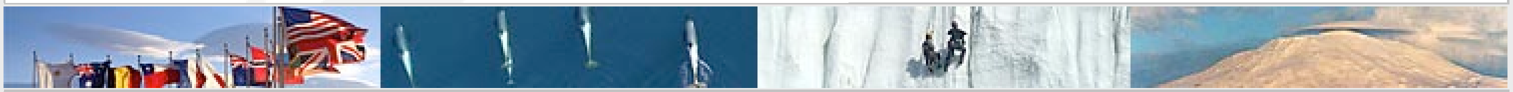

LONG-TERM ECOLOGICAL RESEARCH

Scientist Byron Adams takes a soil sample from Lake Hoare as Adler Dillman and Ed Ayres watch. The three are part of the Long Term Ecological Research project in the Dry Valleys, comprised of seven separate science field groups cooperating in their research to understand the area's unique ecosystem. (*NSF photo by Emily Stone*)

In this section:

Overview

Ecology has taken its place among science's vital, strategic disciplines, thanks to an ever-greater awareness of how the web of life and the Earth's other dynamic processes constitute a closed and coherent system. As part of this evolution, the National Science Foundation's Long-Term Ecological Research (LTER) Program, begun in 1980, has grown into a network of 26 research sites, established to acquire long-term data sets from Alaska to Puerto Rico to Antarctica. Such a geographical spread is necessary to collect information on a variety of ecosystem types, such as grassland, desert, forest, tundra, lake, stream, river, and agricultural and coastal systems.

To enhance understanding of ecological phenomena, the program focuses on the role of cyclical/episodic events (ranging from years to decades to centuries) in the structure and function of these distinctive ecosystems. The Antarctic Biology and Medicine Program supports two of these LTER project sites to facilitate research on unique aspects of antarctic ecology: one near Palmer Station in the Antarctic Peninsula and the other in the McMurdo Dry Valleys.

The Palmer Station/Antarctic Peninsula LTER program studies a polar marine biome that focuses on the antarctic pelagic marine ecosystem, including marine sea ice habitats, regional oceanography, and the terrestrial nesting site of seabird predators. It is ideally sited to probe a fundamental issue: As the pack ice varies (seasonally and year by year), what happens to the antarctic marine community? That is, how do ecological processes influence organisms at different trophic levels? The Palmer Station LTER Program was initiated during the 1991–1992 season with the installation of an automatic meteorological station, annual research cruises in the austral summer, and a focused research program at the station facility. During the austral fall and spring seasons, process-study research cruises develop data that can be compared with data collected from other coastal systems in the Antarctic Peninsula.

Due to its unique site, the McMurdo Dry Valleys LTER project is more wide ranging and focuses on the interdisciplinary study of aquatic and terrestrial ecosystems in a cold desert region of Antarctica. The area is one of the most fascinating and contrarian spots on Earth. In fact, it is almost unearthly. National Aeronautics and Space Administration scientists who wondered what conditions might be like on Mars came here, an island of rock in a sea of ice, the largest ice-free area in Antarctica, where winds howl, where what little water there is dessicates or evaporates, and where the only creatures that can survive are microorganisms, mosses, lichens, and relatively few groups of invertebrates. Higher forms of life are virtually nonexistent.

Thus, LTER projects based here take advantage of perhaps the coldest and driest ecosystem on Earth, where life approaches its environmental limits; as such, this may be seen as an "end-member" in the spectrum of environments included in the LTER network. Why is it necessary to conduct long-term ecological research in such a place? All ecosystems depend on liquid water and are shaped to varying degrees by climate and material transport, but nowhere is this more apparent than in the McMurdo Dry Valleys. In very few places on Earth do minor changes in solar radiation and temperature so dramatically affect the capabilities of organisms to grow and reproduce as in the Dry Valleys. Therefore, this site may well be an important natural, regional-scale laboratory for studying the biological effects of climate changes attributable to human activity. While the antarctic ice sheets respond to climate change on the order of thousands of years, the glaciers, streams, and ice-covered lakes in the McMurdo Dry Valleys often experience nearly immediate (and sometimes profound) change. As such, this area would be one of the first to show the effects of climate change in Antarctica.

The overall objectives of the McMurdo Dry Valleys LTER are to understand the influence of physical and biological constraints on the structure and function of Dry Valley ecosystems and to understand the modifying effects of material transport on these ecosystems. Though driven by the same basic processes found in all ecosystems (microbial use and remineralization of nutrients, for example), the Dry Valley ecosystems lack many of the confounding variables, such as diverse and fecund biota and many levels of plants and higher animals, inherent in other ecosystem research.

The role of resource legacy on contemporary linkages between biodiversity and ecosystem processes in a cold desert ecosystem: The McMurdo Dry Valley Long-Term Ecological Research Program.

W. Berry Lyons, Ohio State University.

The largest ice-free area in Antarctica is found in the McMurdo Dry Valleys, located on the western shore of McMurdo Sound. Among the most extreme deserts in the world, the McMurdo Dry Valleys are the coldest and driest of all the Long-Term Ecological Research (LTER) sites. Consequently, biological systems are limited to microbial populations, microinvertebrates, mosses, and lichens. Yet complex trophic interactions and biogeochemical nutrient cycles develop in the lakes, streams, and soils of the Dry Valleys. In the austral summer, solar energy produces glacial meltwater, providing vital water and nutrients that have a primary influence on the ecosystems. Such material transport and climatic influences shape all ecosystems, but nowhere is this more apparent than in the McMurdo Dry Valleys.

The McMurdo LTER project focuses on the aquatic and terrestrial ecosystems in the Dry Valley landscape as a context to studying biological processes and to exploring material transport and migration. During this phase of this LTER project, we are extending our research by continuing to investigate the McMurdo Dry Valleys as an end-member system, hoping to better ascertain the role of past climatic legacies in ecosystem structure and function. We will test a series of eight hypotheses in three major focus areas—hydrology, biological activity/diversity, and biogeochemical processes—by continuing our monitoring projects and long-term experiments.

Understanding the structure and function of the McMurdo Dry Valleys ecosystem requires deciphering the hydrological response to climate, both now and in the past. Current patterns of biological activity and diversity reflect past and present distributions of water, nutrients, organic carbon, and biota. Biogeochemical processes responsible for the transport, immobilization, and mineralization of nutrients and other chemicals provide the linkages between the region's biota and the physical environment. The timing, duration, and location of biogeochemical processes in the past and present are controlled by the availability of water. We continue to focus on the integration of the biological processes within and among the lakes, streams, and terrestrial ecosystems that comprise the McMurdo Dry Valley landscape. Our interdisciplinary research team will continue to use modeling and other integrative studies to synthesize data and to examine the McMurdo Dry Valleys ecosystem.

During the 2005–2006 field season, the following studies will be conducted in the McMurdo Dry Valleys as part of the LTER project:

Chemistry of streams, lakes, and glaciers. (B–420–M; NSF/OPP 04–23595)
W. Berry Lyons, Ohio State University.

Flow, sediment transport, and productivity of glacial melt streams. (B–421–M; NSF/OPP 04–23595)
Diane M. McKnight, University of Colorado–Boulder.

Lake pelagic and benthic productivity: Microbial food webs. (B–422–M; NSF/OPP 04–23595)
John C. Priscu, Montana State University–Bozeman.

The influence of environmental conditions on carbon and nitrogen cycling and on soil biota, the effects of environmental change and food supply availability on soil biota, and the effects of climate change on biota. (B–423–M and B–424–M; NSF/OPP 04–23595)
Ross A. Virginia, Dartmouth College, and Diana H. Wall, Colorado State University.

Glacier mass balance, melt, and energy balance: Climate monitoring in Taylor, Wright, Victoria, and Beacon Valleys. (B–425–M; NSF/OPP 04–23595)
Andrew G. Fountain, Portland State University.

Paleoclimatology, paleoecology, and meteorological data collection. (B–426–M; NSF/OPP 04–23595)
Peter T. Doran, University of Illinois–Chicago.

Palmer, Antarctica, Long-Term Ecological Research Project: Climate migration, ecological response, and teleconnections in an ice-dominated environment.

Hugh W. Ducklow, College of William and Mary, Virginia Institute of Marine Science.

The Palmer Long-Term Ecological Research Project (PAL LTER) seeks to understand the structure and function of the antarctic marine and terrestrial ecosystem in the context of physical forcing by seasonal to interannual variability in atmospheric and sea-ice dynamics, as well as long-term climate change. PAL LTER studies marine and terrestrial food webs consisting principally of diatom primary producers; the dominant herbivore the antarctic krill, *Euphausia superba;* the apex predator Adélie penguin, *Pygoscelis adeliae;* and an active microbial food web consisting of planktonic bacteria and *Archaea,* bacterivorous protozoa, and dissolved organic matter. A biogeochemical component studies organic and inorganic carbon fluxes and the sedimentation of particulate matter into the deep sea.

This project monitors western Antarctic Peninsula ecosystems regionally over a grid of oceanographic stations and locally at Palmer Station. The extent and variability of sea ice affect changes at all trophic levels. In recent years, sea ice has diminished in response to general climate warming. A long-term population decline of ice-dependent Adélie penguins provides a clear example of the impact of this trend in the Palmer region. Adélie populations at the five major rookeries located near Palmer Station and studied for the past 30 years have all shown a gradual decrease in numbers. The western Antarctic Peninsula, the site of PAL LTER research, runs perpendicular to a strong climatic gradient between the cold, dry continental regime to the south and the warm, moist maritime regime to the north. More maritime conditions appear to be replacing the original polar ecosystem in the northern part of the Peninsula as the climatic gradient shifts southward. To date, this shift appears to be matched by an ecosystem shift along the Peninsula, as evidenced by declines in Adélie penguins, which require a longer snow-cover season, and changes in plankton distribution, as reflected in predator diets.

We hypothesize that ecosystem migration is most clearly manifested by changes in upper-level predators (penguins) and certain polar fishes in predator-foraging environments because these longer lived species integrate recent climate trends and because individual species are more sensitive indicators than aggregated functional groups. We hypothesize that in the years ahead, analogous modifications will also become evident at lower trophic levels, although these changes are likely to be seen only through long-term studies of ecosystem boundaries along the peninsula.

By studying extant food webs in both the marine and terrestrial environments, we will continue to investigate ecosystem changes at lower trophic levels; changes in response to continued, dramatic warming; and shifts in the poleward climatic gradient along the western Antarctic Peninsula.

During the 2005–2006 field season, the following studies will be conducted as part of the PAL LTER project:

Seabird (penguins, giant petrels, and skuas) ecology. (B–013–L/P; NSF/OPP 02–17282)
William R. Fraser, Polar Oceans Research Group.

Primary production and phytoplankton ecology. (B–016–L/P; NSF/OPP 02–17282)
Maria Vernet, University of California–San Diego, Scripps Institution of Oceanography.

Physical oceanography and ocean-climate modeling. (B–021–L; NSF/OPP 02–17282)
Douglas G. Martinson, Columbia University.

Zooplankton and nekton stocks, feeding, and growth. (B–028–L/P; NSF/OPP 02–17282)
Langdon B. Quetin, University of California–Santa Barbara, and Robin M. Ross-Quetin, University of California–Santa Barbara.

Remote sensing and bio-optics. (B–032–L/P; NSF/OPP 02–17282)
Raymond C. Smith, University of California–Santa Barbara.

Microbial ecology and biogeochemistry. (B–045–L/P; NSF/OPP 02–17282)
Hugh W. Ducklow, College of William and Mary, Virginia Institute of Marine Science.